Final Environmental Impact Assessment

Project Number: 41385
October 2011

LAO: Greater Mekong Subregion Nam Ngum 3 Hydropower Project

Prepared by NN3 Power Company

Environmental Impact Assessment

of

The Nam Ngum 3 Hydropower Project

Nam Ngum 3 Power Company

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ABBREVIATIONS

ADB	–	Asian Development Bank
CBD	–	Convention on Biological Diversity
CDM	–	Clean Development Mechanism
CFRD	–	Concrete Face Rockfill Dam
CIA	–	Cumulative Impact Assessment
CITES	–	Convention on International Trade in Endangered Species
COD	–	Commercial Operation Date
EHS	–	Environmental, Health, and Safety Guidelines
EGAT	–	Electricity Generating Authority of Thailand
EIA	–	Environmental Impact Assessment
EMMP	–	Environmental Monitoring and Management Plan
FSL	–	full supply level
GoL	–	Government of Lao PDR
GMS Lao	–	Greater Mekong Subregion Lao Company Ltd., principal developer shareholder
HIV/AIDS	–	Human Immune Virus/Auto Immune Deficiency Syndrome
IFC	–	International Finance Corporation
IFI	–	International Financing Institution
MAF	–	Ministry of Agriculture and Forestry
MoNRE	–	Ministry of Natural Resources and Environment
MOL	–	minimum operating level
MOU	–	Memorandum of Understanding
NES	–	National Environment Standards
NN1	–	Nam Ngum 1 Hydropower Project
NN2	–	Nam Ngum 2 Hydropower Project
NN3	–	Nam Ngum 3 Hydropower Project
NNRBC	–	Nam Ngum River Basin Committee
NPA	–	National Protected Area
NTFP	–	Non Timber Forest Product
PDP	–	Power Development Plan
PKK	–	Phou Khao Khouay
PMF	–	Probable Maximum Flood
REDD	–	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
REMDP	–	Resettlement and Ethnic Minorities Development Plan
RMR	–	Resource Management and Research
SEATEC	–	Southeast Asia Technology Company Limited
SMEC	–	Snowy Mountain Engineering Corporation
SPS	–	Safeguard Policy System
UXOs	–	Unexploded Ordnances

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EIA EXECUTIVE SUMMARY

A. Introduction

1. **Overall situation.** The Nam Ngum 3 Hydropower Project (NN3), a project with an installed capacity of 440 MW and a dam of 220 meters height, will be located along the Nam Ngum River in Vientiane and Xieng Khouang Provinces of Lao PDR, upstream of NN1 and NN2 (both operational), downstream of NN5 (under construction), and downstream of NN4 (in the planning phase). The Project is set 130 km north of Vientiane, about 4.5 km upstream of the confluence of the Nam Ngum River with the Nam Pha.

2. **Schedule of construction.** Main construction activities of NN3 are scheduled to start in October 2011. The NN3 reservoir is planned to be filled during the rainy season of 2016. Electricity will be generated from Commercial Operation Date (COD) in January 2017 onwards during a concession period of 27 years.

3. **Project history.** The Project was identified by the Mekong Secretariat in the 1970s. Developers were selected to develop the site under a Memorandum of Understanding signed with GoL in 1994. The feasibility study, including environmental studies, was finalized by Snowy Mountains Engineering Corporation Limited and Southeast Asia Technology Company Limited in 1995. Resource Management and Research was engaged in 1998 to carry out an Impact Analysis to provide the Developer with detailed Social Action and Environmental Management Plans. These documents were used as a basis for two rounds of public workshops in 2002 and resulted in environmental approval by STEA (now Ministry of Natural Resources and Environment, MONRE) allowing the Developer to start construction. However the SE Asia financial crisis interrupted the development until 2006. By that time, the environmental and social baseline situation had changed and required an update of the environmental and social documentation, which was undertaken from 2007 to 2009 by EcoLao and Norplan.

4. **Shareholders.** Four Companies are the shareholders of the NN3 Power Company: (i) GMS Lao (27%), (ii) Ratchaburi (25%), (iii) Axia Power Holdings B.V. (25%), and (iv) Lao Holding State Enterprise (LHSE) (23%).

5. **Legal Framework.** The Lao legislation, policies, and regulations regarding environmental and social requirements for hydropower development have been put in place during the last 10 years and provide a good framework for the development, construction and operation of such projects. The E&S documentation of the project aims at compliance with this legal framework, the ADB Safeguard Policy Statement, effective since Jan. 2010, and the requirements of other proposed lenders, including IFC.

B. Description of the Project

6. **Design and Location Alternatives**. The present dam site and power station location were confirmed in the original Feasibility Study (SMEC/SEATEC, 1995) on the basis of technical, financial, and economic considerations for electricity generation and subsequent export to Thailand. Subsequent detailed design ensured that basic safety standards for high hazard dams were applied to guarantee that no uncontrolled release of water will take place by: (i) enabling the passage of the maximum probable flood without overtopping the NN3 dam, and (ii) ensuring that the structure can withstand loads applied by the maximum credible earthquake.

7. **Dam and Reservoir.** NN3 will build a 220 m high dam located in the Nam Ngum River just west of Ban Long Cheng. The NN3 catchment is 3,769 km^2 at the dam site. NN3 reservoir will be narrow, long and deep. The reservoir storage capacity will be 1,407 million m^3 at Full Supply Level (FSL, 723 masl) and its active storage, 1,070 million m^3. At this level the total surface area of the reservoir will be 27.5 km^2. The Minimum Operation Level will be at 660 masl at which level the reservoir will cover an area of 9.5 km^2. The total length of the reservoir at FSL will be about 55 km.

8. **Waterways.** Water will be withdrawn from the reservoir hypolimnion. The invert level of the reservoir water off take is 645 masl. Water from the reservoir off take will be channelled by a 10.6 km diversion tunnel to the power station, where it will be discharged in the Nam Ngum River. Spills over the dam normally occur in August and September during wet years.

9. **Power Station.** An underground power station will be sited on the right bank of the Nam Ngum River 15.5 km downstream of the dam. The power station will have an installed capacity of 440 MW. The average annual energy production is estimated to be 2,128 GWh.

10. **Transmission Line.** The 500 kV transmission line, 99 km long, will connect the switchyard at the power station to the Nabong substation. For a large part the NN3 transmission line will run in parallel with the NN2 transmission line. At Nabong substation the NN3 and NN2 transmission lines will link to the joint transmission line for power transmission to recipients in Thailand.

11. **Construction.** NN3PC intends to award three main construction contracts. 3,000 to 4,000 workers will be engaged in construction work over a 5- year period starting October 2011 till end 2016. They will be based at two camps: one at the dam site and one at the power station site.

12. **Operation.** The power station will operate, from January 2017 (COD), on a daily basis in an intermittent mode. The exact production mode will depend on the actual availability of water in NN3 reservoir and dispatches by EGAT.

C. Environmental and Social Background

13. **Climate.** Lao PDR has a tropical monsoon climate. At elevations of the NN3 reservoir area three main seasons prevail. The rainy season lasts from May to October. From November to February it is cool and dry and from March to April it is hot and dry. The southwest monsoon arrives in Laos between May and July and lasts into October. The mean annual rainfall in the NN3 catchment varies from about 1,200 mm in the north-east of the catchment to about 2,700 mm at the damsite. High daily rainfall occurs generally during the months of September and October when typhoons from the South China Sea hit the coast at Vietnam and make their way in Lao PDR.

14. **Topography.** The NN3 catchment area consists of deeply incised valleys and step-sided ridges. The altitudes vary between 280 m asl and 1,500 masl. The main channel of the Nam Ngum River drains the northern part of the catchment, flowing in a south-westerly direction to the confluence with the Nam Ting River. NN5 hydropower dam is under construction in the Nam Ting. Below the confluence with the Nam Ting, the Nam Ngum flows in southern direction to the damsite. Below the damsite the river continues through mountainous terrain with no settlements before it reaches the NN2 reservoir.

15. **Geology and Soil.** The project is located in an area dominated by sediment rocks of Jurassic-Cretaceous age to the west of the reservoir. In the east the geology is dominated by Devonian, Carboniferous and Silurian rocks. Mining concessions have been granted at both sides of the Nam Ngum draining into the lower and the mid part of the NN3 reservoir, including the large Phu Bia mining exploration area.

16. **Hydrology.** The Nam Ngum River discharges depend on the pronounced differences in rainfall during the wet and dry seasons. High discharges occur towards the end of the wet season with the highest daily rainfalls. Low Nam Ngum discharges occur at the end of the dry season. Average monthly inflow in the Nam Ngum reservoir range from 22.4 m^3/s (April) to 286.9 m^3/s. (August). The average flow at the dam site is 96.5 m^3/s.

17. **Sedimentation.** The rate of sediment transport of the Nam Ngum allows for a lifetime of the NN3 reservoir of at least 70 years. When the NN5 and NN4 hydropower projects are operational, the sediment inflow to the NN3 reservoir will be significantly reduced, causing an increase of the lifetime of the reservoir.

18. **Water Quality.** In general the water quality in the Nam Ngum is very good, with a low content of nutrients, indicating oligotrophic conditions. In the rainy season the quality declines as a result of sediment loads increasing turbidity. Nitrate and phosphate concentrations are low throughout the year. The iron content and the concentrations of coliform bacteria indicate that seasonally the Nam Ngum water quality does not meet the water quality standards for drinking water.

19. **UXOs.** The main project construction sites (dam & power station) are considered to have a relatively low risk of UXOs. It is however a serious concern at other locations, in particular in project impacted villages that used to have an airstrip during the 1970s, such as at the villages of Long Cheng, Ban Xiengdet, Nam Sam, and Xam Thong.

20. **Physical Cultural Resources.** Physical resources of archaeological and cultural significance have been identified in Ban Xiengdet (ruins of the former temple of Vat Vangxieng, foundation of Vat Xiengdet, graveyard, spirit), but not at other villages surrounding the NN3 reservoir area.

21. **Vegetation and Land Use.** Little mature stands of dense Moist Upper Mixed Deciduous Forest or Mountain Rain Forest are found in and around the reservoir area. More than 50 % of the land is covered by vegetation classified as temporarily unstocked, resulting from decades of extensive practice of shifting cultivation and logging. The area around the future reservoir has been a major battlefield during the war in the 1970s.

22. **Protected Areas.** None of the Nam Ngum river terrestrial and aquatic habitats to be inundated by the reservoir or located within the relevant part of Nam Ngum catchment are protected, or fall within any Lao National Protected Areas (NPAs) or Province Protected Areas (PPAs). Approximately 33km of the 99km length NN3 transmission line will run through the Phou Khao Khouay National Protected Area (PKK NPA), declared by the Prime Ministerial Decree No 164 in 1993.

23. **Wildlife.** Due to the security that has prevailed in and around the NN3 catchment, comprehensive wildlife surveys have not been undertaken. As such, much of the known information has been taken from secondary sources (literature review, interviews with local villagers and forest officers). Wildlife is impacted by hunting, particularly mammals. The unstocked forest has not been described as supporting a high diversity of wildlife, but of common inhabitants of river valleys in Lao PDR, although species of note have been observed or reported. Further work is required to update a current baseline.

24. **Aquatic Ecology and Fish.** Different aquatic habitats in the Nam Ngum River sustain at least 44 fish species in the section of the Nam Ngum close to the NN3 power station site, and at least 48 fish species occur in the Nam Ting at the upper end of the planned NN3 reservoir. Long distance migrating fish species that migrate from the Mekong River have lost access to the Nam Ngum River upstream of the NN1 reservoir when the NN1 dam was constructed in the early 1970s, and for the ones able to move from the NN1 reservoir upstream, with the closure of the NN2 dam. The reduction of discharges in the Nam Ting by the NN5 project under construction will affect household fish catch at Ban Xiengdet, before the NN3 impacts occur.

25. **Ethnicity.** Lao-Tai groups constitute 42% of the 2,552 households living in Ban Xiengdet, 4 Peri-reservoir, 7 Downstream, and 17 Upstream Villages. Lao-Tai groups are not considered as ethnic minority groups since the Lao language is their native language and their traditions are part of the dominating Lao culture. Khmu represent 33 % (830 households) and Hmong 25% (643 households); both groups fall under the ADB definition of indigenous people as these groups have customary cultural, economic, social, or political institutions that are at variance with those of the dominant upland Lao-Tai groups. The human population of Ban Xiengdet and of the 4 peri-reservoir villages was established after the end of the war in 1974. During the war, Ban Long Cheng and Ban Xam Thong were the headquarters of the "special forces" fighting the Pathet Lao. At that time Ban Long Cheng was Lao's second biggest "city" after Vientiane. These "special forces" abandoned the villages in 1974. Other villages as Ban Xiengdet and Ban Xieng Nga were destroyed by air bombing and abandoned during the war.

26. **Health.** Most villages potentially affected by NN3 have health service within 3 hours of travelling. Three downstream villages (Nong Pou, Mouang Phoun, and Hom Xay) report 8 hours of travel to reach their nearest health centre. The most common causes of death are age, respiratory diseases, intestinal infections, accidents, and malaria. Potential serious threats to long-term health status in the Nam Ngum River Basin are malnutrition and the increase of sexually transmitted infections, in relation with the numerous infrastructure and mining activities in the area.

27. **Education.** All villages have a primary school within their village, but of variable qualities. Some teach up to Grade 2, while others have classes up to Grade 8. The number of teacher per students varies considerably from a student teacher ratio of 53 in the downstream village of Nam Xan to a ratio of 11 in Long Cheng. The primary school attendance for children in schooling age is high with an average of 96 per cent for both girls and boys in peri-reservoir villages, and 88 percent for downstream villages. The secondary school attendance drops considerably in all villages and more so for girls (39 percent) than boys (69 percent). Secondary school attendance is much influenced by the walking distance to the school.

28. **Agriculture.** Glutinous rice is the most common crop. Other crops include maize, peanut, sweet potato, chilly, cucumber and pumpkin. Most of the agriculture crops are for household consumption, and the surplus is sold to nearby markets or to merchants coming into the villages. At most villages not all households produce sufficient rice for consumption. Ban Xiengdet and the 4 peri-reservoir villages can be considered to be non opium producers.

29. **Livestock and Poultry.** Animal raising is common, but with a number of animals per household which varies much. On average each household has 0.8 buffalo, 2.3 cattle, 2.1 pigs and 7.0 chickens. Larger livestock such as buffalos and cattle are normally owned only by a few households considered as relatively well off in the villages.

30. **Forest Utilization.** Households rely on collection of NTFPs for daily food, household utilization, and for cash income. Important NTFPs collected in nearby forests include firewood, cardamom, rattan, mushrooms, bamboo shoots, broom grass, and *Imperata cylindrica*.

31. **Fisheries.** None of the households in the project area fish as the primary activity for household income. Apart from soldiers, no or few households fish in the Nam Ngum River. At Ban Xiengdet nearly all households fish in the Nam Ting. Depending on access to markets, households fish for consumption and/or sell fish for cash. The household fish catch in some upstream and downstream villages is extremely low.

32. **Income.** The total annual income (cash and imputed) for an average household at Ban Xiengdet is 27 million Kip, with most of it coming from agriculture, livestock, and timber/fuel wood. The total annual income for a poor household amounts to about 16 million Kip, while better-off households earn more than 4 times that of the poor ones.

33. **Gender**. Marketing exchanges including both the purchase and sale of goods in distant towns are predominantly male activities. Positions in village leadership are mostly held by males. Some women in ethnic minority communities in the project area experience difficulty communicating effectively with Lao-speaking health care workers and extension workers.

D. Environmental Impacts

34. The main anticipated environmental impacts during impoundment and project operation are caused by the inundation of land, changes in water discharges, and changes in water quality, affecting both terrestrial and aquatic habitats, and therefore agricultural activities and fisheries.

35. By building the NN3 Dam a 64 km section of the Nam Ngum River will be changed from a running river with several rapids into a reservoir with hydrological features halfway between a slow flowing river and a lake. The reservoir will fluctuate between an area of 27.5 km^2 at FSL 723 masl and an area of 9.5 km^2 at MOL, 660 masl, creating a drawdown zone seasonally flooded. Under the current proposed design, the first 4.8 km reach of the Nam Ngum from the dam site to the confluence

with the Nam Pha will have an average monthly discharge reduced to less than 1 m^3/s for all months of the year at the exception of the months of August and September when spills are expected. Thermal stratification is expected in the reservoir, with anoxic conditions in the deeper layers.

36. A total of 10.5 km^2 of forest will be flooded by the reservoir and about 1 km^2 of forest impacted by the clearance of the transmission line corridor. The destruction and degradation of these habitats will in turn impact the associated terrestrial and aquatic wildlife.

37. Construction related environmental impacts are expected and they include dust, noise, vibration, erosion and silting, traffic disruption, community health and safety, land use, and vegetation clearance, etc. A Construction Environmental Management and Monitoring (CEMMP) prepared by each Contractor under the EMMP with mitigation measures, scheduling, and good engineering practice, will address these impacts.

E. Social Impacts

38. 29 villages are directly and indirectly impacted by the Project:

(i) Xiengdet is the only village that needs to be resettled as part of the village area (residential area and 42 ha of agricultural lands) will be periodically inundated by the reservoir. The main impacts are as follows: seasonal flooding of part of the village area, residential area, including fixed assets as houses, home gardens, pig pens, fruit trees, and chicken coops; seasonal and partial inundation of physical and cultural resources; seasonal flooding of part of paddy fields, agricultural land, vegetable gardens, fish ponds, banana orchards, and fruit trees; seasonal flooding of part of village area consisting of governmental land, potentially impacting cattle grazing, collection of Non Timber Forest Products (NTFPs), and hunting wild life.

(ii) The 4 peri-reservoir villages (Nam Sam, Xieng Nga, Xam Thong and Long Cheng) will have only limited governmental lands periodically flooded each year by the reservoir. About 6 households at Nam Sam are expected to be impacted by potential losses in land use of this governmental land as seasonal cattle grazing. Cattle grazing land will not be affected at the other 3 peri-reservoir villages. Only at Long Cheng, household income from collection of NTFPs and hunting of wild life will be partially impacted through flooding of hunting and collection areas. Household fish catch could be positively impacted at Nam Sam and Xieng Nga at the upper end of NN3 reservoir.

(iii) The 7 downstream villages (Louang Phan Xay, Phan Xay, Nam Pha, Nam Xan, Nong Pou, Mouang Phoun, Hom Xay) might experience impacts on their fish catch.

(iv) The 17 upstream villages (Nam Ting, Phouvieng Noi, Phouvieng Nyai, Xayoudom, Somboun, Nam Chat, Bang Pang, Maang, Yong Tang, Souy, Chomsi, Sak Sort, Na Khuan, Nong Kang, Xong, Dook, Xay) could experience a positive impact in terms of fish catch.

39. 782 households are potentially physically and/or economically impacted by the project. From these 782 households:

(i) 144, living at Ban Xiengdet, will need to be resettled,

(ii) 10 living along the access road to Ban Xiengdet, might need to be resettled,

(iii) 40 are potentially impacted along the public road from Nam Ngone to Long Cheng, and

(iv) Approximately 5 households might need to be physically displaced due to the construction of the transmission line.

(v) For the remaining 77%, the households will not be relocated and should experience impacts valued at less than 10% of their annual income.

40. The environmental and social impacts associated with the construction activities of a project of this nature will be avoided, minimized, and mitigated through the implementation of an environmental, health, and safety program and of a Public Health Action Plan, a Gender Action Plan and the Construction Social Management Plan .

F. Entitlement Policy

41. The overall policy of NN3PC is to provide, whenever it is possible, in-kind compensation for the impacts created by the Project at replacement value at the minimum. Cash compensation will only be considered as a last resort option or if some impacted families wish to relocate outside of the Project area, something which has not been expressed so far. In general terms, this means that houses that will be directly impacted by the project and the associated residential lands will be replaced with new houses and with replacement residential lands, properly titled, at no cost for the impacted households. Similarly the lost agricultural lands will be replaced by new agricultural lands that will be developed by the Project and shall be of comparable agricultural value, all this at no cost again for the impacted households. The livelihoods of the impacted households shall be restored and improved through agricultural support programmes that shall be in place until after the commercial operation date of the project. In the case of plantations that might be impacted along the alignment of the Transmission Line, existing timber and products will be purchased at market value and cash compensation shall be provided to replace these plantations on replacement lands that shall be identified and the value of the concession right restored by the Project. (See section 5.3 of the REMDP for a detailed description of the entitlements of the affected households). Grievance redress mechanism for any potential complaints on environmental, health, safety or social aspects is in place, and will be closely and regularly monitored by NN3PC. NN3PC will follow the procedures and mechanisms to redress grievances based on the GoL's Technical Guidelines on Compensation and Resettlement of People Affected by Development Project (March 2010).

G. Public Consultation and Disclosure

42. As of the end of 2011, there have been numerous public consultation and participation briefings, presentations and meetings, which have taken place at the local, regional and national levels (See Table 6.2 of the REMDP). A dialogue has been established with the various stakeholders directly and indirectly involved in the Project and interested in the Project's public consultation programme. Meaningful consultations were undertaken with affected people, including affected ethnic minorities, in the various project impact areas. These consultations shaped the entitlements package in the REMDP and the public health action plan, gender action plan, construction social management plan. The NN3 HPP requires the physical relocation of ethnic minorities in one village – Ban Xiengdet. NN3PC has obtained the consent of the affected ethnic minorities in Ban Xiengdet to the social and resettlement programme developed with them, including the dispute resolution mechanism. The views and concerns of affected people have influenced the project design, the entitlements and benefits package in the REMDP and shaped the future consultation activities to be conducted during the REMDP update process and its subsequent implementation. Public consultation and disclosure will continue during the construction and operation phases of the project. For other project components for which the alignment or final design has not been prepared, the REMDP includes arrangements to obtain the consent of affected ethnic minorities who will be physically displaced.

H. Compensation, Livelihood Restoration and Relocation

43. Eight action plans have been formulated to address the various social impacts identified: (i) the Public Health Action Plan, (ii) the Gender Action Plan, (iii) the Construction Social Management Plan, (iv) the Resettlement Action Plan for the public road Nam Ngone – Long Cheng, (v) the Resettlement Action Plan for the Transmission Line, (vi) the Ban Xiengdet Resettlement Action Plan, (vii) the Peri-Reservoir Action Plan, and (viii) the Downstream Action Plan. These are presented in more details in the section 7 of the REMDP.

I. Environmental Management and Monitoring Plan

44. The Environmental Management and Monitoring Plan (EMMP) provide a framework to ensure transparent and effective monitoring, prevention, minimization, mitigation, compensation, and off setting measures of the environmental impacts created by the NN3 project. Given the rapidly changing E&S baseline in the project area, the EMMP is based on the principles of adaptive management and cumulative impact management. Four main sub-EMMPs have been identified: (i) Integrated watershed

management, targeting in particular biodiversity conservation and reforestation; (ii) Water quality monitoring and management; (iii) Construction Environmental Management and Monitoring Plan and (iv) Environmental Management and Monitoring Plan –Operation Phase (EMMP_OP). The 4 sub-EMMPs are presented in Chapter 9. Sub EMMPs 1 and 2 will be further updated based on the results of the baseline biodiversity survey and additional field surveys.

45. Each contractor will be required to prepare a construction environmental management and monitoring plan (CEMMP), which includes a master plan, thematic sub-plans and site specific environmental plans, regularly updated. The environmental and social requirements set by the Company are the Environmental, Health, and Safety guidelines formulated by the IFC. NN3PC will monitor the compliance of the various construction activities with its requirements. Attention will be given to the management of the social impact of construction activities, in particular of camp followers and service providers, and there will be linkages between the CEMMP and the Construction Social Management Plan and the Public Health Action Plan.

46. In addition to the impacts directly associated with the construction of dam, the power house and directly associated infrastructure, environmental and social impacts of construction works are expected (i) along the NN3 transmission line, (ii) along the public road between Ban Nam Ngone and Long Cheng and (iii) during reservoir impoundment. To address these impacts, sub-plans have been prepared and are discussed in the REMDP. They include (i) Fisheries Management Plan, (ii) Public Roads Environmental Management Plan, and (iii) Transmission Line Impact Assessment and Management Plan.

47. Impacts that will occur during the operation phase will start in January 2017. They were assessed in the EIA. An EMMP-OP shall be prepared not later than 6 months before the start of the operations. All these EMMPs will be updated when the detailed Environmental and Social Impact Assessments for the project components are completed at later stages of the project.

J. Budget

48. The environmental and social budgets of the NN3 project total US$32.2M, including US$22M before COD and US$10.2M after COD, and detailed below:

	Pre-COD	**Post-COD**	**TOTAL**
ESD overall management, coordination & communication	5,247,400	2,404,450	7,651,850
Integrated Watershed Management	1,000,000	2,600,000	3,600,000
Water quality monitoring and management programme	1,340,000	350,000	1,690,000
Construction Social Management Plan	290,000	20,000	310,000
TOTAL ENVIRONMENT BUDGET	**7,877,400**	**5,374,450**	**13,251,850**
ESD overall management, coordination & communication	4,727,600	2,706,450	7,434,050
Public Health Plan	880,000	350,000	1,230,000
Ban Xiengdet Resettlement and Development Plan	7,128,000	906,000	8,034,000
Peri-reservoir and downstream action Plan	550,000	898,000	1,448,000
Management of the social impacts f the TL and new/upgraded public roads	837,000	0	837,000
TOTAL SOCIAL BUDGET	**14,122,600**	**4,860,450**	**18,983,050**

K. Institutional Arrangements and Implementation

49. NN3PC will establish the Environmental and Social Division (ESD) responsible for implementing and coordinating the environmental and social activities of the Project. The ESD will be headed by an E&S Manager reporting to the Project Manager. This person shall be responsible for the overall implementation of the environmental and social obligations set in the Annex C of the Concession Agreement, the Common Terms Agreement, the EMMP, the REMDP and the 11 Action Plans describe therein, and of the necessary interactions and coordination with the numerous parties involved (See figure 9.1 of the REMDP).

50. The ESD will consist of the Environmental Management Office, dealing with all purely environmental issues, including in particular (i) the construction sites environmental compliance, (ii) the biomass clearance programme, (iii) the UXO clearance, and (iv) an environmental monitoring laboratory and the Social Management Office, dealing with (i) the resettlement and relocation programme, (ii) the infrastructure programme, (iii) the livelihood restoration programme, (iv) the social programme, and (v) community liaison.

51. The ESD will have three offices: (i) at the NN3 project office in Vientiane, (ii) in Xaysomboun District, and (iii) in Phou Kout District or at the Xiengdet village.

52. The Project's intention is to work closely with the Provincial Resettlement and Livelihood Restoration Committee, the District Coordination Committees, and with the Village Development Coordination Committees, but also with Nam Ngum River Basin Committee (NNRBC), its Secretariat and its Hydropower and Mining Forum that are currently being established under the auspices of MONRE.

L. Monitoring and Reporting

53. Internal monitoring will be undertaken by the NN3PC's ESD who will report to the GoL (MONRE), IFIs and other lenders on a regular basis. This reporting will cover the various environmental and social activities undertaken during this period and related to the implementation of the active environmental and social programmes. It will present progress against the schedules and milestones set, identify potential difficulties and corrective measures taken, and present the results of its own monitoring against the obligations set in the Concession Agreement and other agreed protocols (e.g. with lenders). With respect to resettlement, ESD will monitor not only its own progress in resettlement and compensation activities for affected households against an agreed schedule, but also the changes in household income (cash and imputed) from affected land uses, as well as from livelihood restoration and development activities.

54. An Independent Monitoring Agency (IMA) comprised of well qualified experts in environmental and social monitoring will be contracted with the objective to ensure compliance of the Company activities with its environmental and social contractual obligations. This monitoring will be undertaken mainly for GOL agencies, IFIs, lenders, affected communities and the general public. The independent monitors will receive the NN3PC quarterly progress reports and other pertinent information. The team will visit the different project sites during the construction and operation phase of the project on a bi-annual basis.

55. Six-monthly monitoring reports of the Independent Monitoring Agency will be made available for public disclosure, either on the project's website, and/or that of MONRE, and/or that of IFIs and other lenders. Other reports for public disclosure include Annual Project Implementation Reports and updated safeguards documents.

I. INTRODUCTION

1. The 440 MW Nam Ngum 3 Hydropower Project (NN3) is located along the Nam Ngum River in Vientiane and Xieng Khouang Provinces. The Project is inserted between other hydropower projects in the Nam Ngum River Basin: upstream of NN1 and NN2 (both operational), downstream of NN5 (under construction), and downstream of NN4 (in the planning phase). The proposed Nam Pha and Nam Phay projects are located on the rivers of the same names, which have their confluences with the Nam Ngum between the NN3 dam site and the NN3 power station site for the Nam Pha project and downstream of the NN3 power station for the Nam Phay project (Figures 1.1 and 1.2). Numerous industrial projects, hydropower and mining, are in operation and planned in the Nam Ngum River Basin.

Figure 1.1: Project Location

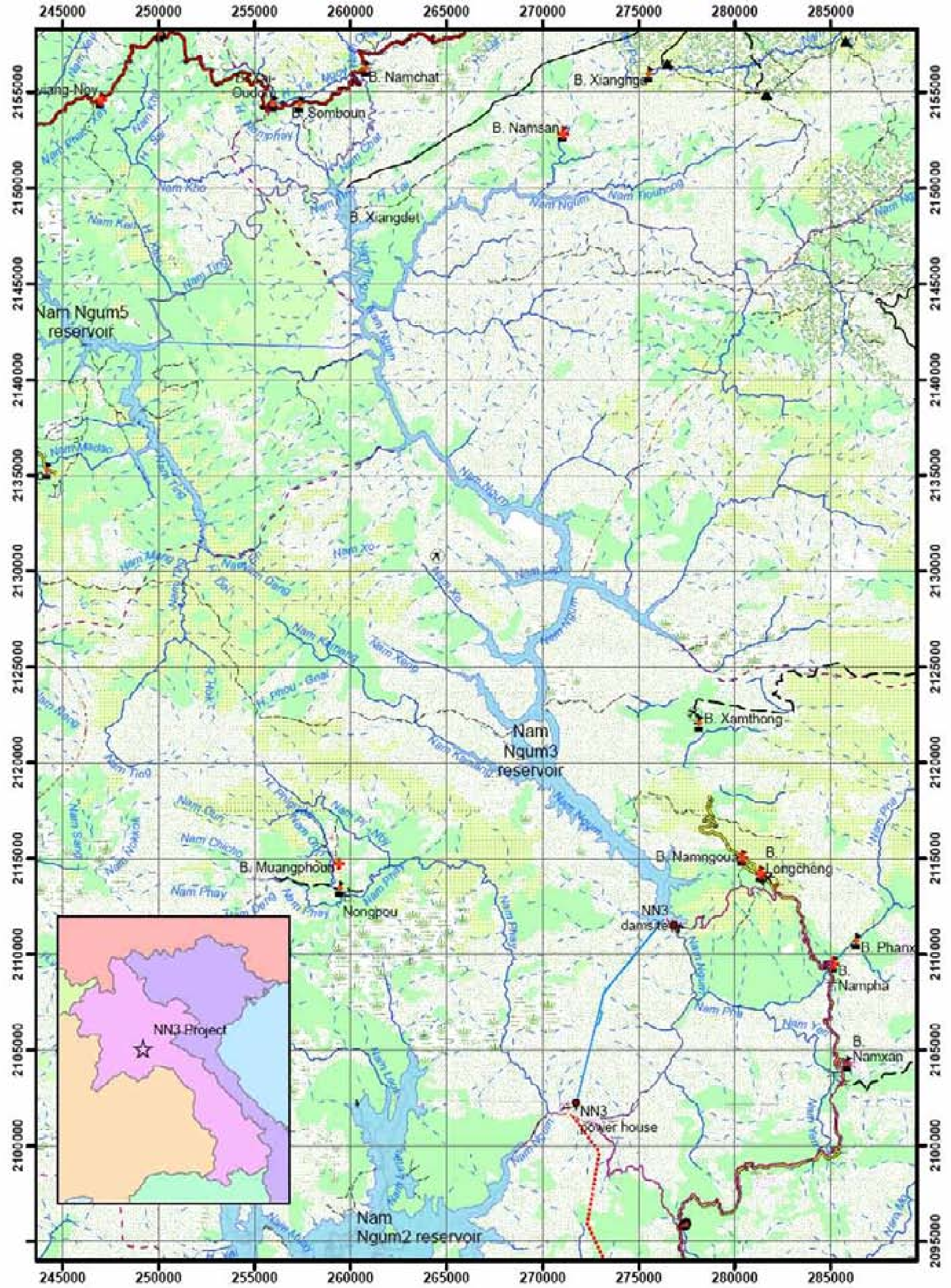
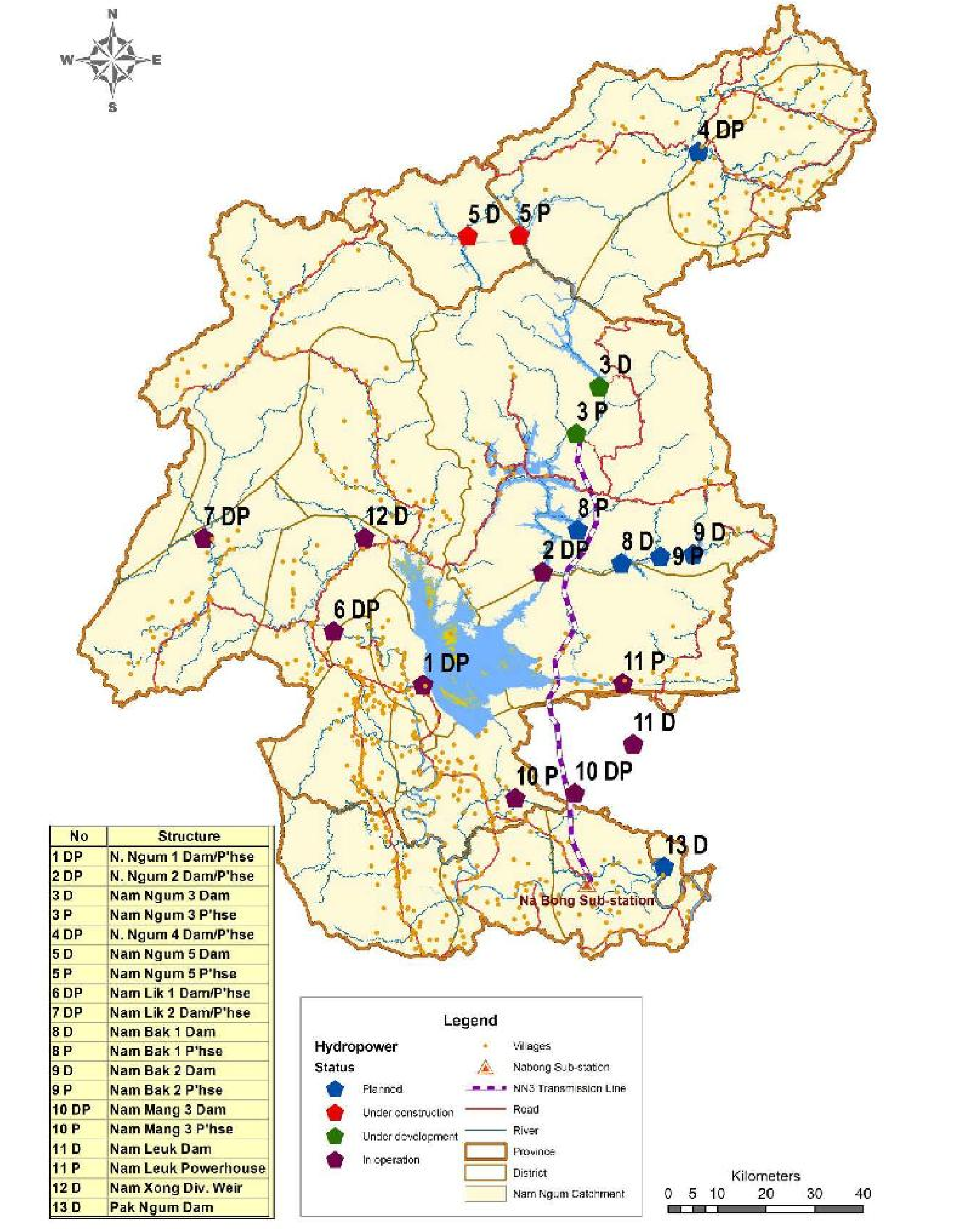


Figure 1.2: Existing, under construction, and main planned hydropower projects in the Nam Ngum River Basin



No	Structure
1 DP	N. Ngum 1 Dam/P'hse
2 DP	N. Ngum 2 Dam/P'hse
3 D	Nam Ngum 3 Dam
3 P	Nam Ngum 3 P'hse
4 DP	N. Ngum 4 Dam/P'hse
5 D	Nam Ngum 5 Dam
5 P	Nam Ngum 5 P'hse
6 DP	Nam Lik 1 Dam/P'hse
7 DP	Nam Lik 2 Dam/P'hse
8 D	Nam Bak 1 Dam
8 P	Nam Bak 1 P'hse
9 D	Nam Bak 2 Dam
9 P	Nam Bak 2 P'hse
10 DP	Nam Mang 3 Dam
10 P	Nam Mang 3 P'hse
11 D	Nam Leuk Dam
11 P	Nam Leuk Powerhouse
12 D	Nam Xong Div. Weir
13 D	Pak Ngum Dam

2. Main construction activities of NN3 are scheduled to start in October 2011. The NN3 reservoir is planned to be filled during the rainy season of 2016. Electricity will be generated from Commercial Operation Date (COD) in January 2017 onwards during a concession period of 27 years.

A. Project History

3. The Nam Ngum 3 Hydropower Project was identified by the Mekong River Secretariat, and as early as in 1979 the Government of Lao PDR (GoL) was actively considering its construction.

4. A project developer was selected to develop the site under a Memorandum of Understanding (MoU) signed with GoL in 1994. The feasibility study of NN3, including environmental studies, was finalized by Snowy Mountains Engineering Corporation (SMEC) and Southeast Asia Technology Company Limited (SEATEC) at the end of 1995.

5. The consulting company Resource Management and Research (RMR) was engaged in 1998 to carry out an Impact Analysis and to provide the project developer with detailed Environmental and Social Action Plans.[1] These documents were issued in 2002 resulting in STEA's (now the Ministry of Natural Resources and Environment, MONRE) issuance of the NN3's environmental compliance certificate allowing the start of construction activities.

6. The South-East Asian financial crisis brought the NN3 project preparation process to a slow down. When the project planning picked up again in 2006 some of the conditions on which the RMR studies were based had changed, including changes in environmental and social regulations, changes in the environmental and social baseline situation, changes in project design, and rapid progress of other hydropower developments and mining activities in the Nam Ngum River Basin (NN2, NN4, NN5, and Phu Bia mining). In the meantime also the Environmental Certificate of NN3 expired.

7. The consulting companies Norplan and EcoLao were engaged in 2007 and 2008 to relaunch the consultation process and finalize the environmental and social safeguard documents for NN3. The final REMDP was submitted in February 2009 to MONRE and potential lenders including the Asian Development Bank (ADB).[2] Subsequently environmental and social policies of MONRE changed with the Prime Minister's Decree No. 112/PM, dated February 2010 on Environment Impact Assessment and Regulation 99/PM with updated Resettlement Guidelines in March 2010. Similarly, ADB issued a new Safeguard Policy Statement (SPS) in June 2009, effective from 20 January 2010.

8. Four companies are the shareholders of the NN3 Power Company (the Company): (i) GMS Lao (27%), (ii) Ratchaburi (25%), (iii) Axia Power Holdings B.V. (25%), and (iv) Lao Holding State Enterprise (23%).

9. NN3 construction works up to September 2011 consisted of (i) a bridge over the Nam Ngum to the power station site, (ii) an exploratory adit at the power station site, and (iii) upgraded access roads from the public road to the dam site and to power station site. These works have been initiated in accordance with the re-issued environmental certificate. An environmental and social compliance audit was undertaken in December 2010 for these existing facilities (Annex B).

10. The updated Environmental Compliance Certificate was issued in April 2011 on the basis of the Environmental and Social Impact Assessment issued in October 2010. Preliminary construction activities were initiated from mid-April 2011 (see section 2.3.3) and interrupted at the end of June 2011.

B. Lao Policy, Legal, and Administrative Framework

1. National laws

11. The Lao legislation, policies, and regulations regarding environmental and social requirements for hydropower development provide powerful tools for the regulating and administrative authorities. Legal references include: (i) The Environmental Protection Law of 1999, (ii) the Regulation on Implementing Environmental Assessment for Electricity Projects in Lao PDR, (iii) the National Policy

[1] Annex A includes the list of RMR's detailed Environmental and Social Action Plans.
[2] Project developers approached ADB in 2006 to request for financing for the project. ADB has been considering supporting this project since then.

on Environmental and Social Sustainability of the Hydropower Sector in Lao PDR, and (iv) the Lao Electric Power Technical Standards.

12. The Ministry of Natural Resources and Environment (MONRE) is responsible for the implementation of the Environmental Protection Law.

13. Recent legal instruments include:

(i) The National Environment Standards (NES) that became applicable in 2009.
(ii) The Decree on Environmental Impact Assessment, No 112/PM, dated 16 February, 2010, which gives responsibilities to district and provincial authorities for the environmental and social management and monitoring.
(iii) The Prime Minister's Decree No. 293 on the Establishment and Activities of the River Basin Committee (June 2010)[3].

2. Regional Commitments

a. Mekong River Commission

14. Lao PDR ratified the April 1995 Agreement on the Cooperation for Sustainable Development of the Mekong River Basin. One purpose of the agreement is to ensure the sustainable development, utilisation, management and conservation of resources associated with the Mekong River. Under this agreement, the member countries are obliged to notify the Commission on all larger development projects on the Mekong River and its tributaries. Notification of the Nam Ngum 3 development plan has been made, although no transboundary negative impacts are expected from the project.

b. Greater Mekong Sub-Region (GMS) Initiative

15. In 1992, with the assistance of ADB, Cambodia, Lao PDR, Myanmar, Thailand, Viet Nam, and Yunnan Province in the People's Republic of China entered into a program of sub-regional economic cooperation, designed to enhance economic relations among the countries. The program has contributed to infrastructure development and better use of the resource base in the sub-region.

3. International Conventions and Treaties

c. Convention on Biological Diversity (CBD)

16. Lao PDR became a signatory to the CBD in 1992, following up the ASEAN Agreement of the Conservation of Nature and Natural Resources, which was signed in 1985. The obligations of CBD have been fulfilled in terms of new policy and legislation and by establishing National Protected Areas (NPAs).

d. Convention on the Protection of World Cultural and Natural Heritage

17. GoL ratified this Convention in 1987. It addresses the protection of both cultural and natural objects and sites of high national and international value.

[3] A decree that puts into place an intergovernmental and multisectoral body to sustainably manage the priority river basins and sub-basins of the country. RBC is a non-permanent organization with a mandate to act as a water resources executive in river basin under the direction of the Lao National Mekong Committee (LNMC) for management, development, conservation, rehabilitation and utilization of water resources in river basin area. Under the Decree, the 17-member RBC will be chaired by a Provincial Governor, elected on a five-year basis by riparian provinces, along with a supporting Secretariat. The Nam Ngum River Basin Committee (NNRBC) was formed at the end of 2010 as the first River Basin Committee in Lao PDR, with a Secretariat established. The Secretariat acts as a technical advisory body to assist the RBC to facilitate and monitor all activities of the RBC.

e. Convention on International Trade in Endangered Species (CITES)

18. Lao PDR ratified this convention in early 2004. Prior to the ratification, the Ministry of Agriculture and Forestry (MAF) issued a regulation that banned all hunting for trade. This outlaws the extensive trade in wildlife from Lao PDR and from Thailand through Lao PDR to its neighbouring countries.

4. ADB Safeguard Policy Statement & IFC Performance Standards

19. ADB's SPS was issued in 2009 and applies to all projects funded by ADB effective from 20 January 2010. This operational policy revision resulted in a consolidated policy outlining common objectives of ADB's safeguards, policy principles, and delivery process for the SPS. It also outlines a set of specific safeguard requirements when addressing social and environmental impacts and risks.

20. ADB’s safeguard policy statement consists of three operational policies on the Environment, Indigenous Peoples, and Involuntary Resettlement.[4] Objectives of ADB’s environmental and social safeguards are to: (i) avoid adverse impacts of projects on the environment and affected people, where possible; (ii) minimize, mitigate, and/or compensate for adverse project impacts on the environment and affected people when avoidance is not possible, and (iii) help borrowers/clients to strengthen their safeguard systems and develop the capacity to manage environmental and social risks. Since the project is Category A for environment, Safeguard Requirements 1: Environment and the eleven policy principles have been triggered (referred to page 16 of the SPS, 2009).

21. The social safeguards, including gender and development and social protection issues, are presented in details in the REMDP (section 1.3).

22. The Environmental and Social documentation of the Project has also aimed compliance with the IFC Policy and Performance Standards on Social and Environmental Sustainability and Policy on Disclosure of Information, dated April 30, 2006.

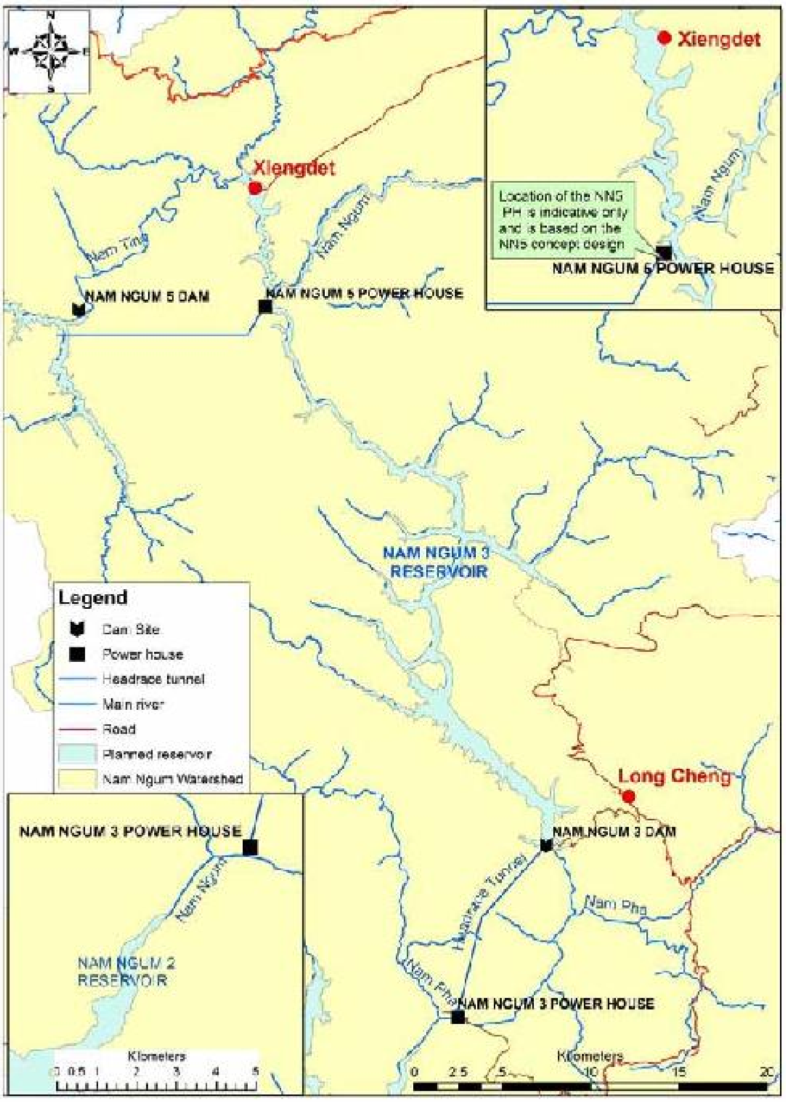
[4] Asian Development Bank, Safeguard Policy Statement (SPS), June 2009.

II. PROJECT DESCRIPTION

A. Project Location

23. The Nam Ngum 3 Hydropower Project is set on the Nam Ngum River 130 km north of Vientiane,[1] located in Vientiane and Xieng Khouang Provinces in the Lao People's Democratic Republic (Lao PDR) (Figure 1.1). The NN3 dam site is located on the mainstream Nam Ngum about 4.8 km upstream of its confluence with the tributary Nam Pha (Figure 2.1 & 2.2).

Figure 2.1: NN3 & NN5 Reservoir and Dams



24. NN3 is one in a cascade of 15 existing or proposed hydropower projects on the Nam Ngum River and in the Nam Ngum River Basin. The NN3 reservoir is located upstream of NN1 which became fully operational in 1972 and also upstream of NN2 which has started commercial operations in 2011. Upstream of the NN3 reservoir, NN5 is under construction (completion expected at the end of 2011), while NN4 A & B, also upstream of NN3, is still in the planning phase. On the Nam Pha tributary, the 5 MW Nam Pha run-of-river hydropower project is also in the planning phase, and on the Nam Phay a 60-MW project is also being planned.

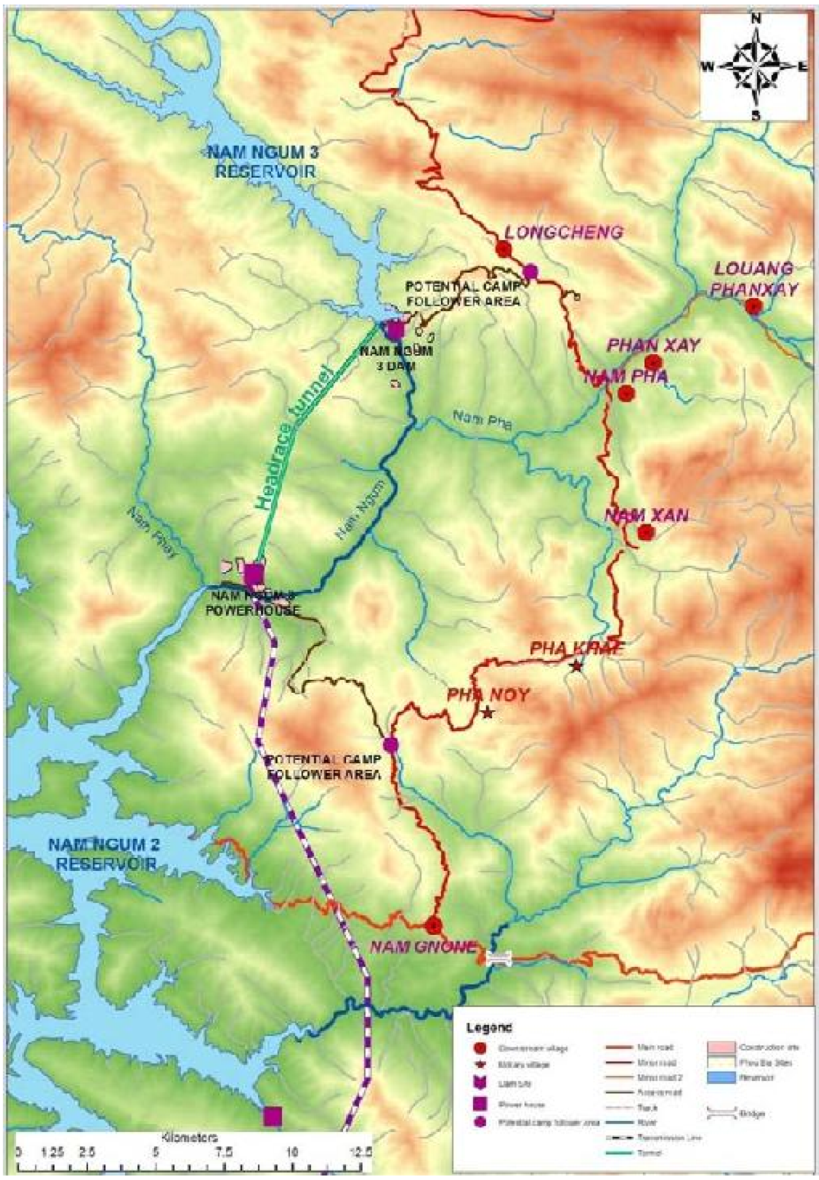
[1] 265 km by road from Vientiane Capital.

B. Project Components

25. The NN3 project involves the construction of a 220 m high Concrete Face Rockfill Dam (CFRD), gated spillway, 10.6 km long headrace tunnel, 213 m deep pressure shaft, 192 m long steel penstock, 900 m long tailrace tunnel, 440MW underground power station housing two 220 MW Francis turbine generator units and a 99 km long 500kV transmission line.

26. The catchment area at the damsite is 3,769 sq. km. Mean annual rainfall over the catchment is 1,200 to 2,700 mm. The average flow at the dam site is 96.5 m^3/s or 3,043 MCM per year. The estimated peak inflow of 10,000 yr return period is 6,316 m^3/s while the Probable Maximum Flood (PMF) is 12,137 m^3/s.

Figure 2.2: NN3 Dam, Diversion Tunnel, Power Station, Access Roads, and Public Road Nam Ngone-Long Cheng



1. River diversion and cofferdams

27. A 11.6 m inner diameter, 910 m long concrete lining diversion tunnel capable of diverting the 500-yr flood of 3,350 m^3/s, and subject to pressure flows during large floods and free surface flows during normal discharge, will be built in the right abutment, after the construction of preliminary

upstream and downstream cofferdams and a main coffer dam. The main cofferdam is designed to provide flood protection up to the 1 in 500 years flood event, as presented in the Table 2.1 below.

Table 2.1: Design Floods of Cofferdams

Pre cofferdam	Dry season flood of 5- year return period flood
Temporary Upstream Cofferdam (TUC)	50 -year return period flood
Integrated Cofferdam (Main Cofferdam)	500- year return period flood

28. An overflow channel and erodible 'fuse plug' is provided to secure the TUC in the event of overtopping by an unexpected flood.

29. Annex K presents the technical drawings of the key project features.

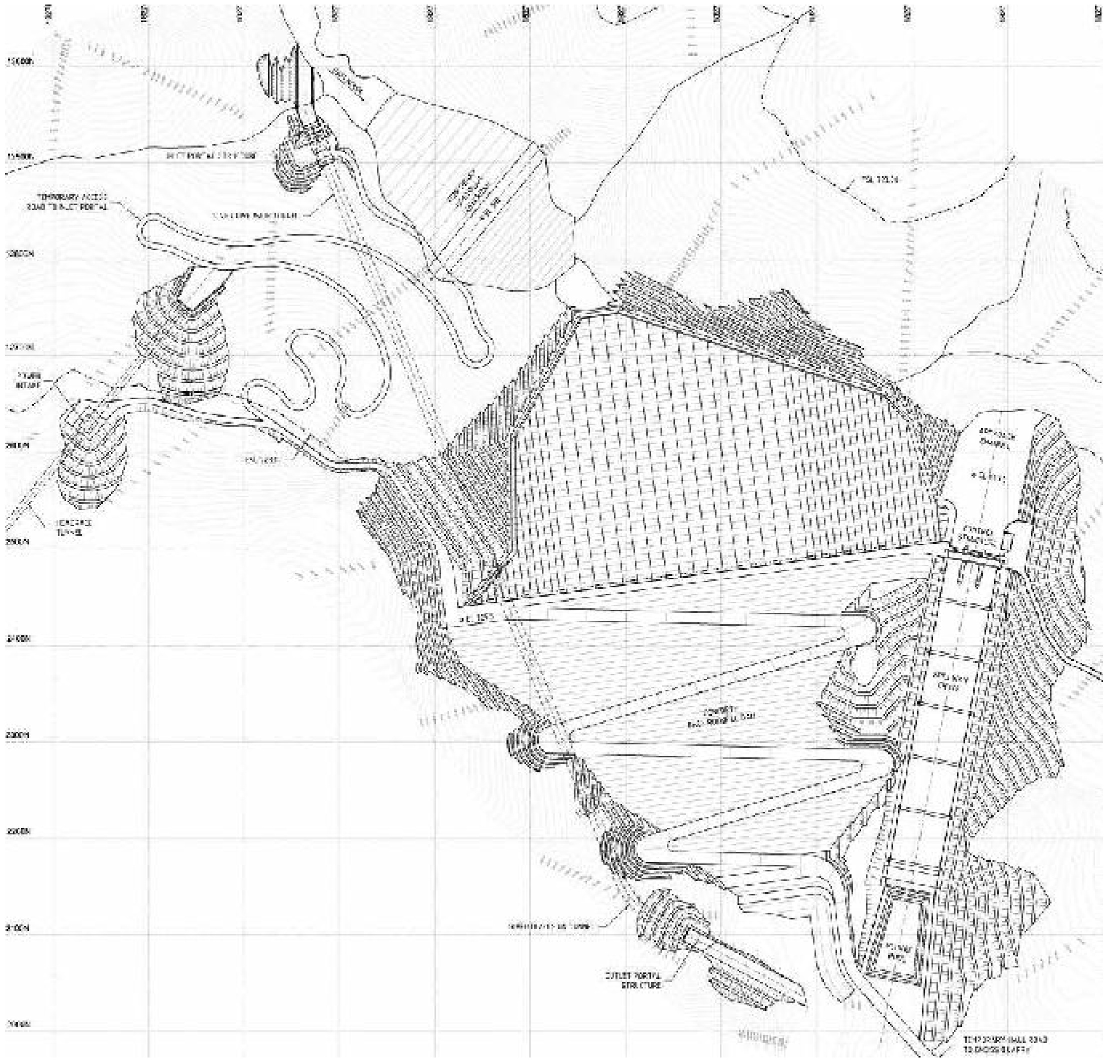
2. Dam

30. The NN3 project will construct a 220 m high dam on the Nam Ngum River just west of Ban Long Cheng. The main characteristics of the dam are presented in Table 2.2 and Figure 2.3.

Table 2.2: Dam main characteristics

Type	Concrete Faced Rockfill – CFRD	Estimated Volumes	Potential Sources
Top of Parapet Wall	El 731 m asl		
Crest elevation	El 729.5 m asl		
Crest length	500 m		
Crest width	8 m		
Dam embankment volume	13.3 million m^3		
Embankment zones:			
Zone 1A Crack filler material	Fine-grained cohesionless soil	119,000 m^3	Common excavation
Zone 1B Support for Zone 1A	Random fill	755,000 m^3	Common excavation
Zone 2A Perimeter zone fine filter	19 mm down sandy gravel	4,000 m^3	Gneiss Quarry
Zone 2B Face slab bedding layer	75 mm down sandy gravel	279,000 m^3	Gneiss Quarry
Zone 3A Transition zone	Small size quarry-run rockfill	301,000 m^3	Gneiss Quarry
Zone 3B 'First-Class' Rockfill	Fresh to slightly weathered rocks	6,226,000 m^3	Gneiss Quarry
Zone 3C 'Second-Class' Rockfill	Moderately weathered rocks	5,201,000 m^3	600,000 m^3 from excavated rock and remaining from Gneiss Quarry
Zone 3D Drainage zone	Coarse graded rockfill	381,000 m^3	Gneiss Quarry
Dam & appurtenant structures excavation required		3,400,000 m^3 1,100,000 m^3	

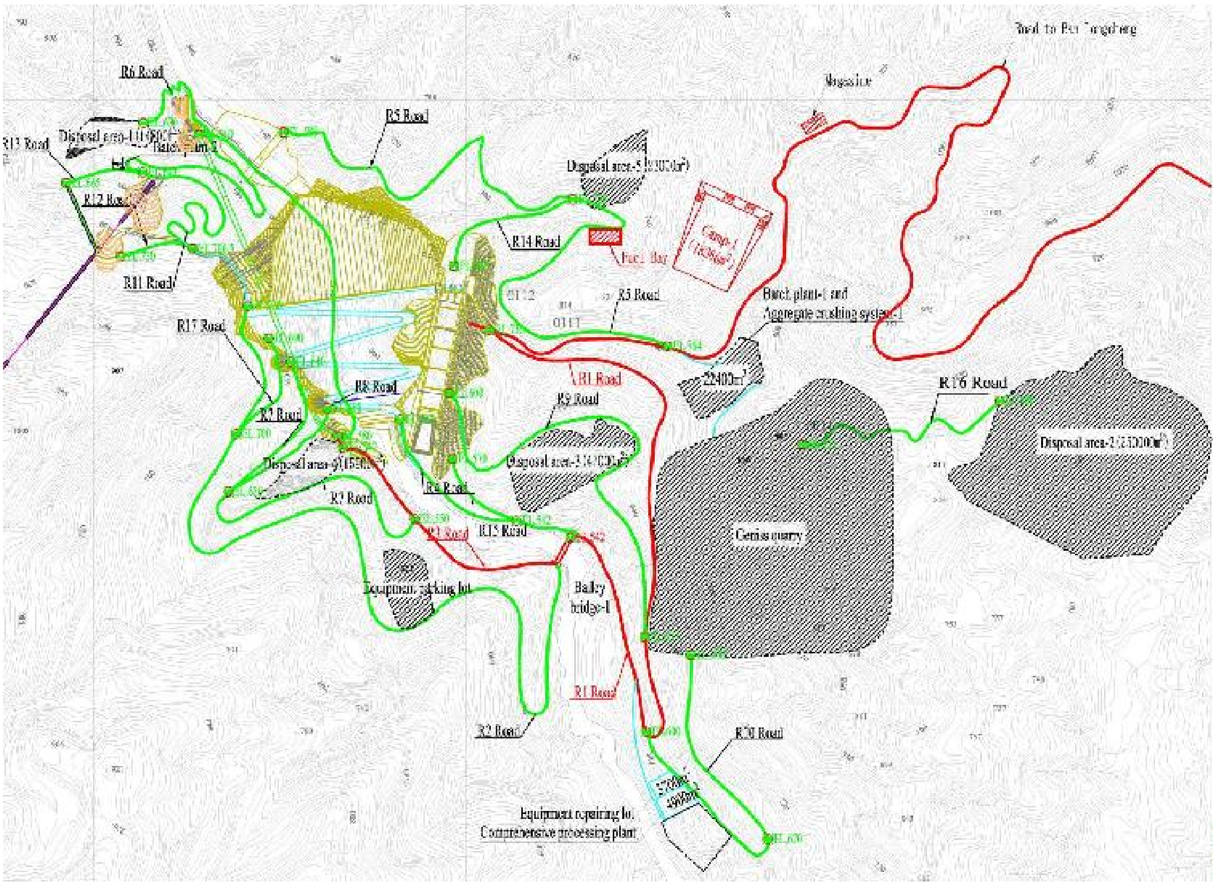
Figure 2.3: Dam, Spillway and Related Structures



31. Approximately 900,000 m^3 of the common excavated material will be stockpiled and used as the impervious blanket upstream of the concrete face slab and the remaining amount, approximately 3.5 Mm^3 will be disposed of at the proposed designated disposal areas as shown in Figure 2.4. It is estimated that approximately 60% of the excavated rock material can be used as the dam embankment.

32. NN3 dam has been designed to avoid failure of one or both of the downstream located NN2 and NN1 dams by an uncontrolled release of water from its reservoir. This will be achieved by: (i) enabling the passage of the maximum probable flood without overtopping the NN3 dam, and (ii) ensuring that the dam withstands loads applied by the maximum credible earthquake.

Figure 2.4: Proposed Site Layout at the Dam Site
(Proposed Location of Quarries, Spoil and Access)



3. Quarries

33. Table 2.3 presents the two possible quarry sites and their characteristics.

Table 2.3: Possible quarry sites & characteristics

Source	Gneiss Quarry	Limestone Quarry
Location	2 km downstream of the dam site	12 km east of the dam site
Size (approx.)	400 x 400 m	400 x 400 m
Type of material	Gneiss for both concrete aggregate and rockfill embankment	Limestone for concrete aggregate
Volume of material to be used (m^3)	11,800,000	Yet to be determined
Volume of material to be disposed (m^3)	1,600,000	Yet to be determined
Location of spoils	Adjacent to the quarry area	Adjacent to the quarry area

34. The limestone quarry will only be used if necessary. The current intention is to use limestone excavated from the headrace tunnel to the fullest extent possible for concrete aggregate. Its location is shown in Figure 2.5 and the location of the proposed gneiss quarry in Figure 2.6.

Figure 2.5: Proposed Location of the Limestone Quarry Site

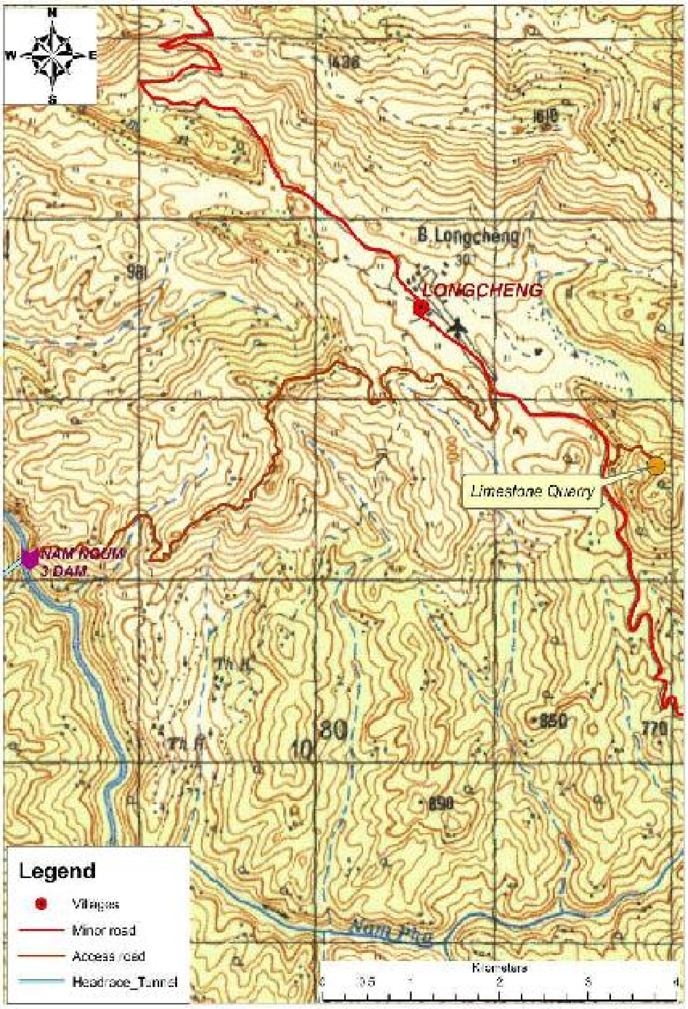
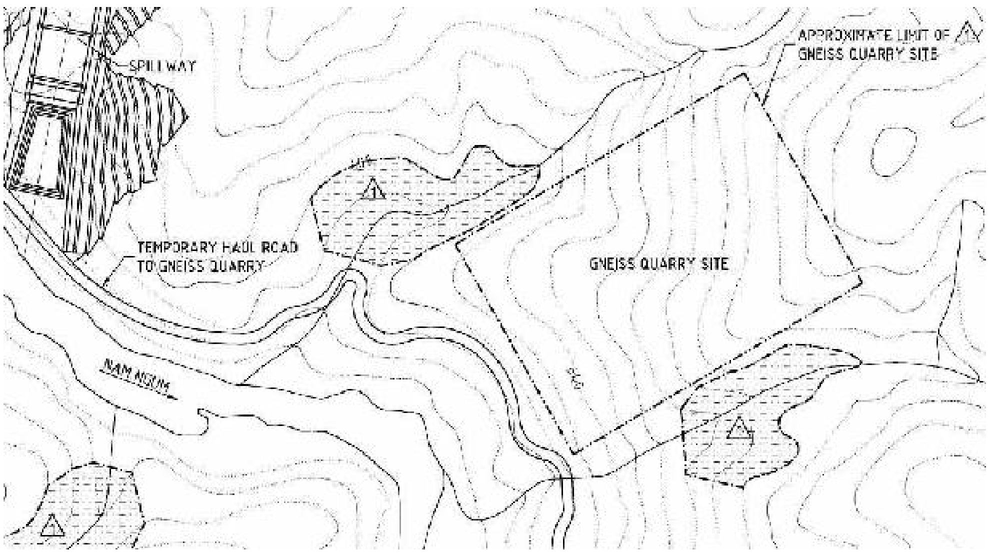


Figure 2.6: Proposed location of the gneiss quarry site (downstream of the dam site)



4. Spillway

35. The spillway is located on the left abutment adjacent to the CFRD and has the following characteristics (Table 2.4):

Table 2.4: Spillway Main Characteristics

Type	Gated ogee crest with lined chute and flip bucket
Size of radial gates	15 m width by 17 m height
Number of radial gates	3
Crest level	El 707 m a.s.l.

36. The flood routing study has given the following results (Table 2.5). An hydraulic model testing of the spillway will be carried out at the early stage of the construction.

Table 2.5: Flood routing study

Flood	Gates in operation	Flood inflow (m3/s)	Flood outflow (m3/s)	Max reservoir water level
10,000 yr	2	6,316	4,768	726.65
PMF	3	12,137	9,352	729.94

37. Based on reservoir simulation using 35 years of daily records from 1972 to 2006, spills from the reservoir occurred about 54% of the years, and normally in August (10 years) and September (15 years) lasting from a few days to several weeks; normally the magnitude of the spill may range from very small to over 1,000 m^3/s. [2]

5. Reservoir

38. NN3 reservoir will be narrow, long and deep. The reservoir storage capacity will be 1,411 million m^3 at Full Supply Level (FSL). Its active storage (water that will be available for power production) will be 1,070 million m^3. The reservoir is designed with the FSL at 723 masl. At this level the total surface area of the reservoir will be 27.5 km^2. The Minimum Operation Level (MOL) will be at 660 masl at which level the reservoir will cover a surface of 9.5 km^2. The longitudinal profile of the reservoir is presented in Figure 7.5.

Table 2.6: Surface and storage capacity of the reservoir at different levels.

	Surface area (km^2)	Storage capacity (MCM)
Full supply level (FSL) at EL 723 m a.s.l.	27.5	1,411
Minimum operating level (MOL) at EL 660 m a.s.l.	9.5	337
Maximum water level (PMF) at 729.94 m a.s.l.	31.9	1631

39. The maximal drawdown of NN3 reservoir is 63 m. The reservoir mean depth is 51.3 m. The rate of sediment transport within the NN3 catchment of the Nam Ngum River Basin shows that the lifetime of NN3 reservoir is at least 76 years in a worst-case scenario (see Table 4.5).

40. Figure 2.7 shows the extent of the reservoir at different water levels.

2 During the nine low flow years spanning from 1985 to 1993, the reservoir simulation did not show spill.

41. NN3 reservoir will be filled during the rainy season of 2016. The estimated reservoir filling time is 3 months. The average water retention time during operation will be 4.2 months.

42. The reservoir level – area – volume curve is presented on Figure 2.8.

Figure 2.7: NN3 Reservoir extent at different water levels

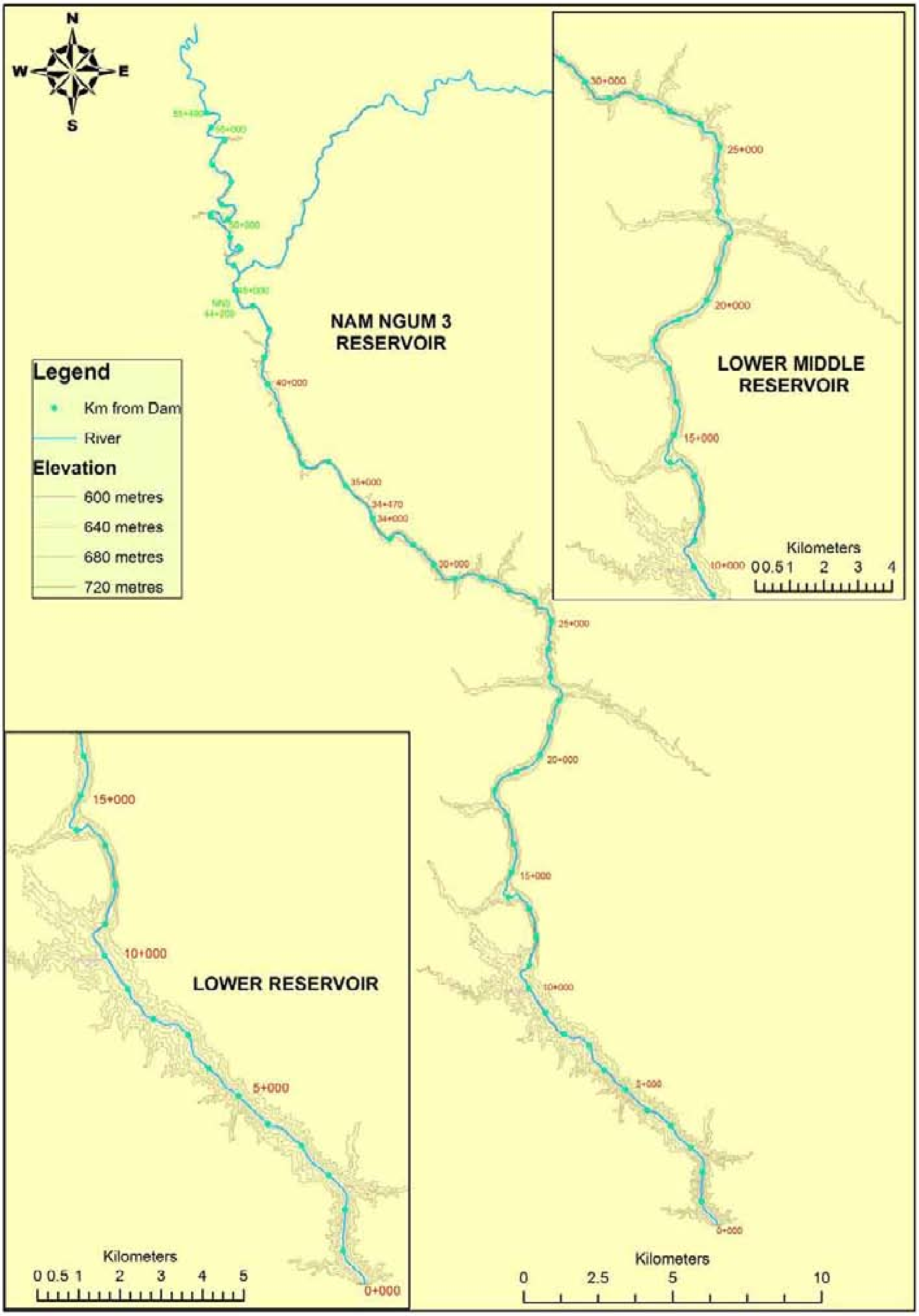
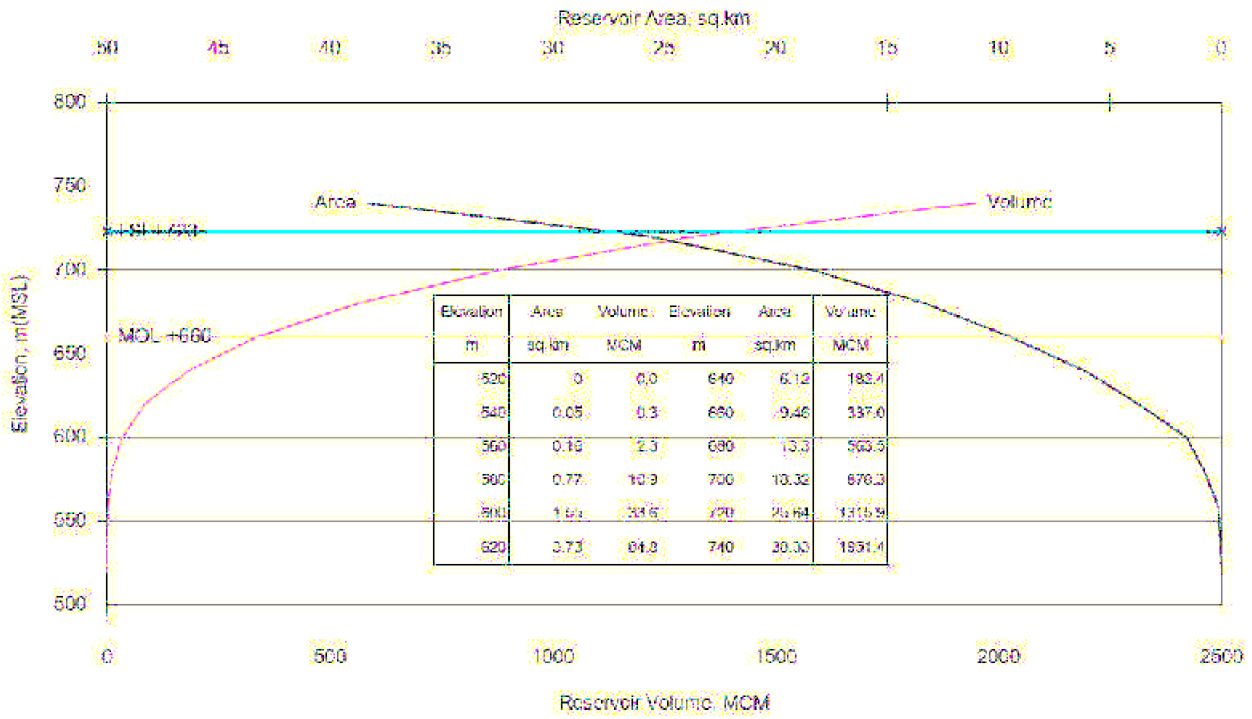


Figure 2.8: NN3 Reservoir Level – Area – Volume Curve



6. Power conduit intake and underground waterways

43. At the dam, water will be withdrawn from the hypolimnion of NN3 reservoir by a 20 m high, submerged concrete structure with trashracks and a 85 m high gate shaft some 140 m into the headrace tunnel from the intake. The invert level of the intake is 645 masl. Water from the reservoir hypolimnion will be channelled by a 10.6 km headrace tunnel to the power station, where the water will be discharged in the Nam Ngum River.

44. The main characteristics of the power conduit intake are summarised in Table 2.7.

Table 2.7: Power Conduit Intake (intake structure and gate shaft)

Intake structure	
Design Discharge	163 m^3/s
Height of Structure	20 m (to operating platform)
Inlet Sill Level	EL 645.0
Operating Platform Level	EL 665.0
Minimum Operating Level	EL 660.0
Gate shaft	
Height of Structure	85.67 m (to operating platform)
Inlet Sill Level	EL 644.33
Operating Platform Level	EL 730.0
Minimum Operating Level	EL 660.0

45. The main characteristics of the power conduit are summarised in Table 2.8.

Table 2.8: Underground Waterways

Headrace tunnel	Concrete lined circular tunnel	7.5 m inner diameter	10.6 km length	15.4 m head loss at maximum load	
Surge shaft	Restricted orifice, vertical open offset	14.0 m inner diameter	205.3 m height above tunnel crown	763.36 m asl max upsurge level	614.20 m asl min downsurge level
Pressure shaft	Concrete lined circular shaft	7.5 m inner diameter	245.356 m length		
High pressure tunnel	Steel lined tunnel	5.5 m inner diameter	117.20 m length		
Penstock & bifurcation	Horizontal steel lined	5.55 inner diameter to bifurcation 2 x 4,6 m inner diameter after bifurcation	192.2 m length		
Draft tunnel	Concrete lined circular tunnel	6.5 m inner diameter			
Tailrace surge chamber		9.5 x 46.5 x 37.5 m		Max surge level 399.82 m asl	Min downsurge level 373.84 m asl
Tailrace tunnel	Concrete lined circular tunnel	7.5 m inner diameter	923.6 m length		

46. Most of the excavated rock from the tunnel excavation will be suitable for the dam embankment. The excavated rock from the upstream part of the waterway will be placed at the dam. The excavated rock from the intermediate section will be disposed off at the approved disposal areas. The rock excavated from the downstream portion of the waterway is mainly the limestone with some granite. These rocks will be stockpiled and used as concrete aggregate for the concrete lining in the tunnel and in the powerhouse. Rock excavated from the powerhouse cavern and transformer hall is mainly limestone and will also be used as concrete aggregate for the concrete lining of the tunnel and the powerhouse.

7. Power Station

47. An underground power station will be sited on the right bank of Nam Ngum River 15.5 km downstream of the dam, in a cavern of the following dimensions: 26 m wide, 95 m long and 48 m high. The transformer hall will also be underground, in a cavern 20.5 m wide, 69.6 m long and 13.5 m high. The switchyard will be of a conventional outdoor type with double bus single breaker and will occupy an area of 120 m by 157 m.

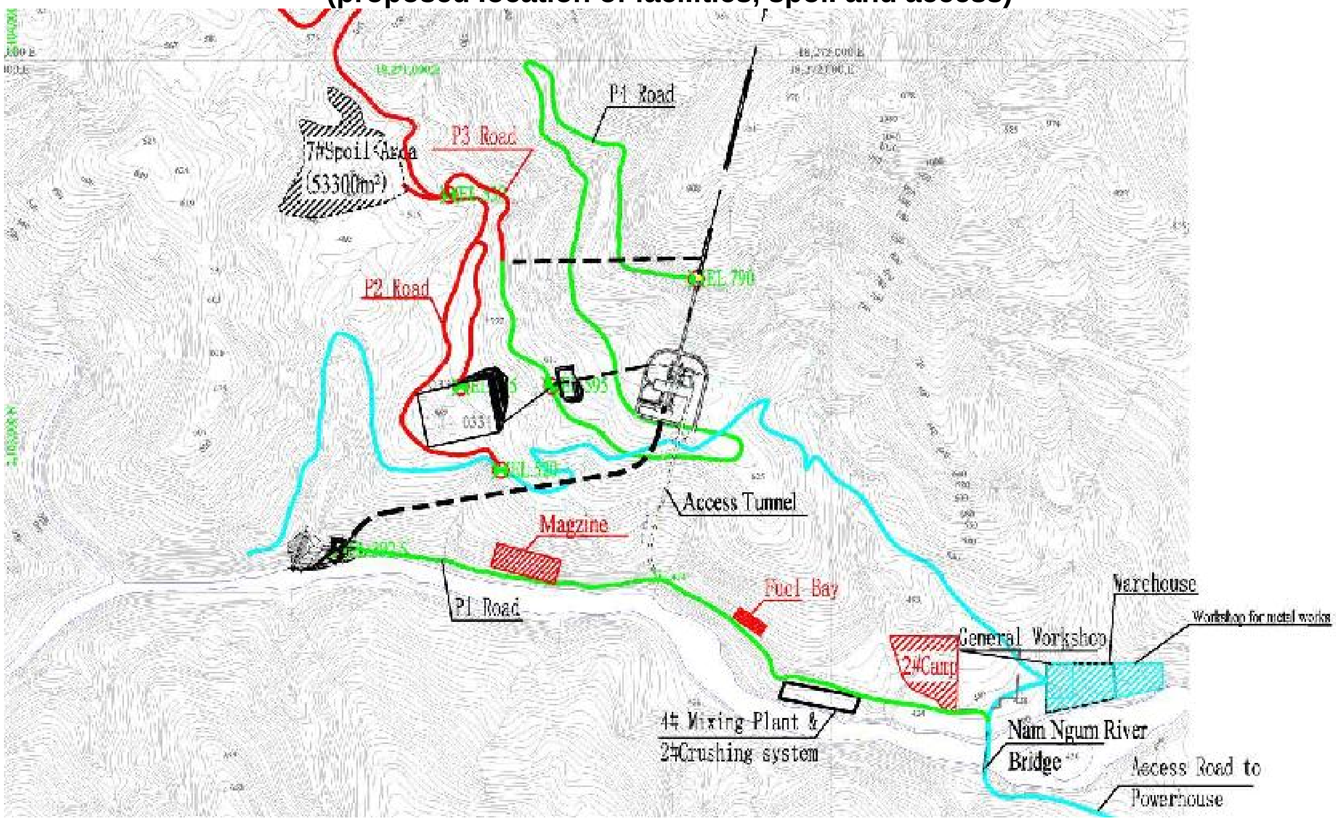
48. The power station will consist of two Francis turbines with a rated capacity of 220 MW each. Maximum power ranges between 360 MW at MOL to 460 MW above 710.5 masl. On average, 2,128.8 GWh of energy will be generated in a year, consisting of 1,929 GWh of primary energy, 151 GWh of secondary energy and 48 GWh of excess energy, as detailed in Table 2.9.

Table 2.9: Monthly energy generation based on daily flow (GMS 2009)

Month	Flow released from PH m^3/s	Average Reservoir levels	Energy generation, GWh			
			Primary	Secondary	Excess	Total
Jan	83.2	707.8	171.5	0.0	0.0	171.5
Feb	84.9	700.3	156.0	0.0	0.0	156.0
Mar	84.8	690.2	166.1	0.0	0.0	166.1
Apr	80.3	679.5	147.0	0.0	0.0	147.0
May	80.1	670.5	145.5	0.5	0.1	146.1
Jun	90.9	670.7	145.0	10.1	2.9	158.1
Jul	103.2	691.2	161.2	24.3	8.1	193.6
Aug	113.1	712.3	174.4	39.2	14.7	228.3
Sep	117.1	719.0	169.7	48.2	17.4	235.3
Oct	96.6	719.9	171.5	28.0	5.1	204.6
Nov	75.4	718.1	153.8	0.7	0.0	154.5
Dec	79.7	713.8	167.0	0.0	0.0	167.0
Total			1,928.8	151.1	48.4	2,128.3
% Energy			90.6	7.1	2.3	100

49. The proposed layout at the power station construction site is presented on Figure 2.9.

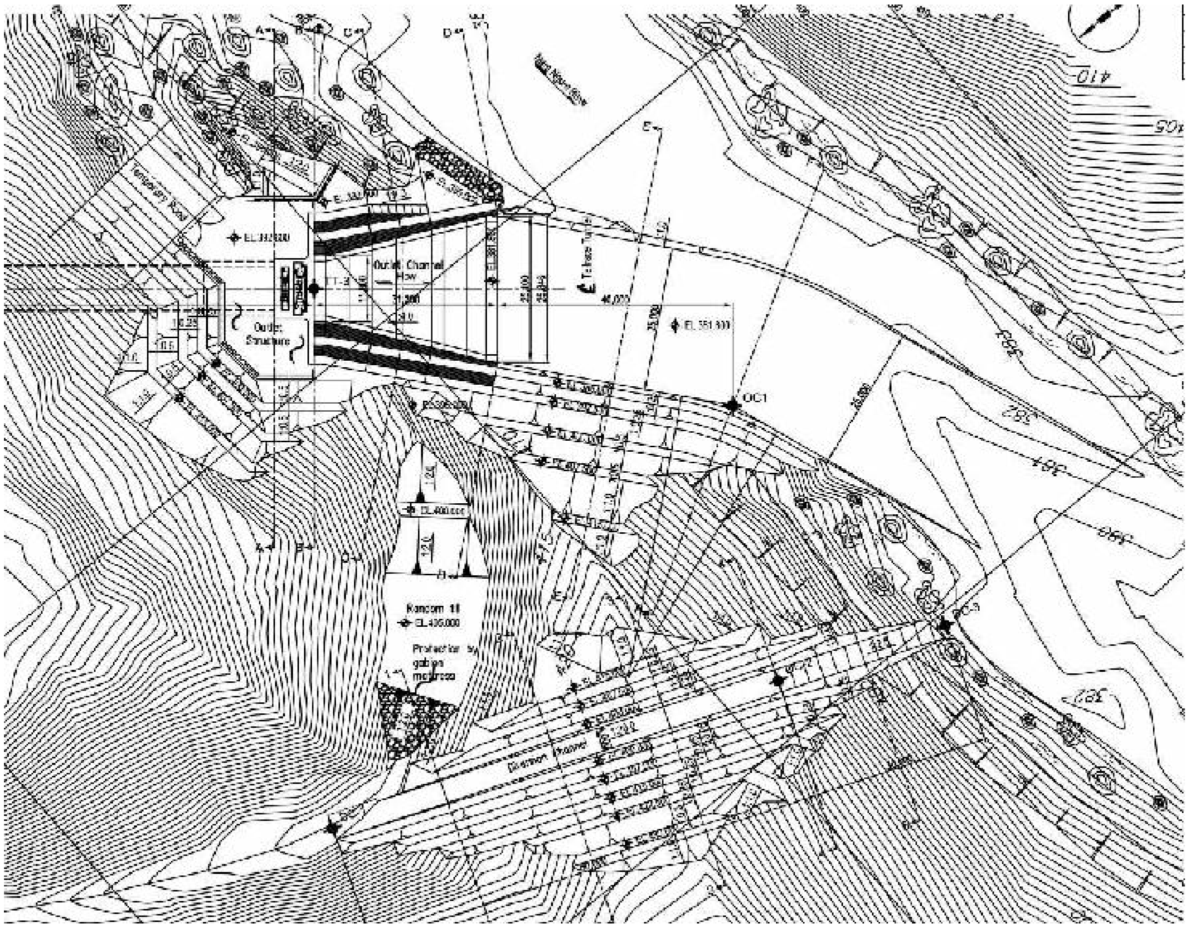
Figure 2.9: Proposed site layout at the power station site (proposed location of facilities, spoil and access)



8. Tailrace

50. The outlet structure discharges and redirects the flow from the tailrace tunnel into the Nam Ngum River as presented on Figure 2.10. The water discharge will occur in an area with rocky and steep banks. The distance from the NN3 tailrace to the NN2 reservoir fluctuates from 0.9 km to 3.7 km, depending on the NN2 reservoir water level.

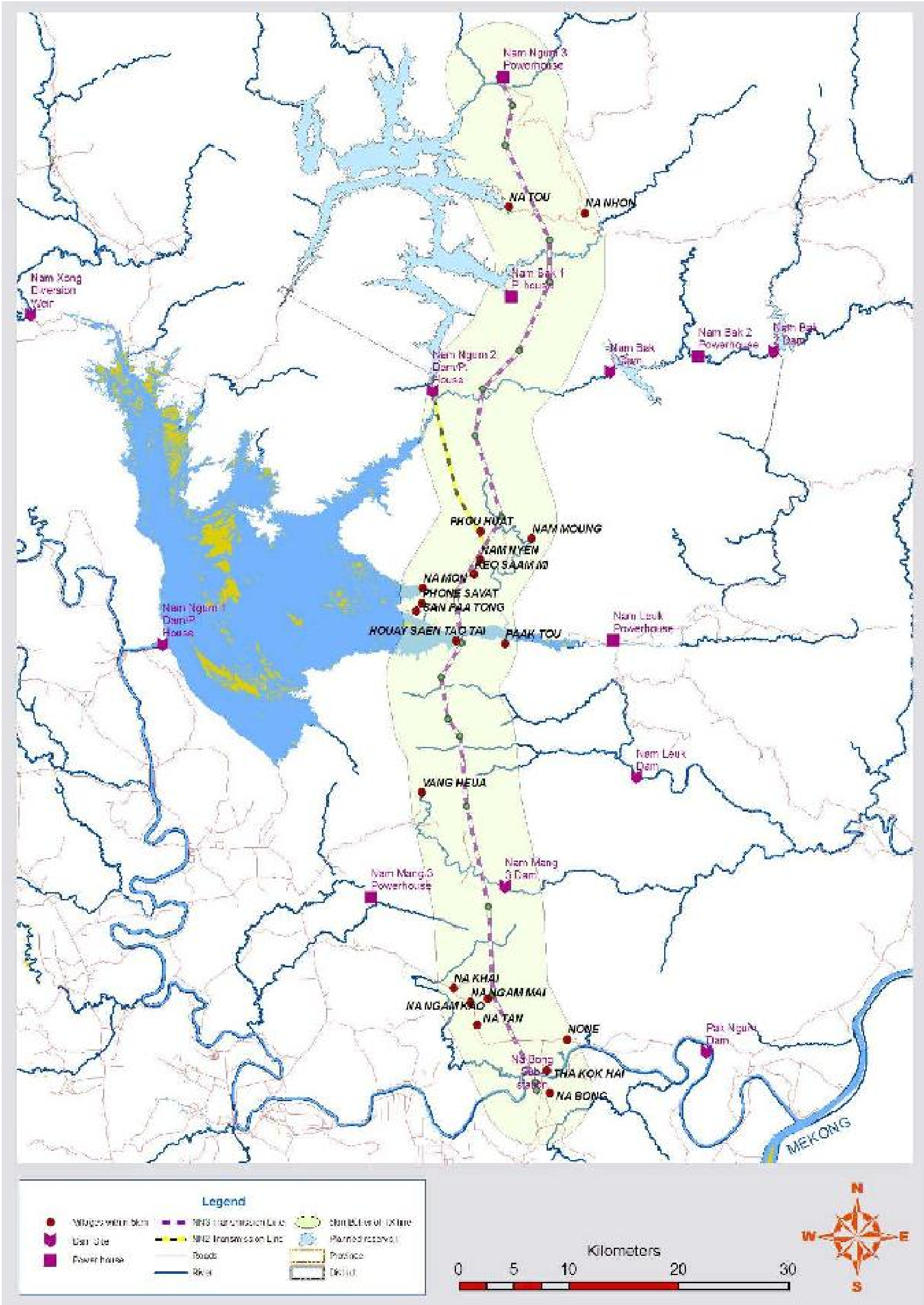
Figure 2.10: Tailrace Tunnel Outlet Structure



9. Transmission Line

51. The double circuit on single tower 500 kV transmission line, will connect the switchyard at the NN3 power station to the Nabong substation. The length of the transmission line will be 99 km (Figure 2.11). From Nabong substation the electricity will be transmitted to Thailand.

Figure 2.11: NN3 Transmission Line corridor



10. Nabong substation

52. Unlike the NN3 Project and the other power projects built or intended to be built within the Nam Ngum river basin or in close proximity, most power projects dedicated to exporting power to Thailand have each built their own project specific transmission lines to interconnect to the EGAT System. EGAT is no longer willing to accept power from multiple power projects with their own project specific transmission lines across the Mekong River interconnecting to the EGAT system. EGAT and the GOL have agreed to have only one transmission interconnection between Lao PDR and Thailand across the Mekong River for power projects within the Nam Ngum river basin.

53. The 500 kV Nabong substation, located at Ban Nabong, 40 kilometers NE of Vientiane Capital, will become over time interconnected with multiple power projects and then deliver power to the EGAT system by means of a 500 kV transmission line between the Nabong Substation and EGAT's Udon Thani Substation.

54. The 500 kV line between the existing NN2 Nabong 230 kV switching station and the EGAT Udon Thani 3 Substation is presently in service, operating at 230 kV. Reconfiguration of each end of the 500 kV line (Nabong and Udon Thani) will be necessary when the new 230/500 kV substation is constructed at Nabong to enable transmission of NN2 and NN3 power at 500 kV.

11. Access Roads

55. Two access roads connect the public road from Nam Gnone to Long Cheng with NN3 dam site and NN3 power station site. The access road to the dam site is 12 km long and the access road to the power station site is 11 km (Figure 2.2). Both roads will have a width of 10 m from shoulder to shoulder, with a carriageway of 7 m.

56. The characteristics of the temporary access roads to the dam site and the powerhouse (see Figures 2.4 and 2.9) are summarised in Table 2.10.

Table 2.10: Temporary access characteristics at dam site and powerhouse site

Road	Length (m)	Start point elevation (m)	End point elevation (m)	Width (m)	Max. slope (%)	Road type
Dam site construction area						
R1	2260	730	542	7.5 – 12	8.3	Clay bound macadam, concrete surface (800m)
R2	2710	542	730	7.5	6.9	Clay-bound macadam
R3	700	542	580	7.5	5.4	
R4	514	542	542	12	0	Concrete
R5	1108	764	588	7.5	4.7	Clay-bound macadam
R6	1367	542	630	7.5	0	
R7	1205	550	640	7.5	7.5	
R8	365	630	610	7.5	5.5	
R9	1351	633	600	7.5	2.4	
R10	1085	700	600	12	9.2	Concrete
R11	1754	730	560	7.5	9.6	Clay-bound macadam
R12	241	706.5	730	7.5	9.8	
R13	256	643	665	7.5	6.00	
R14	414	720	693	7.5	3.60	
R15	350	542	570	7.5	13.70	
R16	652	820	800	7.5	3.1	
R17	315	700	690	7.5	3.2	

Road	Length (m)	Start point elevation (m)	End point elevation (m)	Width (m)	Max. slope (%)	Road type
			Powerhouse			
P1	786	414	392.5	7.5	3	Clay-bound macadam
P2	1171	520	535	6	1.3	Asphalt concrete
P3	940	550	595	7.5	4.8	Clay-bound macadam
P4	2482	595	790	7.5	8	
P5	13270	530	700	7.5	15	
P6	66	393	392.5	7.5	0.8	
P7	683	700	670	7.5	4.3	

12. 22kV transmission line

57. At the existing substation at Thongkhoun, a 22kV transmission line will be connected to the existing 115kV transmission line. The 22kV transmission line will provide electrical power to the construction sites and will be extended to Longcheng passing by Nam Ngone, Nam Pha and Nam Xan. Transmission line poles will be erected along the access road alignments to the power station and the dam site.

C. Construction

1. Construction Material Requirement

a. Dam Embankment

58. Rock material for dam embankment (total volume of 13.3 million m^3) will come from two sources: (i) approximately 12.7 million m^3 will come from the proposed gneiss quarry located on the left bank 2 km downstream of the dam (Figure 2.6) and (ii) another 600,000 m^3 will come from the required rock excavation of the spillway located close to the dam. The spoil areas for the dam foundation excavation and quarry operation will be located adjacent to the dam site and the quarry site (see figure 2.4).

59. Geological investigations conducted in 2010 confirmed that around 38.5 Mm^3 (100 M tonnes) of bulk rock is available from the quarry, which far exceeds the requirements of the Project.

b. Material for Concrete Aggregates

60. The total concrete volume of the appurtenant structures including the concrete face slab and concrete lining is approximately 472,000 m^3.

61. Laboratory tests associated with the 2010 geological investigations included petrographic examination of three samples, and physical testing involving specific gravity analysis and abrasion tests on six samples. They concluded that the material from the gneiss quarry would be suitable not only as rockfill for the CFRD embankment material but also as concrete aggregates. The excavated limestone from the underground works will be another source of concrete aggregates for the concrete lining of the downstream portion of the headrace tunnel and the underground powerhouse.

c. Cement and Reinforcing Steel

62. The required amount of cement and reinforcing steel was estimated at 141,000 tonnes and 21,600 tonnes, respectively. They will be imported from Thailand.

d. Explosives, Fuel and Electric Power

63. The required amount of explosives was estimated at 8,910,000 kg. About 74 milllion litres of fuel and 77,000 MWh of electric power have been estimated to be required during the construction activities.

e. Truck movements

64. Truck movements for the transportation of construction material on public roads would relate to the supply of cement, steel, fuel, construction equipment, permanent plant and equipment, and food and commodities for the NN3 workforce. NN3 truck movements throughout the construction period are estimated at an average of 23 per day[3] peaking at 28 during the period 2014-2015. In addition to this, there will be a daily average of 6 light passenger vehicles and 34 light delivery vehicles during the construction period.

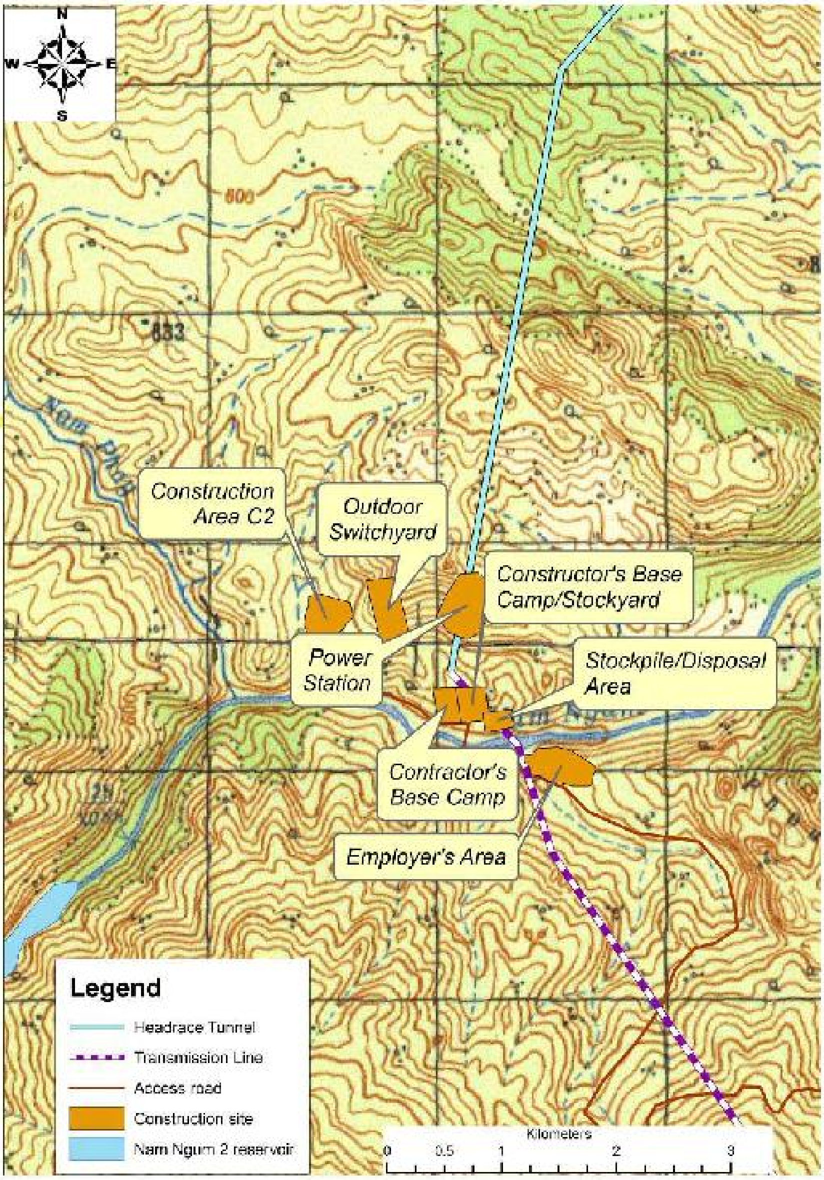
2. Main Construction Activities

65. The Company intends to award three main construction contracts (civil works, electromechanical and transmission system) and may award other supporting contracts as necessary to complete the Project. Approximately between 3,000 and 4,000 workers will be engaged in construction work over a 6-year period starting October 2011 till end 2016. The construction workers will be based at two main camps; one at the dam site and one at the power station site. Workers will also be employed for the construction of the transmission line, including the stringing, and the Nabong sub-station. Figures 2.12 and 2.13 show the location of construction sites at the dam site and the power station site. As shown on these figures, the closest village and habitations are located more than 10 km away from the construction sites.

Figure 2.12: Construction sites at NN3 Dam

[3] This represents the sum of vehicles (heavy truck, above 10T) travelling in both directions.

Figure 2.13: Construction sites at NN3 Power Station



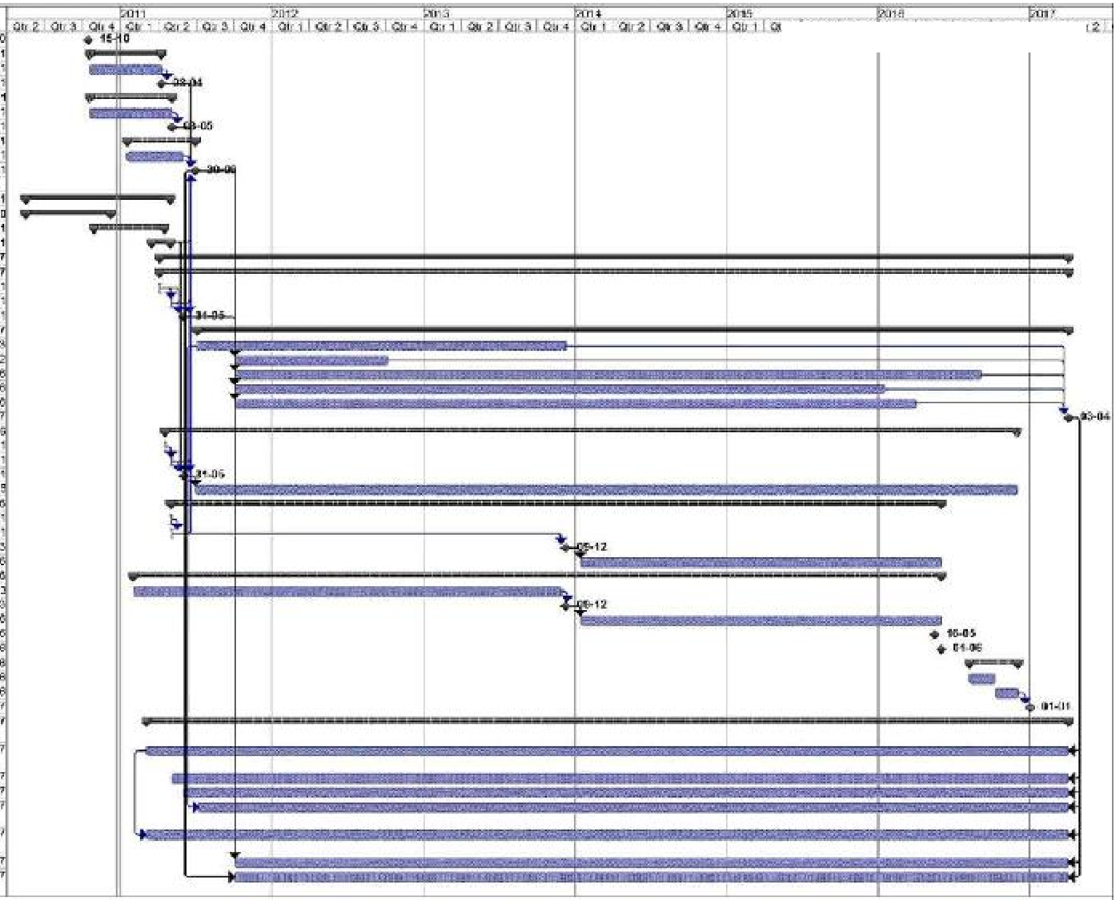
66. Under the condition that the Company fully compensate physically and/ or economically displaced persons during construction of the Project, GoL has allocated land to the Company under a Concession Agreement at project construction areas, including dam site, power station site, transmission line corridor including Nabong substation, and access roads.

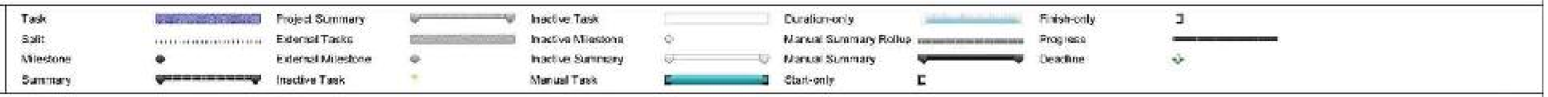
67. Electricity will also be delivered to the dam and the powerstation sites by EDL through the existing 22kV transmission line from Thong Khoun substation (see above) for which the Company will additionally compensate persons that may be affected by accidental crop damage occurring during strengthening of the 22kV transmission line.

68. Figure 2.14 shows the indicative project schedule. The project implementation schedule is however currently under review to take into consideration the short-term and long-term remedial measures that would need to be implemented to re-establish and secure reliable access to the construction sites following the damages inflicted to the site access infrastructure by the severe tropical storm that hit the area at the end of June 2011.

Figure 2.14: Indicative project schedule

ID	Task Name	Duration	Start	Finish
1	**NN3 Power Company Establishment**	0 dys	Fri 15-10-10	Fri 15-10-10
2	**Concession Agreement (CA)**	125 dys	Mon 18-10-10	Fri 08-04-11
3	CA Negotiations and Finalization	125 dys	Mon 18-10-10	Fri 08-04-11
4	CA Signed with GOL	0 dys	Fri 08-04-11	Fri 08-04-11
5	**Power Purchase Agreement (PPA)**	142 dys	Mon 18-10-10	Tue 03-05-11
6	PPA Negotiations and Finalization	142 dys	Mon 18-10-10	Tue 03-05-11
7	PPA Signed with EGAT	0 dys	Tue 03-05-11	Tue 03-05-11
8	**Financing Documents & Financial Close**	118 dys	Mon 17-01-11	Thu 30-06-11
9	Negotiate and Sign Financing Documents	97 dys	Mon 17-01-11	Tue 31-05-11
10	Financial Close	0 dys	Thu 30-06-11	Thu 30-06-11
11				
12	**Tendering Process and Approval**	250 dys	Mon 17-05-10	Fri 29-04-11
13	**Tendering**	147 dys	Mon 17-05-10	Tue 07-12-10
17	**Tender Evaluation and Negotiation**	121 dys	Fri 29-10-10	Fri 15-04-11
26	**Lenders Approval**	33 dys	Wed 16-03-11	Fri 29-04-11
30	**NN3 Construction**	1568 dys	Mon 04-04-11	Mon 03-04-17
31	**Contract C2 Civil Works**	1568 dys	Mon 04-04-11	Mon 03-04-17
32	Letter of Acceptance	1 dy	Mon 04-04-11	Mon 04-04-11
33	Contract Signature	1 dy	Mon 02-05-11	Mon 02-05-11
34	Notice to Commence	0 dys	Tue 31-05-11	Tue 31-05-11
35	**Construction Works**	1503 dys	Mon 04-07-11	Mon 03-04-17
36	Mobilization and Site Preparation Works	637 dys	Mon 04-07-11	Mon 09-12-13
37	River Diversion Tunnel	268 dys	Mon 03-10-11	Fri 05-10-12
38	Dam & Spillway	1287 dys	Mon 03-10-11	Mon 05-09-16
39	Underground Waterway	1121 dys	Mon 03-10-11	Fri 15-01-16
40	Underground Powerhouse Complex	1175 dys	Mon 03-10-11	Thu 31-03-16
41	Overall Completion of Civil Works	0 dys	Mon 03-04-17	Mon 03-04-17
42	**Contract C4 Electromechanical Works**	1469 dys	Mon 18-04-11	Wed 30-11-16
43	Letter of Acceptance	1 dy	Mon 18-04-11	Mon 18-04-11
44	Contract Signature	1 dy	Mon 02-05-11	Mon 02-05-11
45	Notice to Commence	0 dys	Tue 31-05-11	Tue 31-05-11
46	Construction Works	1416 dys	Thu 30-06-11	Wed 30-11-16
47	**Contract C5 Transmission System**	1328 dys	Mon 02-05-11	Wed 01-06-16
48	Letter of Acceptance	1 dy	Mon 02-05-11	Mon 02-05-11
49	Contract Signature	1 dy	Tue 03-05-11	Tue 03-05-11
50	Notice to Commence	0 dys	Mon 09-12-13	Mon 09-12-13
51	Construction Works	622 dys	Mon 13-01-14	Wed 01-06-16
52	**Nabong Substation**	1393 dys	Mon 31-01-11	Wed 01-06-16
53	Tendering and Contract Award	740 dys	Mon 31-01-11	Thu 28-11-13
54	Notice to Commence	0 dys	Mon 09-12-13	Mon 09-12-13
55	Construction Works	622 dys	Mon 13-01-14	Wed 01-06-16
56	**Reservoir Filling**	0 dys	Mon 16-05-16	Mon 16-05-16
57	**500 kV Transmission Line Energizing Date**	0 dys	Wed 01-06-16	Wed 01-06-16
58	**Plant Comissioning**	85 dys	Mon 08-08-16	Fri 02-12-16
59	Unit 1	45 dys	Mon 08-08-16	Fri 07-10-16
60	Unit 2	40 dys	Mon 10-10-16	Fri 02-12-16
61	**COD**	0 dys	Sun 01-01-17	Sun 01-01-17
62	**Environmental and Social Activities - Construction Phase**	1589 dys	Fri 04-03-11	Mon 03-04-17
63	Environmental Management, Coordination & Communication	1589 dys	Fri 04-03-11	Mon 03-04-17
64	Integrated Watershed Management	1546 dys	Wed 04-05-11	Mon 03-04-17
65	Water Quality Management and Monitoring	1526 dys	Wed 01-06-11	Mon 03-04-17
66	Construction Phase E&S Monitoring and Management	1499 dys	Fri 08-07-11	Mon 03-04-17
67	Social Management, Coordination and Communication	1589 dys	Fri 04-03-11	Mon 03-04-17
68	Ban Xiengdet Resettlement and Development	1436 dys	Mon 03-10-11	Mon 03-04-17
69	Social Surveys, Monitoring, Resettlement Action Plans and Compensation	1436 dys	Mon 03-10-11	Mon 03-04-17





3. Preliminary Construction Activities

69. Preliminary construction activities have been undertaken before the start of main construction activities to the extent allowed by the meteorological conditions in the 2011 rainy season. They have been suspended at the end of June 2011 when a severe tropical storm hit the area impacting seriously the access infrastructure. The scope of the PCA included the preparation of camps and offices facilities, maintenance areas, upgrading of access to the dam site and power station site. Part of this work was lost during the tropical storm. PCA are subject to the preparation of a dedicated Environmental Management and Monitoring Plan, which include the necessary re-vegetation and landscaping upon completion.

70. The land where these facilities are located are government land and are not occupied or used by local population.

D. Commissioning Tests and Trial Runs

71. The 500 kV transmission line from NN3 to the Nabong Substation shall be completed and energized by May 2016 after which, the impoundment of NN3 will commence. The erection and installation of the first and second unit of turbine and generator are scheduled to be completed and ready for commissioning in June and August 2016 respectively.

72. The commissioning shall be done according to the requirements of NN3 and the PPA and witnessed by EGAT representative. The commissioning of each unit shall include tests to verify the compliance with the contracted operating characteristics and unit trial run test for a continuous period of 72 hours, which comprises continuous operation test and start-stop test as required in the PPA. The commissioning of the first and second units are scheduled to be completed in August and September 2016 respectively.

73. The two units will also have to complete the global trial run test and required to achieve stable operation for a period of four hours. EGAT will issue the certificate of readiness for operation for both units when the global trial run and other tests are achieved, and will thereafter dispatch the two units into EGAT grid. The completion of the commissioning of the two units shall be in October 2016, two months ahead of the commercial operation date.

E. Operation

74. The Commercial Operation Date is planned to be on 1st January 2017 as specified in the PPA. The concession period is 27 years. The power station will operate on a daily basis in an intermittent mode (8 to 16 hours power generation every day of the week, except Sundays and Thai holidays, when normally no power will be required). The production mode will depend on the actual availability of water in the reservoir and dispatches by EGAT. The average annual energy production is estimated to be 2,128 GWh (see Table 2.9).

75. Under the condition that the Company fully compensate physically and/ or economically displaced persons during operation of the Project, GoL has allocated to the Company the reservoir area.

F. Main Project Features

76. Table 2.11 summarizes NN3's main features.

Table 2.11: Main features of the NN3 Hydropower Project

Feature	Value
Dam	
Height	220 m
Catchment Area	3,769 km²

Feature	Value
Average River Discharge at Dam Site	96.5 m^3/s
Reservoir	
Reservoir Filling Time	3 months
Full Supply Level (FSL)	723 masl
Minimum Operation Level (MOL)	660 masl
Surface Area at FSL	27.5 km^2
Surface Area at MOL	9.5 km^2
Mean Depth	51.3 m
Volume at FSL	1,411 MCM
Active Storage	1,070 MCM
Average Water Retention Time	4.2 months
Invert Level Hypolimnetic Withdrawal	645 masl
Headrace Tunnel	
Length from Dam to Power Station	10.6 km
Power Station	
Downstream Distance from Dam	15.5 km
Total Installed Capacity	440 MW
Average Annual Energy Production	2,128 GWh
Transmission Lines	
Length of 500 kV Transmission	99 km
Access Roads	
Length from Public Road to Power Station	Approx. 12 km
Length from Public Road to Dam	Approx. 11 km
Commercial Operation Date	January 2017
Concession Period	27 Years

G. Project Impacted Areas

77. In addition to the tunnel, the transmission line and the various access roads and tracks, the main construction sites are located at the dam (Figure 2.4) and the power station (Figure 2.9). The area impacted by the Transmission Line is presented in Figure 2.11.

78. Impacts by the NN3 reservoir and fluctuations of its level are anticipated at the village of Ban Xiengdet and four “peri-reservoir” villages (Nam Sam, Xieng Nga, Xam Thong, and Long Cheng). They are located on Figure 2.15. The village of Ban Xiengdet will be relocated a few kilometres away from its current location. This is presented in details in the REMDP and summarised in section 6 of this document. Potential seasonal flooding of governmental lands will take place at the four “peri-reservoir” villages. No residential, or agricultural lands owned by villagers will be impacted as they are located at a significant distance from the future reservoir (see Figure 2.15).

Figure 2.15: Main villages located around the NN3 Reservoir

III. ANALYSIS OF ALTERNATIVES

A. Power Development Priorities and Goals

79. Lao PDR is the country in the Lower Mekong Basin with the largest hydropower potential. Only a small percentage of this potential is yet developed. The only other significant power resource available in the country is coal.

80. The policy of Government of Lao PDR is to develop these resources for the benefit of the country through the two primary strategies:

(i) To provide reliable and affordable power to cover the national demand and thereby promote economic and social development.
(ii) To develop part of the hydropower potential to generate export income for the country by selling power to neighbouring countries.

B. Power Export

81. Bilateral trading of power is already well developed in the region and Lao PDR has been a "pioneer" in this trade.

82. Various forecasts for the power demand in the Greater Mekong Sub-region (GMS) show high figures. The reason for this is primarily a large, unsatisfied need for more energy in Thailand. The main candidates for future supply to Thailand are:

(i) Import of hydropower from Lao PDR, Yunnan Province of PRC and Myanmar.
(ii) Thermal plants based on imported coal.
(iii) Combined cycle gas plants based on domestic and imported gas.

83. Environmental concerns and the ongoing worldwide climate change make the use of coal questionable. According to EGAT 2007 Power Development Plan natural gas will count for 66% of the energy generation by 2020. The purchase of hydropower form Lao PDR is estimated to grow from 2,140 GWh in 2007 to 16,688 GWh in 2020.

84. Regional power strategies underline cost efficiency of an integrated use of the power sources in the Greater Mekong Sub-region compared to a system dominated by each county's own sources.

85. In 2009 the prime ministers/presidents of Cambodia, China, Lao PDR, Myanmar, Thailand, and Vietnam together with the ADB president agreed upon the electricity generation and transmission development between the countries in the Greater Mekong Sub-region. The development of Nam Ngum hydropower cascade is an important part of this agreement.

C. Ranking of Hydropower Development Alternatives

86. The hydropower sector appears to be one of the most thoroughly planned sectors in Lao PDR from an economic and technical viewpoint. With the support of international financing institutions the following 6 hydropower ranking studies have been carried out in Lao PDR over the last 10 years:

(i) Hydropower Development Plan for Lao PDR (HDP) in 1997;
(ii) Power System Planning in the MIH (PSP) in 1997;
(iii) Nam Theun 2: Study of Alternatives (NT2SOA) in 1998 (Lahmeyer & Worley);
(iv) Se Kong, Se San and Nam Theun River Basins Study in 1998 (Halcrow et al.);
(v) Hydropower Development Strategy Study (HDSS) in 2000 (Worley & Lahmeyer);
(vi) Power System Strategy Study (PSSS) in 2002 (Electrowatt & PA);
(vii) Power System Development Plan (PSDP) in 2004 (Meritec & Lahmeyer).

87. The studies present development scenarios for national supply and export projects based on professional judgement of the following factors:

- (i) Economics of the project and quality of the site.
- (ii) Solidity of the sponsor.
- (iii) Market conditions, including demand growth, reserve margin and political support for power trading.
- (iv) Capacity of Lao institutions to manage the implementation of multiple projects.

88. The latest of these studies included environmental and social parameters as factors in ranking and sequencing of the projects.

89. Despite the impressive initiatives for strategic planning and sequencing of the hydropower development it seems that these plans have had little influence on the real developments in the sector. Mechanisms have not been in place to sequence the project according to the economical least cost order advocated by the Master Plan studies (NORPLAN 2004).

90. Comparing the PSDP and *Electricité du Laos* power expansion plans issued in 2004 with the similar plan issued in May 2008, it can be seen that several projects which were not considered feasible in 2004 are now on the list and some even in an advanced stage of planning. This applies for instance to the Nam Ngiep 1 project and the planned projects on the mainstream Mekong. None of the coal-based power generation projects were given priority in the 2004 strategy studies. Nam Ngum 3 and Nam Ngum 2 were in the 2004 scheduled to be in operation in 2021 and 2022 respectively.

91. Several factors have caused the diversion from the recommendations in the master plans. First, there is no link between the overall plans and the decision to sign MoUs with potential developers. This has lead to a situation where the selection of projects and planning progress are to a large extent determined by the initiative of private investors. Adding to this the power demand in Thailand seems to have grown faster than expected, which has made more projects profitable.

D. NN3 Alternative Design and Location Concepts

1. Proposed locations for the dam and the power house

92. The present NN3 dam site and powerhouse location were identified in the Feasibility Study (SMEC 1995). In this study different options for dam structures, dam sites and reservoir sizes were analysed. SMEC considered 5 alternatives for NN3 dam sites, tunnels, and power stations (see Figures 3.1 & 3.2):

Alternative 1:
- Dam at damsite 1 (Upper Damsite) located 4.5 km upstream of the confluence of the Nam Ngum and Nam Pha rivers;
- Tunnel 11.5 km from damsite to power station;
- Power station upstream Nam Phay.

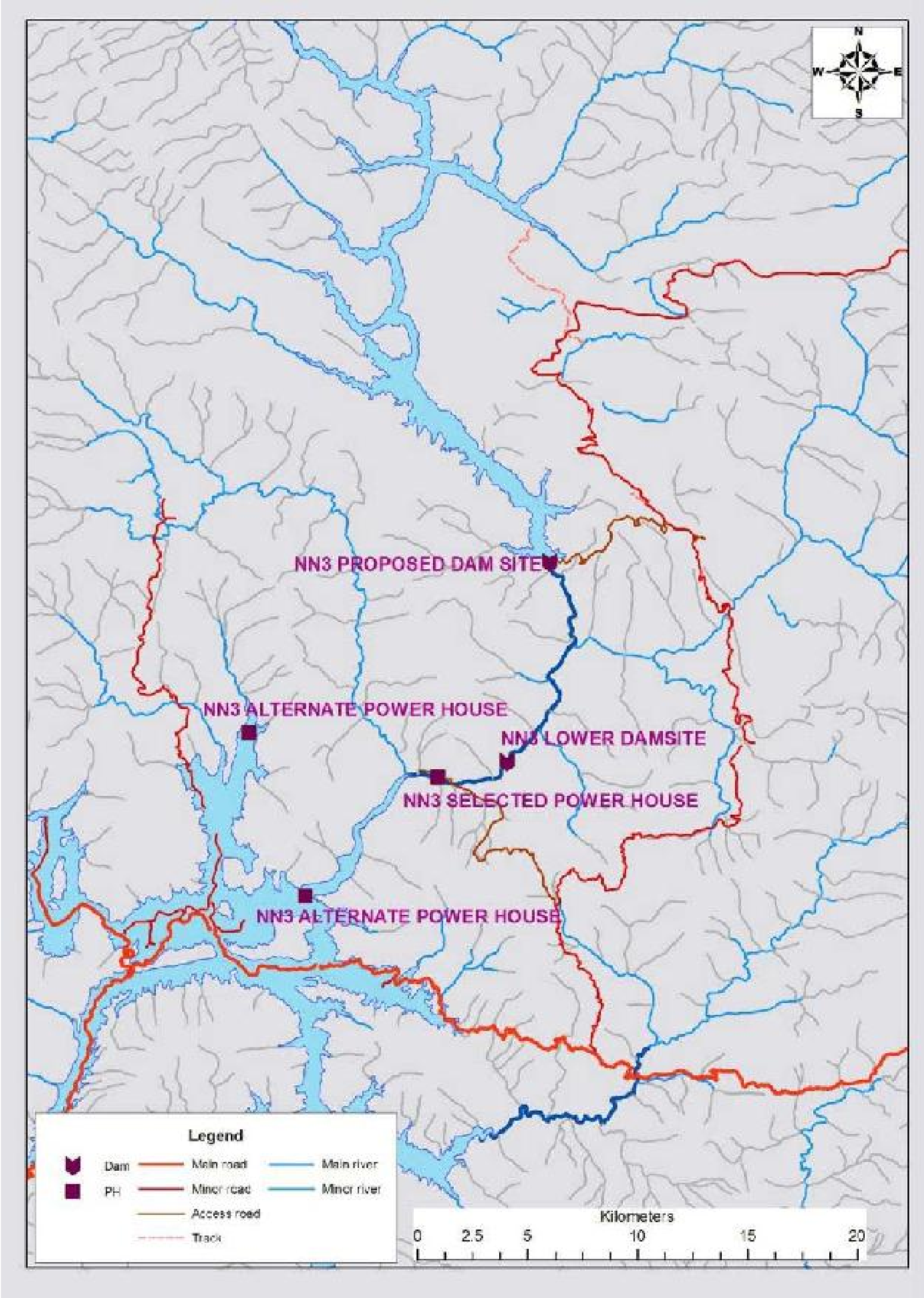
Alternative 2:
- Dam at damsite 2 located downstream of Nam Pha, upstream damsite 3;
- Tunnel 7.5 km from damsite to power station;
- Power station upstream Nam Phay.

Alternative 3:
- Dam at damsite 3 located 5 km downstream of the confluence of the Nam Ngum and Nam Pha rivers;
- Tunnel 6.0 km from damsite to power station;
- Power station upstream Nam Phay.

Alternative 4:
- Two plants scheme;
- High dam at damsite 1 (Upper Damsite) and a low dam at damsite 2;
- Tunnel 7.5 km from damsite 2 to power station;
- Power stations at dam site 1 and upstream Nam Phay.

Alternative 5:
- Two plants scheme;
- High dam at damsite 1 (Upper Damsite) and a low dam at damsite 3
- Tunnel 6 km from damsite 3 to power station;
- Power stations at damsite 1 and upstream Nam Phay.

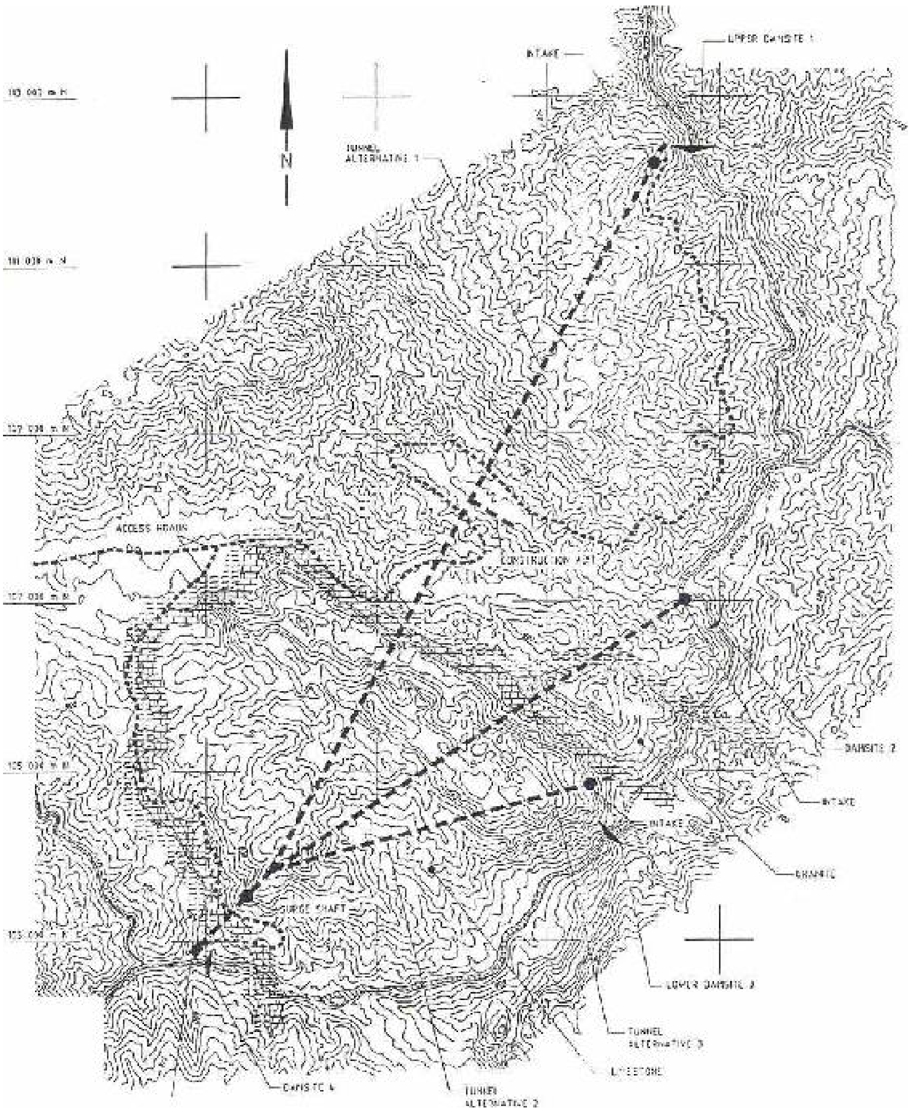
Figure 3.1: Alternative dam sites and power house locations



93. After identifying the alternatives, SMEC carried out optimization studies for the selection of the best alternative indicating the reliability of electricity supply in terms of minimum hours per day the plant can generate electricity in the worst hydrological year.

94. The reliability of electricity supply is primarily associated with the uncertainty of hydrology and the variation of the operation scenario based on monthly river discharge time series for the upper and lower dam sites from 1914 to 1994.

Figure 3.2: Alternative schemes layout (SMEC, 1995)



95. SMEC used METRO software and organized their analysis in the following steps:

(i) Define study cases for the upper damsite consisting of combinations of different installed capacity, full supply level, and minimum operation level for investigation;

(ii) Define study cases for the lower damsite consisting of combinations of different installed capacity;

(iii) Define study cases for a two powerstation layout with upper and lower dam sites consisting of combinations of different installed capacity, full supply level, and minimum operation level for investigation;

(iv) Define different operating scenarios for each study case in order to assess the quality of power supply from NN3 for varying levels of supply reliability using Stochastic Dynamic Programming;

(v) Simulate NN3 operation for the different study cases and different operating scenarios using collected hydrological data ;

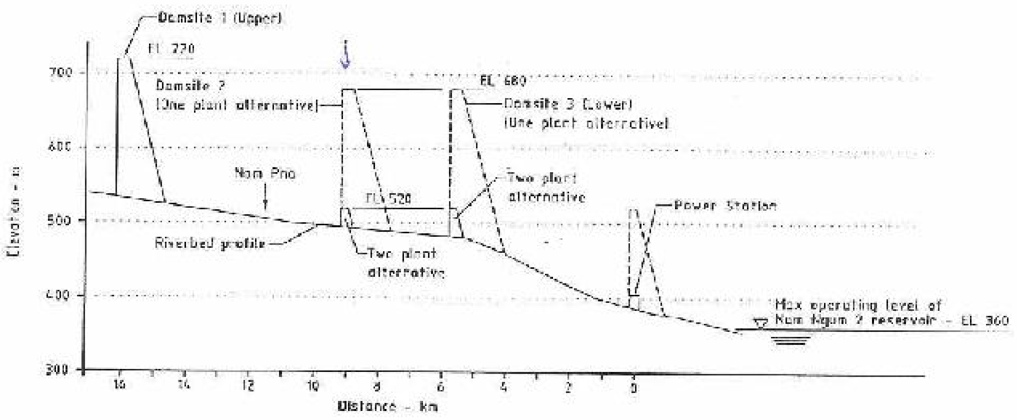
(vi) Assess the plant/reservoir performance and power export revenues on a statistical basis;

(vii) Identify for each case study, the operating scenario which gives the maximum energy output;

(viii) Perform economic analysis for each study case operating on the maximum energy scenario to select the most attractive project configurations, consisting of dam site(s), installed capacity, full supply level, and minimum operating level;

(ix) Perform a detailed supply reliability assessment for the selected study cases to establish sensitivity between energy generation and minimum operating hours which would lead to the establishment of an optimum project configuration in technical terms.

Figure 3.3: River profile and proposed locations of dams



96. Based on geological, topographical, geotechnical investigations, environmental analysis, transmission options investigations, and cost and financial analyses, the Alternative 1 was presented by SMEC as the best one:

(i) Dam at damsite 1 (Upper Damsite) located 4.5 km upstream of the confluence of the Nam Ngum and Nam Pha rivers;
(ii) Tunnel 11.5 km from damsite to power station;
(iii) Power station upstream of the Nam Phay.

97. The downstream options would have implied a lower reservoir FSL, therefore avoiding the inundation of land at Ban Xiengdet. But, these alternatives site would have caused inundation of several villages located along the Nam Pha.

98. MXD also studied 2 more downstream alternatives for the power house location, based on the assumption that the NN2 reservoir level would be reduced from the initially planned FSL of 375 masl to 280 masl (Figure 3.3). As the NN2 project decided to go ahead with the FSL 375 option these new alternatives were not feasible.

2. Construction alternatives: CFR vs. RCC dam

99. A concrete faced rockfill dam (CFRD) was initially recommended. The financial crisis in 1997 changed several of the cost elements of the proposed project. In 1998 a supplementary study was carried out (MXD 1998) and recommended a change from a CFRD to a roller compacted concrete dam (RCCD). This option was however abandoned later and the final design presents a CFRD.

100. A CFRD has been adopted, in preference over the option of a RCCD, as consequence of the following considerations:

(i) Potential problematic foundation conditions for the RCCD option, including the depth of weathering of the foundation rock on both abutments, the characteristic of the alternating soft siltstone and mudstone on the right abutment, and the open fault zone just downstream of the location of the RCCD.
(ii) Construction of RCCD is more complicated and needs much better rock foundation than that needed for the CFRD option (see above).
(iii) The RCCD option requires greater excavation and larger area for the disposal of waste material than is needed for a CFRD.

(iv) The RCCD option would also require importation of a very large volume of construction material, including cement, fly-ash and steel. Such importation would involve a large number of truck movements each day on the long and narrow access road from Ban Thabok to the dam site, thereby increasing road safety risks to the other users of the road, particularly on the public road between Ban Thabok and Ban Long Cheng.

(v) The CFRD plinth slab can be located on moderately weathered rock foundation, and the CFRD dam embankment can be constructed on firm ground.

(vi) Construction of the CFRD is simpler than for the RCCD option. Most of the construction material will be exploited near to the dam site.

(vii) Following receipt and evaluation of tenders for both the CFRD and RCCD options, the CFRD option was shown to be significantly lower in cost than the RCC dam alternative.

101. The CFRD option has more advantages in terms of geology and is inherently more stable in terms of resistance to seismic forces, but has some disadvantage compared with the RCC dam option in the unlikely event of the dam being overtopped. Consequently, very careful review of the Nam Ngum hydrology and the spillway capacity has been undertaken to ensure the safety of the CFRD.

E. Environmental Flow

1. Background

102. The 1996 NN3 feasibility study recommended a riparian outlet be constructed through the left abutment of the dam, with a capacity to release 15 m^3/s with a reservoir at 660 m. The functions assigned to the riparian release, at a time when the NN2 project was not under consideration, were to compensate for times the power station is not in operation and to periodically “flush-out” the river between the dam and the power station in the dry season.

103. This recommendation was later revisited by RMR with a detailed study of the ecological and economic values of the water in the reach downstream of the dam (Chapter 7 of RMR Studies). The analysis discussed the costs and benefits of a minimum riparian release at the NN3 dam of 15 m^3/sec. It showed that from a technical, environmental and economic point of view, this release would result in only a slight mitigation of downstream water quality and water flow impacts, and concluded that such a release could not be recommended. Lao PDR has no requirements regarding a minimum riparian release and environmental flow. The construction of the NN2 project, between NN1 and NN3, and the associated resettlement of the NN2 impacted villages to a location outside of the area, since this assessment was made, has further confirmed this analysis.

2. Stretches of the river impacted

104. Figure 3.4 shows the Nam Ngum river stretch between the NN3 dam and the NN2 reservoir. It is made of a first stretch of 15.5 km from the NN3 dam site to the tailrace of the NN3 power station, and then of a stretch of about 1.3 km from the NN3 tailrace to the confluence with the Nam Phay, which corresponds to the FSL of the NN2 reservoir at some periods of the year. This length changes over the months with the fluctuations of the level of the NN2 reservoir.

Figure 3.4: Flow Diversion Area Downstream NN3 Dam

105. The 15.5 km between the NN3 dam site and the NN3 tailrace can be decomposed in a 4.8 km stretch from the dam site to the confluence with the Nam Pha; and a 10.7 km stretch from the Nam Pha confluence to the NN3 tailrace.

106. The first 4.8 km stretch of the Nam Ngum River between the NN3 dam site and the confluence with the Nam Pha is made of a succession of rapids, pools and sand bars. The river is joined by a number of small ephemeral streams but most of the flow comes from upstream, and a limited portion from ground water.

107. At the confluence with the Nam Pha, the morphology of the river bed and bank is unchanged and the flow is increased by the contribution of the Nam Pha, a perennial river. The feasibility of a new 5 MW run-of-river hydropower project is being considered in the watershed of the Nam Pha. If the development and the construction are confirmed, it will impact the natural discharge of water in the Nam Ngum River in a way that is not yet known.

108. In the 10.7 km long Nam Ngum River stretch between the Nam Pha confluence and the NN3 tailrace, additional perennial and ephemeral rivers and streams, rainfall, and ground water add to the Nam Ngum natural monthly discharges. The morphology of the riverbed and banks is similar to upstream stretches.

109. The perennial river Nam Phay joins the Nam Ngum, 1.3 km downstream of the NN3 tailrace, which happens to be directly into the NN2 reservoir during some periods of the year, and otherwise slightly upstream of the NN2 reservoir.

110. The natural average monthly Nam Ngum discharges at the NN3 dam site is shown on Figure 3.5 below and the average monthly discharges into the NN2 reservoir, with and without the NN3 project, are presented on Figure 3.6.

Figure 3.5: Natural Average Monthly Nam Ngum Discharges at the NN3 Dam Site

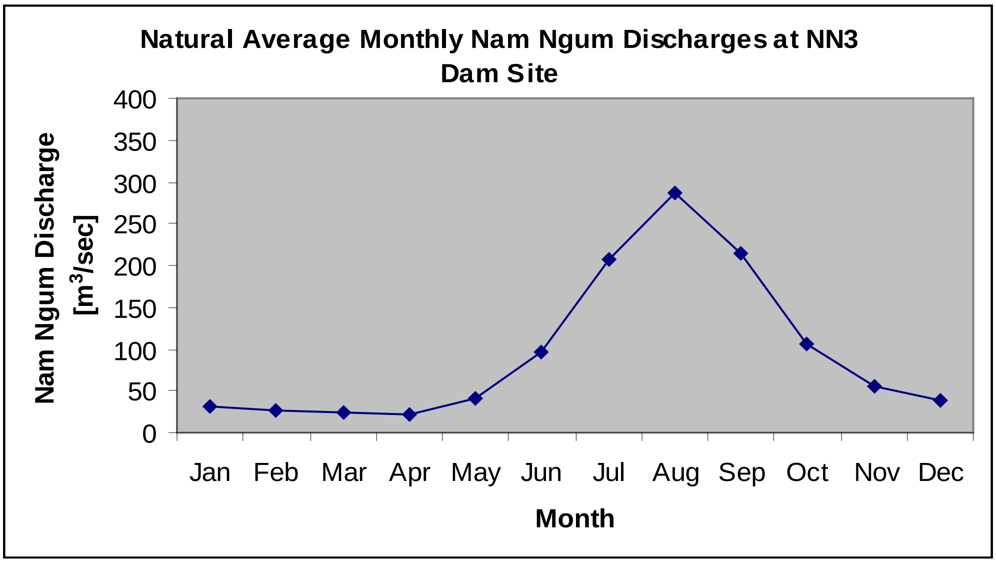
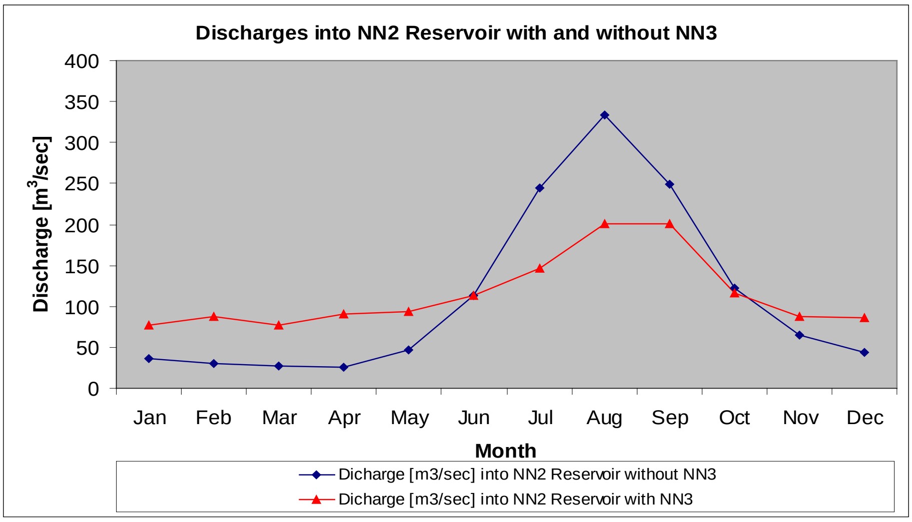


Figure 3.6: Discharges into NN2 Reservoir with and without NN3



3. Discharges downstream of the NN3 Dam

111. During the filling of the NN3 reservoir and during project operation no water will be released at the NN3 dam, except for (i) dam seepage (estimated at between 0.3 to 1 m^3/s) and (ii) spills over the dam that will occur in some years during the months of August and September. In the 4.8 km long river stretch immediately downstream of the NN3 dam, rainfall, ephemeral streams, and groundwater (side flows estimated to be in the range of 0.10 to 0.12 m^3/s) add to the seepage and spills at NN3 dam.

112. Table 3.1 below shows the discharges downstream of the NN3 dam in the 15.5 km long Nam Ngum stretch to the NN3 power station as percentage of natural discharges. Table 3.1 shows that at the first 4.8 km downstream of the NN3 dam river discharges are between 0.7% and 19. 1% of the natural flow without the project. In years when there is spill, the percentage in August and September would be larger. However, at the river stretch between 4.8 km and 15.5 km downstream of the NN3 dam, the flows will be in the range from 12.4% to 32.2% of the natural discharges.

Table 3.1: Nam Ngum discharges downstream of NN3 Dam in the 15.5 km long river stretch to NN3 Power Station as a percentage of natural discharges at NN3 Dam Site

% of natural discharges without NN3 project downstream of dam	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Between 0 – 4.8 km from dam	2.1	2.8	3.3	3.3	1.8	1.1	0.7	0.6	0.7	0.9	1.4	1.7
At confluence with Nam Pha	10.2	11.1	11.8	13.1	13.0	12.6	11.5	10.9	11.0	11.1	11.0	10.3
Between 4.8 – 15.5 km from dam	12.3	13.4	14.2	15.9	15.7	14.4	13.6	13.7	13.9	13.5	12.6	14.0
At 15.5 km, NN3 power station	263.0	349.0	414.2	391.1	224.5	113.3	62.9	52.7	68.3	104.9	142.6	208.9

4. Impact of spills on natural habitats downstream of the dam

113. Table 3.1 shows the average monthly spills of August and September (this is based on averages over a 35 year period). In fact, actual daily spills are expected to be significant higher than spills averaged over one month. Such intermittent discharges could flush out aquatic life which could reinstall itself in this stretch of the river during the low flow period, including, to some extent, the one which could be present in deep pools, and adapted to slow water velocity.

114. In addition, because the water discharged will plunge into the river bed at some distance from the dam toe to avoid erosion at the foot of the dam, it is expected that the water of the spills will get supersaturated with dissolved oxygen and nitrogen, which will lead to fish kills immediately downstream of the dam, when fishes happen to be there.

115. These considerations will tend to support the limited value of a riparian release, which could not function as an environmental flow and maintain the integrity of the habitats and species found in this stretch of the river.

5. Difficulties to achieve a high water quality release at the NN3 dam site

116. The release of high water quality at the NN3 dam would be technically difficult and costly to achieve due to the high draw down zone of the NN3 reservoir. Water levels of the NN3 reservoir fluctuate annually as much as 63 meters, and in May, the reservoir will be approximately 35 m below the elevation of the crest of the spillway.

117. Water diverted at the dam through the power conduit to the NN3 power station could be an option to provide a riparian release at NN3 dam, although its technical feasibility and significant cost would need to be considered against the benefits that would be expected in the 4.8 km stretch of river.

118. Due to (i) the occurrence of flushing effects by spills, (ii) the absence of long distance migrating fish species upstream of NN3 reservoir area, and (iii) limited use of aquatic resources immediately downstream, a guarantee minimum riparian release at the NN3 dam will most probably not serve its purpose of sustaining continued ecosystem services in the 4.8 km long river stretch downstream of the NN3 dam. The water needs of terrestrial wildlife should be fulfilled, although altered in their nature and distribution, through the seepage and groundwater flows.

F. Aeration Structures

119. In the first EIA stage RMR assessed different options for aeration of the oxygen deficient water drawn from deeper reservoir layers and discharged trough the power station tailrace (RMR Chapter 15). The RMR study concluded that the function of the reservoir salvage logging and biomass

clearance programmes and the natural mixing and aeration in the downstream river channel would be satisfactory for alleviating the water quality problems before reaching the downstream settlements.

120. With the construction of the NN2 reservoir these settlements have now been moved outside the NN3 impact area. The new situation with a short distance from the NN3 tailrace to the NN2 reservoir water (0.9 km at NN2 FSL of 375 m and 3.7 km at NN2 MOL of 345 m) has, however, reduced the opportunities for natural aeration and thus will reduce the self cleaning capacity of this Nam Ngum River stretch downstream NN3 powerhouse.

121. The following aeration options have therefore been considered:

- (i) variable/multiple intake structure;
- (ii) hypolimnic aeration/oxygenation device in the reservoir;
- (iii) downstream aeration weir.

122. Variable off-take mechanisms are used to draw water from the upper and dissolved oxygen - rich (epilimnion) upper water layer of the reservoir. In the case of NN3 where the annual draw down will be about 60 m this solution would be technically difficult. Reservoir withdrawal from the epilimnion instead of from the hypolimnion would improve water quality at downstream locations, but will reduce dissolved oxygen exchange from the epilimnion to the hypolimnion, and hence will increase anaerobic conditions in the reservoir and the duration of these conditions. The option of variable off-takes was also rejected both from a cost and an operational reliability point of view. In Southeast Asia, none of the existing reservoirs or the reservoirs under construction includes a variable water off-take to the powerhouse.

123. Reservoir aeration or oxygenation improves downstream water quality and also improves dissolved oxygen concentrations in the reservoir itself. The best alternative is oxygenation instead of aeration since infusion of air in reservoir water can cause nitrogen super saturation in turn leading to fish mortality. Reservoir infusion of oxygen instead of air will need production and storage of liquid oxygen on site. As a result, reservoir oxygenation using liquid oxygen is not feasible for the whole reservoir hypolimnion, only for a limited part of the reservoir close to the dam.

124. Hypolimnion oxygenation is complicated. At existing reservoirs in USA and Australia there have been difficulties in even distribution of oxygen over the reservoir area. Actual oxygenation of the hypolimnion requires high capital and operation costs that do not necessarily guarantee sound results due to application of high technology and required operation skills. None of the existing reservoirs or the reservoirs under construction in Southeast Asia apply hypolimnion oxygenation. However, the Company will look into the feasibility of aeration devices that operates on solar energy and have been effectively used to overcome water quality stratification and algal growth problems in lakes and reservoirs.

125. The third option is the construction of an aeration weir or weirs downstream of the NN3 tailrace discharge point and upstream of the NN2 reservoir. The short reach between the tailrace and the NN2 reservoir is steep with several existing rapids. A combination of weir(s) and rapids would allow a significant improvement of the dissolved oxygen concentrations in the water. The weir system is a technically simple but robust option for water quality improvement that has been applied at other hydropower projects in Lao PDR, including in the Nam Ngum River Basin. The option of modifying the morphology of some rapids downstream of the powerstation will be explored. The option of a dedicated aeration weir was considered; however, it was determined that this option was not cost effective in reducing ammonia concentrations and chemical oxygen demand, while potential biological oxygen demand would be relatively slightly reduced.

126. In addition to the two options that will be explored, aeration/oxygenation in the reservoir and physical aeration downstream of the powerstation, it is expected that aeration and oxygenation will occur from (i) spills over NN3 dam, (ii) discharges from tributaries into the Nam Ngum between NN3 dam and NN2 reservoir, and (iii) by the self cleaning capacity caused by the many rapids between NN3 power station and NN2 reservoir.

G. Regulating Reservoir

127. The need for and the costs and benefits of a regulating reservoir downstream the NN3 tailrace was assessed by RMR (Chapter 8) in a configuration without the NN2 project, which is now in operation. A structure for the regulation of water level fluctuations downstream of the NN3 powerhouse would have required a storage capacity of about 2.8 M m^3. Its cost was estimated to be in the order of 15-40 million USD.

128. The NN2 hydropower project is now in operation and the villages and river users who would have benefited from a regulation reservoir downstream of the NN3 reservoir have now been resettled outside the area. Thus fisheries, riverbank gardening, and water supply are not an issue anymore. As there are no virtual benefits anymore the cost – benefit ratio has become even more unfavourable and it was decided not to build such a structure.

129. Furthermore, there are no relevant human activities in or close to the very short reach between the NN3 tailrace and the NN2 reservoir. Further down, the NN2 reservoir will function as a regulating pond. Shore bank erosion is not expected as the full operation discharge will be confined within the natural riverbed, which consists of rock and large boulders, and surrounded by rocky and steep banks.

H. Transmission Line Alternatives

1. Initial Plans and New Conditions

130. At an early stage several options for evacuation of the power were considered including an alternative of going north of the NN1 reservoir. This was later abandoned.

131. During the initial planning it was decided to link power lines from plants both to the north and to the south at the Nabong sub-station for further transmission into Thailand. In this configuration, crossing the central parts of the Phou Khao Khouay National Protected Area was considered the best alternative (see Figure 3.7). This alternative is presented in the Project Description Chapter and is the basis for the main impact analysis in Chapter 7. Even though efforts were made to locate the lines close to parts of the National Protected Area already modified by the Nam Leuk Hydropower reservoir, the main concern of this alignment was the impacts on the forest and biodiversity of Phou Khao Khouay National Protected Area (PKK NPA).

132. Since this alignment was proposed several developments have taken place:

(i) The Phu Bia mining complexes have caused major development and land take within the corridor proposed for the transmission line.
(ii) A corridor further to the west in the Phou Khao Khouay National Protected Area was selected and used for the NN2 power plant.
(iii) Due to the Phu Bia mining activities the public road through the NPA has been significantly upgraded and represents a more "natural" corridor through the Park.

133. This situation initiated the EIA to investigate other options for revision of the original alternative (in the following called the "RMR option"). Objectives for proposing these new options have been to:

(i) Minimise conflicts with existing settlements, land use and economic activities;
(ii) Minimise the negative impacts on the integrity of the National Protected Area by avoiding loss of forest land and by reducing the potential for unsustainable human activities (logging, hunting, agricultural development, etc);
(iii) Minimise or avoid the adverse impact to the population centre of Ban Nam Gnone and the mining area, building complex and main copper processing plants of Phu Bia Mining Ltd.

2. Routing Options

a. Original alignment (RMR)

134. This option is the original alignment assessed by RMR. It has a total length of approximately 96 km. This alignment has significant adverse impact as it passes straight through the PKK NPA. It will also cross the Phu Bia mining area which was not fully established at the time of the RMR study. It will to some degree impact residential housings and shops in Ban Nam Gnone.

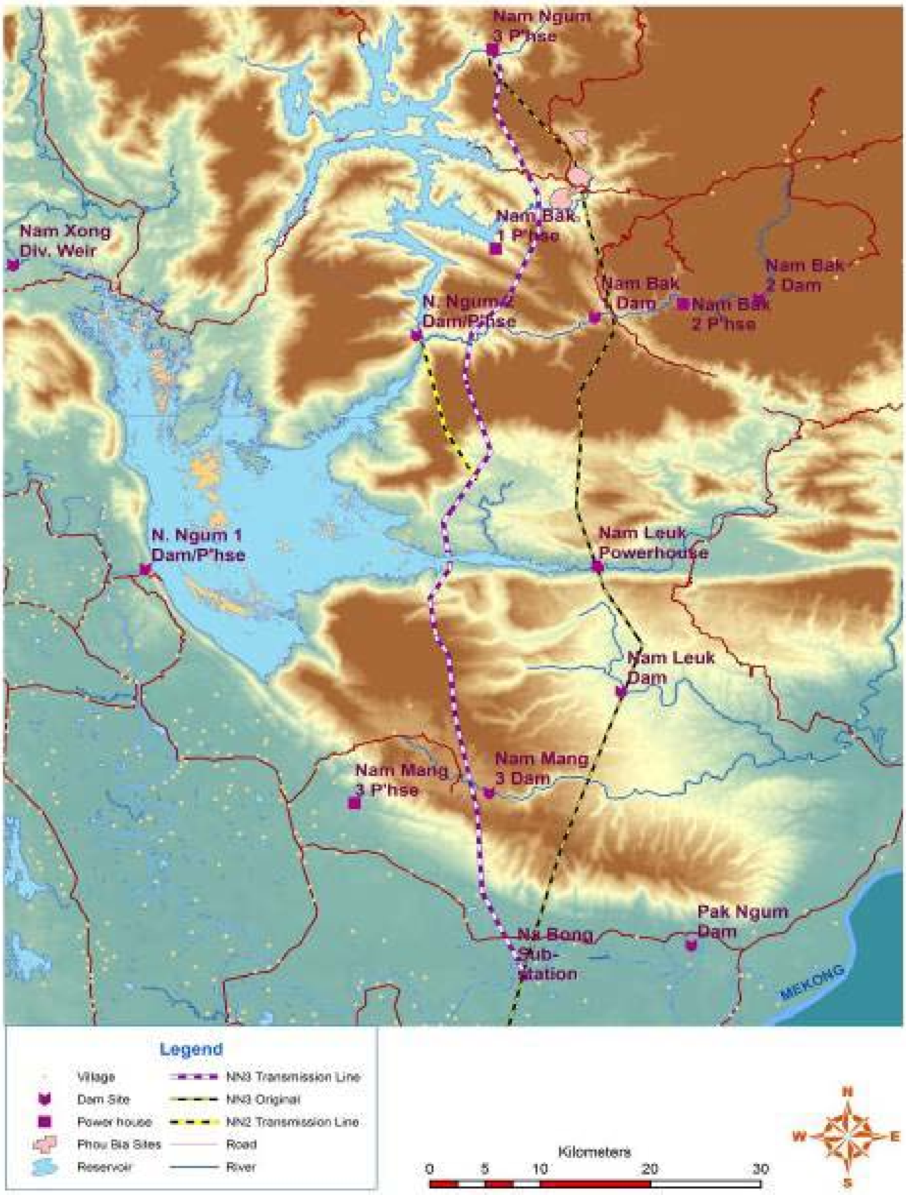
b. Passing Phu Bia

135. Two options to avoid or bypass all of the Phu Bia industrial complexes were studied. One option, causing an increase of the total length by 0.3 km, diverts to the west in order to avoid the main copper processing complex and buildings. It has, however, still some minor impacts on residential housings in Ban Nam Gnone. The other option deviates from the power house in a south-east direction, on the western side of Phuxang, bypassing Ban Nam Gnone, Phu Bia mining area and industrial complexes, before it joins with the original alignment. This option increases the total length of the alignment by 0.9 km. The accessibility of this line is somewhat restricted. However, the line is quite close to the power house access road and the main road from Ban Nam Gnone to Houay Mo.

c. Western (NN2) Option

136. This option deviates from the original corridor in the southwest direction to join with the NN2 230 kV transmission line which cuts through Phou Khao Khouay NPA to the west of the original corridor. This option is aimed at reducing the total negative impacts to the integrity of the National Protected Area by having only one corridor crossing instead of two. This will reduce the total loss of forests and make management and control of the Park easier.

Figure 3.7: Transmission Line Routing Options



d. Eastern (Road) Option

137. This option was also designed to minimise the impact of the corridor on PKK NPA. It follows more or less the existing road from Mouang Hom to Thabok and then follow the NT1 500 kV corridor along highway 13 to Ban Nabong substation. This route will reduce the impact on the PKK NPA but will, however, pass through the northern edge of the populated area of Thabok.

138. Some of the options described above have been combined into alternatives as shown in Table 3.2.

Table 3.2: Main features of transmission line alternatives

Alternatives	Total length (km)	Villages located within 600 m from the TL corridor	NPA land in ROW (ha)
1. RMR	96	9	142
2. Diverting Phu Bia and Western Option	98.9	5	133
3. Diverting Phu Bia and Eastern Option	128.8	23	93

139. From an environmental and social perspective alternatives 2 and 3 appear to be better than the initially proposed corridor (RMR):

(i) The mining complex at Phu Bia and the settlements close to Ban Nabong are easily avoided by a slight rerouting of the line.

(ii) The potential negative impacts on the Phou Khao Khouay National Protected Area can be reduced by either parallel location with the NN2 transmission line or by following the main road corridor through the Park. Of these the alternative of joining the NN2 corridor is the most favourable as it is shorter and has less impact on existing settlements than the alternative following the road.

140. Assuming that significant negative impacts to the Park integrity have already been caused by the NN2 power line development, a parallel NN3 line will only add marginal additional impacts. The forest loss as indicated in Table 3.2 is based on a 50 m ROW corridor also for NN3 line. If the two lines share the same corridor the additional width will be 25 m. The two lines can use the same access roads and labour camps for construction.

3. Selected Transmission Line Route

141. Based on the findings and recommendation emerging from this EIA process, a new transmission line corridor has been selected which follows the alignment proposed for Alternative 2 in the table above. The original and the proposed alignments are shown in Figure 5.10. The final alignment of the transmission line, within the corridor, will be selected at a later stage in relation with the design and the detailed impact assessment that will be undertaken.

142. The selected NN3 transmission line corridor runs parallel to NN2 transmission line through Phou Khao Kouay National Park. It has a number of advantages compared to the former selected route: (i) no interference with the mining activities of Phu Bia Mining, (ii) crossing of Phou Khao Khouay National Park at less sensitive biodiversity areas, (iii) joining NN2 transmission line and using the existing corridor will result in less disturbance of biodiversity and/or land uses, (iv) allowing NN3 to make use of the same access roads to the joint transmission line corridor as provided by NN2 resulting in less land take and less disturbance of land uses, (v) reducing land acquisition impacts and (vi) avoiding crossing urban areas and residential areas of villages.

143. For the selected NN3 transmission line corridor, the approximate distance of the new corridor between the switchyard at NN3 power station to the junction point of NN2 power transmission line is 52 km and the distance from this point to Nabong substation utilizing the existing NN2 transmission corridor is 47 km. By running parallel to the NN2 transmission line, the number and length of new access roads to the NN3 transmission line will be reduced. A total of 210 transmission towers will be erected along this final selected transmission route.

I. No-project scenario

144. Referring to the overall global, regional, national, and local power strategies and policies, the alternative not to develop the NN3 hydropower project would not be in accordance with (i) the Greater Mekong Sub region's strategy for the energy sector, (ii) the Lao national development priorities, (iii) the GoL's plans and policies for the power sector, (iv) the MoU signed between GoL and the Government of Thailand, (v) the MoU signed between GoL and the developer, and (vi) the Nam Ngum River Basin Development Sector Project.

145. Energy production on a similar scale as NN3 by other means, and using the latest technologies available, for example a thermal power plant using fossil fuels would significantly contribute to climate change by the emission of greenhouse gases.

146. Without the increase of electricity production by NN3 in the GMS, the growing regional demand in energy will be less satisfied in a sustainable manner, the regional energy production targets may not be reached fully, power outages may occur in the future, and less money will be made available for development activities and poverty alleviation in the country.

147. The Electricity Generating Authority of Thailand (EGAT) regularly prepares a Power Development Plan (PDP) for least-cost system expansion. PDP 2010 proposes a total capacity increase of more than 21,500 MWfrom 2010 through 2020 to meet forecast demand growth and planned retirements (5,933 MW).

148. PDP 2010 considered several candidate power plants for domestic development in its least-cost optimization analysis: (i) clean coal, (ii) combined cycle gas turbine (CCGT), (iii) nuclear, and (iv) pumped storage hydro plant. With respect to clean coal, these were not for immediate implementation because of difficulties with location, greenhouse gas emissions and public acceptance. The first clean coal plant is scheduled for 2019. Nuclear, on the other hand requires long lead times, heavy investment, establishment of nuclear in-country capacity. Because public acceptance for nuclear is perceived as an issue, PDP 2010 only considered 5 units for development with a maximum energy generation share of 10% starting in 2020. Pumped storage operates as a peaking plant and is usually developed as a complimentary generating facility to baseload power plants such as coal and nuclear and therefore would not strictly replace Nam Ngum 3.

149. PDP 2010 considered other relevant criteria beyond cost minimization. Fuel diversification was stressed given that Thailand's fuel supply mix is already highly concentrated with natural gas accounting for 58% of generation as of January 2011. Therefore, PDP 2010 stressed the importance of diversifying and securing alternative sources of fuel for power generation with the goal of diminishing power generation from natural gas to about 50% by 2030. New gas fired power plants would be developed to replace retiring gas fired power plants.

150. PDP 2010 also recognizes that there are promising power purchase projects from neighboring countries. Since most of these are hydropower plants that do not discharge greenhouse gases, PDP 2010 targets to source up to 25% of the system's power requirements by 2030 from neighboring countries.

151. In case the Project was to be replaced by another power plant of equivalent operational characteristics, the CCGT or another import hydropower project would be the most appropriate alternative. Based on EGAT's least-cost planning assumptions and imported fuel prices (since domestic gas supply is constrained), the resulting the avoided cost of CCGT is $0.137/kWh. With a levelized tariff of $0.056/kWh at constant 2011 prices, the resulting analysis would indicate that the Project is a least cost alternative compared CCGT.

152. Given that the sponsors of the Project have signed a tariff Memorandum of Understanding with EGAT and that the Project has progressed toward a draft power purchase agreement, the Project therefore has been included in PDP 2010 as a firm addition.

153. Major risks and mitigating measures are described in detail in the risk assessment Table 3.3 below:

Table 3.3: Risks Assessment

Risks	Description	Mitigating Measures
Hydrological Risks (construction phase)	Floods during construction could damage the unfinished dam	A 50-year flood of 2,180 m^3/s and a 500-year flood of 3,350 m^3/s have been adopted for the diversion arrangements of the CFRD which is considered appropriate.
Hydrological Risk (operation phase)	Massive deforestation would mean increased total runoff volumes. There will, also be a change of the flow dynamics with increased flood volumes and lower dry season flow. It is thus probable that the increased volume would be lost through spilling and not be utilized for energy production. In addition, the erosion and thereby the riverine sediment transport will increase into the reservoir.	Compensatory reforestation in NN3 catchment area Coordination with the Nam Ngum River Basin Organization on watershed management
	Climate change may impact the amount and distribution of inflows into the reservoir	A recent study quoted by Mekong River Commission suggests an increase in total annual runoff by 2030 that will maintain or improve annual availability in all catchments in the Lower Mekong Basin. Such effects, if any, will probably not be noticeable for decades, and before that the effects are likely to be relatively small compared to the natural variability of the flow.
Geological Risk (construction phase)	Unanticipated geological conditions that could result in project delays and increased cost	Geological investigations done during feasibility stage indicate reservoir slope stability is not considered a cause for concern During construction, further exploratory holes will be drilled at the face of heading of the tunnels, caverns during excavation to gain advanced notice of the geological conditions ahead such that appropriate measures can be prepared in advance.
Earthquake Risk	A reservoir induced earthquake event is unlikely to occur as there are no major faults in the area and the rock is sedimentary.	The Maximum Credible Earthquake (MCE) of 0.22 g and the Operating Basis Earthquake (OBE) of 0.12 g were adopted as the design seismic parameter for the project. No effect in the Project Area in excess of the MCE

Risks	Description	Mitigating Measures
		amplitude is expected to result from a reservoir induced earthquake (RIS) event of a size equivalent to the largest RIS earthquakes so far recorded worldwide (M = 6.5).
Concrete Faced Rockfill Dam (CFRD)	The planned 220 m high CFRD will be one of the highest CFRD in the world.	The CFRD technology is well established and has been in use since 1895. The conceptual layout and design of the dam for the Project incorporates recent practice and trends and includes design improvements to address risk of the occurrence of cracks in the face slabs experienced by high CFRDs several years ago. A Dam Safety Review Panel will be established to review the detailed design of the project, monitor construction and opine on the emergency contingency plan.
Presence of Unexploded Ordinances (UXO)	Available reports identify the Project Area as an area with a relatively medium risk of encountering UXOs.	Arrangements to handle the presence of UXO in all relevant project construction sites and transmission line route include (i) detailed procedures for identifying, securing and disposing of UXO; and (ii) clear instructions and training of all staff on how to behave if UXO is found.
	UXOs are encountered at Project impacted villages, including the villages of Ban Long Cheng and Ban Xiengdet.	For the resettlement site, consultations will be held with the villagers on the need for removal of UXO at the proposed resettlement site, irrigated area and the existing paddy fields. UXO will thereafter be removed by a UXO removal and demining contractor.

IV. PHYSICAL ENVIRONMENT

A. Climate

154. Lao PDR has a tropical monsoon climate. At elevations of the NN3 reservoir area three main seasons prevail. The rainy season lasts from May to October. From November to February it is cool and dry and from March to April it is hot and dry. The southwest monsoon arrives in Laos between May and July and lasts into October. The mean annual rainfall in the NN3 catchment varies from about 1,200 mm in the north-east of the catchment to about 2,700 mm at the dam site. High daily rainfall occurs generally during the months of September and October when typhoons from the South China Sea hit the coast at Vietnam and peter out in Lao PDR. Rainfall at the NN3 reservoir has an average of 2,100 mm over more than a 15 year period. Maximum daily rainfall received has been recorded to 225 mm and a 72-h maximum at approximately 300 mm (RMR 2001).

155. The monthly averages of maximum daily air temperatures range between 23.3 and 27.2 ^{o}C, and the monthly averages of minimum daily air temperatures between 5.5 and 17.1 ^{o}C at the Xaysomboun meteorological station in 2006. A minimum daily air temperature of 0.5 ^{o}C was measured at NN3 dam site in January 2009.

156. The transmission line corridor runs through areas with relatively large differences in climatic conditions. The data are available from two stations: Xaysoumboun station (which represents Long Cheng and Nam Gnone area) in the North and Na Pheng station (which represents Mouang Hom and Nabong areas) in the South. These stations reflect the characteristics of the transmission line area climate (Table 4.1). Quite significant differences in temperature occur between the two stations. The average maximum temperatures range from about 26 °C in the North to about 32 °C in the South, while the average minimum is around 13 °C in the North and 22 ° C in the South. The annual mean rainfall difference is also significant: in the North the rainfall is approximately 2,730 mm, whereas in the South the rainfall is much less with mean annual average of 1,753 mm.

Table 4.1: 2006 Climatic Data from Xaysomboun and Na Pheng Meteorological Stations

Month	Xaysomboun[a]			Na Pheng[b]		
	Av max temp. (^{o}C)	Av min temp (^{o}C)	Av rain (mm)	Av max temp (^{o}C)	Av min temp (^{o}C)	Av rain (mm)
January	25.8	5.5	0.0	30.1	18.0	0
February	26.0	8.0	26.2	31.4	18.9	1.5
March	27.0	13.0	85.9	31.9	21.0	98.8
April	27.2	14.9	364.9	33.9	21.7	63.7
May	26.5	15.5	448.7	32.9	21.5	283.4
June	27.0	16.8	230.5	32.7	24.3	282.2
July	24.8	17.1	845.7	31.6	24.1	659.0
August	24.9	15.8	403.7	31.4	24.2	210.5
September	24.6	15.2	166.0	32.4	24.5	100.6
October	26.0	15.6	154.0	32.6	23.8	52.9
November	26.7	11.1	0.0	32.4	20.9	0.0
December	23.3	8.9	0.0	29.9	17.2	0.0
Annual Mean	25.8	13.1	2725.6	31.9	21.7	1752.6

[a] Represents the northern project areas.
[b] Represents southern project area (Na Pheng situated at the foot of Phou Khao Khouay, 60 km Northeast of Vientiane).
Source: Department of Meteorology.

157. Winds are generally light throughout the year, with increase in mean wind speeds during the dry season. During thunderstorms, convective currents may produce strong surface winds, usually of brief duration. Tropical cyclone activity may also occur in the catchment and give rise to strong winds of longer duration.

B. Topography

1. Mountainous terrain

158. The topography of the Nam Ngum 3 project area consists of deeply incised valleys and step-sided ridges which show evidence of continent forming uplift in the late Cenozoic (66-23 million years ago). The altitudes vary generally between 280 masl and 1500 masl. Major streams have moderate slopes with frequent rock bars and rapids.

2. Drainage pattern

159. The main channel of the Nam Ngum River itself has generally a steep gradient and drains the northern part of the catchment, flowing in a south-westerly direction up to the confluence with the Nam Ting. After the confluence the river changes its direction and flows in a south-easterly direction to the NN3 powerhouse site. The main tributaries upstream of the Nam Ngum 2 reservoir are:

- (i) the Nam Kho River, which drains the north-eastern section of the catchment, flows in a north-westerly direction to join the Nan Ngum near Ban Phianglounag village,
- (ii) the Nam Ting River, which drains the central western section of the catchment, flows in a south-easterly direction to join the Nam Ngum near Ban Xiengdet village, and
- (iii) the Nam Pha River, which drains the south eastern section of the Nam Ngum at about 4.8 km downstream of the NN3 dam site and
- (iv) The Nam Phay river, which drains the south-western section of the Nam Ngum at about 1 km downstream of the NN3 tailrace.

160. Downstream of the planned NN3 dam site the river continues through mountainous terrain into the Nam Ngum 2 reservoir and into the Nam Ngum 1 reservoir. After being joined by the Nam Lik downstream of the Nam Ngum 1 reservoir, the Nam Ngum flows into the Vientiane plains at a low gradient.

3. Nam Ngum River

161. The Nam Ngum River has a total length of just over 400 km from its source near Ban Gnot Ngum in Peak District, Xieng Khouang Province, to where it enters the Mekong River at Ban Pak Ngum, Vientiane Municipality (see Figure 1.2). The Nam Ngum River with its catchment of 16,841 km^2 is one of the main tributaries of the Mekong River in Lao PDR. The NN3 catchment area of 3,769 km^2 at the dam site. The NN3 tailrace is about 256 km from the confluence with the Mekong. Two reservoirs have so far been built on the river downstream of NN3: the Nam Ngum 1 and the Nam Ngum 2 reservoirs. Two other reservoirs are built on its tributaries, the120 MW Nam Lik 1/2 in the upper reaches of the Nam Lik (2010) and the 100 MW Nam Ngum 5 on the Nam Ting (under construction). About 65.5 km of the Nam Ngum have been directly impacted by the reservoirs at FSL of the NN1 (31.7 km) and the NN2 (33.8 km) at FSL.

4. Karst

162. Limestone forms distinctive rugged karst topography and pinnacles bound by steep, rocky slopes. Sinkholes and caves are common in the limestone, particularly to the north of the NN3 reservoir area. The sinkholes result from the dissolution of the limestone, forming holes that eventually collapse and become filled with residual soils and other weathering products.

5. River bed

163. Cascades and rock bars are common along most of the riverbed. The river flows swiftly flowing with large boulders and debris strewn across much of the riverbed and lower banks. Fine alluvium is confined to small isolated deposits in the slow flowing parts of the river.

C. Geology

1. General geology

164. The project is located in an area dominated by sediment rocks of Jurassic-Cretaceous age to the west of the reservoir. In the east the geology is dominated with Devonian, Carboniferous and Silurian rocks. The bedrock can generally be said to be highly eroded. The dam site is located in a Paleozoic sequence of clastic rocks formed by cyclic sedimentation of basal conglomerates and coarse gritty sandstones, followed by siltstones and phyllitic shales. The rocks have been subjected to a low-grade regional metamorphosis with chlorite-sericite as dominating clay minerals. The rock at the dam site is meta sediments – intermeddled phylitte, phyllitic and slatey shale, mudstone, arenite and minor conglomerate. Fresh rock has high to very high strength and low permeability. The rock at the planned power station is fresh limestone with minor evidence of dissolution.

165. Downstream of the dam axis, the lithology changes abruptly to high-grade metamorphic sedimentary rocks consisting of quartzitic schists, gneiss, marble (metamorphed limestone), calc-silicates (metamorphed impure carbonates or calcareous sandstone) and hard mylonite.

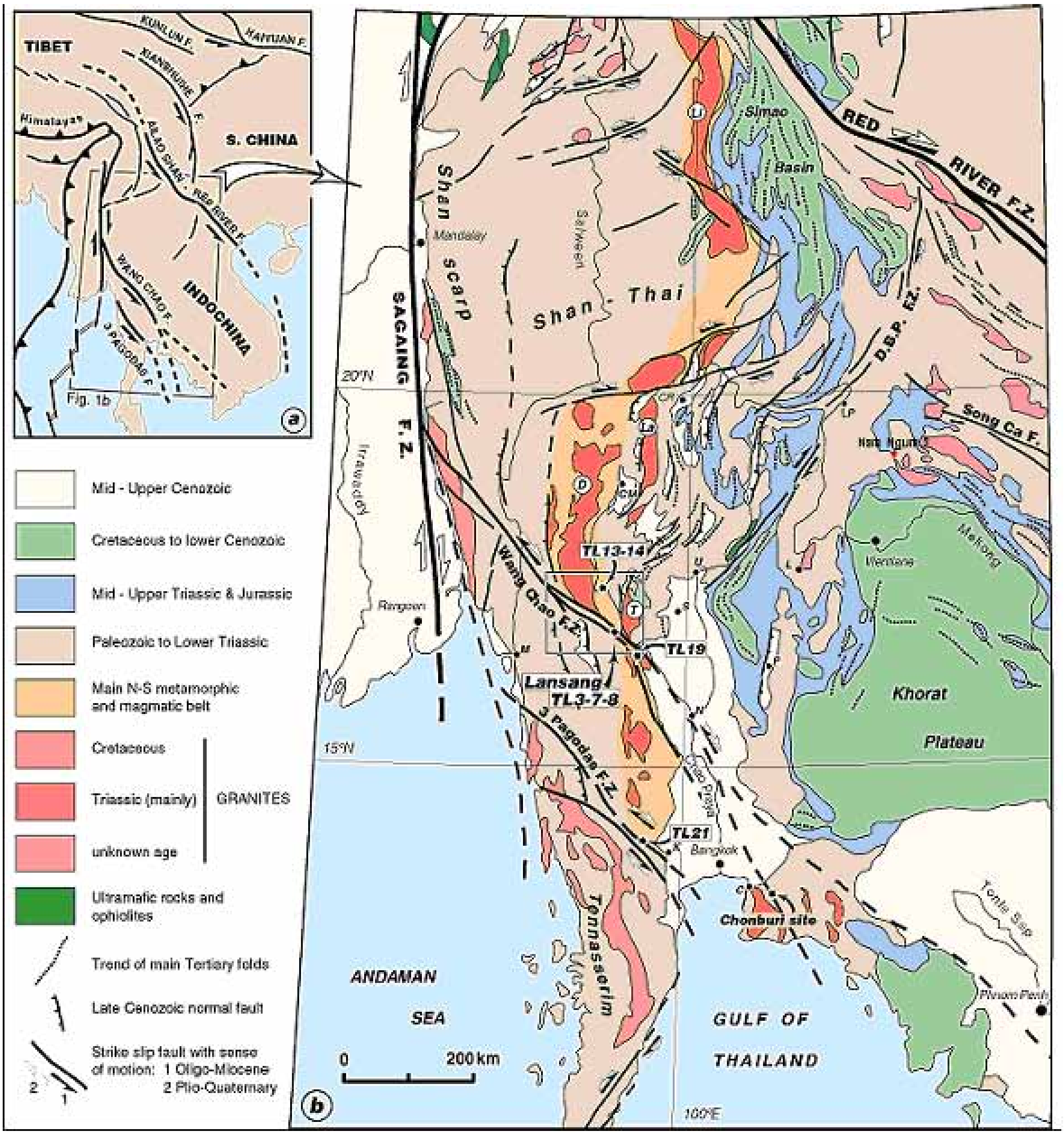
166. The structural geology is dominated by East – West striking bedding planes, dipping steeply at 50-90° to both direction due to compressive folding. Therefore, the principal direction of rock mass anisotropy is approximately parallel to the dam axis and steeply inclined. There is a distinct fault of the same orientation has been observed downstream of the dam axis at both abutments, outside of the dam footprint area.

167. Although the geology of the dam site is rather simple, the foundation conditions are not. This is due to the sub-vertical inclination of interbedded strata and a rapid alternation of different lithologies with variable material properties. The steep orientation of structures and main discontinuities is generally favourable for dam stability against sliding and for seepage, as the bedding planes and foliation do not represent a direct hydraulic connection from upstream to downstream. On the other hand, the steep bedding is less favourable for grouting as vertical grout holes would intersect only a few of these discontinuities.

168. The particularity of the dam Nam Ngum 3 site is the development of the weathering profile in the abutments. Whereas fresh and competent hard rocks occur in the river valley, there is a significant weathered layer reaching a thickness of several tens of meters is observed in the upper part of both abutments. Given the sub-vertical orientation of the main anisotropy, the weathering intensity does not linearly decrease with increasing depth from the surface, as it is the case in a homogeneous rock mass, but is highly irregular. The higher permeable gritty sandstones are highly susceptible to weathering (and chemical alteration of rock-forming minerals) in contrast to the dense and low-permeable mudstones. The steeply oriented mechanical and hydraulic anisotropy enables a deep penetration of weathering fluids into the rockmass. As a result, the bore hole cores show a deep-reaching chemical weathering of sandstones is observed in the borehole cores, whereas the intercalated cores of mudstones remain rather intact. The chemical alteration of sandstones, locally found even at depths of 50-60 m, might be indicative for hydrothermal weathering caused by tectonic or magmatic activities. Due to this selective weathering along inclined layers there are no clear boundaries between the weathering classes.

169. Compression stresses led to the folding of the Palaeozoic beds during the late Carboniferous followed by depositions of sandstones. Slight folding and faulting of the sediment cover started during the late Mesozoic. The resulting anticlines and synclinals are open folds with E-W striking axes.

Figure 4.1: Geology of the Region and Faults



170. Several types of rocks are expected to be encountered along the headrace power tunnel route, such as Paleozoic sequences subjected to a low-grade regional metamorphosis near the intake, high-grade metamorphic sedimentary rocks as quartzitic schists, gneiss, mylonite, downstream of the damsite and then granite or limestone to the intermediate work adit and then, calc-silicates (metamorphed impure carbonates or calcareous sandstone) near the powerhouse cavern. Some of sedimentary rocks are foliated along the bedding planes but some rocks as massive limestone are not foliated. Many of regional metamorphic rocks are foliated with mineral grains specifically oriented by the metamorphism but marble and quartzite are not foliated, and granite and diorite are massive with typical directions of joints. In addition, it is reported that metamorphic rock is folded and mylonite (which is cataclastic containing many grains broken fragmented by high confining pressure) is distributed just downstream of damsite.

171. From the geological profile, diorite is distributed in the lower part of the surge shaft, pressure shaft and half of the penstock tunnel, and calc-silicate rocks are distributed at the upper part of the surge shaft and the downstream part of the penstock tunnel. The boundary between diorite and calc-

silicate is altered by a quartz vein and sulphide minerals between 91.70 and 95.00 m with small sheared zone between 92.75 and 92.90 m according to the geological log report. Therefore such zone altered with quarts vein and sulphide minerals and with small sheared zone may be continuously distributed all along this boundary.

2. Mineral resources

172. The Nam Ngum catchment is rich in mineral resources. Mineralization is known in the headwaters of the Nam Ngum in Xieng Khouang Province and includes occurrences of gold, tin, copper, lead, zinc and iron. Copper, lead and zinc sulphide mineralization is widespread as hydrothermal veins. Copper is also known to occur in skarn and limestone intruded by granite.

173. Gold dispersed within the river and creek alluvium is found at different locations in the Nam Ngum River, especially between the NN3 dam site and the NN1 reservoir. Villagers practise to some extent alluvial mining (RMR 2001).

3. Commercial mining

174. The river basin is home to 39 official operation mines and more than 6,000 km^2 of mine concession areas (Vattenfall 2008). The Australian Phu Bia Mining Limited are owner of the largest mining exploration area within the catchment (Figure 4.2). This exploration area covers 2,673 km^2 to the south and east of the NN3 reservoir (Lao PDR, Ministry of Energy and Mines, 2007), and includes the NN3 concession area at the dam site and powerhouse area, and access roads to these sites. NN3PC and Phu Bia Mining Limited have agreed that there will be no mining operations within the NN3 concession area.

175. There are today no ongoing commercial mining activities in the direct catchment area of the NN3 project, but there are several Phu Bia "exploitation targets" identified which might in the future have an influence on the NN3 catchment water resources. There are several sites in the headwater areas of the Nam Ngum but there are also a copper, gold and molybdenum prospect called Pha Nai close to the site where the public road to Long Cheng crosses the Nam Pha.

176. About 20 km southeast of the powerhouse lies the mining area operated and owned by Phu Bia Mining Company. (Figure 4.2). Here in the southeastern part of their Contract Area, Pan Australian Resources Limited, owner of the PMB Company, has since 2005 operated the Phu Bia Gold Mine from the gold-cap deposit. Early in 2008 the Phou Kham operation started extraction of the underling copper-gold deposits (Pan Australian 2008). The operations involve a conventional open-pit mining (drilling, blasting, excavation and hauling) and heap-leach operation for the extraction.

177. In addition to the Phu Bia and Phu Kham mines, the NNRB is home to 8 other internationally held concessions, 21 state-owned, and 9 Lao-foreign joint venture projects. Minerals mined are mainly gold, copper, zinc, barium, iron and coal. These small concession areas are located outside the Nam Ngum 3 catchment (Ministry of Energy and Mines 2007).

178. Artisanal mining activities are carried out in the Nam Ngum River and its tributaries. Villagers carry out these activities without permits during the dry season when water levels are low.

179. The CIA Study (Vattenfall 2008) underlines that the cumulative impacts from mining and hydropower activities can be significant if activities are not coordinated or properly regulated.

4. Soils

180. The soil profile along the Nam Ngum River contains shallow silts and silty clay loams with some clay content. The soil cover is however thin and is anticipated to be relatively stable. The soil indicates that the clays are of low plasticity silts and clays and are at least partly colluvial rather than residual in origin (RMR 2001).

5. Seismicity

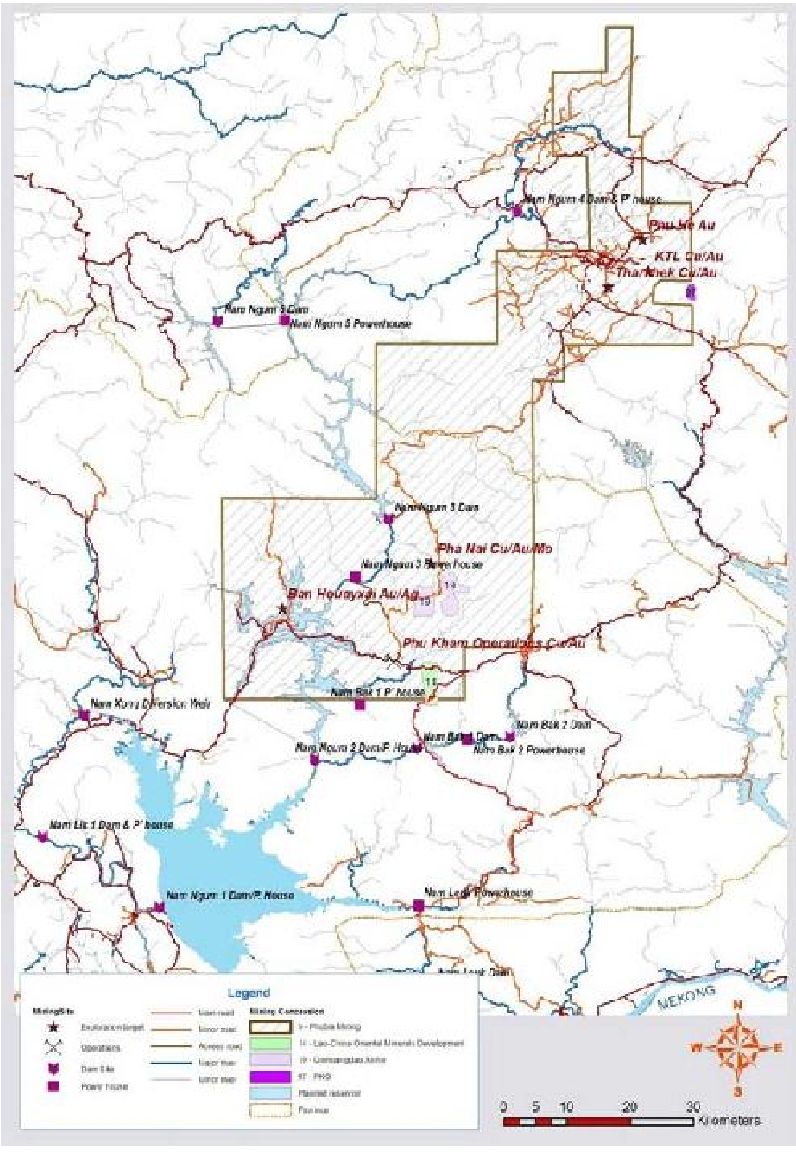
181. The Project Area lies in what is called the "*Indochina Platform*", in a tectonically and seismically quiet context, and at substantial distances from regional major active faults and plate boundaries. The Cenozoic and Quaternary tectonics of the region is mainly developed at the boundaries, but locally also within the interior of the Indochina Platform (see also Annex C).

182. The recorded seismic history within the region of largest influence to the earthquake hazard in the Project Area is rather short: 99% of the recorded data (updated to February 2007) relates to post-1972 earthquakes. An earthquake with magnitude 6.3 was recorded on 16 May 2007, with the epicenter located about 300 km from the Nam Ngum 3 Project Area. No major earthquakes have been located within 200 km of the site, and there is little or no seismograph coverage for moderate to small events.

183. The Maximum Credible Earthquake (MCE) of 0.22 g and the Operating Basis Earthquake (OBE) of 0.12 g were adopted as the design seismic parameter for the project.

184. No effect in the Project Area in excess of the MCE amplitude is expected to result from a reservoir induced earthquake (RIS) event of a size equivalent to the largest RIS earthquake so far recorded worldwide (M = 6.5). A RIS earthquake of this or smaller size at Nam Ngum 3 Reservoir is considered more likely than the MCE.

Figure 4.2: Phu Bia Mining Exploration Area and Its Ongoing Mining Activities



D. Hydrology

1. Main features

185. The main hydrological features of the Nam Ngum 3 catchment are summarised in Table 4.2 below. More detailed information can be found in the Nam Ngum Social Action Plan and Environmental Management Plan, volume 3 (RMR 2001c), the Hydrology Appendix to the Feasibility study (SMEC 1996) and the Final Detailed Design Report (Colenco/Nippon Koei 2007).

Table 4.2: Main Features of the NN3 Catchment

Reservoir catchment	3,769km²
Range in elevation of the catchment	280 m to 1500 masl
Mean annual rainfall over the riverbed	1,200 mm to 2,700 mm
Mean annual rainfall at Nam Ngum 3 reservoir	2,100 mm
Annual rainfall from April to October (%)	95%
Mean annual open water evaporation	1,227 mm
Mean annual discharge (1972-2006) at dam site	96.5 m3/s

2. Surface hydrology

186. Water discharges are influenced by the pronounced differences in rainfall during the wet and dry seasons that prevail within the catchment. The river experiences highest discharges towards the end of the wet season when the heaviest rainfall occurs and is lowest at the end of the dry season. Average monthly flows for the Nam Ngum at the NN3 dam site show a very strong seasonal nature. Mean monthly flows range from 10.4 m^3/s (April 1993) to 557.7 m^3/s (August 1995) (GMS 2009). Figure 4.3 shows the mean monthly unregulated inflows into the NN3 reservoir based on 35 years of records.

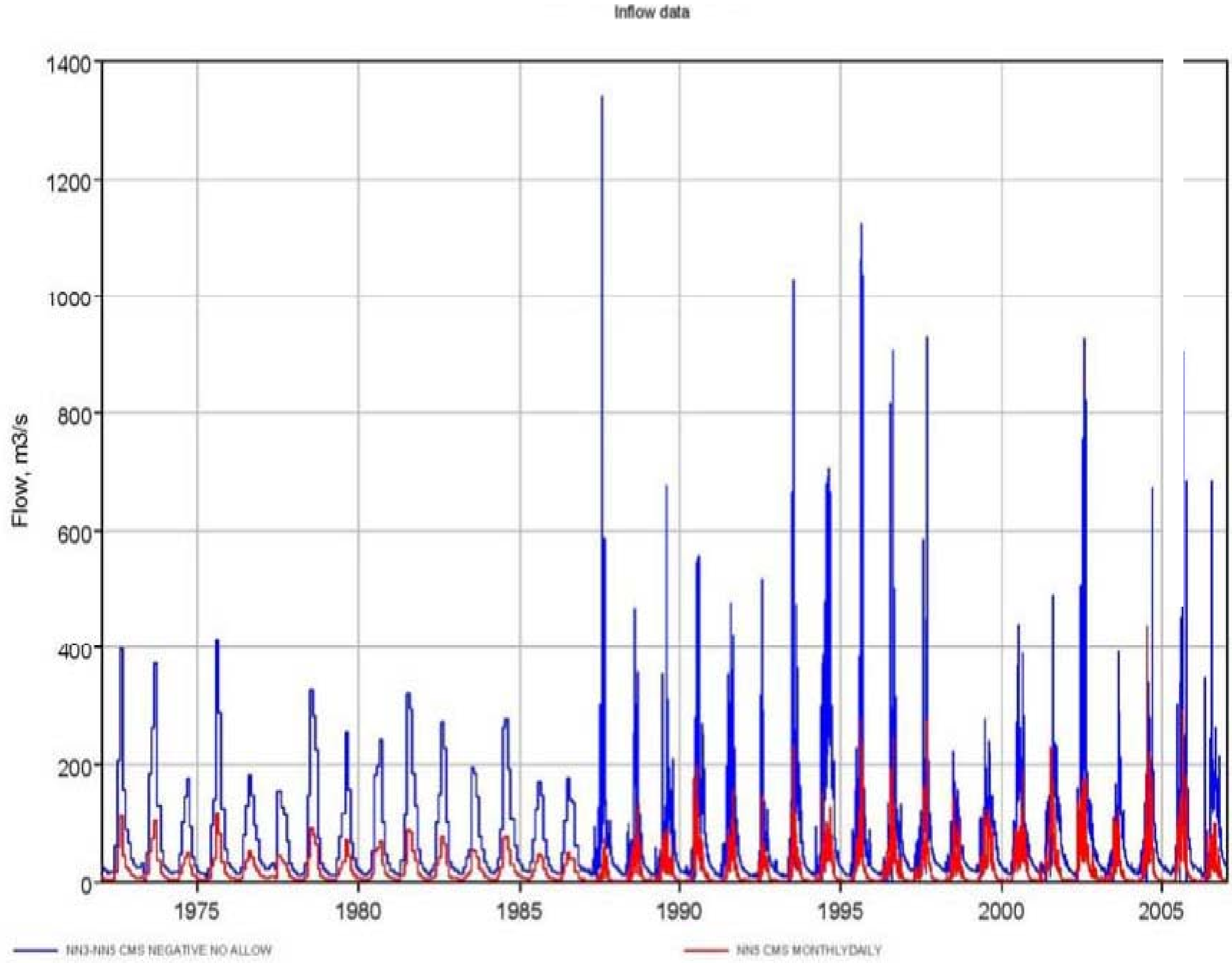
Table 4.3: Average Monthly Unregulated Inflow in NN3 Reservoir

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Inflow m3/s	25.9	20.3	17.9	20.4	40.7	104.1	225.5	290.5	214.8	105.4	54.9	34.2

Note: Excludes regulation of flows by upstream NN5 hydropower on Nam Ting
Source: GMS 2009.

187. Figure 4.3 shows the flow records for the period 1972 to 2006. From 1972 to 1986, flows are mean monthly flows, while 1987 to 2006 are daily flows.

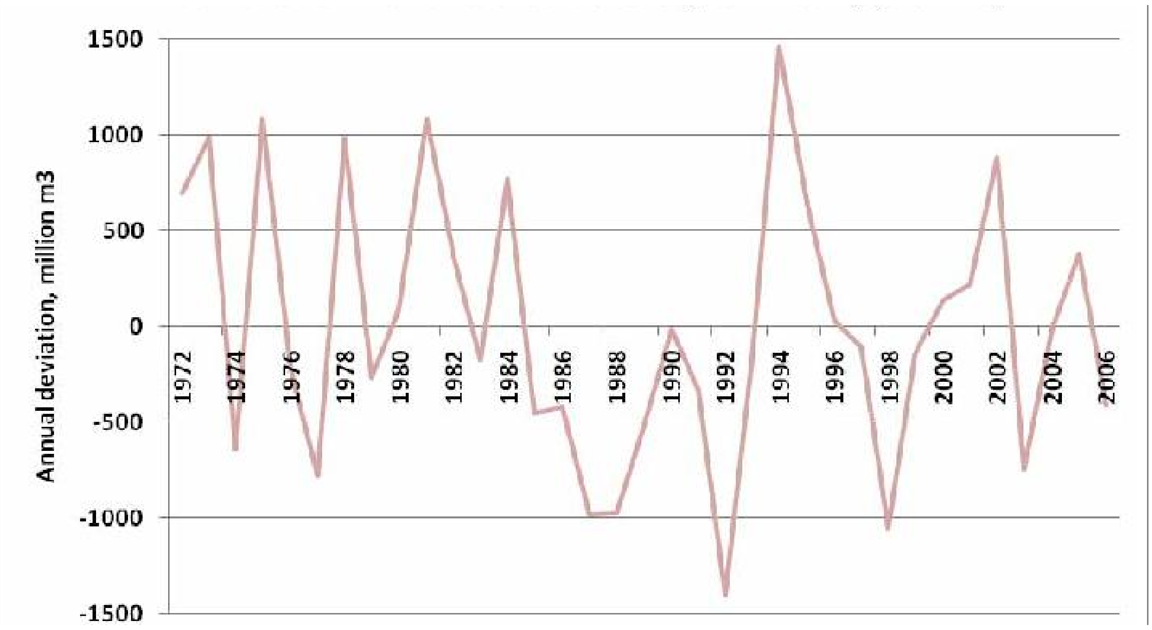
Figure 4.3: NN3 Inflow Data



Source: Resevoir Simulation Operations and Sensitivity Analysis Report (GMS 2009).

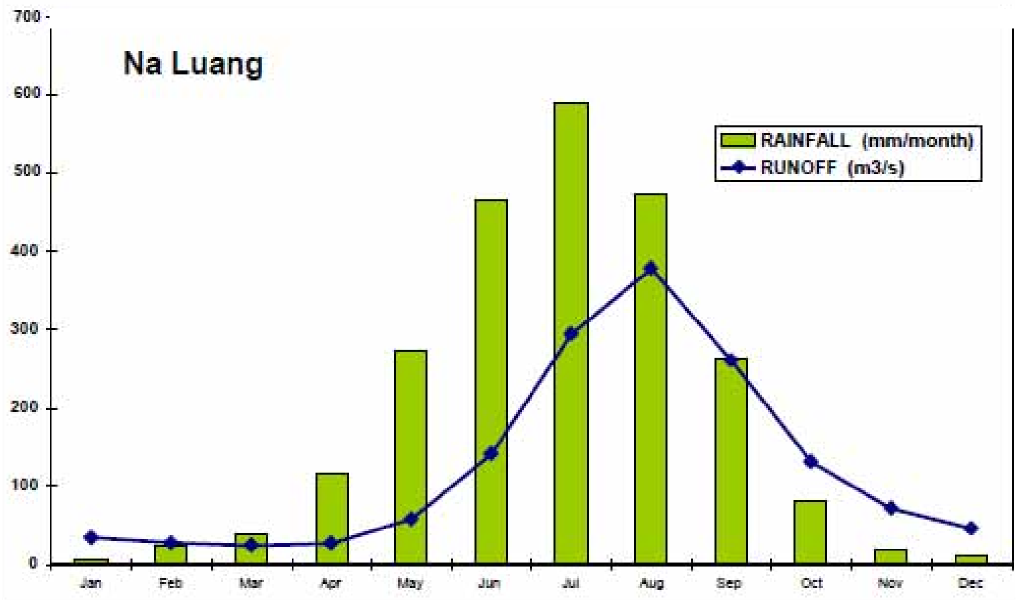
188. Figure 4.4 shows the deviation from the long-term mean annual runoff of 3,043 million m^3, and it can be seen that the nine-year period from 1985 to 1993 was particularly dry.

Figure 4.4: Annual Runoff at NN3 Damsite Relative to Long-Term Mean (3,043 Mm^3)



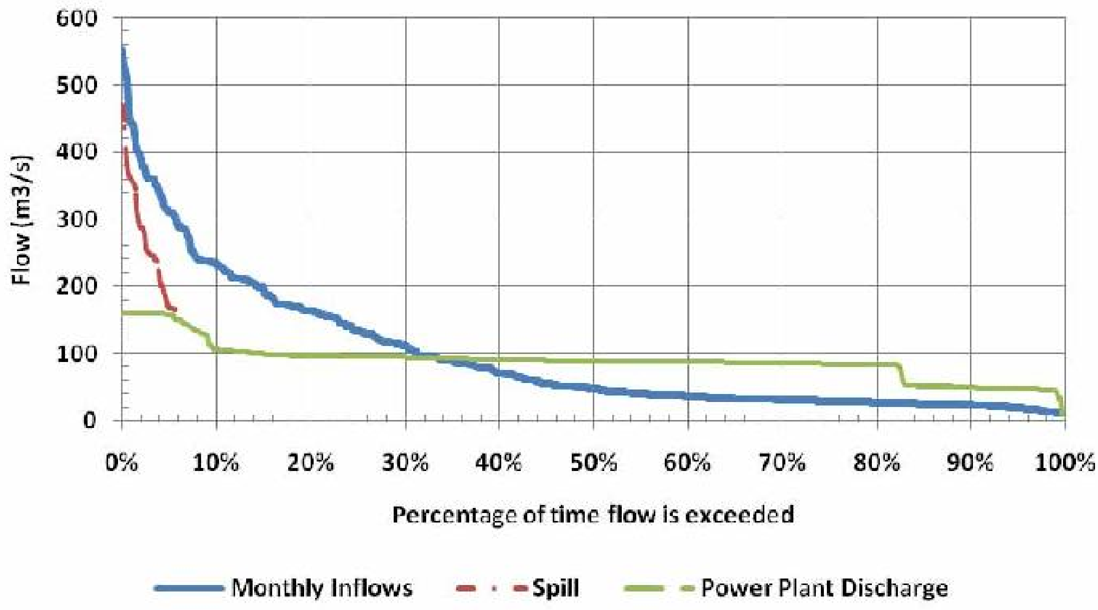
189. The flows at the NN3 dam site were determined using several hydro-meteorological stations in the Nam Ngum river basin. The main station being the Naluang gauging station, which recorded flows and rainfall from 1987 to 2006. The Naluang gauging station was located (14 km) downstream of the NN3 tailrace at the National Road 5 bridge crossing the Nam Ngum. National Road 5 connected National Road 13 North on the north end of NN1 reservoir with Phu Bia Mine and Xaysomboun district to the east of Nam Ngum river; it is now submerged by the NN2 reservoir. The Nam Ngum catchment area at this location is 4,653 km^2. Figure 4.5 shows the average monthly flow and rainfall at Naluang.

Figure 4.5: Average Monthly Rainfall and Flows at Naluang Hydro-Meteorological Station



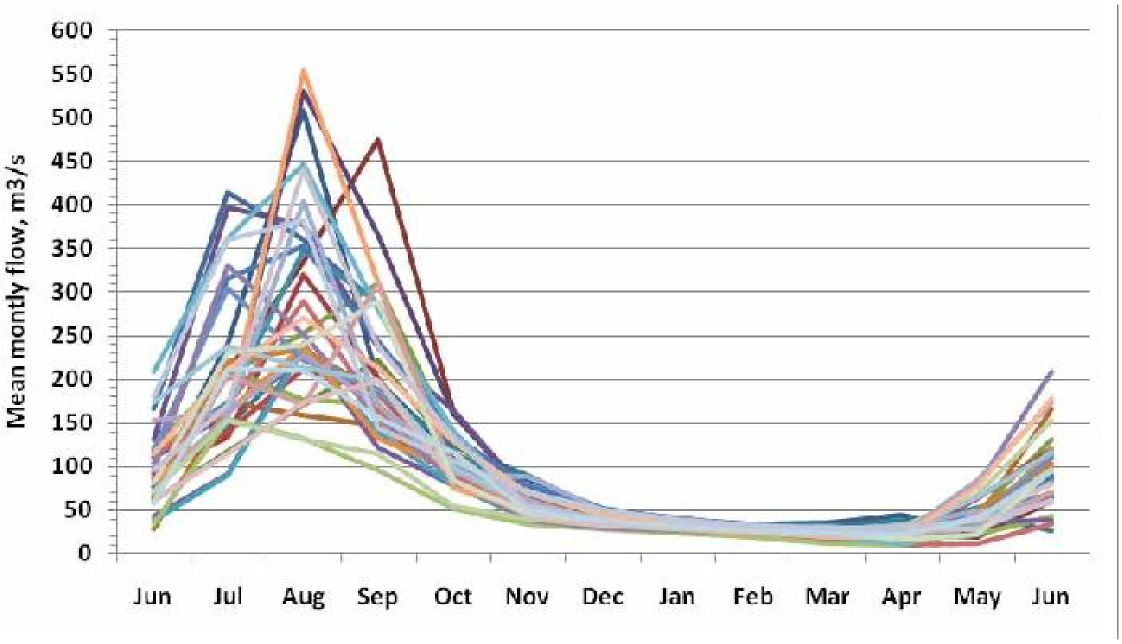
190. Figure 4.6 shows the duration curve for the regulated flows in and out of the NN3 reservoir. The Firm Flow (flow exceeded 90% of the time) into the reservoirs is 24 m^3/s; the mean annual flow of 96.5 m^3/s is exceeded 32% of the time. The figure shows that the firm discharge from the power plant would increase the firm flow contribution into the NN2 reservoir to 49 m^3/s, which would lead to increased generation at NN1 and NN2 power plants.

Figure 4.6: Duration Curve Inflows



191. Figure 4.7 shows the 35 years of monthly flows at the NN3 dam site. In the rainy season there is a very high variability of flows between years. In the dry season however, from November to May, flows decrease gradually and have little variation between the wettest and the driest year.

Figure 4.7: Monthly Flows 1972-2006



3. Groundwater

192. There is little information available on groundwater within the area. Karstic formations allows for complex drainage passages.

4. Erosion

193. The rock is resistant to erosion and has not been deformed and shattered by particular tectonic activity and remains relatively stable. Erosion that provides the river with sediment, originates from natural geologic weathering processes.

5. Sediment supply

194. Present rate of sediment transport of the Nam Ngum shows considerable variations. There are difficulties in estimating annual sediment transport, largely as a consequence of the way sediment transport fluctuates over time. A single few day flood event can carry more sediment than a year of normal supply. The differences in sediment transport are illustrated by the seasonal difference in turbidity of Nam Ngum during the dry season and the wet season Figure 4.8.

195. The lifetime of the reservoir is considered as the time until sediments fill a reservoir to a level that the reservoir can no longer be in operation. In our case, the maximum level of sediment filling is set at 645 masl, as the power intake level.

Figure 4.8: Nam Ngum at Power House Site May 2007 (left), March 2007 (right)

196. The Feasibility Study (SMEC 1996) suggested the present annual sediment transport at the proposed NN3 dam site to be 326, 000 tonnes (84.5 tonnes/km^2). RMR recommended using the Axelsson's equation which resulted in a sediment transport figure of 821,000 tonnes per year (211 tonnes/km^2). A worst case scenario accommodating for future adverse land-use trends in the catchment came to an erosion rate of 1000 tonnes/km^2/yr. Based on the different erosion rates above the lifetime of the NN3 reservoir has been estimated at 76 years according to a worst case scenario (Table 4.4).

Table 4.4: Anticipated Lifetime of Nam Ngum3 Reservoir

Items	SMEC	RMR	Worst case
Erosion rate (t/km^2/year)	84.5	211	1,000
Catchment area (km^2)	3,888	3,888	3,769*
Sediment density (t/m^3)	0.46	1.29	1.29
Annual sediment inflow (mill m^3)	0.715	0.636	2.9
Reservoir lifetime (year)	309	347	76

Note: Revised catchment area.
Source: GMS 2008.

197. Sediment will settle and distribute unevenly along a reservoir and sediment density increases in time. Therefore the total life of the NN3 reservoir could be longer than estimated above. Moreover, when the upper dams, NN4 and NN5, are built, sediment will be trapped in these reservoirs, reducing sediment load in the Nam Ngum 3 reservoir.

198. Sedimentation takes place in a reservoir particularly during the rainy season when the water levels in the river upstream of the reservoir show high fluctuations and thus cause riverbank erosion, resulting in high turbidity and high suspended solid concentrations. These suspended solids settle out in reservoirs mostly during the rainy season as a result of the lower water velocities as they reach the reservoir. In the case of NN3, riverbank erosion particularly takes place upstream of NN4. In the NN3 reservoir area itself, where the riverbanks are rocky, little or no riverbank erosion takes place.

6. Flooding

199. Maximum flood events are likely to happen from July to October. Return periods of flooding events calculated by SMEC (1995) and Colenco/Nippon Koei (2007) are shown in Table 4.5 below.

Table 4.5: Calculated flood events

Flood frequency	Flood, m^3/s	
	Flood Nam Ngum3 dam site	Nam Ting at Ban Xiengdet
5 yr	1,230	305
10 yr	1,490	370
50 yr	2,000	496
100 yr	2,220	551
500yr	3,050	757
10,000 yr	6,316	na
PMF	12,137	1,960

Source: SMEC, 1995 and Colenco/Nippon Koei, 2007.

7. Surface Water Quality

200. Water quality data have been collected at different locations in the Nam Ngum in the last two decades. The main source of water quality data is the Water Quality Monitoring Network, managed by the Department of Irrigation, Ministry of Agriculture and Forestry. In addition water quality data of particular relevance for the NN3 case has been sampled in an extensive program carried out by RMR in 1999. The methods used and the results of the water quality measurements are presented in RMR, Chapter 6 (2001). Water quality has been subsequently monitored, as a recommendation of the Cumulative Impact Assessment study, just upstream of the NN3 reservoir on a monthly basis from March 2008 to December 2009 focusing on the following parameters: (i) water temperature, (ii) pH, (iii)

dissolved oxygen, (iv) DO saturation, (v) nitrate (NO_3-N), (vi) ammonia (NH_3-N), (vii) turbidity, and (viii) total suspended solids.

201. In general the **water quality** in the river is considered to be very good, with a low content of nutrients, indicating oligotrophic conditions. The quality is best in the dry season. In the rainy season the quality declines as a result of sediment loads and contamination by organic material. Nitrogen and phosphorous values, which are important determinants for primary production, show very low concentrations throughout the year. However, the iron content, and to some extent the concentrations of coliform bacteria indicate that seasonally the water does not meet the quality standard for drinking water.

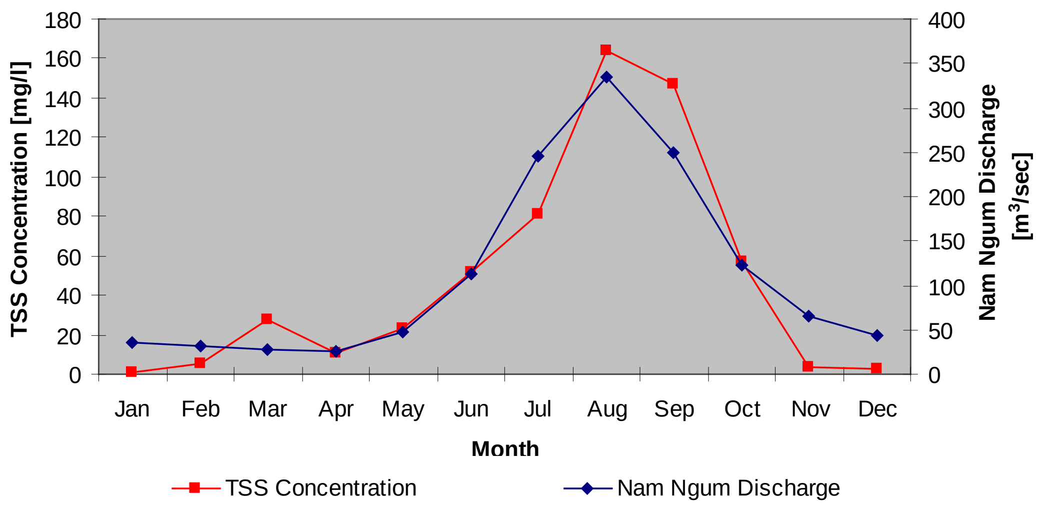
202. Monthly monitoring of **water temperatures** of Nam Ngum River showed a range from 18.5 to 24.5 ^{o}C during 2008 – 2009.

203. The Nam Ngum catchment indicates an alkaline system with **pH** values above 7 (up to 7.9), but with occasional seasonal measurements below neutral in the lower areas (6). In the Nam Ngum River system, pH at all three sampling stations shows a slight increase in acidity as the dry season progresses. This is reversed when the flow in the river increases as the result of the start of the rains.

204. Changes in **conductivity** down the river system are slight, with evidence of a small increase in conductivity in periods of low flows as one proceeds down the river towards NN1 Reservoir. In the reservoir conductivity values are stabilised at low values.

205. Figure 4.9 shows the increase of concentrations of **total suspended solids** with the increase of natural average monthly Nam Ngum discharges.

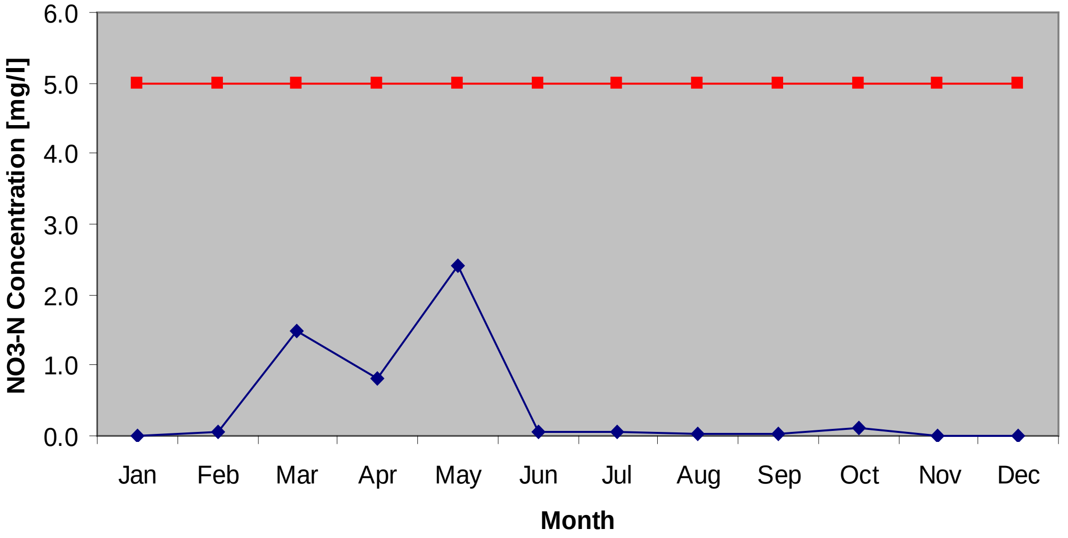
Figure 4.9: Monthly Nam Ngum discharges and TSS concentration



206. **Dissolved Oxygen** concentrations in the Nam Ngum were measured to be higher than 6.1 mg/l.

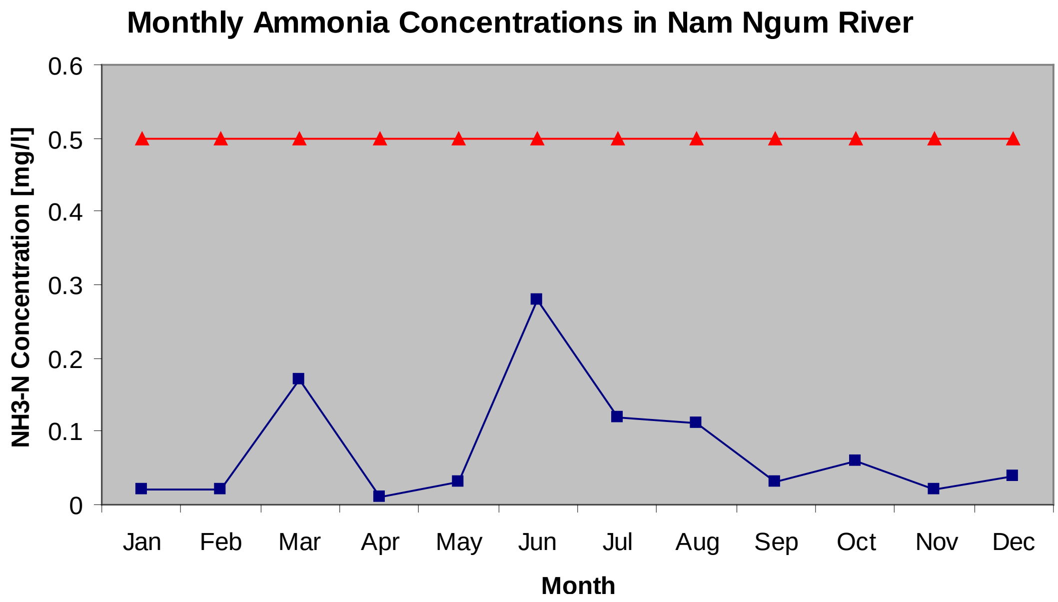
207. **Nitrate** concentrations have been measured consistently well below the Lao water quality standard of 5 mg/l for classification class 1 of surface waters (Figure 4.10).

Figure 4.10: Monthly Measured Nitrate Concentrations in the Nam Ngum River and Lao Water Quality Standard for Nitrate (Surface Water)



208. Measured ammonia concentrations were consistently below 0.5 mg/l (Figure 4.11).

Figure 4.11: Monthly measured Ammonia concentrations in the Nam Ngum River and Thai Water Quality Standard for Ammonia. Lao Water Quality standard set at 0.2 mg/l for Ammonia



V. BIOLOGICAL ENVIRONMENT

A. Vegetation and Land Use

209. The natural vegetation of the hilly landscape in this part of Lao PDR would be Moist Upper Mixed Deciduous Forest with small stands of Mountain Rain Forest and Hill Forests on the mountain ridges and higher elevations. Very little of mature stands of these forest categories are at present found in the region. Decades of logging and in particular extensive use of swidden cultivation has changed the vegetation into early succession stages of woodland or vegetation types favoured by regular fire (bamboo and grass domination). Only very few and small patches can be found of the old natural forests.

1. Catchment Area

210. The distribution of vegetation and land use categories in the NN3 catchment was undertaken on the basis of Landsat images from 2002. The total catchment covers 3,769 km². The area coverage of the different land use and vegetation categories shown in Figure 5.1 is summarised in Table 5.1.

Table 5.1: Land use and vegetation types of the NN3 catchment (2002)

Land use & vegetation types	Area (ha)	%
Current Forest	**122,486**	**32.5**
Dry Evergreen Forest	*6,410*	*1.7*
Mixed Deciduous Forest	*84,868*	*22.5*
Mixed Coniferous & Broadleaved Forest	*31,208*	*8.3*
Unstocked Forest	**128,260**	**34.0**
Ray	3,221	0.9
Rice paddy	47,226	12.5
Other agricultural land	125	0.03
Savannah	405	0.1
Grassland	75,043	19.9
Other land	135	0.04
Grand Total	**376,900**	**100**

Source: Based on 2002 Landsat image interpretation in 2006 by FIPD.

a. Forest

211. Table 5.1 shows that about 32.5 % of the land in the NN3 catchment is covered with what can be classified as forests. The dominant category is Mixed Deciduous Forest. Evergreen Forest and Coniferous Forest are less abundant and restricted to high lying areas which receive most rain. In species diversity they are comparable to Mixed Deciduous Forest, exhibiting a large variety of tree and other plant species. Dry evergreen and mixed deciduous forested areas are located in the central part of the NN3 catchment.

Figure 5.1: Forest and land use in the NN3 catchment (2002)

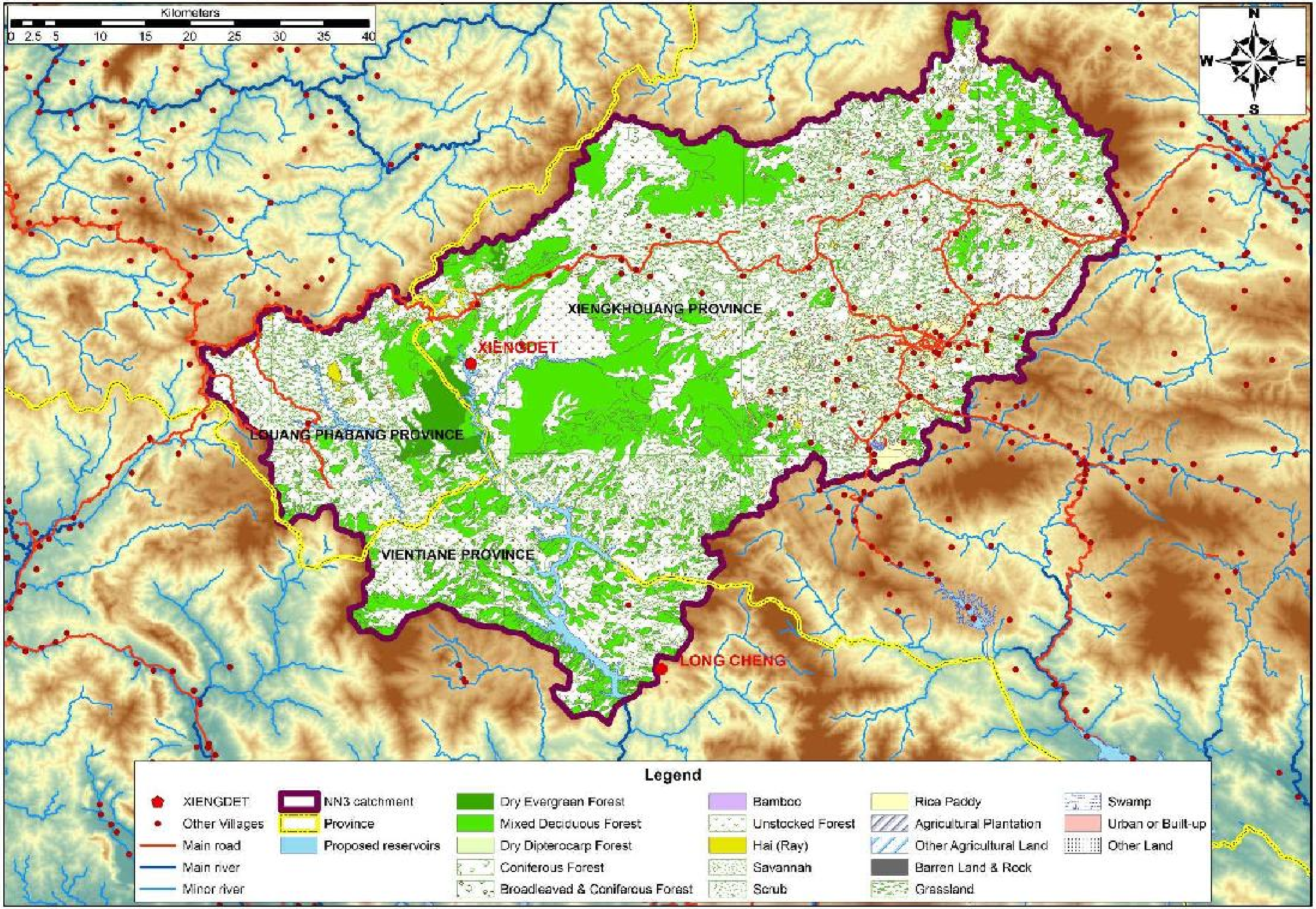
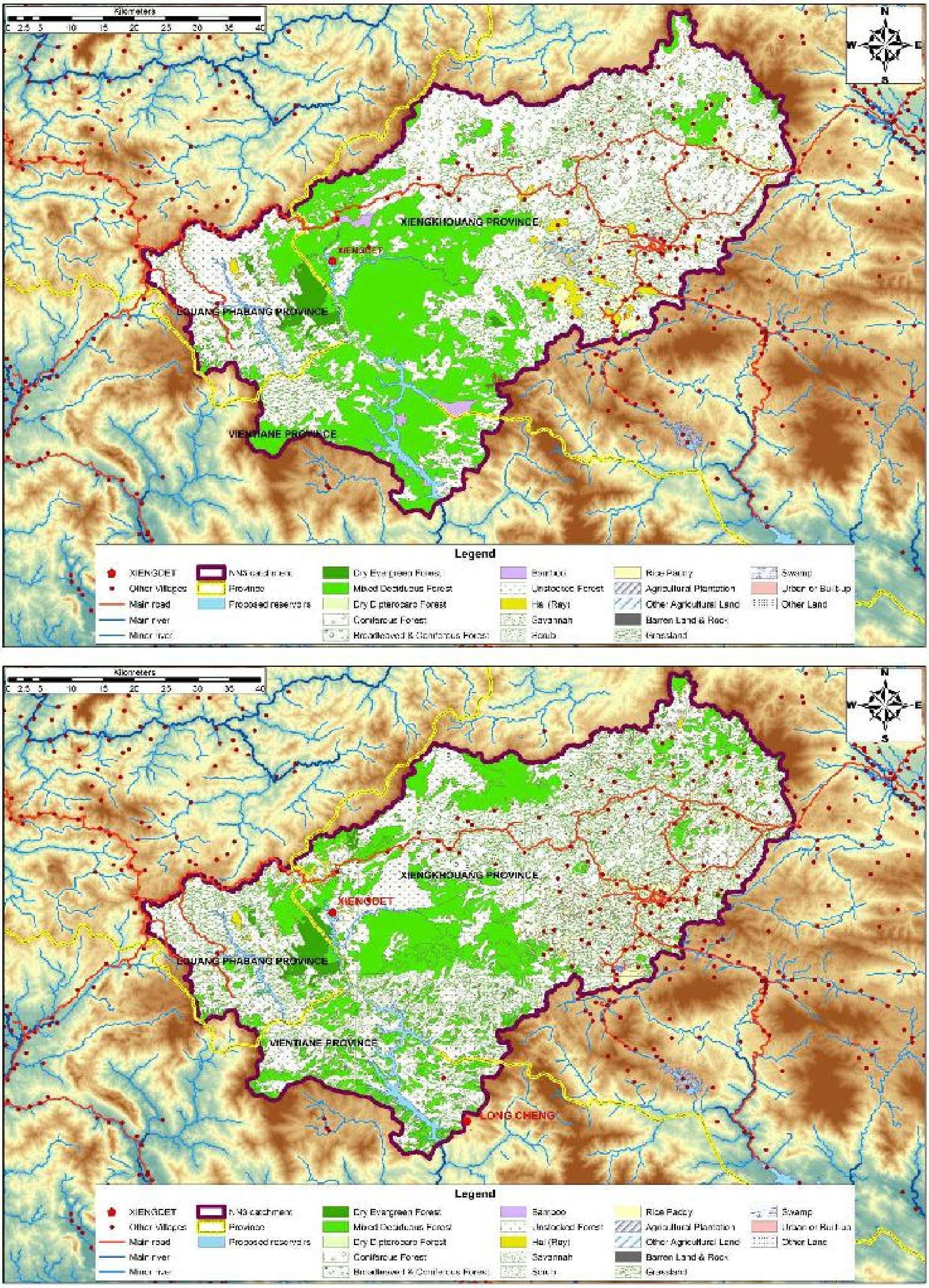


Figure 5.2: Natural vegetation with moist Upper Mixed Deciduous Forest upstream of the NN3 dam site

Figure 5.3: Natural vegetation at the NN3 dam site

212. The RMR studies in 2000-2001 and recent observations (Ramboll, 2007) indicate that the category Mixed Deciduous Forest has been significantly reduced in coverage since the early 1990s, as shown on Figure 5.4. The decline has continued since.

Figure 5.4: Comparison of forest cover between 1992 (top) and 2002 (bottom)



b. Unstocked forest

213. Almost 35 % of the catchment area is covered with unstocked forest (unstocked and shifting cultivation). Such forests are early succession stages which cover a wide variety of steps in the process of forest development, from very young fallow land with tree seedlings and samplings of not

much more than one metre in height to patchy stands of young trees and to closed canopy forest of more than 20 years of age. There are no large trees. Species diversity is limited.

214. A large part of the category "Unstocked Forest" consists of bamboo dominant vegetation. Large areas throughout the whole catchment are covered with very dense stands of invading bamboo, which virtually shade out all other vegetation. Tree regeneration is very slow on these areas. Dominating bamboo species are *Cephalostachyum virgatum* and *Oxyternanthera parvifolia*. Bamboo is an important material for construction and other purposes, and the young shoots are eaten.

Figure 5.5 A and B: Unstocked Forest and Shifting Cultivation in the NN3 Catchment Area

215. Hill rice fields (Ray) regeneration areas are covered by uniform low woody vegetation, and in some cases grassland, which has been used for hill rice cropping in the previous 5-10 years.

216. Hill-top grassland is land with growing tall, clumped, perennial grasses mostly *Imperata cylindrica*. These areas are regularly (or annually) burned. Unusually severe fires, aerially applied defoliants and extensive maize and poppy cultivations could explain why they are so widespread in the NN3 catchment (RMR 2001).

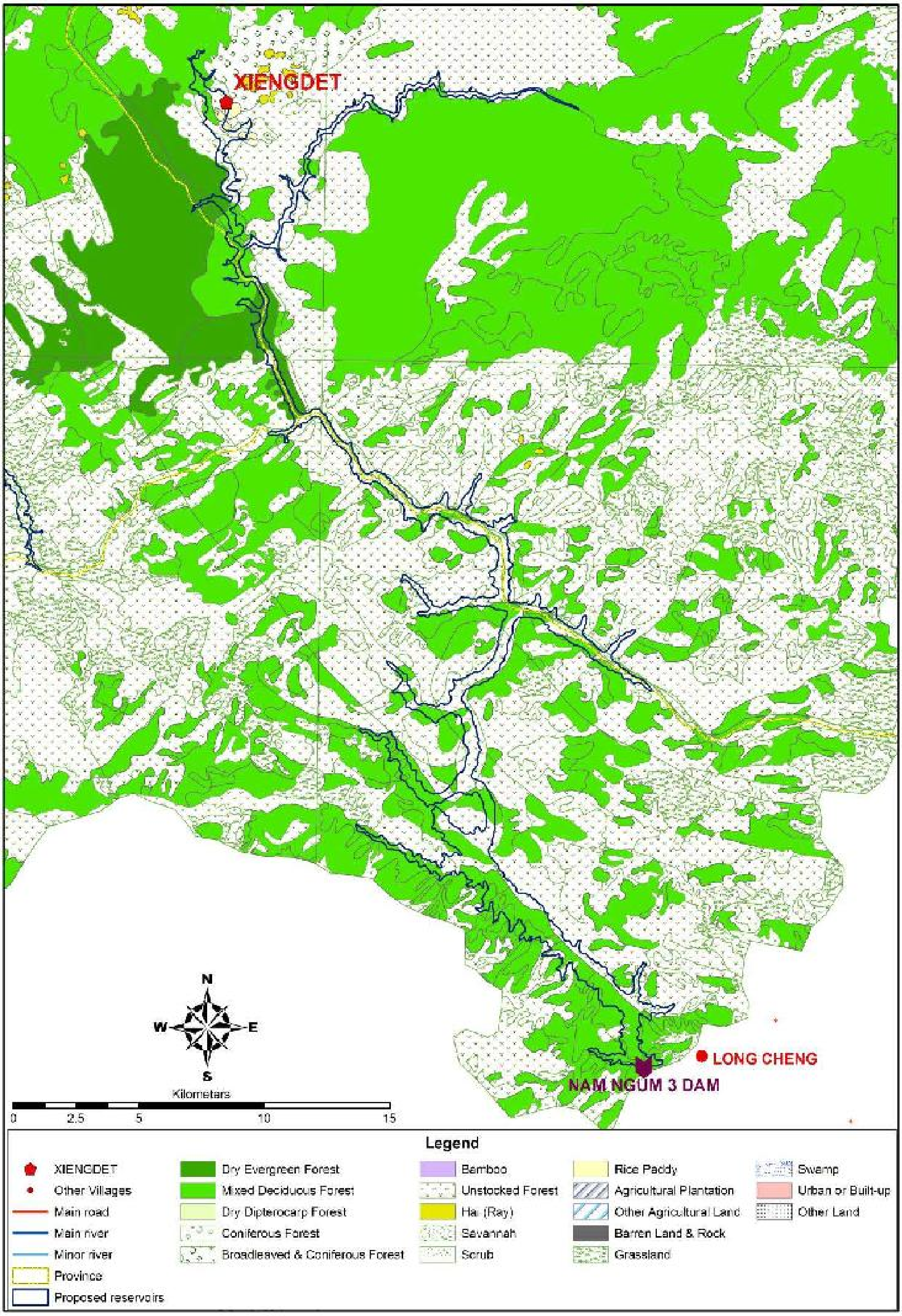
217. This potential forest type follows the Nam Ngum and stretches to the south-eastern part of the catchment area. At the south eastern part of the catchment near the dam site near Long Cheng also patches of *Imperata* grasslands occur.

218. Unstocked forested areas can be the result of fallow laying land during the present or past practices of shifting cultivation. Active shifting cultivation is shown in Figure 5.5 B. Unstocked forest can also be the result of eradication of poppy cultivation. Presently, Ban Xiengdet and the villages located in the vicinity of the reservoir area are considered to be non opium producers.

2. Reservoir Area

219. The same dataset used for calculating the forest coverage of the catchment has been used for the reservoir area. The results of the categorisation of vegetation and land use within the area below the 723 m FSL contour are shown in Table 5.2 and Figure 5.6 below. At FSL, the reservoir will cover an area of 27.5 km^2.

Figure 5.6: Land Use in the Area of the Reservoir (2002)



220. As can be seen from the table, the reservoir area is dominated by Un-stocked forest (51.8%). Within this category the Bamboo vegetation types are dominant. These data show the highly degraded state of the land which will be inundated by the reservoir.

Table 5.2: Land Use and Vegetation Types at Future NN3 Reservoir Area

Vegetation Types, River Area, and Land Use	Area (ha)	% of Total NN3 Reservoir Area
Current Forest	**1,047**	**38.0**
Upper Dry Evergreen	63	2.3
Upper Mixed Deciduous	964	35.0
Mixed Coniferous and Broadleaved	19	0.7
Un-Stocked Forest	**1,427**	**51.8**
Permanent Agriculture Land	**49**	**1.8**
Other Non-Forest Area	**231**	**8.4**
Grassland	19	0.7
Water	212	7.7
GRAND TOTAL	**2,754**	**100.0**

Source: Ramboll, 2007, based on 2002 Landsat Image Interpretation in 2006 by Forest Inventory and Planning Division.

221. The forest categories (as defined in this present study and on the basis of 2002 data) amount to about 38 % of the total area, with Upper Mixed Deciduous forest counting for 35%. RMR (2001) study concluded that hardly any primary forest was left in the reservoir area. The forest cover distribution will be updated in the dry season 2011-2012.

222. Open grassland is not very frequently found in the reservoir area as these are mostly concentrated on the higher elevations.

223. About 3.5 km^2 of the Phou Pha Pieng Production Forest will be inundated. The lost area will consist of 150 ha Upper Mixed Deciduous forest and 200 ha of Unstocked forests.

224. Paddy rice fields are only found in the upper end of the reservoir at Ban Xiengdet.

a. Salvage logging of the impoundment area

225. The Prime Minister's Office notified the project developers on the 22nd of October 2004 that GoL planned to start removing the commercial valuable timber from the proposed NN3 reservoir area. The Ministry of Defence with assistance from the Ministry of Agriculture and Forestry carried out the demarcation of the Full Supply Level of the reservoir and the timber inventory estimating the commercial valuable timber volume to be about 86,000 m^3. Subsequently, GoL contracted three companies to undertake the logging of the NN3 reservoir area including part of Phou Pha Phieng Production Forest Area from valuable timber. The logging of the area is now completed.

b. Biomass

226. RMR had calculated in 2001 that about 335,000 tonnes dry vegetation biomass will be inundated at FSL. This includes the timber already removed during the recent salvage logging operations. It is likely that the biomass removed during the salvage logging includes the annual growth seen since the estimations were made. An inventory will be undertaken prior to the biomass removal programme to update this figure.

c. Agriculture

227. The 25.4 km² of terrestrial habitats in the reservoir has very limited value for present or future food production. Only a small part is now used for paddy rice production at Ban Xiengdet, and only a few additional hectares could be developed. Data from 2001 showed that hill rice production was taking place, or had recently been practised, on only about 3% of the reservoir land. Slopes below 723 m elevation are steep, with more than half of the reservoir area being steeper then 20^o and only 14% of the reservoir area having slopes less steep than 10^o. This accounts for the unsuitability of the area for hill rice cropping.

d. Non Timber Forest Product (NTFP)

228. It is expected that the some of the nearby villages have made use of the reservoir terrestrial habitats for hunting and gathering food (wildlife, vegetables, fungi, honey, insects, roots, fruits, nuts, etc.). There is little evident difference between the habitats below 723 m and those above (except for the narrow riverine vegetation strip, which occurs sporadically along the river whenever a narrow terrace has become stabilised), and there is therefore no practical reason to assume that the loss of about 25 km^2 of forests, bamboo and grasslands will have a significant impact on the food supply of the local people.

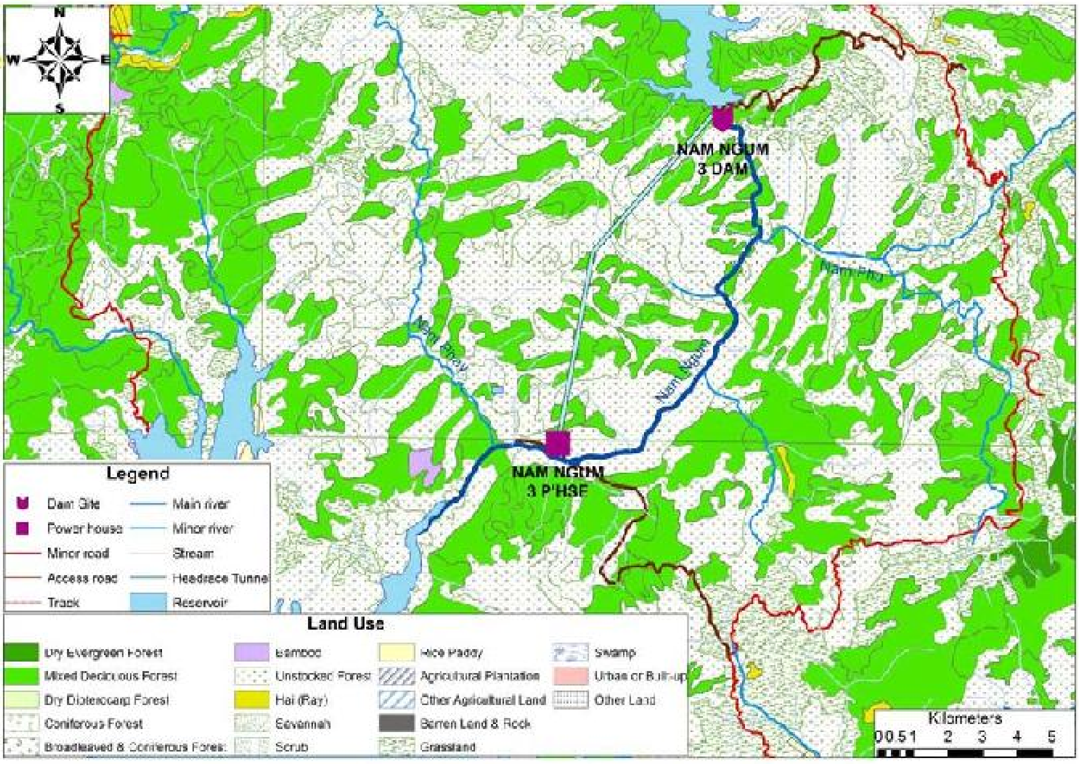
229. The low level of present use of terrestrial habitats in the NN3 reservoir area is probably due to (i) the distance and limited access from the residential areas to the Nam Ngum River, (ii) the steep slopes in the Nam Ngum River Valley and (iii) concerns over security, which has prevails for a long period of time. Villagers to the north and south of the area consider it unsafe for hunting and collecting expeditions. In the future it is likely that levels of use of these habitats could increase if security improves, leading to the possibility that unsustainable exploitation of resources occur.

3. Roads

230. Almost the entire public road from Ban Nam Gnone to Ban Long Cheng passes through what is classified as Unstocked Forest (intermixed with some small pockets of Mixed Deciduous). Rice paddies and dry land cultivations (mainly Ray) and other crops (bananas, cassava, etc.) are found along this road and mainly confined to the peripheries of major villages such as Ban Pha Gnai and Ban Long Cheng.

231. The vegetation along the dam site access roads is mainly Unstocked Forest, with major portions of open grassland. Along this road rice paddy or dry land crops were nonexistent at the time of the survey.

Figure 5.7: Land Use along the Construction Roads (dam site, powerhouse, Nam Gnone – Long Cheng)



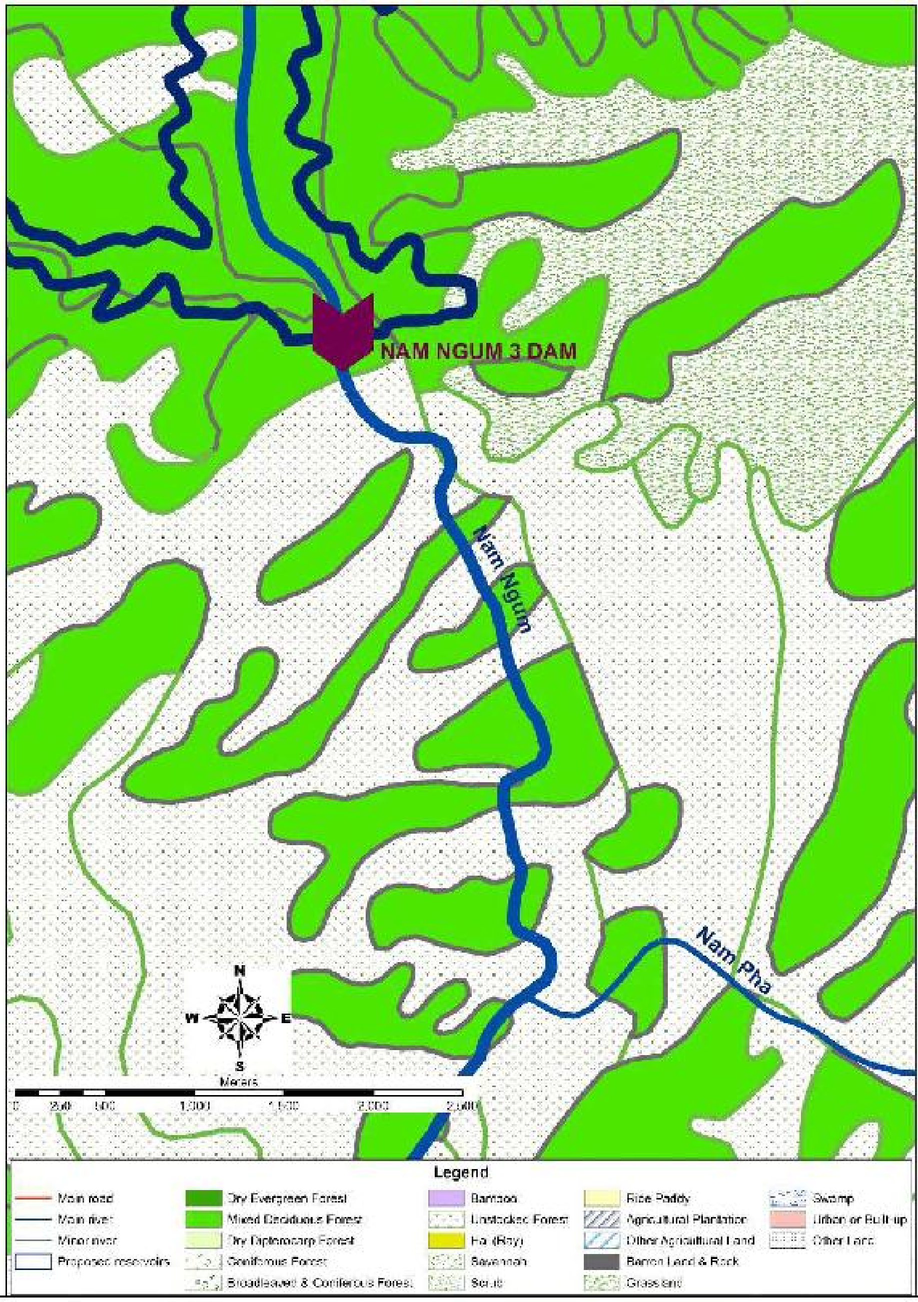
232. Vegetation along the power house access road is mainly Mixed Deciduous Forest with portions of Unstocked Forest, intermixed with Bamboo Forest. Due to rugged and steep mountains, as well as inaccessibility and remoteness, cultivation of rice or other crops were nonexistent. At the powerhouse the vegetation is Mixed Deciduous Forest.

4. Downstream NN3 Dam Site

233. One of the better preserved forest sections can be found on the left bank of Nam Ngum River downstream of NN3 reservoir and the dam site, south of the NN3 access road from Long Cheng to NN3 dam site to NN2 reservoir and west of the public road from Nam Gnone to Long Cheng.

234. This forest area is part of the Phu Bia Mining Exploration Area (see Figure 4.2) and the vegetation and land use will not be physically impacted by NN3.

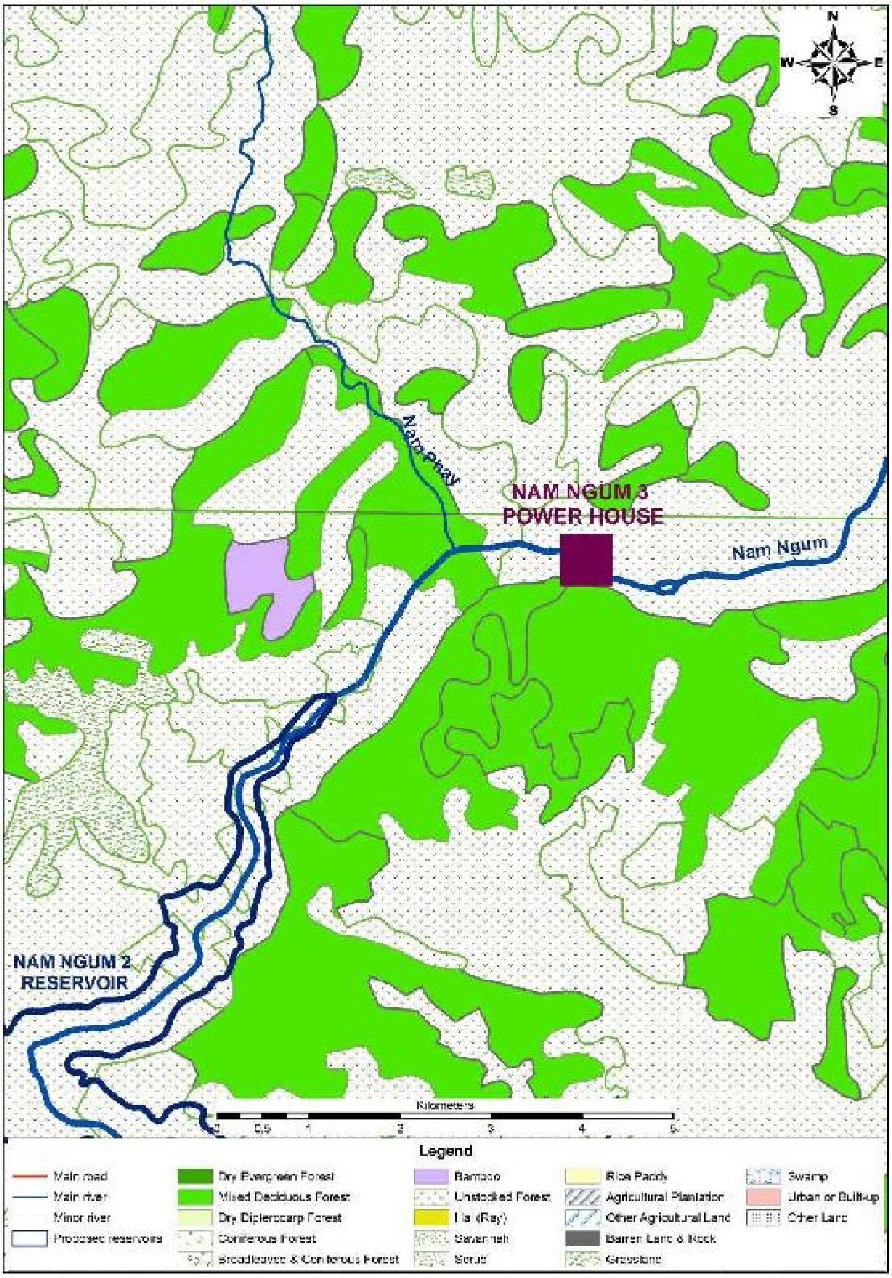
Figure 5.8: Land Use in the Area Downstream of the Dam Site, including Quarry (2002)



5. Powerhouse and downstream

235. Figure 5.9 shows the vegetation types in the area immediately around the powerhouse and up to the NN2 reservoir. The main vegetation is made of unstocked forests and mixed deciduous forests.

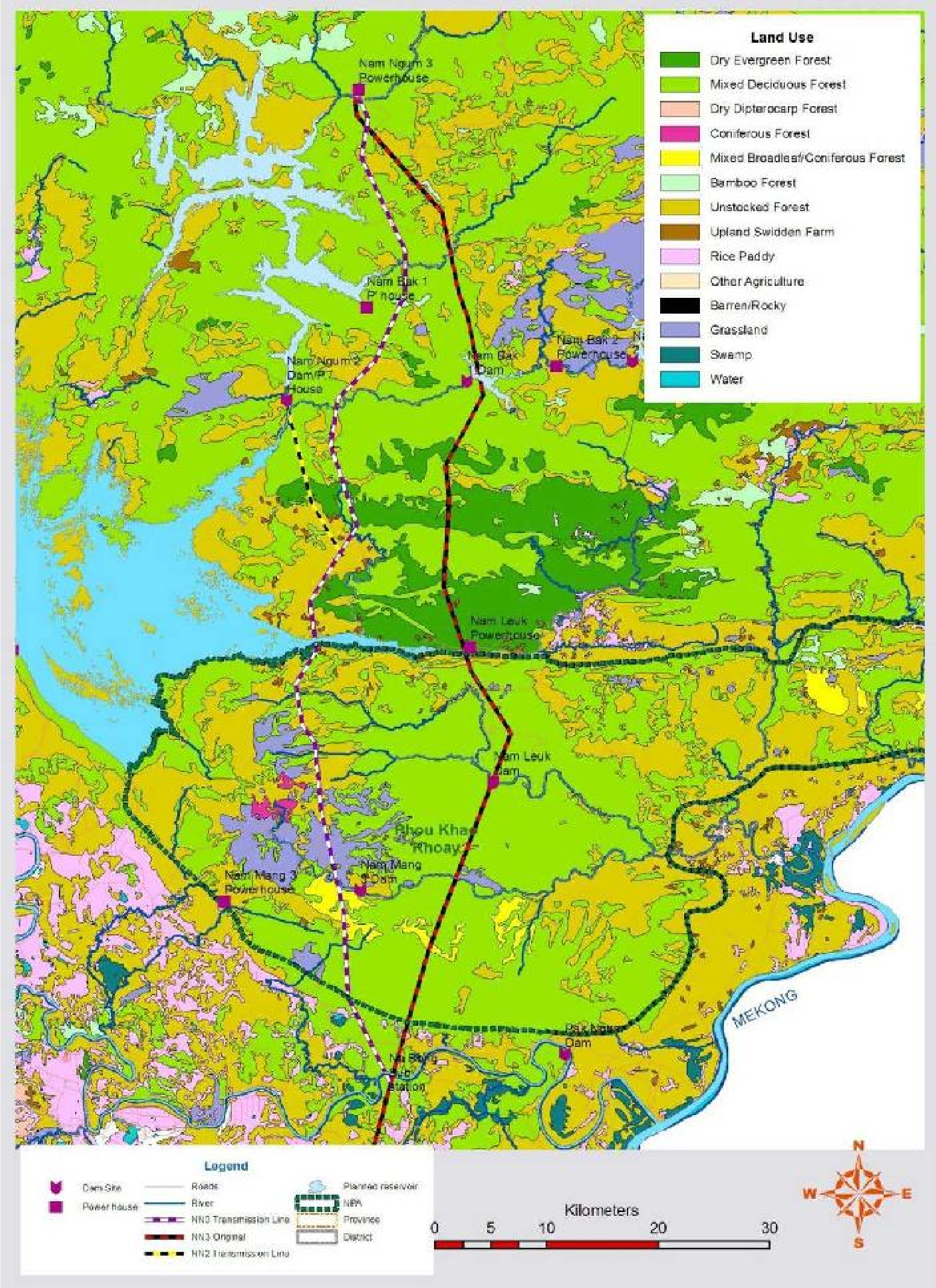
Figure 5.9: Land Use in the Area of the Powerhouse (2002)



6. Transmission Line

236. Figure 5.10 shows the land use and vegetation types along the NN3 transmission line corridor (original and final) and the NN2 transmission corridor as well as the area occupied by the Phou Khao Khouay (PKK) National Protected Area. To the north the main vegetation is made up of Dry Evergreen Forest alternating with open grassland and unstocked areas. The area used for commercial tree plantation is rapidly growing in the region (Ramboll 2007). PKK NPA has a forest cover of 60%, which is higher compared to the NN3 catchment.

Figure 5.10: Land use and forests along the NN3 Transmission Line Corridor



237. Since 1997 PKK NPA has been the location for (i) two hydropower reservoirs (Nam Leuk and Nam Mang 3), (ii) part of location of the transmission lines of these two hydropower projects, (iii) part of the location of the upgrading of the public road from Thabok to Xaysomboun with increased traffic to Phu Bia, and (iv) resettlement sites for refugees.

B. Wildlife

1. Catchment Area

238. Due to concerns over security which has prevailed in and around the NN3 catchment for many years, none of the formal and extensive assessment of wildlife surveys was allowed to carry out systematic wildlife surveys in the valley between Ban Long Cheng and Ban Xiengdet. Both SMEC (1995), RMR (2001), Dongsay (2006) and the EcoLao-NORPLAN update (2007) have been limited to collect second hand information about wildlife from local villagers, forest officers, and literature review. A summary of the mammal species reported from village interviews in these studies is presented below.

Table 5.3: Mammal species from the reservoir area reported by village interviews (SMEC (1995), RMR (2001), Dongsay (2006) and EcoLao-NORPLAN (2007))

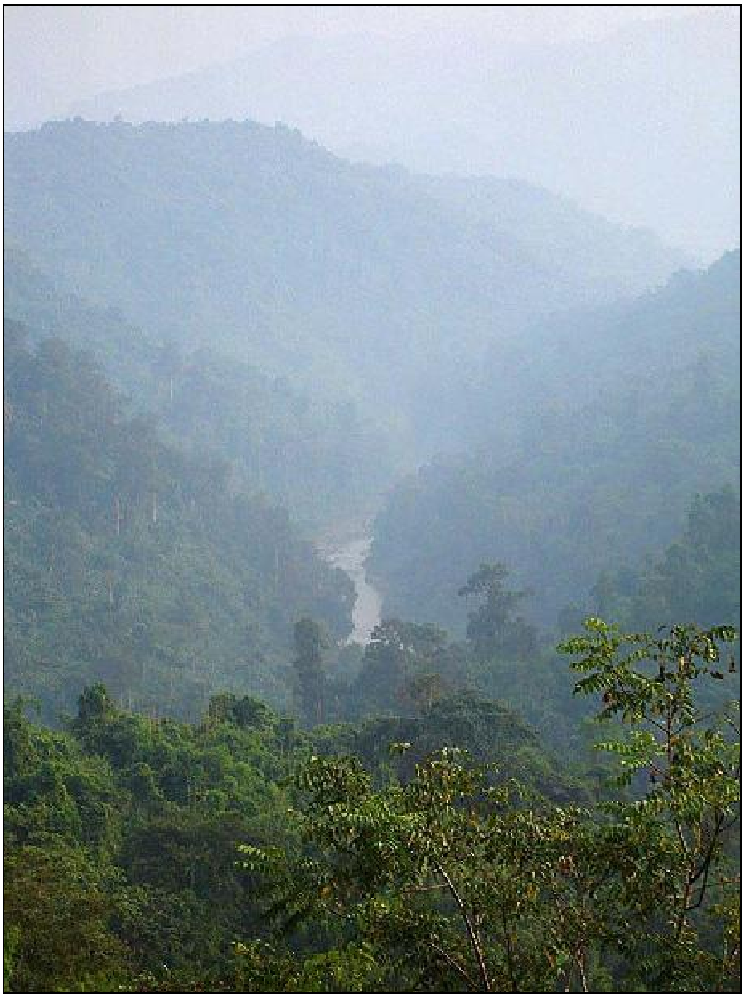
Mammal Species from Reservoir Area	IUCN national priority status (risk of extinction) RMR, 1998-2001
Mountain goat	1 / 0
Wild boar	1 / 0
Eurasian Wild Pig	1 / 0
Pangolin	1 / 0
Rusa deer	1 / 0
Barking deer (Muntjac)	1 / 0
Porcupine	1 / 0
Horseshoe Bat	1 / 0
Common Bat	1 / 0
Fruit Bat	1 / 0
Slow Loris	1 / 0
Macaques	2
Asiatic Black Bear	2
Sun Bear	2
Siberian Weasel	1 / 0
Back Striped Weasel	1 / 0
Hog Badger	1 / 0
Large-Toothed Ferret Badger	1 / 0
Small-Toothed Ferret Badger	1 / 0
Civet	1 / 0
Otter	1 / 0
Binturong	1 / 0
Sambar	1 / 0
Serow	2
Squirrel	1 / 0
Marbled Cat	2
Fishing Cat	1 / 0
Clouded Leopard	2
Star Leopard	1 / 0
Asian Golden Cat	1 / 0
Tiger	3

3. High Risk of National Extinction (or already nationally extinct), 2. Medium Risk of National Extinction, 1. Low Risk of National Extinction, 0. Negligible Risk of National Extinction

239. Even though the list of wildlife species claimed to be present in the reservoir catchment is rather impressive, the degraded status of the forest leads experts to believe that the wildlife density is limited (Duckworth, 2010). Larger herbivores and carnivores dominate the list of species. The grass covered hills surrounding the reservoir provide seasonally excellent feeding habitats for wild and domestic herbivores, which might again attract large carnivores such as bears, leopards, and tigers. It is however believed that the overall density of wild ungulates is insufficient to maintain significant populations of carnivores. The baseline biodiversity survey will update their status.

240. One of the more well- preserved forest sections in the project area is found in the Nam Ngum valley between the dam and the powerhouse (Figure 5.6). Ramboll (2007) made the assumption that based on the diversity and quality of the forest it might contain a relatively rich biodiversity. However, this area is now part of Phu Bia mining exploration area. The responsibility for and the actual management of biodiversity in the near future at this area depends largely on the proposed exploration activities by Phu Bia Mining and the management that will be set by the NN River Basin Committee.

Figure 5.11: Downstream sub catchments with wildlife potential



2. Roads and Project Lands Impact Area

241. The project access roads for most parts go through degraded bush land with very low potential of valuable wildlife resources. However, some potentially valuable habitats still remain, especially within the peripheries of the dam site (on the right bank of Nam Ngum) and at the powerhouse area. This will be investigated during the update of the biodiversity survey.

3. River stretch from the NN3 dam to the NN2 reservoir

242. Actual field survey investigation of the baseline aquatic habitats within the river stretch was conducted by RMR in 1998 (RMR Studies Chapter 9, May 2001). The coverage of the actual survey is the entire river stretch from Mekong to NN3 dam site that was divided into seven river sections. Based on the existing river morphology, the aquatic habitat zone was then sub-divided into categories such as: (i) River bed and channel – permanently immersed, (ii) islands and banks – regularly temporarily immersed areas and (iii) terraces and flood plains (occasionally immersed areas). Table 5.4 below describes each coverage and limits per river section, its length, width, river hydraulics (gradient, river flow), river morphology and general features and land morphology (floodplain, gorge, deeply incised valley) as of 1998. Table 5.5 shows the animal ecology (mammals, reptiles, and amphibians) within the riverine habitat and the frequency seen in the sections of the river from the Tailrace to the dam site (River Sections 6 and 7) as of 1998.

Table 5.4: Description of Surveyed River Section from Mekong to NN3 Dam Site (RMR,1998-2000)

River Section No. and Limits	Section Length (km)	Average Width (m)	River Mophology and General Features: 1. River Bed & Chanel (Permanently immersed)	2. Islands and Banks (Regularly temporarily immersed areas)	3. Terraces, Flood plains, Cliffs and Caves (Occasionally immersed areas)	River Hydraulics	Land Morphology
1. Mekong to Nam Ngum 1	182	150	Some rapids near Nam Ngum 1 Dam. None elsewhere. Very wide (150 m) sandy, silty bed.	Few islands especially in wide, shallow stretches. Silty banks heavily cultivated in dry season as water level falls.	Flood plain with numerous nongs and gardens. Highly productive agricultural area. Flooded less frequently since construction NN1. Low bluffs and eroded steep banks, but no cliffs or caves.	Low gradient (0.03%). Slow flow. Many river bends. A meandering depositional river section. Frequently experiencing backwater flooding when Mekong River levels are high.	River flows through flood plain in a weakly incised bed.
2. Nam Ngum 1 Dam to Nam Bak Junction	34	70 (At Nam Bak Junction)	Reservoir with silty bed. Some underwater rocky promontories. No rapids or cataracts. Drowned valleys where the old tributary system of Nam Ngum river enter the reservoir.	Numerous variably sized mostly earth and silt islands. Some rocky promontories. Large earth/silt drawdown area at terrace banks and islands. Cultivated and used for livestock grazing.	No terraces or flood plains. Water level limited by Nam Ngum 1 full supply level. No cliff or caves.	Almost no gradient (when NN1 at FSL). Very slow to no flow of warm water at top layer with faster flow of cold water underneath.	River runs for a short distance through a deeply incised valley before entering a reservoir with mainly gently shelving shoreline. Some stretches of steeply sloping shoreline (especially along southern and western edges).
3. Nambak Junction to Nam Muay Junction (Since 2010 within NN2 reservoir)	31	45	Narrow rocky/pebbly bed with many boulders.	Extensive and numerous rocky, pebbly islands. Rocky banks.	A few flattish terraces areas. Most of which cultivated with hill rice or gardens.	Moderate gradient (0.19%). Fast to moderate flow. Few river bends. A highly erosive river section.	Steeply and deeply incised gorges/valleys with occasional terraces.

River Section No. and Limits	Section Length (km)	Average Width (m)	River Mophology and General Features 1. River Bed & Chanel (Permanently immersed)	2. Islands and Banks (Regularly temporarily immersed areas)	3. Terraces, Flood plains, Cliffs and Caves (Occasionally immersed areas)	River Hydraulics	Land Morphology
			Abundant cataracts and rapids. Numerous deep s low flowing pools	Numerous small temporary ponds an d pools.	Shalow s oils o f silty loams. Some stee escarpments with c liffs and many s mall c aves at the below high water level.		
4. Nam Muay Junction to Nam Phay Junction (Since 2010 within NN2 reservoir)	14	35	Narrow rocky/pebbly bed with many boulders. Abundant cataracts and rapids. W ider and more sandy b ed toward bottom of section.	Large numerous rocky, p ebbly islands. Rocky banks. Numerous small temporary ponds an d pools.	No t erraces i n t he very steep rocky gorge. O pens t o area with s everal terraces. T erraces as v illage s ite or are c ultivated with gardens/hill r ice. Only 2 oc cupied villages at present. Shallow soils at silty loams. Some steep escarpments with c liffs and manay s mall caves at an d below h igh water level.	High gradient (0.75%) becoming moderate at bottom s ection. F ast to moderate flow. F ew r iver bends. A high erosive river section.	Very s teeply incised gorge/valley opening i nto f latter area w ith t erraced banks.
5. Nam Phay Junction to Tailrace Discharge	2	30	Narrow ro cky bed with many boulders, cataracts and rapids.	Large rocks and b oulders make up islands an d banks. S andy, siilty soils virtually absent. S ome small temporary	No terraces or flood p lains. M any cliffs a nd s mall caves at an d below h igh water level.	Very high gradient (1.57%). Very fast flow. F ew river bends. A very erosive river section.	Steeply i ncised gorge/valley.
6. Tailrace Discharge to Nam Pha Junction	10	30			Steeply i ncised gorge with a f ew terraces near stream j untions.		

River Section No. and Limits	Section Length (km)	Average Width (m)	River Mophology and General Features			River Hydraulics	Land Morphology
			1. River Bed & Chanel (Permanently immersed)	2. Islands and Banks (Regularly temporarily immersed areas)	3. Terraces, Flood plains, Cliffs and Caves (Occasionally immersed areas)		
				ponds an d pools.	Many c liffs and small caves at and below h igh water level.		
7. Nam Pha Junction to Dam Site	4	20	Narrow ro cky bed with many boulders.	Large rocks and b oulders make up islands an d banks with sandy, silty soils. Many temporary ponds an d pools.	Very s teeply incised gor ge. Only one terrace 800 m ups tream junction of N am Pha J unction. Numerous s mall ponds (nongs). Veryseondary woodland an d grassy flood meadows (possibly site of old v illage on this terrace). M any cliffs a nd s mall caves at the below high water level.	Very high gradient (0.84%). Very fast flow. Very few river bends. A very er osive section.	Steeply i ncised gorge/valley.

Table 5.5: Description of Terrestrial and Aquatic Habitats from Tailrace to NN3 Dam Site, RMR (1998-2000)

No.	River Section	Section Length (km)	Section Width (m)	General immersion pattern	HABITAT ZONE 1. River Bed & Channel (Permanently immersed)	2. Islands and Banks (Regularly temporarily immersed)	3. Terraces and Flood Plains (occasionally immersed areas)
Terrestrial Habitat (Animal Ecology)							
6	Tailrace to Discharge Nam Pha Junction	10	30		A newly established fish migration route from NN1 reservoir upstream to spawning grounds. Fish species able to penetrate rapids and cataracts in colder fast-flowing waters.	Rocky islands and banks supporting low density of animals (Fishing cats, leopard cats, crestless Himalayan porcupine, pythos, geckos, water monitor, several columbrid snake spp.) Some more specialised species (otters, 2 spp.), widespread and common; stripe necked terrapin, occasional; big-headed turtle, rare; water shrews, commong; voles, rare; numerous toads and frogs;crab-eating mongoose, rare) use these islands and banks and their shallow temporary waters. Numerous small temporary ponds and pools supporting specialised frogs, small fish and reptile populations. Forktails, blue whistling thrush, sand pipers, grey nightjars, kingfishers (blackheaded, white wagtails, grey wagtails, coucal (2spp.), black drongo, frogmouths.	Terrace fauna thought to be similar to above Nam Pha, i.e. wild pig, deer, cats. Forktails, blue whistling thrush, sand pipers, grey nightjars, kingfishers (blackheaded, white wagtails, grey wagtails, coucal (2spp.), black drongo, frogmouths. Caves and cliff underhangs are used by several bat spp. (one large fruit bat, tomb bat, Myotis spp., and horseshoe bat) in the dry season. Viverrids, small cats, macaques, otters use drier caves at high water level.
7	Nam Pha Junction to Dam site	4	20		A newly established fish migration route from NN1 reservoir upstream to spawning grounds. Fish species able to penetrate rapids and cataracts in colder fast-flowing waters.	Rocky islands and banks supporting low density of animals (Fishing cats, leopard cats which feed on fish, frogs and crabs and molluscs, etc., water monitor, crestless Himalayan porcupine, water dragons and skinks). Some specialised species (otters (2 spp), widespread and common; stripe necked terrapin, occasional; big-headed turtle, rare; water shrews, common; voles, rare; numerous toads and frogs; crab-eating mongoose, rare) use these islands and banks and their	Terrace 800 m above Nam Pha Junction with more abundant fauna (Three striped palm civet, binturong, leopard cats, golden cat (?), barking deer, sambar, loris, serow, wild pigs) than seen on any bank or island along this section. Several small “nongs”. Now used as site for fishing/hunting camps. Caves and cliff underhangs are

No.	River Section	Section Length (km)	Section Width (m)	General immersion pattern	HABITAT ZONE 1. River Bed & Channel (Permanently immersed)	2. Islands and Banks (Regularly temporarily immersed)	3. Terraces and Flood Plains (occasionally immersed areas)
						shallow waters. Numerous small temporary ponds and pools supporting specialised frogs, small fish and reptile populations. Many large mammal tracks seen where river has sandy bank close to the Nam Pha Terrace. Bat hawk common over river gorge. Forktails, blue whistling thrush, sandpipers, grey nighjars, kingfishers (blackheaded, white wagtails, grey wagtails, coucal 92 spp.), black drongo, frogmouths, banded broadbill, rock pigeon.	used by several bat spp. (one large fruit bat, tomb bat, Myotis spp. and horseshoe bat) in the dry season. Viverrids, small cats, macaques, otter use drier caves at high water level. Bat hawks common over river gorge, forktails, blue whistling thrush, sandpipers, grey nightjars, kingfishers (blackheaded, white wagtails, grey wagtails, coucal(2 spp), black drongo, frogmouths, banded broadbill, rock pigeon.
Aquatic Habitat 6-7	Tailrace to Dam site	4	20	From the NN3 dam to the NN1 reservoir river flows in the dry season are 5.4% of wet season flows and 15% of average flows. The river base flow is low because the catchment has been severely eroded over very long periods and has low water retention capacity. Another consequence of this is the frequency of flooding which is high.	Permanent river is a relatively small water body, found as deep pools connected by shallow narrow streams flowing over rocks in rapids, cataracts and small waterfalls. The river bed is virtually abiotic, being composed of rocks, boulders and pebbles of mostly limestone or igin, on which a few stone algae can grow in the dry season.	Zone 2 the seasonal river and its banks represent the predominant habitat zone component for the Nam Ngum river. The terrestrial zone 2 habitats have classical rheophytic ecology, being fairly low in productivity and diversity but supporting highly specialised plant and animal species. Aquatic zone 2 habitats are very unproductive and have low diversity.	Floods will be ephemeral and mostly drain quickly away, a very small number of pools and small nongs occur which can develop distinct eutrophic stagnant water habitats. Aquatic habitats (other than the very few ponds and nongs) are too short lived to develop any recognisable productivity or diversity features. Terrestrial habitats in zone 3 are only slightly different from terrestrial habitats above zone 3. Occasional or seasonal floods reduce the occupation of river gorge caves and prevent the build up of guano which can create a distinct and productive habitat (This may be the most significant input of these floods).

243. The RMR aquatic habitat studies showed that, in 1998, the rocky islands and banks of the Nam Ngum supported low density of animals specialised in feeding on fish, frogs, crab and molluscs like fishing cats, leopard cats, otters and mongoose. On higher land striped palm civet, binturong, golden cat(?), barking deer, sambar, loris, serow, wild pigs and porcupine were found. Caves and cliff under hangs were reported to be used by several bat species in the dry season (large fruit bat, tomb bat, *Myotis* spp. and horseshoe bat).

244. Bird species in this reach included: bat hawks (common over river gorge), forktails, blue whistling thrush, sandpipers, grey nightjars, kingfishers, white wagtails, grey wagtails, coucal (2 spp.), black drongo, frogmouths, banded broadbill and rock pigeon.

245. The Tables 5.6 and 5.7 summarises the results of the RMR (Chapter 33, 2001) fauna surveys in the Nam Ngum Reach from the NN3 dam to the NN1 reservoir and highlight the fauna found in the sections of the river from the tailrace to the Nam Pha confluence (River Section 6) and then from the Nam Pha confluence to the Dam site (River Section 7). The tables also showed the status of these fauna in 1998 (during the survey) and compared it against the IUCN status.

246. The column "IUCN National Priority" in Table 5.6 and 5.7 describes the risk level for the species' survival in Lao PDR. The classification of Duckworth *et al* has been simplified to show 4 categories of risk, namely:

Risk Level for next ten years and Risk (0-3)		Duckworth *et al* classification
3	High risk of National Extinction (or already nationally extinct)	"Acute National Priority Category and some "Indeterminate National Priority spp." Occurring in small populations in restricted areas and any new rare species
2	Medium Risk of National Extinction	"High National Priority category" and some "Indeterminate National Priority spp." Occurring in small populations and reasonably distributed.
1	Low Risk of National Extinction	All listed "key" species except those in the Acute High and Indeterminate Priority Groups and some "Indeterminate National Priority spp." With large and widespread populations.
0	Negligible Risk or National Extinction	All common species not listed as key species.

247. In addition, the column "Global Status of Lao Population" in Tables 5.6 and 5.7 is taken from Duckworth et al's ranking of Global Significance of Lao Populations. There are 5 categories of risk, as shown below:

Importance Level for next ten years and Importance Index (0-4)		Duckworth *et al* classification
4	Very High Risk of Global Extinction: Lao population critical	Species close to global extinction. Lao population is a critical component
3	High Risk of Global Extinction: Lao population is very significant	Species has small numbers and/or restricted range. Lao population is very significant component.
2	Medium Risk of Global Extinction: Lao population is significant	Species has a regionally concentrated distribution. Lao population is significant component.
1	Low Risk of Global Extinction: Lao population unimportant	Species numerous in region. Lao population is unimportant component.
0	Negligible Risk of Global Extinction : Lao population relevant	All common species is not listed as key species. Also population not a relevant component.

248. It has to be noted, however, that since the RMR survey, Phu Bia mining has started operations, NN2 dam has been built, and its reservoir filled and construction activities for Nam Ngum 5 have commenced. These projects were covered by the Cumulative Impact Assessment study (2008), and have impacted directly and indirectly the natural habitats in this area.

Table 5.6: Mammal, Reptile, and Amphibian species recorded by RMR (2001) NN3 Dam Site to the confluence of the Nam Ngum with the Mekong River (River Sections 1 to 7)

English Name	Latin Name	River Section No. (Sections 6 & 7 are of areas of concern)	Frequency Seen	No. of Species	IUCN National Priority (1998-2000)	No. of Species	Global Status of Lao Population	2010 IUCN
MAMMALS								
Macaque	*Macaca spp.*	3,4,5,6.7	Common	*1*	*1*	*3*	**2**	
				Several	*0*	*2*	**1**	
Common Barking Deer	*Muntiacus muntjak*	6,7	Occasional	*1*	*0*	*1*	**1**	
Sambar	*Cervus unicolor*	6,7	Occasional	*1*	*1*	*1*	**0**	
Tomb cat	*Taphozous theobaldi*	3,4,5,6.7	Common	*1*	*1*	*1*	**1**	
Fishing cat	*Prionailurus viveriinus*	3,4,5,6.7	Common	*1*	*1*	*1*	**1**	EN
Leopard cat	*Prionailurus bengalensis*	4,5,6.7	Occasional	*1*	*0*	*1*	**0**	LC
Crestless Himalayan Porcupine	*Felis bengalensis*	3,4,5,6.7	Occasional	*1*	*0*	*1*	**0**	
Otters	*Lutra ssp.*	3,4,5,6.7	Very common	*3*	*2*	*2*	**2**	4 otter species in Laos, including 3 possible in the project area, 1 NT and 2 VU
				1	*1*	*2*	**1**	
Vole		4,5,6.	Rarely seen	*1*	*0*	*1*	**0**	
Fruit Bat	*Several spp.*	3,4,5,6.7	Common	*1*	*1*		**1**	
Horseshoe Bat	*Rinolophus sp. Or spp.*	3,4,5,6.7	Common	*1*	*1*	*12*	**1**	
						1	**Unknown**	
Large Bamboo Rat	*Rhizomys sumatrensis*	3,4,6.7	Common	*1*	*0*	*1*	**0**	
Variable Squirrel	*Callosciurus finlaysoni*	3,4,6.7	Common	*1*	*0*	*1*	**0**	

English Name	Latin Name	River Section No. (Sections 6 & 7 are of areas of concern)	Frequency Seen	No. o f Species	IUCN National Priority (1998-2000)	No. of Species	Global Status of Lao Population	2010 IUCN
Water Shrews	*sp. Or ssp*	3,4,5,6.7	Common (rare in Section 3)	*1*	*0*	*1*	**0**	5 to 7 species in Laos
Common Wild Pig	*Sus crofa*	3,4,5,6.7	Common	*1*	*1*	*1*	**1**	
Lesser Mouse Deer	*Tragulus javanicus*	5,6.7	Occasional	*1*	*0*	*1*	**0**	
Common Bat	*Myotis sp. Or spp.*	3,4,5,6.7	Common	***5***	*1*	5	**1**	
				Several	*0*	*Several*	**0**	
Three Striped Palm Civet	*Arctogalida trivirgataFelidae*	6.7	Rarely seen	*1*	*0*	1	**0**	
Civet	Several spp	3,4,5,6.7	Common	*1*	*3*	1	**3**	
				1	*2*	1	**2**	
				Several	*0*	*Several*	**0**	
Crab eating Mongoose	*Herpestes urva*	4,6.7	Rarely seen	*1*	*0*	1	**0**	LC
REPTILES								
Asian Water Dragon	*Physignathus cocuncius*	3,4,5,6.7	Unknown	*1*	*0*	1	**0**	NE
Reticulated Python	*Morelia reticulatus*	4,5,6.7	Occasional	*2*	*1*	1	**2**	
Colubrine Snake	*sp. or spp*	4,5,6.7	Common	*2*	*1*	2	**1**	
				Many	*0*	Many	**0**	
Stripe –necked Terrapin	*Geomyda tcheponensis*	4,6.7	Occasional	*1*	*0*	1	**0**	
Big Headed Turtle	*Platysternon megacephalum*	4,6.7	Rarely seen	*1*	*2*	1	**2**	EN
Water Monitor	*Varanus salvato*	1,3,4,5,6.7	Common	*1*	*1*	1	**1**	LC

English Name	Latin Name	River Section No. (Sections 6 & 7 are of areas of concern)	Frequency Seen	No. of Species	IUCN National Priority (1998-2000)	No. of Species	Global Status of Lao Population	2010 IUCN
Yellow Tree Monitor	*Varanus bengalensis*	3,4,5,6.7	Common	*1*	*0*	1	**0**	
Toads	*Bufo melanostictus*	1,2,3,4,5,6.7	Very common	*Several*	**0**	*Several*	**0**	**-**
Frogs	Rana sp. or ssp.	1,2,3,4,5,6.7	Very common	*Several*	**0**	*Several*	**0**	**-**

EN = endangered, LC = least concern, NT = near threatened, VU = vulnerable.

Table 5.7: Bird Species recorded by RMR (2001) from Nam Ngum aquatic habitats downstream of the NN3 Dam Site

English Name	Latin Name	River Section No.	Frequency Seen	No. o f Species	IUCN National Priority (1998-2000)	No. of Species	Global Status of Lao Population	2010 IUCN
Bat Hawk	*Macheiramphus alcinus*	7	Rarely	*1*	*0*	*1*	**1**	**LC**
Black-Capped Kingfisher	*Halcyon pileata*	3,4,5,6.7	Common	*1*	*0*	*1*	**0**	
Frogmouth	*Batrachostomus sp. or spp.*	5,6,7	Occasional	*1*	*0*	*1*	**0**	
Grey Nightjar	*Caprimulgus indicus*	3,4,5,6,7	Common	*1*	*0*	*1*	**0**	**LC**
Rock Pigeon	*Columba punicea*	7	Common	*1*	*0*	*1*	**0**	
Coucal	*Centropus spp.*	3,4,5,6,7	Common	*1*	*0*	*1*	**0**	
Black Drongo	*Dicrurus macrocercus*	5,6,7	Common	*1*	*0*	*1*	**0**	
Banded Broadbill	*Eurylaimus javanicus*	7	Occasional	*1*	*0*	*1*	**0**	
White wagtail	*Motabilla alba*	3,4,5,6,7	Occasional	*1*	*0*	*1*	**0**	**LC**
Grey Wagtail	*Motabilla cinerea*	3,4,5,6,7	Common	*1*	*0*	*1*	**0**	**LC**
Sandpipers	*Tringa sp. or spp.*	3,4,5,6,7	Rarely	*1*	*0*	*1*	**0**	**-**
Forktails	*Enicurus spp.*	5,6,7	Common	*1*	*0*	*1*	**0**	**-**
Blue Whistling Thrush	*Myiophoneus caeruleus*	5,6,7	Common	*1*	*0*	*1*	**0**	

LC = least concern, NT = near threatened.

249. Of the fauna identified to species level civet and crab eating mongoose and big headed turtle are included in the categories "High Risk of National Extinction" or "Medium Risk of National Extinction", as per the Duckworth *et al*. classification. However, data needs to be updated during the conduct of the baseline biodiversity survey in 2011-2012.

4. Transmission Line Area

250. Wildlife habitats in the first section of the transmission line (outside of the PKK NPA) have been to a great extent severely impacted and destroyed through agricultural activities (slash and burn agriculture), mining and population expansion, resettlement and relentless hunting pressure. Wildlife that escape hunting and habitat destruction have retreated to the comparative safety area due to inaccessible habitats of PKK NPA.

251. On the section of the alignment crossing the PKK NPA, the corridor follows the existing NN2 TL, which is not located in significant wildlife habitats of PKK, which are found in the steep and inaccessible areas of the PKK NPA.

252. Table 5.8 lists the birds and mammals species found in Phou Khao Khouay NPA which have been categorised as "*Appendix I species – species threatened with extinction*" and "*Appendix II species – species that may become threatened unless trade is closely controlled*" by the Convention on International Trade in Endangered Species of Wild Fauna and Flora. The most significant wildlife habitats are found in the steep, inaccessible areas of the PKK NPA.

Table 5.8: Priority mammal and bird species in the Phou Khao Khouay NPA (PKK NPA Fact sheet 2001)

Common Name	Scientific Name	National Priority	Global Threat Category	Lao Risk Status
MAMMALS				
Pangolin species	Species not identified	-	-	-
Loris species	Species not identified	-	-	-
Pig-tailed Macaque	Macaca nemestrina	-	VU	PARL
Rhesus Macaque	Macaca mulatta	-	GNT	PARL
Phayre's Langur	Semnopithecus phayrei	INPA	DD	ARL
White-cheeked Crested Gibbon	Hylobates leucogenys	HNPA	DD	PARL
Yellow-cheeked Crested Gibbon	Hylobates gabriellae	INPA	DD	LKL
Dhole	Cuon alpinus	HNPA	VU	ARL
Bear species	Species not identified	-	-	-
Hog Badger	Arctonyx collaris	-	O	LKL
Otter species	Species not identified	-	-	-
Clouded Leopard	Pardofelis nebulosa	HNPA	VU	ARL
Big cat species	Species not identified	-	-	-
Asian Elephant	Elephas maximus	HNPA	EN	ARL
Pig species	Species not identified	-	-	-
Sambar	Cervus unicolor	-	O	PARL
Small flying squirrel Sp	Species not identified	-	-	-
East Asian Porcupine	Hytrix brachyura	-	VU	O
BIRDS				
Blue-breasted Quail	Cortunix chinesis	-	O	PARL

Common Name	Scientific Name	National Priority	Global Threat Category	Lao Risk Status
Siamese Fireback	Lophura diardi	-	VU	ARL
Green Peafowl	Pavo muticus	HNPA	VU	O
Red-collard Woodpecker	Picus rabieri	-	VU	O
Coral-billed Ground Cuckoo	Carpcoccyx renaudi	-	GNT	-
Fish owl species	Species not identified	-	-	
Watercock	Gallicrex cinerea	INPA	O	ARL
Purple Swamphen	Porphyrio porphyrio	INPA	O	ARL
Grey-headed Lapwing	Vanellus cinereus	-	GNT-	PARL
Jerdon's Baza	Avicida jerdoni	-	GNT	O
Fish eagle species	Species not identified	-	-	-
Purple Heron	Ardea purpurea	-	O	PARL
Yellow-vented Warbler	Phylloscopus cantator	-	GNT	O
Rufous-throated Fulvetta	Alcippe ruficapilla	-	GNT	LKL

Legend: National Priority:ANPA-Acute National Priority; HNPA- High National Priority; INPA-intermediate National Priority.

Global Threat category: O – not listed as of concern; DD- data deficient; GNT-global near threatened; GT-CR- global threatened critical; GT-EN- globally threatened –endangered; GT-VU globally threatened-vulnerable.

Lao PDR Risk Status:O- not at risk in Laos; ARL -at risk in Laos; CARL-conditionally at risk in Laos; LKL- little known in Laos; PARL-potentially at risk in Laos.

5. Evolving wildlife situation

253. It has to be noted that the wildlife situation is evolving rapidly because of the land take by numerous new hydropower reservoirs (Nam Leuk, Nam Mang 3, Nam Mang 1), the transmission lines of Nam Leuk, NN2 and NN3, the recently upgraded public road through Phou Khao Khouay National Protected Area to Nam Ngone to improve access to Phu Bia mining, and the establishment of new village areas for refugees, and other numerous activities happening at various scales. All these activities are expected to have impacted and to impact in the future the various habitats and the wildlife associated.

C. Aquatic ecology

254. Aquatic ecology and fisheries studies have been conducted as a part of the Feasibility Study (SMEC & SEATEC, 1996). In addition the RMR reports, in particular Chapters 21 and 36 , give valuable information on this issue. The EIA for Nam Ngum 2 (Electrowatt, 1998) has also provided valuable information. The insecurity situation in the area has prevented new surveys to take place.

1. Aquatic Habitats

255. The Nam Ngum River gorge shows a varied substrate, mostly hard rocky riverbed but also sandy, silt and clay riverbed. The river flows in level reaches broken up by many rapids and riffles. The river has no major drops or larger waterfalls. Deep pools can be found close to rapid areas.

256. These varied conditions give rise to different habitats for aquatic organisms which also reflect the overall diversity. The species composition within the different river habitats have been investigated by RMR (2001) for phytoplankton, zooplankton, bentic fauna and fish. The sampling campaign was conducted both during summer and winter periods. This and previous studies have provided comprehensive lists indicating high flora and fauna diversity of investigated aquatic habitats.

2. Phytoplankton

257. Phytoplankton found in the Nam Ngum River during summer and winter sampling periods included diatoms (mainly Bacillariphyceae), green algae, euglenoids and cryptomonads. A total of 78 species, 58 in winter and 23 in summer was found, with recorded densities of 10,385 – 18,077 cells/m^3 in winter and 2,190-14,192 cells/m^3 in summer. The findings indicate a relatively high diversity.

3. Zooplankton

258. For zooplankton (including protozoans) a total number of 15 different species were found. The major groups were rotifers and arthropods. Zooplankton showed highest concentrations in wintertime as for phytoplankton. The diversity and abundance varies with location. The diversity of plankton clearly indicates that the Nam Ngum is rich and diverse.

4. Benthos

259. Only arthropods were found in the Nam Ngum river bottom during the sampling periods in winter and summer. Eleven species of arthropods, 10 winter and 7 in summer, with density ranges of 0 to 650 individuals/m^2 in winter and 59-295 individuals/m^2 in summer were recorded.

5. Weeds

260. The occurrence of different aquatic weeds is prominent in the river system, especially in the dry season. Floating weeds like Azolla (Water fern: *Nae Daeng*) Pistina (Water lettuce: *Chok*), Eichornia (Water hyacinth: *Phak Tob Java*) and Salvinia (*Chok Hoo Noo*) are dominant. The great difference between high and low water levels and the sudden influx of water in the rainy season probably prevents the development of floating plants during wet seasons.

6. Fish

261. 269 different fish species have been recorded in rivers and freshwater systems in Lao PDR. General estimates (RMR 2001) indicate a likelihood of more than 50 species in the project area of NN3. The EIA report for the Nam Ngum 2 project area (Electrowatt 1998) recorded 19 different species, but this is probably only a part of the total number. Studies conducted as part of the RMRs Environmental Management Plan report 24 species in the NN3 reservoir and downstream reach. Of the species listed in the table *Mystus sp/spp, Mystus wyckioides, Labeo chrysophekadion, Wallago sp* and *Bagarius yarelii* are known to be migrating from the NN1 reservoir upstream in the Nam Ngum.

262. At least 44 fish species were recorded in 2009 in the section of the Nam Ngum close to the NN3 power station site. The number of species could have changed significantly since the impoundment of the NN2 reservoir. The NN3 Cumulative Impact Assessment Study found that at least 48 fish species are forming part of the household fish catch at Ban Xiengdet, on the basis of a monitoring undertaken of 3 households along the Nam Ting at the upper end of the planned NN3 reservoir.

263. The data indicate the potential for quite high fish species diversity. This would be expected in this area, as the river water quality is relatively good, with low input of contaminants, a wide range of habitats, and the rivers themselves are in a relatively natural state. Exceptions are however the Nam Ngum 1 reservoir and its dam, and then the NN2 dam that block migrations from downstream areas and Mekong.

264. At least 66 fish species have been recorded from Nam Ngum 1 reservoir but not all of them occur in the river systems.

265. Despite the rather intensive surveying efforts carried out so far it is not unlikely that there could still be a small number of undiscovered rare or endemic fish species found in rivers impacted by the Nam Ngum 3 and the other hydropower projects in the basin. Surveys will be undertaken to confirm this assumption.

7. Fish migration

266. Long distance migrating fish species that migrate all the way from the Mekong River such as fish species belonging to the Pangasiidae family have lost access to the Nam Ngum River upstream of NN1 reservoir since the early 1970s when the NN1 dam was constructed. Nevertheless, some migrating fish species as *Wallago leeri* (Pba Khoun) still occurred upstream of NN1 dam at the end of the 1990s. Presently, Pha Koun has not been caught in the Nam Ngum River at the NN3 power station site, nor at Ban Xiengdet. The completed NN2 dam, upstream of NN1 reservoir, blocks any potential migration of *Wallago sp.* into the Nam Ngum River. *Hemibagrus wyckioides* (Pba Keung) and *Bagarius yarelli* (Pba Ke) are migrating fish species that could be found, before the construction of NN2, in the Nam Ngum close to the NN3 power station site, but not (or very rarely) in the Nam Ngum and the Nam Ting at the upper end of the future NN3 reservoir as at Ban Xiengdet[1].

267. The pre-project disappearance of migrating fish species from household fish catch north of the confluence of the Nam Ting with the Nam Ngum can be explained to be the result of (i) destructive fisheries practices observed in the Nam Ngum, and/or (ii) the lower water temperatures in the Nam Ngum at higher elevations which may form a natural barrier for some migratory fish species. The Full Supply Level of NN1 reservoir is at 212 masl, while Ban Xiengdet village area is at elevation of around 723 masl. More than 500 meters difference in elevation has significant consequences for water temperatures and aquatic biodiversity.

268. Despite the general lack of diversity in migrating fish species, particularly in the northern parts of Nam Ngum at elevations higher than 720 masl, some short distance migratory fish species such as *Tor tambroides* (Pba Thone) are caught at Ban Xiengdet. *T. tambroides* generally does not migrate more than 20 km from their spawning habitats of rapids and pools.

269. The NN3 Water Quality and Fish Catch Monitoring (2008-2009) has found, however, that downstream impacts of NN5 (increased sedimentation and turbidity) occur upstream of Ban Xiengdet in the Nam Ting and are likely to affect aquatic habitats and abundance of fish species. Once the NN5 reservoir is filled, reduced discharges will be observed impacting in turn the aquatic habitats, before the NN3 project is completed.

270. Table 5.9 shows the 12 most common fish species in the catch at Ban Xiengdet that form 92 % of the total fish catch of the three selected fishers at Ban Xiengdet, confirming that long distance migrating fish species are presently (well before construction of NN3) not forming a significant part of the fish catch upstream of NN3 reservoir area.

Table 5.9: Twelve Most Common Fish Species in Fish Catch at Ban Xiengdet[2]

	Scientific Name Fish Species	Lao Name Fish Species	% in Weight of Total Fish Catch
1	Poropuntius laoensis	Pba chat	19
2	Labeo dyocheilus	Pba saii, Pba wa saii, Pba wa, Pba phaow	16
3	Garra theunensis	Pba phee	13
4	Osteochilus lini	Pba mawm, Pba namong, Pba iithai, Pba pohk	12
5	Neolossochilus blanci	Pba deng	7
6	Tor tambroides	Pba pohng, Pba tone, Pba xong	7
7	Clarias batrachus	Pba duk	6
8	Poropuntius carinatus	Pba kom	4
9	Luciocyprinus striolatus	Pba yoi	3

[1] Data from the fish catch monitoring undertaken at Ban Xiengdet under the NN3 Cumulative Impact Assessment Technical Assistance.
[2] Water Quality and Fisheries Monitoring in Nam Ngum River Basin, 2008-2009

	Scientific Name Fish Species	Lao Name Fish Species	% in Weight of Total Fish Catch
10	?	Pba dam	2
11	Cirrhinus cirrhosis	Pba kin ya, Pba nouan chan	1
12	Channa striata	Pba cau	1
		% of Village Fish Catch at Ban Xiengdet	92

Source: NN3 Cumulative Impact Assessment Technical Assistance.1 Water Quality and Fisheries Monitoring in Nam Ngum River Basin, 2008-2009.

D. Nature Conservation Status of the Project Impact Areas

1. Reservoir and other Project Impact Zones

271. At the present time none of the Nam Ngum river terrestrial and aquatic habitats to be inundated by the reservoir or located within the relevant part of Nam Ngum catchment are protected, or fall within any Lao National Protected Areas (NPAs) or Province Protected Areas (PPAs) (Vattenfall 2008).

272. The reservoir and catchment terrestrial habitats are typical of more than half of the Lao hill land with steeply sloping hillsides of shallow silty limestone based soils and frequent out croppings of sedimentary rocks, supporting bamboo and young secondary woodlands. These ecosystems are widespread and impoverished from the biodiversity standpoint. None has so far been classified by IUCN as rare or threatened (Claridge, 1993), and no NPAs in Lao PDR have been created to protect this type of habitat. The bio-diversity surveys to be undertaken in 2011-2012 dry season will evaluate and update this assessment.

2. Phou Khao Khouay NPA

273. The planned transmission line will run through the Phou Khao Khouay NPA, declared by the Prime Ministerial Decree No 164 in 1993 as a National Biodiversity Conservation Area of 200,000 ha. PKK is the oldest and one of the largest NPAs in Lao PDR. It is famous, not only because of its biodiversity values but because of its accessibility and proximity to the nation's capital. The area is an important tourist attraction and generates income for the local citizens in the area. Investments have been made in tourism facilities in the form of the Elephant Watchtower, for example.

274. The conservation value of the PKK NPA has in recent years been reduced by the Nam Mang and Nam Leuk hydropower projects, upgrading of the main road, and by unsustainable exploitation of forest resource and outside pressure and unplanned developments (Vattenfall 2008).

275. The PKK is mountainous with its highest peaks reaching more than 1660 masl. It is drained by three larger rivers (Nam Mang, Nam Leuk and Nam Gnong) and numerous short tributaries, forming intricate river system which created numerous spectacular waterfalls and rapids. The major waterfalls and cascades include Tad Phou Khao Khouay, Tad Leuk, Tad Xay and Pha Xay.

276. Biodiversity values of PKK include mammals and birds of national and global significance; it harbours various "*Global Near Threatened*" (GNT) as well as "*Globally Threatened-Vulnerable*" (GT-VU), "*Globally threatened -endangered*" (GT-EN) and "*Data Deficient*" (DD) category of mammals and birdlife.

E. Comprehensive Biodiversity Survey

277. NN3PC will undertake a comprehensive biodiversity survey of project areas commencing in the dry season 2011-2012 to update the project specific impacts on biodiversity.

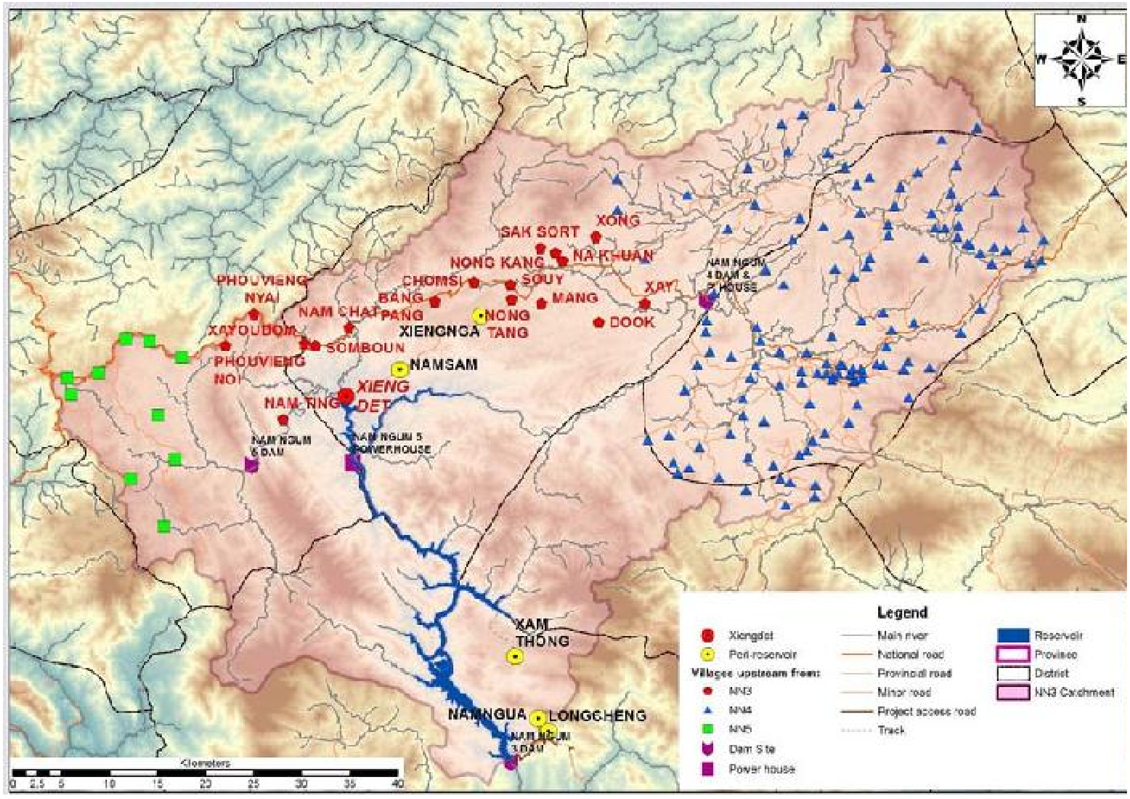
VI. SOCIO-CULTURAL ENVIRONMENT

278. The socio-cultural environment of the villages impacted by the project is briefly summarised in this section. More information is available in the Resettlement and Ethnic Minorities Development Plan (REMDP).

A. Villages impacted by the project

279. Impacts by the NN3 reservoir impoundment and fluctuations of the level of the reservoir will occur at the village areas of Ban Xiengdet, and four peri-reservoir villages (Nam Sam, Xieng Nga, Xam Thong, and Long Cheng). Impacts of project operation on livelihood are also likely to occur in the area of the 17 upstream villages (Nam Ting, Phouvong Noi, Phouvieng Nyai, Xayoudom, Somboun, Nam Chat, Ban Pang, Maang, Yong Tang, Souay, Chomsi, Sak Chort, Na Khuan, Yong Kang, Xong, Dook, and Xay), and in 7 downstream villages (Louang Phan Xay, Phan Xay, Nam Pha, Nam Xan, Nong Pou, Hom Xay, and Mouang Phoun). They are located on Figures 6.1 & 6.2.

Figure 6.1: Upstream villages and Ban Xiengdet (shown in red), Peri-reservoir villages (shown in black)



1. Xiengdet Village

280. Ban Xiengdet is the only village where the village residential area needs to be relocated affecting 144 households, including households that have established themselves after the cut off date. Only part of the agricultural lands will be affected limiting the number of Ban Xiengdet households that will be economically displaced to 36. The main impacts expected are as follows:

- (i) Seasonal flooding of part of the village area.
- (ii) Seasonal flooding of residential area, including fixed assets as houses, home gardens, pig pens, fruit trees, and chicken coops.
- (iii) Seasonal and partial inundation of physical and cultural resources.

(iv) Seasonal flooding of part of paddy fields, agricultural land, vegetable gardens, fish ponds, banana orchards, and fruit trees.
(v) Seasonal flooding of part of village area consisting of governmental land,[1] potentially impacting cattle grazing, collection of Non Timber Forest Products (NTFPs), and hunting wild life.

2. 4 Peri-Reservoir Villages

281. Seasonal flooding of a small part of the village territory consisting of governmental land will occur at the four peri-reservoir villages of Nam Sam, Xieng Nga (both in Phou Kout district, Xieng Khouang Province), and Long Cheng[2] and Xam Thong (both in Xaysomboun district, Vientiane Province). The residential areas of the 4 peri-reservoir villages are located at considerable distance of potentially flooded governmental land. Houses and structures, including field huts will not be affected.

(i) About 6 households at Nam Sam are expected to be impacted by potential losses in land use of this governmental land as seasonal cattle grazing. Cattle grazing land will not be affected at the other 3 peri-reservoir villages.
(ii) Only at Long Cheng, household income from collection of NTFPs and hunting of wild life will be partially impacted through flooding of hunting and collection areas.
(iii) Household fish catch could be positively impacted at Nam Sam and Xieng Nga at the upper end of NN3 reservoir.

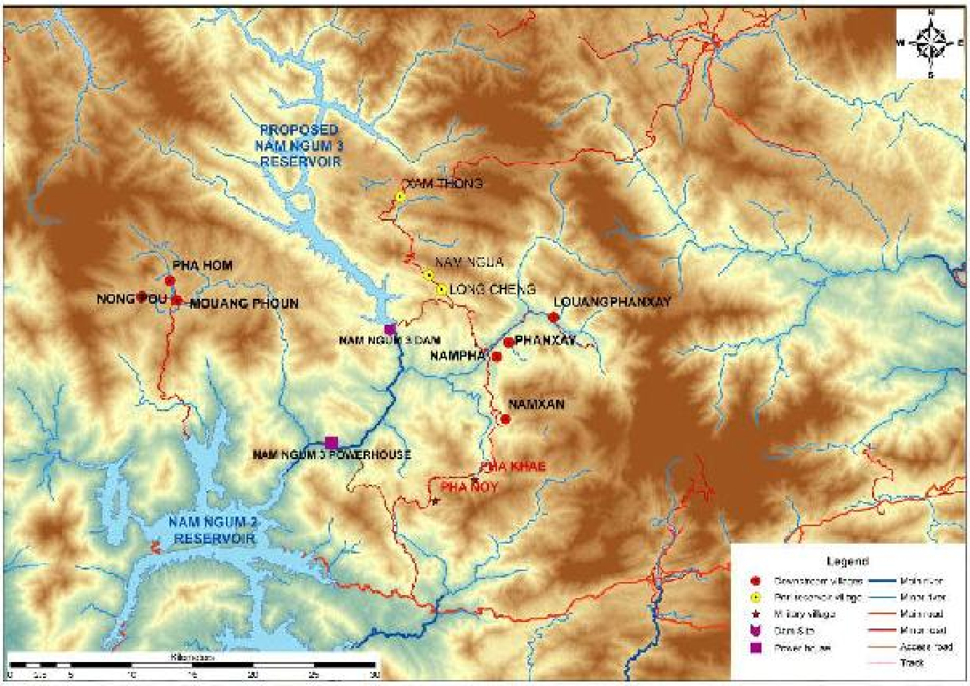
282. Potential adverse impacts on household fish catch will occur at Long Cheng and Xam Thong, located at the south end of NN3 reservoir, near NN3 dam depending on (i) occurrence of migrating fish species in household fish catch, (ii) locations of affected and non affected fishing grounds, and (iii) new opportunities for households to fish in NN3 reservoir.

3. Seven Downstream Villages

283. Potential adverse impacts on household fish catch might materialise depending on (i) occurrence of migrating fish species in household fish catch, (ii) locations of affected and non affected fishing grounds, (iii) potential upstream impacts on migrating fish species by NN2, and (iv) new opportunities for households at Nong Pou, Hom Xay, and Mouang Phoun to fish in NN2 reservoir, downstream of NN3 power station. None of the "downstream villages" are located immediately along the Nam Ngum.

[1] Governmental Land is the Lao expression of land possibly in use by communities, but without specific private land ownership or specific private land use right. Governmental land may be in common use by households for use of natural resources, including hunting, collection of NTFPs, cattle and buffalo grazing, fisheries or even agriculture practices, including shifting cultivation. In these circumstances, such community-used land is designated "community land", to distinguish it from state land use.
[2] The village of Nam Ngua was merged with Long Cheng.

Figure 6.2: Downstream villages



B. History

1. Ban Xiengdet

284. Ban Xiengdet village is believed to be at least two hundred years old. In the 1960s, across the bank of the Nam Ting from Ban Xiengdet, an airfield with a 2 km long runway was constructed for military purposes. In the 1970s, the village fell under air raids and the inhabitants who escaped fled to neighbouring villages and Ban Xiengdet was completely abandoned. After the war, during the 1980s the new government encouraged farmers to find suitable farm land and settle down in order to improve living conditions through increased agricultural production. This led to a re-occupation of Ban Xiengdet in 1982 when eight families migrating from Mouang Kham decided to rebuild the village. In 1986, the village expanded and received a second wave of in-migrants.

2. Nam Sam

285. Nam Sam was established in 1982 when 48 Khmu households came from Long Khone located along the Khone River in Phou Kout District (Xieng Khouang Province). Their main reason for moving was to look for sustainable production lands. Five years later another group of Khmu (27 Households) also from within Phou Kout District arrived in Nam Sam. Nam Sam consists of three different hamlets.

3. Xieng Nga

286. Xieng Nga was established before anyone remembers. During the war, 1969 to 1975, villagers temporarily moved to Ban Nam Chim, Phone Hong District, Vientiane Province, returning to the village when it was safe.

4. Xam Thong

287. Xam Thong was established at least in the early 1960s as it was made the capital of the Xam Thong-Long Cheng Special Zone. Due to the Second Indo-China War, the village was abandoned in

the 1970s and was re-established in 2000, when 23 Khmu and 23 Tai Khang households moved into the village. Both groups came from Muang village in Houaphan Province.

5. Long Cheng

288. Long Cheng is known as the American CIA "*secret airbase*" during the Second Indo-China War. Before and during the war, Long Cheng was inhabited by Hmong but they were forced to move to other places after the war. At the height of its activity, Long Cheng became the second largest city in Laos, estimated at 300,000 inhabitants with 200,000 ethnic Hmong and 100,000 people of other ethnic background. When the Hmong left, Tai and Khmu ethnic groups settled at Long Cheng from their forest refuges during the war. Recently Nam Ngua, established in 2001, became part of Long Cheng.

6. Louang Phan Xay, Phan Xay, Nam Pha, and Nam Xan (Nam Pha watershed)

289. Louang Phan Xay and Phan Xay were established in 1999 - 2000 when large groups of Tai Deng and some Khmu and Tai Dam families moved from Houaphan Province mainly due to poor agricultural conditions at previous locations. Two small villages of Na Xom and Phou Kong Khao were merged with Louang Phan Xay in 2005.

290. Not much is known about the history of Nam Pha apart from that it was re-established in 1976 by mainly Khmu households.

291. Nam Xan was established in 2000, when about 100 Hmong households moved from various villages in Vientiane and Xieng Khouang Provinces to settle in the village. Their main reason for moving was lack of agricultural land.

7. Nong Pou, Pha Hom, and Mouang Phoun (Nam Phay watershed)

292. Nong Pou was formed back in 1975 when Khmu households came from Vientiane Province. In 1998 two other Khmu families joined the village. Their main reason for moving was lack of land for agricultural production in their previous village.

293. The most recent established villages are Mouang Phoun and Hom Xay which were formed in 2005, when Hmong, Khmu and Lao ethnic groups moved from various villages in Xieng Khouang and Luang Phabang Provinces. Mouang Phoun was re established.

C. Demography

1. Ban Xiengdet

294. A village survey carried out in March 2007 identified 90 households permanently residing at Ban Xiengdet. Four months later (July 2007) the number of households was 88. In October, 2008 the number of households was 104.[3] Average household size is 5.6 persons. Males form 52% of the village population. The total population was 583 persons in 2008. The rapid growth of the population at Ban Xiengdet is believed to be partially caused by the influx of new households hoping to become eligible for resettlement and livelihood restoration activities to be implemented by the project. In April 2010, the number of households has grown to 120 households. In July 2011, the number of households in Ban Xiengdet has increased from 120 to 144 households. The 144 households is comprised of the 107 originally eligible households (96 + 11 natural growth households in April 2010), plus a further 21 "natural growth" households (identified by Ecolao in July 2011), plus 16 ineligible households.

[3] The cut-off date was set as the 9th October 2008.

2. Peri-reservoir villages

295. The village survey identified 420 households with a total population of 2,321 people in the peri-reservoir villages. The average household size is 5.5 persons.

3. Upstream villages

296. The total population of the 17 villages is 10,312 persons with 1,645 households. The average household size is 6.3 persons ranging from 5.5 persons in Xong to 7.6 in Nam Ting. Overall, there is an even distribution of men and women. However, in Xay and Nam Chat only 46% and 47% of the village population are women.

4. Downstream villages

297. At the 7 downstream villages about 2,455 people live in 397 houses. An average downstream household has 6.2 family members, with the highest numbers found in Louang Phan Xay with 7.3 persons per household, while Hom Xay only has 5.6 persons per household. In all downstream villages there are more men than women with an average female representation of 48 percent.

D. Ethnicity

1. Ban Xiengdet

298. In 2008, 88% of the households living at Ban Xiengdet belonged to the Khmu ethnic group, while 12% of the households were Thai Phouan. In Lao PDR, Lao-Tai groups (Lao, Tai Deng, Tai Phouan, Tai Khouane and Tai Khang) are not considered as ethnic minority groups since Lao language is their native language and their traditions are similar to the dominant Lao culture. Khmu are part of the Mon-Khmer language family and are considered an ethnic minority as they have customary cultural, economic, social, or political institutions that are at variance with those of the dominant upland Lao-Tai groups. One of the main differences is in livelihood strategies, the Khmu traditionally rely on natural resources, particularly forest and river resources, and on swidden cultivation. In Ban Xiengdet, Khmu undertake a combination of swidden and fixed paddy cultivation. The dominance of Khmu people at Xiengdet is reflected in the leadership where only one of the deputy heads is Tai Phouan, all the other being Khmu.

2. Peri-reservoir villages

299. The villagers in the 4 peri-reservoir villages belong to two main ethnic groups, Khmu and Lao-Tai.

3. Upstream villages

300. Most of the 17 upstream villages have a mixed ethnic composition, with the 3 main ethnic groups being Lao-Tai (41%), Hmong (32%) and Khmu (26%). Seven villages are predominantly Lao-Tai, three Hmong and four Khmu. Three villages do not have a dominating ethnic majority. The Hmong and Khmu groups are ethnic minorities in Lao PDR as these groups have customary cultural, economic, social, or political institutions that are at variance with those of the dominant upland Lao-Tai groups. But, both Hmong and Khmu are the dominant ethnic groups at most of the 17 upstream villages.

4. Downstream villages

301. There are three main ethnic groups in the seven downstream villages. Lao-Tai groups (especially Tai Deng) constitute the biggest group (37%). The Khmu, which is a part of the Mon Khmer Language family constitute a large part of the population in Hom Xay and Nong Pou, while Hmong are the majority in Nam Xan and Mouang Phoun.

E. Infrastructure

1. Ban Xiengdet

302. A public access road of about 40 km length connects Ban Xiengdet with the highway at Nong Tang. A footpath connects Ban Xiengdet with the highway at Nam Chat at about 2.5 hours walking distance.

303. Households swim, bath, and wash in the Nam Ting River. Mostly women and children carry water from the Nam Ting to their houses for cooking, cleaning, and drinking.

304. Most households have no toilets.

305. Ban Xiengdet is not connected to the electricity grid.

306. Two public buildings exist at Ban Xiengdet, one, a primary school, and the second a lean-to-against the house of the village head's house, used as a meeting and administration facility. The primary school consists of two classrooms, teaching children to grade 3. Children at the age of grade 4 used to walk to Nam Sam primary school at more than 2 hours walking distance along the public road.

307. Recently, villagers have constructed a new school at higher elevations with support from the District. The new primary school has 5 classrooms to teach children to grade 5, avoiding the 5 hours walk each day to Nam Sam. The nearest secondary school is at Nong Tang along highway No. 7, at approximately 40 kilometers from Ban Xiengdet. If weather permits, school children travel the existing access road between Xiengdet and Nong Tang each week end. Access by school children from Xiengdet to secondary education is affected, particularly during the rainy seasons.

2. Nam Sam and Xieng Nga

308. Nam Sam and Xieng Nga are located along the 40 kilometers long access road from Ban Xiengdet to the highway at Nong Tang. Access to Nam Sam and Xieng Nga has been more difficult due to the increased transport of timber from Ban Xiengdet and due to the construction of a new transmission line to NN5.

309. Households at Nam Sam and Xieng Nga now have the opportunity to get connected to the electricity grid.

3. Xam Thong, Nam Ngua and Long Cheng

310. Xam Thong, Nam Ngua, and Long Cheng are located along the public road. Recently a transmission line has been constructed giving households at these villages the opportunity to get connected to the electricity grid.

311. Water supply at the peri-reservoir villages is making use of small streams. Particularly during the dry seasons, insufficient water supply is encountered when natural discharges of these small streams reduce.

312. Sanitation facilities differ on a household per household basis. Particularly, the poor households generally are in need of sanitation facilities. Pigs are used as removers of human faeces.

313. Long Cheng has many buildings in use by the military and a large former airstrip in the middle of the village. Recently a new guesthouse was opened at Long Cheng.

F. Education

1. Ban Xiengdet

314. The school attendance in Primary School is of 89% for the boys and 72% for the girls, and for Secondary School, 10% for the boys and 47% for the girls. There are 2 primary school teachers resident in Ban Xiengdet.

315. Literacy data for Ban Xiengdet shows that men are more literate than women for both ethnic groups. The Tai Phouan are more literate than the Khmu, which can be explained by the fact that Lao language is the mother tongue of Tai Phouan. Khmu children generally communicate at home in Khmu language learning to speak and write in Lao language at the Primary School. Children in Xiengdet have restricted opportunities to attend higher grades of primary school and secondary school. Girls in particular tend to have less access to higher levels of education due to gender norms and attitudes.

2. Peri-reservoir villages

316. All peri-reservoir villages have access to primary schooling. Long Cheng has classes until Grade 8, while Nam Ngua only has classes until Grade 3. The number of pupils per teacher varies significantly between the villages, with Long Cheng having the lowest ratio with only 11 pupils per teacher, and while Nam Ngua and Xam Thong have the highest with 38 and 34 pupils per teacher, respectively.

317. Nam Sam and Xieng Nga have the highest school attendance among girls and boys for both primary (100%) and secondary school (100% and 94%).

3. Downstream villages

318. Except from Hom Xay all villages have schools that teach up to grade 5, which is the end of primary school. The number of pupils per teacher is the highest in Hom Xay and Nam Xan with only one teacher per 55 and 53 pupils, respectively. At the other end of the scale are Phan Xay and Mouang Phoun, which have pupil-teacher ratios of 6 and 10, respectively.

319. The school attendance in primary school is almost the same for boys and girls (88 percent). The lowest school attendance is found in Hom Xay, which only teaches up to grade two. For secondary school the school attendance drops from 88 percent down to 61 percent of boys and to 39 percent for girls. In two of the villages, Phan Xay and Hom Xay the secondary school attendance for girls is zero.

G. Health

1. Ban Xiengdet

320. The nearest public health clinic is the health center at Nam Sam, located at a 3-hour walk. Ban Xiengdet has no trained village health workers.

321. The women in Xiengdet have primary responsibility for family health yet their own health is compromised by heavy workloads, frequent pregnancies and inadequate health services. Many of the women complain of chronic reproductive tract infections.

322. Discussions with women during a focus group in Xiengdet revealed very different levels of knowledge about family planning options between the women. Several women of childbearing age in the focus group had never heard of any family planning methods. There are traditional birth attendants in the village, but no formal village health workers.

2. Peri-reservoir villages

323. Long Cheng, Nam Sam, and Xam Thong have small health centres, while villagers of Xieng Nga and Nam Ngua have to rely on health services provided at neighbouring villages. The health post in Nam Sam has five staff who includes volunteers, while the one in Xam Thong has only 1 staff. Long Cheng has a district hospital with 15 staff.

324. The relatively high number of accidents at Xam Thong is believed to be mainly attributable to high occurrence of UXOs in the village.

3. Downstream villages

325. The 3 downstream villages (Hom Xay, Nong Pou, Mouang Phoun) located in Nam Phay watershed report to need 8-9 hours travel to reach their nearest health post, which was in Ban Sone (resettled due to NN2). The other downstream villages located at in Nam Pha watershed report to need less than 2 hours travel on foot to reach their health services at Louang Phan Xay and Long Cheng.

H. Agriculture

1. Ban Xiengdet

326. Agricultural and horticultural products form 22% of the average household cash income at Ban Xiengdet. Almost two thirds of the households in Xiengdet have paddy fields where lowland rice can be grown, but most households have upland plots growing hill rice. In some cases, hill rice is grown on swidden land, requiring fallow areas. The average size of paddy land per household at Ban Xiengdet is 1.5 ha while 1.33 ha is used annually by the average household as upland hill rice plots. Most households at Ban Xiengdet own paddy field. They have provided these with supplemental irrigation during the rainy seasons by diversion of small streams.

327. Other agricultural crops include corn, peanut, sweet potato, chilly, cucumber, and pumpkin. Vegetables are grown close to the homestead mostly at home gardens. Fruit trees are grown at banana orchards, but also at the residential area, often in conjunction with home gardens (coconut, tamarind, mango, jackfruit, jujube, banana, citrus).

328. Sixty-five households (74%) at Ban Xiengdet report to have sufficient rice the whole year around. Among the 26% of households not having enough rice as imputed income for the entire year, four households have enough for 10-11 months, seven for seven-nine months while nine households have rice sufficient only for 3-6 months consumption. Households cover this deficiency by growing other crops and horticultural products, and simply eat less rice for part of the year as they do not have enough cash to buy rice. Percentage wise, Khmu households suffer more from rice deficiency than Tai Phouan households. There are 18 Khmu households at Ban Xiengdet that do not have sufficient rice year round.

2. Peri-reservoir villages

329. All villages grow hill and paddy rice, while paddy and vegetable farming also contribute to the livelihoods at Nam Sam, Xieng Ngua, Nam Ngua, and Long Cheng. At Xam Thong agricultural development is ongoing by making use of an old irrigation weir. Its irrigation reservoir is running out of water during the dry seasons.

3. Downstream villages

330. In these villages paddy cultivation is more dominating than swidden agriculture. The average paddy for a household is 0.7 hectare, while only 0.1 hectare for swidden land. Lack of available paddy land is often compensated by additional swidden land for rice production.

331. More than half of the households are self-sufficient with rice year round. However, in Louang Phan Xay 76% of the households produce not more rice than sufficient for six months only.

I. Livestock

1. Ban Xiengdet

332. Livestock forms 16% of the average cash household income source at Ban Xiengdet. It is an attractive source of wealth accumulation in kind, quickly to be returned in cash as livestock can be readily sold when cash needs are high.

333. The common practice of local villagers having livestock, particularly big animals like buffaloes and cattle, is to let these animals graze largely unattended on community land during the dry season. During the wet season, they are often placed in pens at night within the village to prevent them from damaging crops. In general, there is no supplementary feeding, nor management of natural forage through controlled grazing of different areas at different times of the year. Many households do not provide salt licks for cattle.

334. Only nine percent of the households own buffaloes – on average six animals – while 37% of the households own cattle – on average four cows.

335. Pigs are owned by almost all households, mainly to recycle waste and as a source of income, but also for household consumption and for consumption on festive occasions. In general, pigs are not penned and are left to forage with minimal supplementary feeding. An average household owns about 4 pigs.

336. Chickens and ducks are owned by almost all households, with average ownership of 17 animals. Poultry are kept for sale, household consumption and festive occasions. Chickens are generally allowed to roam free within the residential area with little supplemental feeding.

337. Veterinary services are poor; cattle, buffaloes, pigs, and poultry are generally not vaccinated. Public health risks, particularly for small children, are caused by allowing livestock into the residential area without penning.

2. Peri-reservoir villages

338. Many households in Xieng Nga and Long Cheng have buffalos, which is not the case in the other villages. Cattle are common in most villages, except in Nam Ngua. Pigs are owned by almost all households in Xieng Nga and Nam Ngua. Poultry (i.e. mainly chickens) are owned by all households in Nam Sam, Xieng Nga and Long Cheng and by most households in Xam Thong and Nam Ngua.

3. Downstream villages

339. Poultry and pigs are by far the most commonly owned by households in the downstream villages. An average household has three pigs and seven fowls which are mainly held for consumption and important in religious practices. Goats are only held by some households in Nam Pha and Nam Xan. Buffalo and especially cattle are also common, but not held by all households.

J. Forest Utilization

1. Ban Xiengdet

340. Almost all households report to be collecting Non Timber Forest Products (NTFPs) making out 8% of the average household cash income. Broom grass (28% of NTFP value), mulberry (27%) and *Imperata cylindrica* (17%) are the NTFPs generating the highest value.

2. Downstream villages

341. NTFPs are an important source of livelihood for households in the downstream villages. Many of the products listed are described as very important for their livelihood and daily food consumption,

especially bamboo, bamboo shoots, mushrooms, *Imperata cylindrica* and fuel wood. These items are also mentioned as important for cash income generation, although then valued as medium important. Men and women have a shared responsibility for collection of most NTFPs, but some of the products are dominated by men such as cutting of rattan and bamboo, while women are more involved in collection of bamboo shoots, mushrooms, and fuel wood.

K. Fish Catch

1. Ban Xiengdet

342. All households at Ban Xiengdet fish. Most of the fish is caught at rivers and streams, while also some fish is caught in ponds and paddy fields, resulting from diversion of small streams.

343. The main fishing season in Xiengdet is at the end of the dry season and beginning of the rainy season (March – June). Both men and women are fishing throughout the year. The total annual number of days with fishing for men and women is 161 and 96, respectively.

344. The total annual fish catch in Xiengdet is estimated at 7,300 kg, of which women catch a third. Variation in the catch effort is reflected in the actual catch with April, May and December being the months with the highest catch.

345. The total value of fish catch, both consumed and sold, amounts to 1.6 million Kip, which is 6% of the total income (cash and imputed) for an average household. About 55% of the fish catch is consumed, while the rest is shared with neighbours and relatives, or old within the village and at nearby markets or to visitors/merchants coming to the village.

2. Peri-reservoir villages

346. Fish in the peri-reservoir area is mainly obtained from rivers and streams (in average 88%). Villagers in Xam Thong constructed and stocked 43 fish ponds in 2007 with the assistance from the World Food Program, but most of the ponds did not have sufficient water and fish died in the ponds after stocking. All 43 fishponds are presently abandoned. Long Cheng has a large pond of which the village has rented out the fishing rights.

347. There is considerable variation between the peri-reservoir villages in terms of how much fish is consumed and how much fish is sold. The survey shows that villagers in Xieng Nga, Xam Thong and Nam Ngua consume almost all their fish, while villagers in Nam Sam and Long Cheng are more market oriented. Part of the explanation is that both Nam Sam and Long Cheng host the military. Also a big fish pond at Long Cheng provides a vital source for the local market.

348. Villagers in the peri-reservoir villages fish throughout the year with an average of 98 days for men and 87 days for women. The dry season from November to May see a marked higher intensity of fishing. The main reason is that it is easier to catch fish when water levels in the rivers are low. Also, the dry season is a low season in the agriculture calendar, as after the rice harvest at the end of each year, there is little to do in the fields.

349. The total annual fish catch in the peri-reservoir villages is 13,000 kg of which men catch 94%. The highest annual catch is obtained in Long Cheng (5,800 kg) and Xieng Nga (4,400 kg), whereas fish catch in Xam Thong and Nam Ngua is very low.

3. Upstream villages

350. In Nam Chat and Nam Ting, rivers and streams account for the entire amount of fish harvested. The majority of fish caught in the two upstream villages is consumed by the households (73%). However, proximity to National Route 7 (most obviously for Nam Chat) provides an opportunity for marketing some of the catch.

351. Fishing takes place especially towards the end of the dry season. Fish are mainly caught in the dry season with April showing the highest catch (460 kg). For women, 78% of the annual catch is obtained in April and May. The total annual fish catch for Nam Chat and Nam Ting is 580 kg and 1,500 kg, respectively. Men bring in 80% of this catch and women 20%.

352. Annual fish consumption per household is 4 kg at Nam Chat and 14 kg at Nam Ting.

4. Downstream villages

353. Villagers in the downstream area get most of their fish from rivers and streams, i.e. Nam Pha and Nam Phay and smaller tributaries. Fishing in the Nam Ngum itself does not take place.

354. In average, 87% of fish caught are harvested in the rivers and streams. Fish ponds are an important source of fish in some villages, especially Louang Phan Xay.

355. Fish are entirely caught for household consumption, except for Nam Pha where 10% of the fish caught is sold.

356. The total catch for the seven downstream villages is 19,900 kg of which 73% is caught by men and 27% by women. More than half of this catch would be obtained in the Nam Xan (11,200 kg). Total fish catch in Louang Phan Xay, Phan Xay and especially Hom Xay is very low.

L. Poverty

357. At the time of the village survey, the official rural poverty line was 80,000 Kip ($10.0) per month per capita. Data provided in this document reflect this line. Since 2008, it has been updated to 180,000 kip (US$22.5) per month per capita.[4]

358. All households in Xiengdet have average monthly incomes above the official rural poverty line from 1997/98, which indicates that this marker might no longer be up-to-date. The lowest average monthly income per capita was 37.500 Kip in 2007 and two other households have average monthly incomes per capita below the adjusted rural poverty line from 2000 at 80,000 Kip. These households are all Khmu.

359. As average household size in the village is 5.3 persons, meaning that the average monthly per capita income for those in prosperous households is 424,528 kip (almost $52), while in poorer households it is 251,572 kip (almost $31).

360. The average overall monthly income per capita (cash and imputed) in Xiengdet was 385,000 Kip (2007). The figure for Khmu was 373,000 Kip while it was 449,000 Kip for Tai Phouan villagers.

M. Physical Cultural Resources

361. A study on Physical Cultural Resources (PCR) within the area of influence of the Nam Ngum 3 Hydropower Project has been carried out. The full report is issued as Annex E to this report.

362. During the study several sites and objects of archaeological and cultural significance have been identified. The impact of the hydropower project on these sites has been assessed. Plans and recommendations for management and mitigation measures have been drawn up and included in the Construction Phase Environment Plan and the Operation Activities Environment Plan.

363. Six villages and eleven sites have been investigated. These include Ban Xiengdet and the Peri-reservoir villages. The nature and significance for the sites have been assessed according to prehistory, history, cultural heritage and natural scenic beauty relevance (Table 6.1).

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[4] Decree 285/PM, On Poverty and Development Criteria for 2010-1015, 13th October 2009.

Table 6.1. Sites of PDR relevance in the project influence area

Site	Location	Description
Vat Vangsiang	Ban Xiengdet. Inside reservoir FSL	More than 200 year old temple destroyed by bombing in 1970
Vat Xiengdet	Ban Xiengdet. Inside reservoir FSL	Foundations of unfinished temple. Silver Buddha's buried at the site.
Airfield	Ban Xiengdet. Inside reservoir FSL	War memorial
Dongmuang	Ban Xiengdet. Inside reservoir FSL	Large tree held as a spiritual site.
Tham Phra Cave	Ban Xieng Nga, Outside	Archaeological site with an important collection of objects that evidenced Buddhism practice and associated ritual usage.
Vat Xieng Nga	Ban Xieng Nga, Outside	Old temple destroyed by bombing. Constructions for storage of antiquities from Tham Phra.
Vat Chomcheng	Ban Long Cheng, Outside	Abandoned temple in fairly good shape.
Tham Nam Lod Cave	Ban. Nam Ngua, Outside	Scenic cave
Tham Tintok Cave	Ban. Nam Ngua, Outside	Scenic cave.
Tham Phachao Cave	Ban. Nam Ngua, Outside	Scenic cave. Used for military purposes.
Tham Phadork Cave	Ban. Xamthong, Outside	Scenic cave. Has spiritual significance.

364. The most critical impact to the sites would be the cases where there is a risk for inundation or destruction from construction activities. Such sites and objects are recorded in Ban Xiengdet. This includes the temple Vat Vangsiang which is more than 200 years old, the temple Vat Xieng Det, which is said that it still contains treasures at its foundation and also the small airfield (war history) to the east of the village.

Figure 6.3: Remains of Vat Vangsiang (left), Remains of Vat Xiengdet Foundation (right)

365. A graveyard and spirit houses might be flooded a number of months each year at Ban Xiengdet, but no other PCR items at other villages surrounding the NN3 reservoir area are expected to be. Physical and Cultural Resources identified in the peri-reservoir villages are not considered to be in danger of flooding.

366. However, at Ban Xiengdet, not more than 4 % of the Xiengdet's graveyard may seasonally be inundated, while the remains of Vat Vangsiang and the remaining foundations of Vat Xiengdet and additional spirit houses might be inundated for not more than some months per year.

367. Vat Vangsiang, is located about 1 km north of Ban Xiengdet at elevation of about 721 masl. The temple ruins occupy an area of 18 m x 11 m. The ruins are 2.2 m high. It is thought that the temple has been built at the end of the 17th century. The temple ruins still have a large Buddha image now very damaged. The temple was damaged during air bombing in the 1970s and is not used anymore by villagers. Villagers grow corn at the location of Vat Vangsiang.

368. As early as the 1960s Vat Vangsiang was not visited or used any more by villagers. In the1960’s even an effort has been made to construct a new temple (Vat Xiengdet) using material of Vat Vangsiang. While Vat Vangsiang was abandoned already in the 1960s, the construction of Vat Xiengdet never has been extended beyond some preliminary foundation activities. These foundations are presently barely visible. Vat Xiengdet has thus never functioned as a religious or cultural site and only emphasized the non-use of Vat Vangsiang.

369. Both remains of Vat Vangsiang and Vat Xiengdet will be inundated by NN3 reservoir for not longer than a few months per year. Both Vat Vangsiang and the foundations of Vat Xiengdet are abandoned and not in use. Therefore, households will not be directly affected when both sites will be seasonally inundated by NN3 reservoir each year. However, both temple sites still have a spiritual meaning and are respected by households.

370. There is also one kind of holy tree at Ban Xiengdet at an elevation of Full Supply Level of NN3 reservoir that may be impacted.

1. Caves

371. Sites of remarkable scenic beauty are found outside the reservoir area such as Tham Nam Lod Cave and other cave sites which contain underground rivers and cascades and particular features of karstic formation.

2. Stone tools

372. The human occupation during the prehistoric time has been evidenced at several places by stone tools that were shown or reported to the PCR study team. These stone tools were found by chance by the villagers and were kept as heirloom because they were believed to possess some mysterious value and/or magical power. There is no indication that the future reservoir area is richer in such object than the surrounding area.

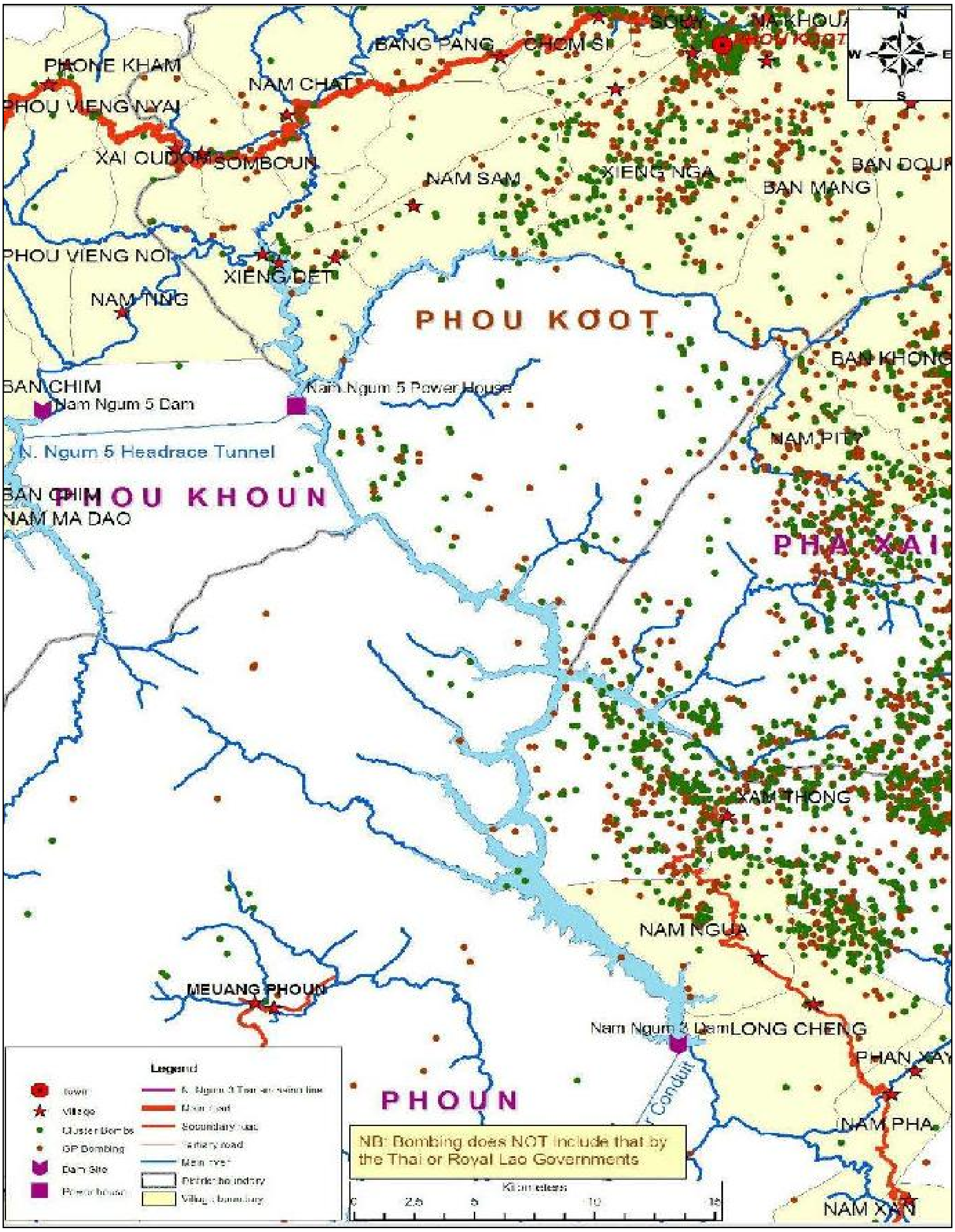
Figure 6.4: Ground Stone Axe Found at Ban Xiengdet

N. UXOs

373. The main project construction sites such as the dam site, the power station site, the access roads to these sites and the transmission line corridor are considered to have a relatively low risk of occurrences of Unexploded Ordnances (UXOs).

374. The UXOs contamination is a serious concern at some of the villages that will surround the future NN3 reservoir and formed a battlefield during the "*secret war*" in the 1960s and 70s. At the outskirts of the village of Long Cheng an UXOs dumping area exists. Also at villages that used to have an airstrip during the war, such as at the villages of Long Cheng, Ban Xiengdet, Nam Sam, and Xam Thong UXOs are encountered. See Figure 6-5. At these villages, farmers have piled up UXOs at the fringes of their paddy fields.

Figure 6.5: Distribution of UXOs around NN3 Reservoir



VII. PROJECT IMPACTS

A. Introduction

375. In the following sections, the potential consequences and impacts of the project on the physical and biological environment are presented. The analysis is based on the findings of RMR,[1] updated by EcoLao-NORPLAN, in particular when there have been changes in the base line conditions. This includes in particular the construction of the Nam Ngum 2 dam and power plant between the NN3 power plant and the NN1 reservoir and the construction of the Nam Ngum 5 project upstream of the proposed NN3 reservoir.

376. The sections of the assessment relate to the impacts predicted for (i) the reservoir, (ii) the upstream section of the river, (iii) the downstream stretch of the river, (iv) the construction lands and access road, and (v) the initial assessment for the transmission line.

377. A section on the cumulative impacts is included, based to a large extent on the NN3 - CIA study (Vattenfall 2008) and addresses impact issues which might result from the combined impacts of the NN3 project, other hydropower projects in the catchment, and other probable development projects, including mining activities, and development trends.

378. The social impacts of this Project are discussed in detail in the Resettlement and Ethnic Minorities Development Plan (REMDP) issued as separate document and are not repeated here.

379. The purpose of this section is to provide the background for the proposed mitigation measures and compensatory actions presented in the Environmental Management Plan Section, and to justify the need for the proposed monitoring activities.

380. The presentation below makes it clear that some of the detrimental outcomes of the project cannot be mitigated (inundation of the Nam Ngum river for example), whereas others can be fully or partly mitigated or avoided (biodiversity, reforestation, for example). Some impacts can be predicted with reasonable certainty, whereas additional monitoring during construction and first years of operation will be needed to adequately ascertain some others..For the inherent impacts by NN3, project affected people will be compensated (see REMDP) and offsets will be developed in the environmental management plans.

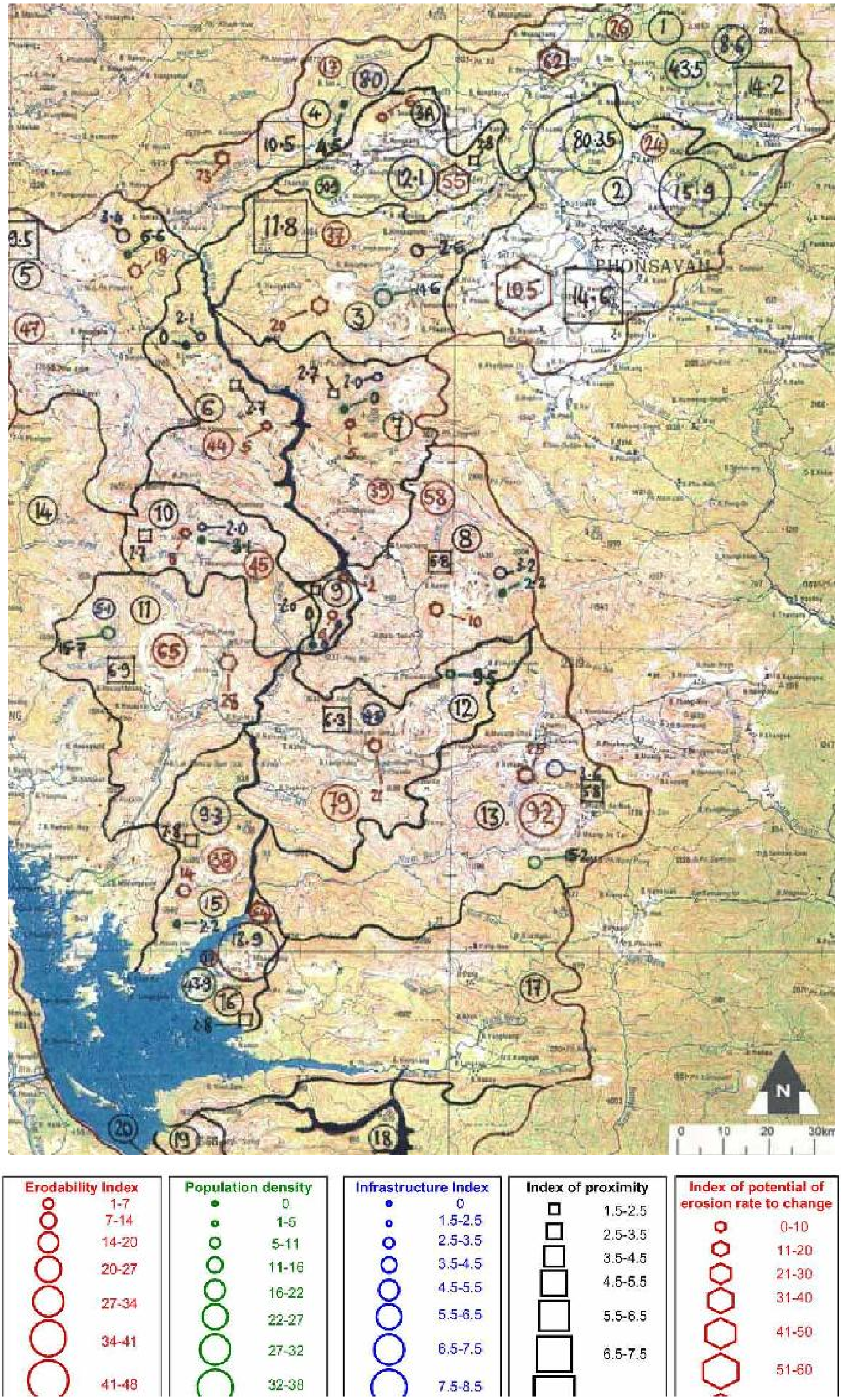
B. Impacts on Reservoir and River Morphology

381. The landscape in the NN3 reservoir area, both below and above the FSL is steep with about one third of the land having slopes of more than 27^{o}. The potential for landslides (superficial or deeper structurally-based) in the reservoir is significant (See RMR Studies, Chapter 3 for further information and Figure 7.1 below). There is however no permanent settlements in the areas of high landslide risk.

382. In relation to the downstream river stretch, the project includes design features that channel the tailrace discharge into the river. Some bank erosion and slumping in the short reach between NN3 tailrace and the NN2 reservoir, though, might be experienced at sites with sandy and clay banks. The rapid changes in river flow following the intermittent operation of the power plant, and the fact that the water will not be loaded with sediments, will increase the erosive power of the water. However, most of the bank structure in the reach from the tailrace to the NN2 reservoir is dominated by larger stones and boulders and thus less at risk of bank erosion and slumping.

[1] Draft Social Action Plan and Environmental Management Plan, Final Report volumes 1-4 and Individual Management Plans Chapter 1 to 95.

Figure 7.1: Indices of erodibility above the Nam Ngum 1 reservoir (RMR, 2001, Chapter 3)



383. The most prominent impacts of the project on river hydrology and water quality are the following:

(i) Establishment of a storage reservoir, by flooding;
(ii) Reduction on the water flow between the dam and the power station tailrace;
(iii) Changes in the flow pattern downstream of the power station discharge point.

1. Reservoir

384. By building the NN3 dam a 64 km section of the Nam Ngum River (and part of the Nam Ting) will be changed from a running river with several rapids into a reservoir with hydrological features halfway between a slow flowing river and a lake.

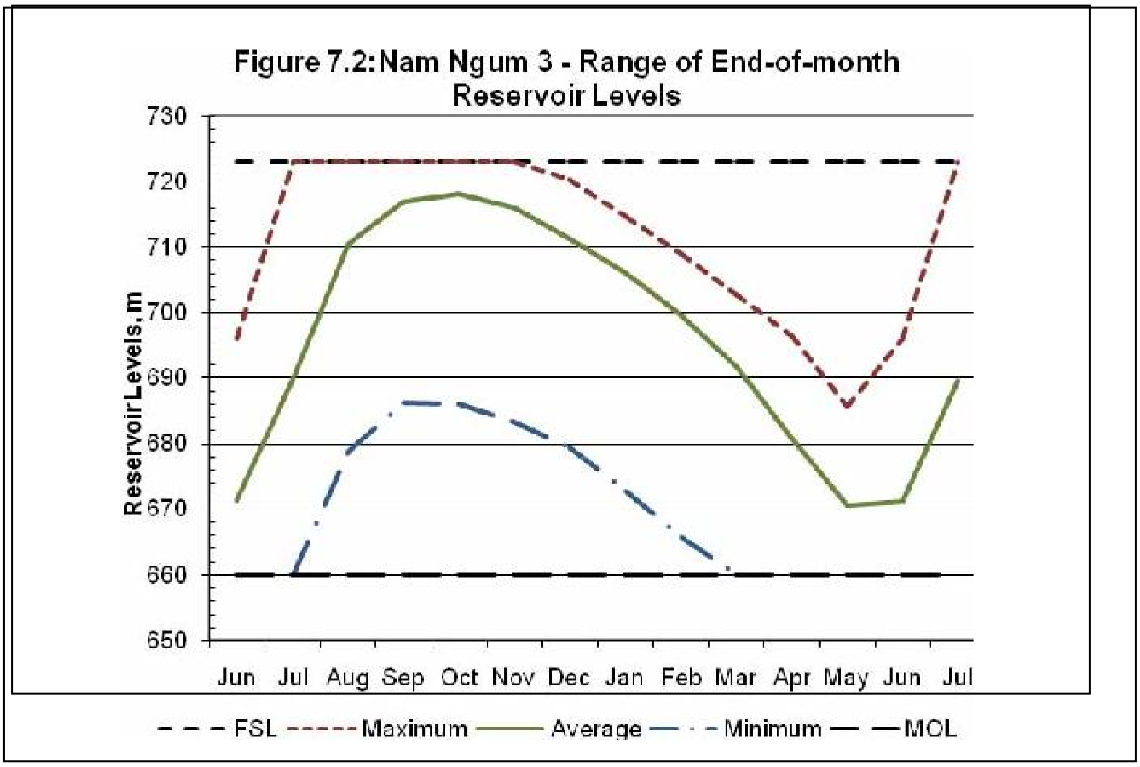
385. The reservoir water balance flow and levels have been determined based on topography, dam height, elevation of the spillway, reservoir inflow, and reservoir outflow, and are presented in Table 7.1 and. These represent the average over a 35-year period.

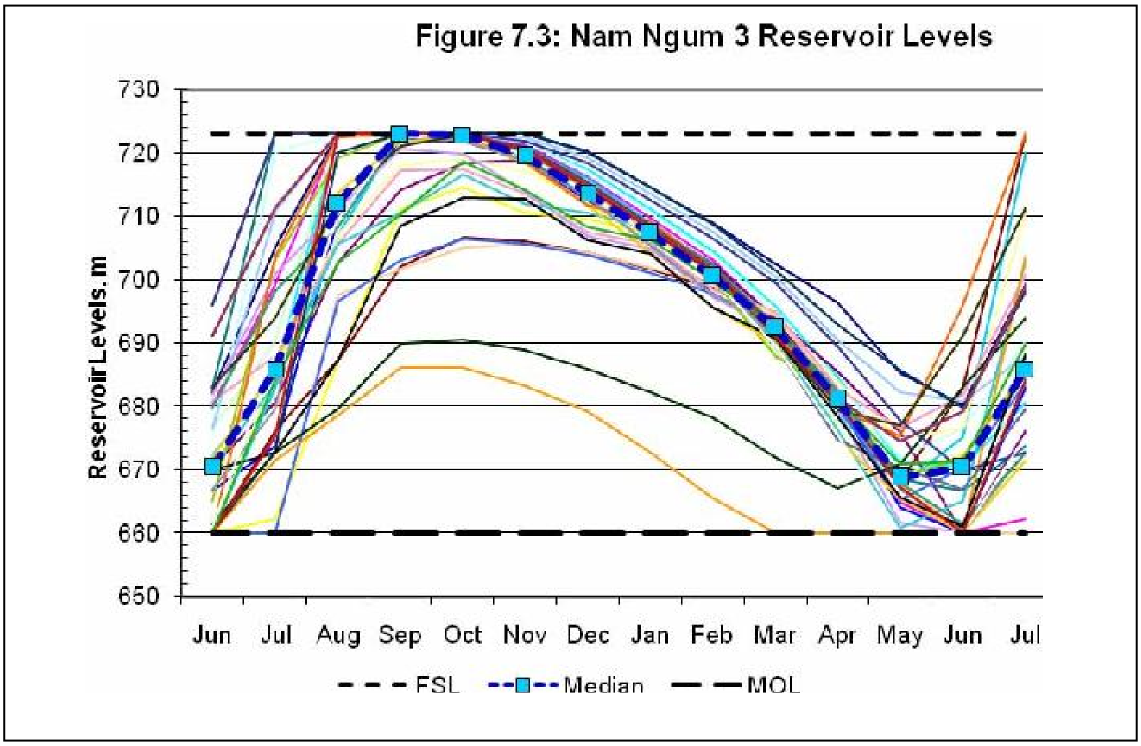
Table 7.1: Average monthly inflow and out-flow of NN3 reservoir in m^3/s (GMS, 2009)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly inflow in NN3 reservoir including nn5 discharge	33.2	25.3	21.2	21.4	38.4	93.1	213.2	289.6	214.6	106.1	58.4	40.6
Average monthly spill over NN3 dam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.1	39.6	0.2	0.0	0.0
Average monthly release from NN3 powerhouse	83.2	84.9	84.8	80.3	80.1	90.9	103.2	113.1	117.1	96.6	75.4	79.7
Maximum release from NN3 powerhouse	89.2	90.9	89.0	89.9	98.7	147.0	164.4	165.1	165.1	164.5	90.5	88.3
Average monthly outflow from NN3 reservoir	83.2	84.9	84.8	80.3	80.1	90.9	103.2	141.2	156.0	97.3	75.4	79.7

386. Table 7.1 shows the spill from the NN3 reservoir will occur normally in August and September only. However, the reservoir simulations based on 35 years of daily flows that there was no spill in 18 of those years. The longest period when significant spill did not occur is nine years between 1985 and 1993, when inflows to the reservoir were significantly lower than long-term average. When spill does occur, it is expected to vary from a few cubic meters per second for a few days to several hundred cubic meter per second for several weeks, and in extreme situations even peaking at several thousand cubic meters per second.

387. Table 7. 2 shows the average monthly reservoir level, the full supply level (FSL) and the minimum operating level (MOL). The minimum reservoir level will normally be reached in May and June. There is however a large variability in the reservoir level over the 35 years of reservoir simulations and MOL is reached in ten of those years. Figure 7-3 shows the end–of month live storage for each of the 35 years records, and the monthly median.





2. Flooding

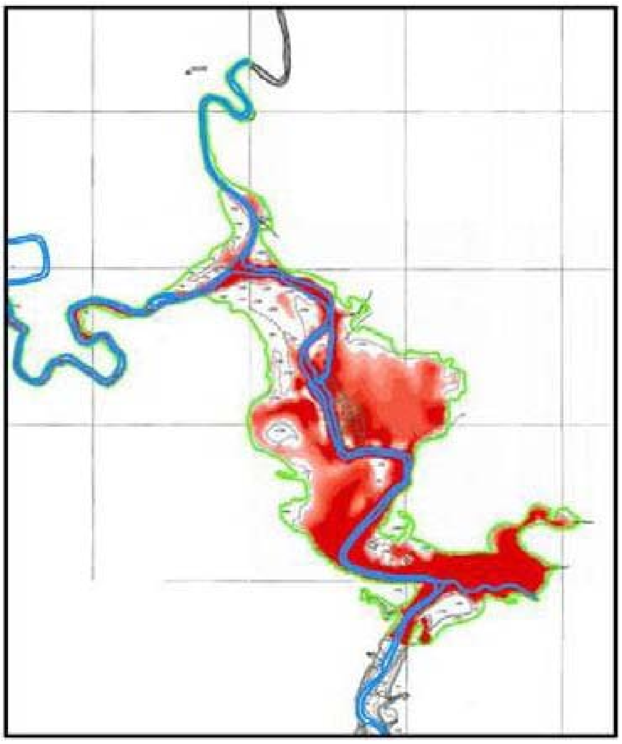
a. Ban Xiengdet

388. The maximum reservoir level elevations will cause partial inundation for limited duration at the village of Ban Xiengdet, which is located at the end of NN3 reservoir close to the confluence with the Nam Ting and the Nam Chat. The elevation of some rice paddy areas in Ban Xiengdet hovers around FSL (723 masl) of the reservoir. Flood risks at Ban Xiengdet will occur each year only during the period from August to November. The impacts of partial flooding at Ban Xiengdet will not occur earlier than the wet season of 2016. The extent of probable maximum flood at Ban Xiengdet is presented on

Figure 7.4 and in more details in the backwater study annex (Annex F). Flooding is likely not to occur every year of the concession period.

389. In Ban Xiengdet, NN3 reservoir seasonally floods the (i) residential area, (ii) physical-cultural resources, (iii) part of permanent agricultural land (rice paddies, maize fields, orchards, fish ponds, fruit trees), and (iv) part of land under community use.

Figure 7.4: Extent of Probable Maximum Flood at Ban Xiengdet (See Annex F for further information)



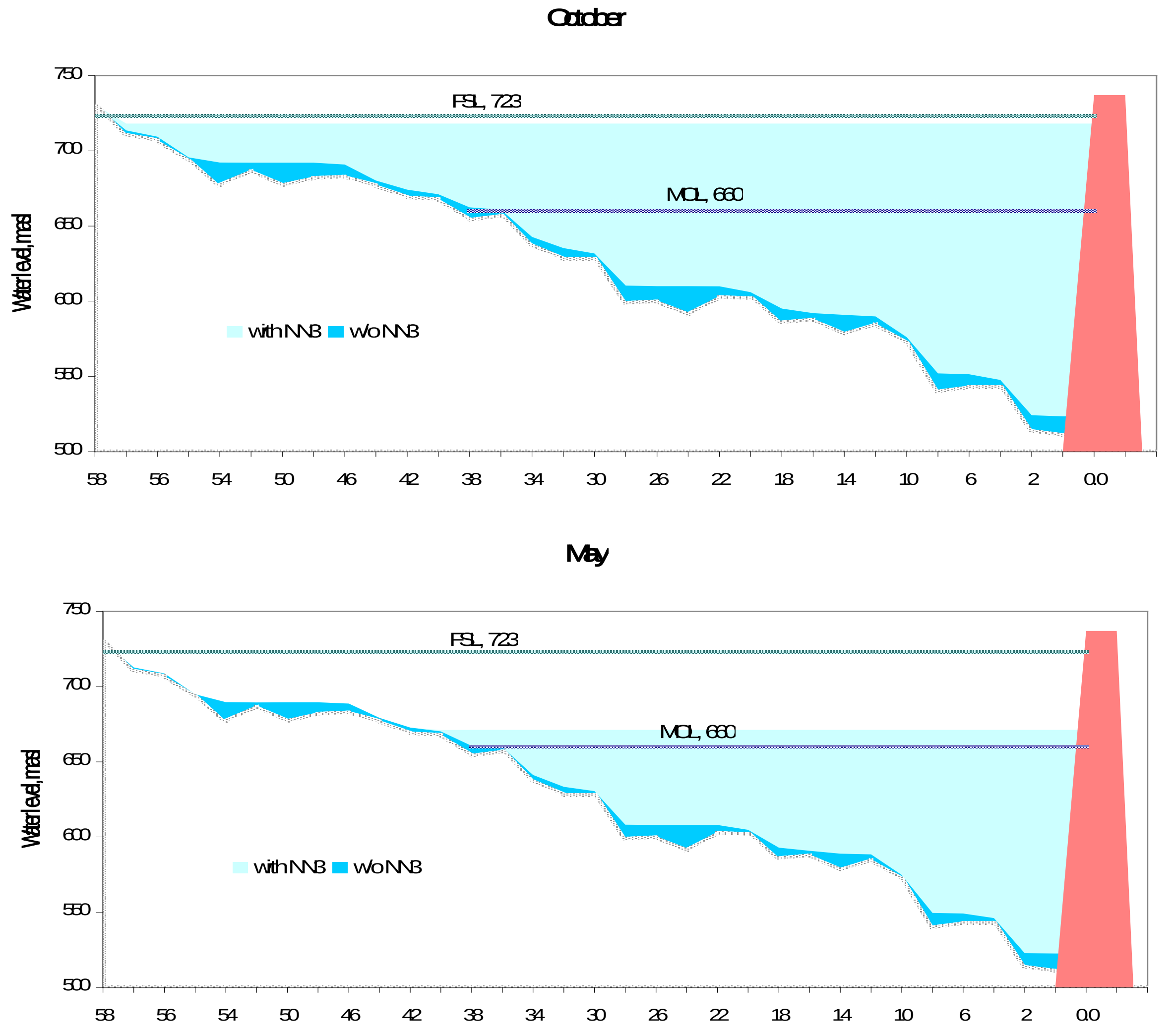
390. The Xiengdet households will be resettled within the Xiengdet village area at higher elevation, less than 2 km from the present housing area, as agreed upon by the Xiengdet villagers and the authorities of the District of Phou Kout. The resettlement plan and livelihood and village development plans for Ban Xiengdet are formulated in the Resettlement and Ethnic Minority Development Plan (REMDP).

391. No other villages around the reservoir area will be affected by flooding other than potential small losses in village livestock grazing areas (see REMDP). Ban Xiengdet is the only village that will need to be resettled.

b. FSL and MOL

392. Figure 7.5 show the maximum and minimum estimated average water levels of NN3 reservoir (light blue) and the water elevation of the Nam Ngum River under natural conditions (dark blue) during the month of October when NN3 reservoir water is close to Full Supply Level and the month of May when NN3 reservoir water is close to Minimum Operation Level (See also Annex F).

Figure 7.5 A and B: Maximum and Minimum NN3 Reservoir Water Levels in October and May during an Average Year



393. The NN3 reservoir surface area at Full Supply Level is 27.5 km^2, but the water surface area of the reservoir is only about 9.5 km^2 at Minimum Operation Level. Land permanently flooded has elevations up to MOL, while the flooded area within the drawdown is seasonally flooded. Land elevation within the NN3 drawdown zone might differ as much as 63 meters during extreme years.

394. Land located below FSL, but at elevations close to FSL, such as at Ban Xiengdet, might therefore not be flooded during some years. Most of the land at elevations within the drawdown zone will be seasonally flooded in an average year either for days, weeks, or months, while land at elevations below MOL will be permanently flooded.

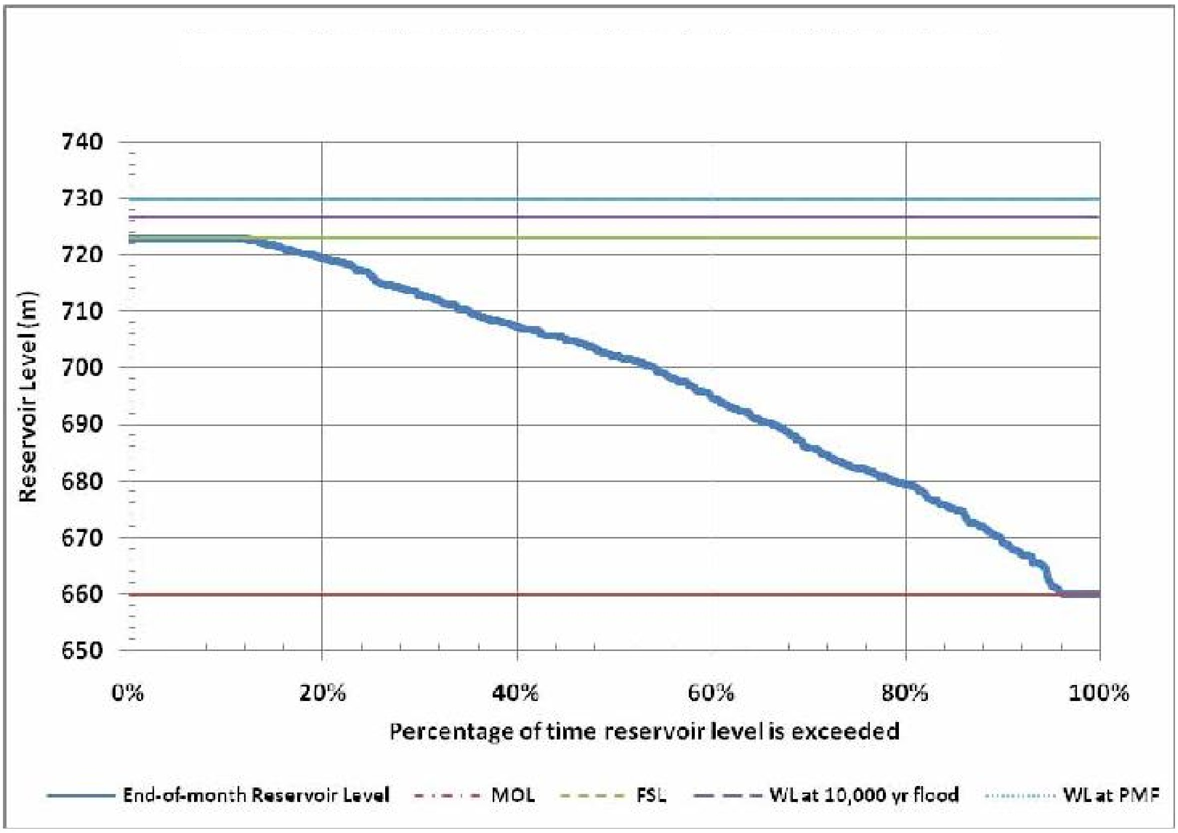
395. Figure 7.6 shows the duration curve for end-of-month reservoir water level. Under extreme flooding conditions the water level may rise above FSL and may reach 726.7 m during a 10,000-yr flood occurrence. The graph shows that the reservoir level will be below 680 masl for 20% of the time and above 720 masl also for 20% of the time (or about 10 weeks each). The elevation of some of the lands in Ban Xiengdet land is about 723 masl. On average, one can expect that the elevation of 723 masl will occur 12% of the time (or 6 weeks). However, during the 35-year simulation, the reservoir did not reach 723 masl in 13 years (37%) and 722 masl in 16 years (46%).

396. The reservoir simulations showed that the reservoir reached MOL 10 out of 35 years, and experienced a minimum storage of less than 100 million m^3 in another 12 years. However, the

remaining storage and the dry weather flow is sufficient to meet the requirement of the PPA of at least 8 hours per day of generation six days a week in 34 out of 35 years.

397. To meet the PPA obligations, the project needs to retain the entire river inflows, especially during the low rainfall years, for the purpose of power generation. Any outflows from the reservoir therefore are not possible without defaulting on PPA obligations and incurring associated financial penalties.

Figure 7.6: Duration Curve for NN3 Reservoir end-of-month Water Level



3. River Hydrology - Discharges

a. River stretch from the dam site to the power station

398. Under the current design, the river flow in the Nam Ngum between the dam site and the power plant tailrace site will be dramatically reduced and is presented in Table 7.2. Contributions to the flow from the NN3 dam to the confluence with the Nam Pha are from seepages and side flows, estimated at 0.3 to 1.0 m^3/s and 0.10 to 0.12 m^3/s respectively. Table 7.2 shows mean annual flows at various section of the Nam Ngum downstream of the NN3 dam with the exclusion of spills that normally occur in August and September during wet years. Spill only occur in 10 out of 35 years in August, and 15 out of 35 years in September. The respective long-term average monthly spill when they occur is respectively 98 m^3/s and 90 m^3/s although the actual spill from year to year may vary from very low for a few days to several weeks, and could peak at over 1,000 m^3/s.

Table 7.2: Average monthly river flows in various Nam Ngum sections between NN3 dam and NN2 reservoir (m^3/sec), excluding the spills that normally occur in August and September

Section	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Average monthly inflow in NN3 reservoir incl NN5 discharge	33.2	25.3	21.2	21.4	38.4	93.1	213.2	289.6	214.6	106.1	58.4	40.6
Seepage and groundwater	0.5	0.4	0.4	0.4	0.6	1.0	1.5	1.7	1.4	1.0	0.8	0.6
Nam Pha	2.7	2.1	1.8	2.1	4.3	10.7	23.1	29.8	22.1	10.8	5.6	3.5
Nam Pha Confluence	3.2	2.5	2.2	2.5	4.9	11.7	24.6	31.5	23.5	11.8	6.4	4.1
Local Inflow between Nam Pha confluence and NN3 tailrace	0.7	0.6	0.5	0.6	1.1	2.9	6.2	8.0	5.9	2.9	1.5	0.9
NN flows at NN3 tailrace	3.9	3.1	2.7	3.1	6.0	14.6	30.8	39.5	29.4	14.7	7.9	5.0
Average power plant discharge	83.2	84.9	84.8	80.3	80.1	90.9	103.2	113.1	117.1	96.6	75.4	79.7
Flow downstream of tailrace	87.1	88.0	87.5	83.4	86.1	105.5	134.0	152.6	146.5	111.3	83.3	84.7
Average flow into NN2 reservoir with average turbine discharge	88.6	89.2	88.6	84.6	88.5	111.6	147.2	169.6	159.1	117.5	86.5	90.7
Average flow into NN2 when NN3 power plant not generating	5.4	4.3	3.8	4.3	8.4	20.7	44.0	56.5	42.0	20.9	11.1	11.0
Average flow into NN2 when NN3 power plant generating at full capacity	94.6	95.2	92.8	94.2	107.1	168.4	208.4	221.6	207.1	185.4	101.6	99.3

Source RMR Chapter 7 updated with revised figures from GMS.

399. Without any riparian release from the dam, the 4.8 km reach of the Nam Ngum from the dam site to the confluence with the Nam Pha will become almost dry during the impoundment of the reservoir. In this reach only ground water inflow and seepage from the dam (estimated at 0.4 m^3/s), and ephemeral tributaries will feed the river in the dry season. Significant water volumes could be experienced in August and September in those years that water is released over the NN3 spillway.

400. From the Nam Pha confluence to the NN3 tailrace (11 km, from 4.8 km downstream of the dam to 15.5 km of the dam), the Nam Ngum River will regain the characteristics of a permanent river. The water from the Nam Pha will, however, only provide about 10% of the normal water flow compared to the situation before the project came into operation.

401. Downstream the NN3 tailrace (15.5 km from the dam) the overall annual discharge will (except for some water loss by evaporation from the reservoir) not be changed. There will, however, be a significant increase in the average dry season flow, and reduction in the average wet season flow. After this point, the Nam Ngum will then receive additional flow from the Nam Phay.

402. **Discharge at the NN2 Reservoir.** Figure 7.7 shows the expected average redistribution of the discharge at the NN2 reservoir expected after the completion of the NN3 project and Table 7.3 the contribution of the NN3 power station flows to the total inflows entering the NN2 reservoir.

Figure 7.7: Average Inflows into NN2 Reservoir with and without NN3

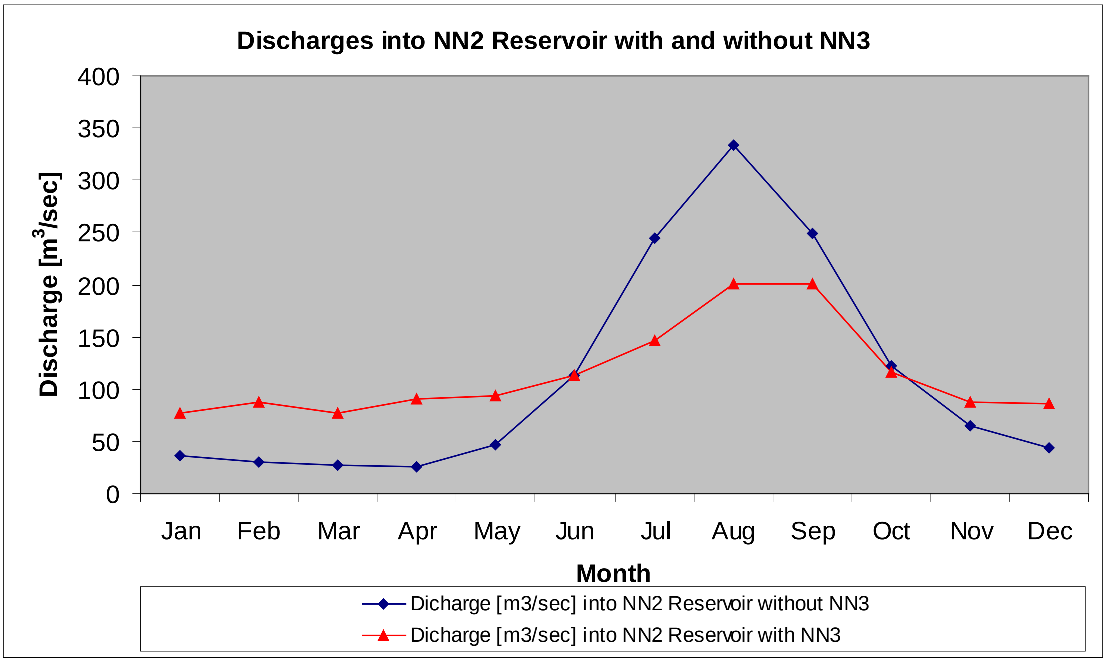


Table 7.3:Contribution of NN3 Power Station Discharges into NN2 Reservoir Nam Ngum river inflows

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average discharges by NN3 Power Station [m3/sec]	83	85	85	80	80	91	103	113	117	97	75	80
Inflows into NN2 Reservoir [m^3/sec]	89	90	89	85	89	112	147	170	159	118	87	91
Discharges by NN3 Power Station as % of Discharges into NN2 Reservoir	94	95	95	95	90	81	70	67	74	82	87	88

b. Daily variations of flows

403. More striking than the seasonal flow regulation, will be the daily variation in flow in turbine discharge into the Nam Ngum as a result of the planned intermittent generation patterns of the power plant under the EGAT power purchase agreement. The most likely pattern of operation will be between 8 hours and 16 hours power generation every day of the week except Sundays and Thai holidays, when no power will normally be generated. Daily water level fluctuations downstream of the tailrace could reach 1.8 m in April, but this will be quickly absorbed by the NN2 reservoir, then 3.7 km, or less, from the NN3 tailrace discharge point.

404. When the power plant is not operating the only water flowing in the river will be the water discharged from the Nam Pha (and seasonal spills from the NN3 dam when they happen). Each time the turbines are turned on flow of up to between 83 and 163 m^3/sec will be discharged into the Nam Ngum depending on the available head. The intermittent flow variations will have a flushing impact on the downstream river reach.

c. Impacts of modified discharges on habitats and aquatic resources

405. The changes in hydrology and water quality will modify river habitats, which in turn will lead to changes in aquatic ecology, creating social impacts linked to a change of utilization of aquatic resources, including fisheries. This is presented below.

C. Impacts on Water Quality

406. The main impact on water quality will be seen in the reservoir and in the water discharged from the power plant, in particular through reduced Dissolved Oxygen concentrations, impacting the aquatic habitats and their associated life.

407. The consequences, in terms of water quality, from the storage of water in the reservoir and the release of a regulated flow downstream of the power station, are as follows:

(i) A change from running water to a lake ecosystem water body will take place in the reservoir. Thermal stratification will evolve in parts of the year, with a warmer surface layer and cooler bottom layer. This stratification will probably be rather stable. The narrow reservoir is protected by steep hills and only strong winds parallel to the reservoir main north - south axis will manage to create significant wind induced circulation. Thus the main force for circulation will be large floods in the beginning of the wet season and inflow of cold water in the months of November to February.

(ii) Decomposition of inundated organic material in the new reservoir will require large amounts of oxygen. Most likely this will deplete all the oxygen available in the deeper layers and lead to anoxic conditions.

(iii) The reservoirs will, through sedimentation, trap some of the inflowing nutrients and also buffer the seasonal changes in concentration of nitrogen and phosphorous in the inflowing water.

(iv) Assumed anoxic conditions in the deeper layers of the reservoir might cause release of soluble iron from reservoir bottom sediments. As NN3 has a deep intake the water discharged from the power plant might have an increased concentration of iron. On the other hand the NN3 reservoir might buffer seasonal upstream discharges in iron.

(v) The temperature of the discharge water from the power plant will be influenced by the deep intake in the reservoir. In the hot season this will result in a lower water temperature in the river water downstream of the NN3 tailrace. The temperature of residual water in the river between the dam site and the power house will be more modified by the shifts in air temperature than before, because of the reduced river flow volume.

(vi) The assumed situation of anoxic conditions in bottom strata of the reservoir will create CH_4, H_2S, SO_2. In particular, hydrogen sulphuric water will lower the pH in the bottom water and to some extent also in the water discharged from the power plant.

408. The anoxic conditions in reservoir water quality are likely to moderate over the years and expected to last for the first five to ten years of operations. These negative impacts though can be minimised by effective vegetation clearance in the inundation zone. The final water quality will be influenced by the NN5 project now under construction upstream and the NN4 development, also upstream of which no technical and operational details are available at this stage (Vattenfall 2008). Effective vegetation clearance in the inundation zones of NN5 and NN4 will minimise the negative impacts from these projects on NN3 water quality.

409. Considering the height of the dam and experience from other projects it is possible that the water spilled from the reservoir will be super-saturated in nitrogen in the first few hundred meters downstream of the dam, which could cause fish kills there.

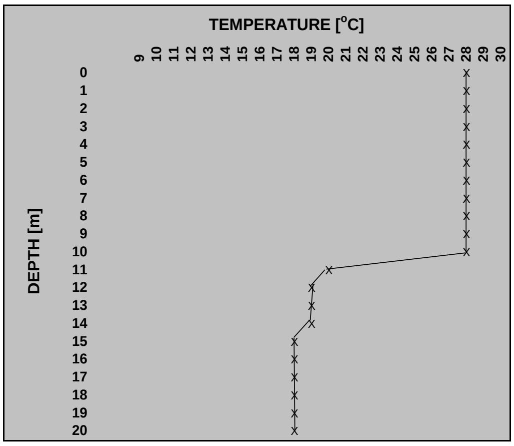
410. In addition, downstream of the dam and power station, the water will have low concentrations of total suspended solids, as the sediments will be trapped by the reservoir.

1. Thermal stratification

411. Similar to any reservoir deeper than 10 meters located in Lao PDR or northern Thailand, NN3 Reservoir is expected to be stratified during the period from March to December. A surface water layer (epilimnion, generally occupying the upper 10 meters of the reservoir) with temperatures close to air temperatures will float on a bottom water layer (hypolimnion) with lower temperatures. The epilimnion and hypolimnion are separated by a thermocline where temperatures strongly drop. The separation is established because the density of water with low temperature is higher than density of water with high temperature. The situation will be similar to what is shown for NN1 reservoir in Figure 7.8..

412. NN3 Reservoir as all deep reservoirs in the Nam Ngum River Basin can be assigned to the category of "warm monomictic". The main features of "warm monomictic" reservoirs are: (i) water temperature will not be below 4 ^oC, (ii) lake/reservoir shows a thermal gradient, and (iii) period of circulation or turn-over will occur during the cold season.

Figure 7.8: Change of Water Temperature with Reservoir Depth in NN 1 Reservoir



Source: Interim Committee for Coordination of Investigations of the Lower Mekong Basin, 1984, Development and Management of Fisheries in Nam Ngum Reservoir, Lao PDR, MKG/112.

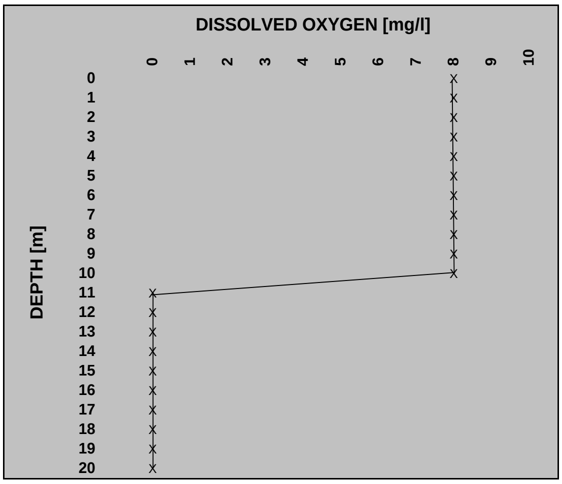
413. At higher altitudes in Lao PDR, such as at the NN3 Reservoir, air temperatures can be as low as around 0^oC in December, January, and February. With low air temperatures, the temperature of the reservoir epilimnion drops until it is the same as that of the hypolimnion. When both epilimnion and hypolimnion have the same water temperature the water in the entire NN3 Reservoir will start circulating, the thermocline disappears and the water of the epilimnion and the hypolimnion will mix. During this mixing process also the upper layers of the reservoir will see low level of oxygen. During this period, the water quality of the power station discharges will improve with higher DO concentrations.

414. When the air temperature rises again the stratification will be re-established. A stable epilimnion of 10 meters is expected to be established each year from March up till the rainy season. During the rainy season, the thermocline will wobble as a result of increased reservoir inflows and increased wind and wave action. Increased inflows during the rainy season and increased wind and wave action may even cause an additional turnover of the reservoir during the months of July, August, and September.

415. Due to the effect of reservoir stratification, water quality parameters of the epilimnion and hypolimnion will differ considerably.

416. The epilimnion is continuously in contact with air and therefore contains high Dissolved Oxygen (DO) content. Photo synthetic activity of algae and aquatic plants may push DO levels in the surface water layer even to over-saturation.

Figure 7.9: Change of DO concentrations with Reservoir Depth in NN 1 Reservoir



Source: Interim Committee for Coordination of Investigations of the Lower Mekong Basin, 1984, Development and Management of Fisheries in Nam Ngum Reservoir, Lao PDR, MKG/112.

417. In the bottom water layer the lack of sunlight will impede the oxygen producing oxygen algae and aquatic plants. Lacking aeration and photo synthetic activity in the bottom water layer and oxygen consumption by the de composition of organic material will create low DO concentrations or even anaerobic conditions in the hypolimnion as seen in NN1 (Figure 7.9). Under anaerobic conditions, decomposition of biomass produces also methane, hydrogen sulfide, ferrous iron, and ammonia that are all toxic for aquatic life. As a result, a reservoir hypolimnion does not sustain much aquatic life. In Lao PDR, at reservoirs deeper than 10 meters, DO concentrations in the hypolimnion are normally as low as 0 mg/l. The situation can be illustrated by water quality data from Nam Leuk (Table 7.4).

Table 7.4: Measured Chemical parameters in the epilimnion and hypolimnion of Nam Leuk Reservoir, April, 2004

	Measured concentrations in epilimnion. Depth less than 5 m	Measured concentrations in hypolimnion. Depth more than 10 m
Dissolved Oxygen	8.3 mg/l	0.0 mg/l
Ammonium	0.0 mg/l	0.40 – 3.40 mg/l
Ferrous Iron	0.0 mg/l	2.0 – 8.6 mg/l
Methane	0.02 – 0.04 mg/l	0.23 – 2.20 mg/l

Source: Hydreco, NT2 Hydropower Project in Lao PDR, The Dissolved Oxygen Consumption Kinetics in the Water Turbined by the Nam Leuk Power Plant.

418. In the case of NN3, the volume of water in the hypolimnion is much higher than the volume of water in the epilimnion. A risk exists that during de-stratification of NN3 reservoir, decomposition of organic material not only induces poor water quality in the deeper parts of the reservoir, but also close to the surface (see also Annex G).

419. In addition, temperatures and pH will be much lower in the hypolimnion than in the epilimnion. Values of Biological and Chemical Oxygen Demand (BOD and COD), hardness, conductivity, and turbidity will be significantly higher in the hypolimnion than in the epilimnion.

420. There are not any realistic opportunities to de-stratify deep reservoirs and there are no realistic opportunities to mix stratified reservoirs artificially to avoid a hypolimnion with lower DO concentrations, lower temperatures, lower pH and higher turbidity, higher hardness, and higher conductivity than in the epilimnion. The most important measure is to avoid high Biological and Chemical Oxygen Demands (BOD and COD) by removing appropriately biomass from the reservoir inundation area.

2. Dissolved oxygen

421. The depletion of oxygen in the reservoir will be dependent on the available organic materials. Algae and other water plant growth in the upper water layers produce oxygen during day and consume oxygen during night. But when the algae die and sink their decomposition will require oxygen. The small surface of the reservoir should however lead to limited quantities of algae. So will also inflowing organic material from the catchment. In the first years after the filling of the reservoir, the level of oxygenation will be heavily determined by the organic material (biomass) left on the inundated land. This consists of wood, leaves, roots, other plant debris and organic acids in the soil. An efficient programme for removing biomass from the reservoir area before inundation will reduce the oxygen depletion problem, and corresponding problems of eutrophication.

422. Experience has shown that tail water from reservoirs has been damaging natural fish populations several km downstream when discharged into a slow flowing river without specific mitigation arrangements. In slow flowing rivers the naturally occurring process of re-oxygenation will be very slow. Where there are waterfalls or rapids the natural re-oxygenation is much more efficient. In the NN3 case, a number of white water rapids are found between the tailrace and the NN2 reservoir. The distance is however, very short (0.9 km at FSL and 3.7 km at MOL). There will be some improvement of oxygen but the water will most likely not be fully re-aerated before it reaches the stagnant water of the NN2 reservoir.

3. Sediments

423. The NN3 reservoir will trap sediments carried with the inflow water. Most sediment will settle on the bottom of the reservoir and thus reduce the life length of the reservoir (Table 4.4). With the construction of upstream hydropower projects, sediments will be trapped in NN4 and NN5 reservoirs and increase the NN3 reservoir life length compared to what is calculated in (Table 4.4).

424. The water that spills at the dam and the water released through the turbines will have lower sediment content than the pre-project natural inflows. Sediment-poor water will have a higher erosive capacity than sediment rich water and thus have the potential to pick up sediments through bank and bottom erosion as it flows down to the NN2 reservoir. The actual impact though will be observed during the operation phase and if observed to be significant, will be mitigated by bank protection measures.

4. Benefits of hypolimnetic withdrawal from the NN3 reservoir

425. Hypolimnetic withdrawal from NN3 reservoir is beneficial in reducing potential poor water quality conditions within NN3 reservoir. It will: (i) increase water temperature in the hypolimnion, (ii) decrease stability of reservoir stratification, (iii) shorten the period of reservoir stratification, (iv) increase period of de-stratification, (v) increase transfer of DO from the epilimnion into the hypolimnion, and (vi) reduce risk of poor water quality close to the reservoir surface during de-stratification of NN3 reservoir.

5. Downstream impacts on NN2 and NN1 reservoir

426. With a fixed power station intake at 645 masl, the water drawn into the power station will contain low levels of dissolved oxygen or be anoxic for periods of the year. Some replenishment of the oxygen content will take place in the tailrace and in the immediate 1.3 km downstream river reach, which includes some rapids, before reaching the NN2 reservoir.

427. Nam Ngum discharges downstream the NN3 power station into the NN2 reservoir will consist of (i) NN3 power station discharges that originate from the reservoir hypolymnion, (ii) discharges from the 15.5 km Nam Ngum stretch downstream of the NN3 dam, including spills at the NN3 dam and natural inflows from the Nam Pha and the Nam Phay.

428. Poor water quality of the NN3 power station discharges will be improved slightly by dilution before entering the NN2 reservoir. Spills and the perennial Nam Pha and Nam Phay rivers are the main contributors to dilution of power station discharges. This could however change, should hydropower projects on the Nam Pha and the Nam Phay be constructed, contributing then to potential poor water quality downstream. Table 7.5 shows the percentage of NN3 power station discharges as a percentage of the inflow into the NN2 reservoir.

Table 7.5: Dilution of Power Station Discharges as % of NN2 Reservoir Inflow

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dilution	7%	5%	4%	5%	10%	23%	43%	50%	36%	22%	15%	14%

429. It is expected that the low dilution will only alleviate partially poor water quality of NN2 reservoir inflows. As this 0.9 to 3.7 km stretch of the Nam Ngum River consists mainly of rapids, natural aeration should occur and to some extent improve the water quality.

430. It is thus possible that poor water quality from the NN3 downstream discharges might affect the potential fish yields in the upper part of NN2 reservoir and its attractiveness, and could cause fish kills, at least for a number of years, if the biomass removal programme of the project and other projects upstream are not implemented properly. It will also depend on the actual water quality in the NN2 reservoir, the water quality of NN3 reservoir inflows and the water quality of tributaries of the Nam Ngum, including the Nam Pha and Nam Phay. The water quality downstream of the tailrace discharge will be monitored and if observed to be significant will be mitigated by modifying the river morphology to enhance aeration.

431. The shallow Nam Ngum 1 reservoir will be impacted by the combined influences of the oxygen status of water from all the upstream reservoirs. The impact is of particular concern as the part of the NN1 reservoir which will receive water of reduced quality is the most important breeding ground for a number of economically important fish species. How much of the impact on NN1 that can be attributed to NN3 cannot be calculated but it is assumed that NN2 reservoir processes will be far more dominant than the impact of NN3 inflow water, as there was no biomass removal from the NN2 reservoir before its impoundment.

6. Other impacts

432. The operation of the power plant itself does not create any pollution problems other than those mentioned above. The periodically reduced water flow in the downstream reach will, however, reduce the river potential to dilute hazardous discharges, such as toxic run off and spills from potential future industrial and artisanal mining operations, should the catchment of the river reach from the NN3 dam site to the NN2 reservoir become the object of such activities in the future.

D. Impacts on Vegetation and Land Use

433. The proposed development of Nam Ngum 3 Hydropower Project will have impacts on the terrestrial ecosystems in the area. Forest and other vegetation types will be permanently lost or altered by inundation and project land take. Increased human activities and changes in ecological factors might also cause changes. Vegetation and land uses within the NN3 catchment area will not be physically impacted by NN3.

434. In total an area of 2,754 ha of different vegetation categories is represented in the reservoir inundation zone. There will also be losses of forest in connection with the construction of access roads and project features and from the clearance of the transmission line corridor (Table 7.7).

435. Impacts of the creation of the reservoir and the operation of the project on land used by surrounding villages are presented in details in the REMDP. The NN3 reservoir will mainly flood agricultural and residential lands at Ban Xiengdet.

436. Annex H presents the interpretation of 2008 satellite images conducted to identify potential existing land uses, location of houses, buildings, and assets on the left bank and right bank of the Nam Ngum River within the reservoir area, but outside the village areas of Ban Xiengdet and the peri-reservoir villages. No such occupation was found.

1. Reservoir

437. As indicated above, the reservoir area is mainly dominated by unstocked forest i.e. original forest land which is now covered with young and very young woodland and bamboo vegetation. Only minor patches of primary forest are found intact. As a result, the dominant vegetation types are believed to have low inherent conservation and biodiversity value, and will be surveyed in the dry season 2011-12.

438. The 10.47 km^2 forested areas lost consist of 1 km^2 primary forest. This area is considered to form wildlife habitats for deer, serow, and other wildlife with medium or low risk of risk of national extinction. The forested areas within the NN3 reservoir area form less than 1% of the forested areas within NN3 catchment: 0.7% of NN3 catchment; 0.6% of the forested areas in NN3 catchment are located within NN3 reservoir area; 0.3% of the primary forested areas in the NN3 catchment are located within NN3 reservoir area; and 0.7% of the secondary forested areas in the NN3 catchment are located within NN3 reservoir area.

439. The riverbank habitats constitute a transition zone between terrestrial and aquatic ecosystems, with specific and often rich flora and fauna. This transition zone will be lost by establishing a fluctuating reservoir.

Table 7.6: Vegetation and land categories lost within the reservoir area (2002)

Land use & vegetation types	NN3 Reservoir Area		NN3 Area
	Area (ha)	%	Percentage of Catchment Area
Current forest	**1,047**	**38.0**	**0.28%**
Upper Dry Evergreen	63	2.3	
Upper Mixed Deciduous	964	35.0	
Mixed Coniferous & Broadleaved	19	0.7	
Unstocked Forest	**1,427**	**51.8**	**0.38%**
Permanent agriculture land	**49**	**1.8**	**0.01%**
Other Non-forest Area	**231**	**8.4**	**0.06%**
Grassland	19	0.7	
Water	212	7.7	
Grand Total	**2,754**	**100.0**	**0.73%**

440. The reservoir drawdown zone will comprise about 2/3 of the total reservoir area. In this zone, new habitats will develop. It will be somewhat similar to the existing riverbanks, but will be much wider. It is expected that the upper part of this zone will develop towards semi-natural habitats, e.g. swamp

bush land or annual grasslands, whereas the lower part of the drawdown zone will be dominated by bare soils and rocks.

441. **Floating debris**. It has been estimated that about 8,000 tonnes of floating debris will move towards the intake during the first 3 years of reservoir operations, before reducing to a range between 300 and 1,000 tonnes/year for the duration of the Concession Period (RMR, 2001).

2. Downstream

442. The relatively well-developed forest found in the Nam Ngum valley between the dam site and the power house will not be directly impacted by the project but might experience unsustainable exploitation because of the general increase in population and level of activities in the project area just outside this forest. Also the new roads to the dam site and to the power house site will make access to the undisturbed parts of this forest easier. The long period of construction poses a particular threat. These threats will need to be mitigated.

443. The habitats of riparian vegetation between the dam and the power plant tailrace will be changed. The generally reduced flow, with close to normal flow at the end of the wet season, could result, by natural colonisation of the former banks, in denser vegetation and tree coverage along the river banks compared to today's situation.

3. Transmission Line

444. The 99 km transmission line will entail permanent acquisition of about 8 ha of land for tower foundations and immediate safety zone.

445. According to the Lao Electric Power Technical Standards the right-of-way (ROW) for the 500 kV transmission line is 50 m (25 m to each side of the centreline), which makes a corridor of 500 ha. In addition construction sites, access roads and camps will occupy land, mostly temporary. As the NN2 and NN3 use a joint corridor (approx. 53 km long) the land take from NN3 will be reduced to about 300 ha.

446. The land use distribution in the transmission line corridor is shown in Table 7.7.

Table 7.7: Vegetation categories within the new transmission line corridor.

Vegetation category	Corridor distance (m)	Approx. land in 50 m ROW (ha)	%
Water	1,115	6	1.1
Grassland	4,882	24	5.0
Rice Paddy	953	5	1.0
Upland Swidden Farm	525	3	0.5
Unstocked Forest	32,764	164	33.1
Bamboo	1,139	6	1.2
Mixed Broadleaf/Coniferous Forest	3,353	17	3.4
Mixed Deciduous Forest	49,669	248	50.2
Dry Evergreen Forest	4,494	22	4.5
TOTAL	**98,894**	**494**	**100.0**

447. Forest categories cover about 60% of the land crossed by the Transmission Line. This includes Mixed Deciduous Forest, Dry Evergreen, Mixed Broad Leaved and Coniferous Forests. Unstocked Forest constitutes a significant part of the corridor (33%). Water counts for about 1 %. Most of this is because of the crossing of an arm of NN1 reservoir. Approximately 1% of the lands (close to Ban Na

Bong) are paddy fields. These will still be possible to cultivate after the transmission line has been established. Only the land taken by the footprints of the towers will be lost, as will be the forested areas that will need to be cleared under the line.

Table 7.8: Vegetation categories within the new transmission line corridor within PKK NPA

Vegetation category	Corridor distance in (m)	%
Water	287	1
Grassland	4,882	14
Unstocked Forest	12,416	37
Mixed Broadleaf/Coniferous Forest	3,353	10
Mixed Deciduous Forest	12,748	38
TOTAL	**33,687**	**100**

448. In addition to the 300 ha of land which will have to be cleared for vegetation in the transmission line ROW it is estimated that about 150 ha of land will be temporary occupied mainly for access roads during the construction period. Some portions of these roads will have to be permanently maintained for operation and maintenance works, throughout the project life. Most of the temporary occupied land will be in the category of light scrub or un-stocked forest, and grassland.

449. Portions of the NN3 transmission line corridor will run through the Phou Khao Khouay (PKK) National Protected Area (NPA) (Table 7.8). The project will: (i) act in a manner consistent with the existing protected area management plans, (ii) consult with the NPA management, local communities, and other key stakeholders, and (iii) implement additional programs, as appropriate, to promote and enhance the conservation aims of the protected area (See Chapter 9). Surveys will update the status of the biodiversity in the area of the TL corridor.

E. Impacts on Wildlife

1. General Habitat Loss

450. The creation of the reservoir and to some extent the land take caused by the other project features will have an impact on the wildlife associated with the impacted vegetation and habitats.

451. For most of the forest and vegetation categories lost by inundation similar land can be found in the surroundings of the reservoir. These will need to be protected. From a biodiversity perspective the most negative impact is expected for species utilizing the river itself or the near river surroundings for their livelihood (food, shelter, breeding, etc.).

2. Riverine Fauna

452. **Mammal, reptile and amphibian species.** Tables 7.9 and 7.10 present the list of species recorded during the RMR surveys undertaken in 1998 in the project area. The list will be updated during the biodiversity study to identify the species that will be directly impacted by the project and unable to adapt to the new environment created by the impoundment of the reservoir and the modifications upstream and downstream.

Table 7.9: Mammal, reptile and amphibian species recorded from Nam Ngum riverine habitats found in sections of the River from the Tailrace to the Dam site (RMR 2001)

English Name	Latin Name (as of 2001)
MAMMALS	
Macaque	*Macaca spp.*
Sambar	*Cervus unicolor*
Common Barking deer	*Muntiacus muntjak*
Tomb bat	*Taphozous thoebaldi*
Fishing cat	*Felis viverrina*
Leopard cat	*Felis bangaliensis*
Crestless Himalayan Porcupine	*Hystrix hodgsonii*
Otters	*Lutra*
Vole	*Sp. Or ssp*
Fruit bat	*Several spp.*
Horseshoe bat	*Rhizomys sumatrensis*
Large bamboo bat	*Rhizomys sumatrensis*
Variable squirrel	*Callosciurus finlaysoni*
Water Shrews	*Sp. or ssp*
Common wild pig	*Sus scrofa*
Lesser Mouse Deer	*Tragulus javanicus*
Common bat	*Myotis sp. Or spp.*
Three Striped Palm Civet	*Arctogalida trivirgata-Felidae*
Civet	*Several spp*
Crab eating Mongoose	*Herpestes urva*
REPTILES	
Asian Water Dragon	*Physignathus cocuncius*
Reticulated Phython	*Morelia reticulatus*
Colubrine Snake	*Sp. Or spp.*
Strip-necked terrapin	*Geomyda tcheponensis*
Big Headed Turtle	*Platysternon megacephalum*
Yellow tree monitor	*Varanus bengalensis*
Water Monitor	*Varanus salvato*
Toads	*Ssp.*
Frogs	*Ssp.*

Table 7.10: Bird species recorded from Nam Ngum riverine habitats found in sections of the River from the Tailrace to the Dam site, (RMR 2001)

English Name	Latin Name (as of 2001)
Bat Hawk	*Macheirampus alcinus*
Black-Capped Kingfisher	*Halcyon pileata*
Frogmouth	*Batrachostomus sp. Or spp.*
Grey Nightjar	*Caprimulgus indicus*
Rock Pigeon	*Columba punicea*
Coucal	*Centropus spp.*
Black Drongo	*Dicrurus macrocercus*

English Name	Latin Name (as of 2001)
Banded Broadbill	*Eurylaimus javanicus*
White Wagtail	*Motacilla alba*
Grey Wagtail	*Motacilla cinerea*
Sandpipers	*Tringa sp. or spp.*
Forktails	*Enicurus spp.*
Blue whistling thrush	*Upupa epops*

453. If the presence of the species listed above is confirmed along the stretch of the river, it is expected that otters and kingfishers will be impacted, i.e. the populations of these species could be significantly reduced, or eliminated, by reduced discharges between the NN3 dam site and the NN3 power station and anaerobic conditions of the water released from the NN3 power station. Otters and kingfishers rely on fish for food.

454. Most of these species are common inhabitants of river valley habitats in Lao PDR. Species recorded as having "*moderate risk of national extinction*" are: Big Headed Turtle and Pied Kingfisher, although the later is probably not found in the project area (Duckworth, 2011). The big headed turtle (*Platysternon megacephalum*) was categorized in 2010 as endangered (IUCN Red List, version 2010). In addition the undetermined groups Otters, Ducks, Geese and Lapwings might contain species of this category.

3. Migration Barrier and Stranding

455. The long and narrow reservoir will separate the forest and hill landscape of the near reservoir catchment into an eastern and a western part. Some larger animals might have territories on both sides, which in the future will be separated by the reservoir. Some migration routes might also pass from one side to the other. It is however, not expected that the transition from a river to a lake will make the crossing significantly more difficult. The distance will increase but the reservoir will be easier to swim than a rapid flowing river (RMR, 2001).

456. There is a risk that small, slow moving animals, or animals which retreat up trees, or strictly diurnal or nocturnal animals, will be in danger of being stranded or drowned as the reservoir waters rise during reservoir filling. The extent of this problem will however, also be very limited since the reservoir will be confined into a narrow valley, with short distances between the banks (see Figure 2.7).

457. The clearance of the remaining biomass before impoundment and the subsequent inundation will have consequences for terrestrial plant and animal species that occurred within the NN3 reservoir area, as by disturbing their habitats, it will push them away from the area and/or expose them to predators and hunting.

4. Endemic and Endangered Species

458. Some species classified as endangered or vulnerable in the updated IUCN list of animal species of "National" or "Global Significance" (Duckworth et al, 1999) is reported seen in the near reservoir catchment of Nam Ngum 3 or in downstream river areas. Anecdotal information of the occurrence of bears, tigers and other large cats in the land surrounding the reservoir is an indication of a potential negative impact on wildlife if human presence and land use increases in the area. This will be confirmed by the biodiversity surveys scheduled to commence in the dry season 2011-12.

5. Biodiversity Stress

459. A significant stress to the biodiversity of the project area will result from an assumed increase in human activities in the area caused by:

(i) Improved access opportunities from improved project roads, and the potential for continuous boat access from Ban Long Cheng to Ban Xiengdet and even further up Nam Ngum.
(ii) Logging trails constructed for the timber harvest of the NN3 reservoir.
(iii) General increased human population and economic activity in the project area.

460. The reservoir section of the Nam Ngum valley - apart from the mid part where people occasionally settle on the surrounding land - has seen little exploitation of wildlife and NTFP. This section will come under much more pressure than before. Increased logging and risk of unsustainable collection of NTFP will reduce the habitats for some species. It is also assumed that increased hunting pressure caused by improved access will affect animals valued in the wildlife trade. There is, however, at present a weak legal framework and minimum enforcement capacity to protect the forest resources from exploration by outsiders.

F. Impacts on Aquatic Life and Fish

461. Construction and operation of the proposed Nam Ngum 3 Project will alter the flow, the morphological and physical characteristics of the Nam Ngum River, and its water quality. In the upstream area a new reservoir will be formed, changing the ecosystem from a lotic environment to a lentic environment. This will affect the ecological structure of the water system, the natural habitats and have impacts on composition, diversity and abundance of the aquatic communities. In addition, upstream developments (NN5 and NN4) will influence the eutrophication process in the NN3 reservoir and water quality further downstream.

462. Important aquatic habitats for aquatic life such as rapids and deep pools will be temporary or permanently inundated in the reservoir area, will receive adjusted flows downstream of the NN3 dam, and will receive regulated flows of poor water quality in the Nam Ngum River stretch between NN3 power station and NN2 reservoir.

463. The construction of the NN3 dam will also fragment aquatic habitats, by forming a physical barrier for potential fish migration[2] upstream into the Nam Ngum.

464. As a result of modification and fragmentation of aquatic habitats upstream of NN3 dam and between NN3 dam and NN2 reservoir, changes will occur in the occurrence of aquatic life that potentially lead to impacts on the human uses of aquatic resources, such as fisheries.

1. Reservoir

465. **Ecosystem changes and consequences**. The change in the river ecosystem will have fundamental impacts on the indigenous fish composition and other aquatic fauna. Some life forms might be able to adapt to the new conditions, but for the most part, a noticeable shift in species composition and population density of various species will be seen. The diversity of aquatic life in the reservoir is expected to be lower than in the original river habitats.

466. During reservoir filling the riverine fish species, mostly existing of bottom feeders will try to escape lentic reservoir conditions and anaerobic conditions of the reservoir hypolimnion, by moving upstream. From the experience of other reservoir in the country, after filling of NN3 reservoir it can be expected that less than 50% of the 45 presently occurring fish species in this stretch of Nam Ngum will be able to adapt to reservoir conditions.

467. However, as lentic and anaerobic conditions do not occur at those reservoir areas where the Nam Ngum River and its main tributaries are flowing into the NN3 reservoir, a higher aquatic biodiversity can be expected at the upstream parts of NN3 reservoir area that forms part of the 63 meters drawdown zone.

[2] A two-year monitoring of fish species at Ban Xiengdet at the upper end of the reservoir has confirmed that no long distance fish migrating fish species do occur upstream of NN3 dam site. Migrating species have been blocked by the NN1 project, and more recently by the NN2 project.

468. There will be a transition period of several years after the reservoir is established until a stable new ecosystem is formed. In this period a significant decline in the number of aquatic species must be expected. The main problem in the first years will be caused by internal reservoir erosion and oxygen depletion due to degradation of the biomass left in the reservoir. In periods of water mixing experience from other reservoirs in the region has shown that only a narrow upper layer will allow for fish survival.

469. In the Nam Ngum 1 reservoir a dramatic eutrophication process was experienced and low oxygen levels were seen in the first years after commissioning. After some years, however, the reservoir "matured" and increased productivity could be seen, forming the basis for new fisheries to develop. The small herring like fish Clupeichthus goniognathus which forms more than 20 % of the NN1 reservoir yield is also recorded from other parts of the catchment and might proliferate also in the NN3 reservoir.

470. It cannot be ascertained, however, that the NN3 reservoir will follow the same pattern of increased fish production as seen in NN1. Because of the much larger depth of anoxic conditions within the NN3 reservoir might become a permanent feature, and there will be problems with low oxygen in the upper layers in periods of circulation. This will restrict the development of new fish populations to the upper layers and determine the possibility to establish new fisheries.

471. Deep, but small reservoirs such as NN3 have relatively small littoral zones, and will be mostly populated with fish species that can survive under pelagic conditions. If no filter feeding fish species occur also larger predatory fish species cannot find their food source. The annual average sustainable reservoir fish yield of the NN3 reservoir is expected to be around 10 kg/ha, with a possible minimum of 4 kg/ha and a possible maximum of 16 kg/ha.

472. Before the impacts by NN3 might occur at Ban Xiengdet, NN5 will be completed and the river discharges into the Nam Ting will be significantly reduced since the NN5 powerhouse will discharge into the NN3 reservoir. Such reduction in the Nam Ting River discharges by NN5 will likely result in adverse impacts on household fish catch at Ban Xiengdet. During filling of the NN3 reservoir, riverine fish species from the NN3 inundated area will move upstream to avoid reservoir conditions. After the rainy season of 2016, villagers at Ban Xiengdet are likely to catch more fish for at least for two years. Depending on fishing practices by house holds at Ban Xiengdet, this period of two years can be extended for as long as fishing practices will stay sustainable.

473. As the NN3 reservoir is narrow and deep, the surviving fish species after filling will be fish species that can adapt to pelagic conditions such as *Clupeichthus goniognathus* (Pba Keo). Pba Keo might proliferate in NN3 reservoir. Pba Keo proliferated in other reservoirs in Nam Ngum River Basin (NN1 reservoir) and Northeast Thailand (Sirinthorn reservoir). In these reservoirs Pba Keo forms as much as 60% of the total annual reservoir fish catch. The small herring like Pba Keo is a filter feeder and therefore occurs even in the pelagic parts of the epilimnion of reservoirs where it in turn forms a food source for larger fish species.

474. The aquatic habitats upstream of NN3 reservoir will not be modified by NN3. But likely be modified by NN5 and NN4 A and B.

475. **Pools.** Sandbanks, rapids, and deep pools are important habitats that will be modified or lost by the reservoir. Deep pools in rivers like the Nam Ngum are important aquatic habitats for many different kinds of fish species. Deep pools are important fish spawning grounds and also important as refuge area for riverine fish species during the dry season when river discharges are low and natural occurring river water levels are low as well.

476. The deep pools located in the middle of the NN3 reservoir and close to the dam will be permanently flooded and thus will lose their significance as important aquatic habitats. The deep pools located close to Ban Xiengdet, however, will only be flooded during the rainy season and keep their importance as a dry season refuge area for migrating fish species and probably will keep on functioning as an important fish spawning area during the dry season. However, the pools close to Ban Xiengdet will lose their function as a spawning area for those fish species that spawn during the

rainy season mainly in the months of August and September when the deep pools are inundated. Important fish species that spawn during the months of August and September still widely occur in the Mekong River Basin, but not in Nam Ngum anymore due to the NN1 dam.

477. In the NN3 reservoir area only short distance migrating fish species occur that mostly migrate from deep pools in the Nam Ngum to spawn in tributaries, floodplains, and upstream areas. These short distance migrating fish species generally migrate at the beginning of the rainy season when water levels and turbidity increase.

478. **Rapids.** Rapids are mostly located just upstream or downstream of deep pools. These habitats will also be lost by inundation. Rapids are important aquatic habitats as they house specific riverine fish species that require high Dissolved Oxygen concentrations and high flow conditions. Rapids and deep pools are in general the favourite locations for fishing, but are not much in use in this case as their access is long and difficult.

479. **Filter feeders.** Reservoir conditions change water levels, but also include reductions in water velocity that specifically impacts filter feeders such as mussels. Snails that generally do not occur in fast flowing rivers as the Nam Ngum and only occur in aquatic habitats with low flow are likely to establish populations in the NN3 reservoir.

480. **Plankton.** Phytoplankton and zooplankton densities will increase in the NN3 reservoir compared to the natural Nam Ngum River conditions. Under reservoir conditions, phytoplankton and zooplankton populations and densities will not fluctuate seasonally as much as they do in the river. Major changes in the aquatic food chain will occur with the creation of NN3 reservoir that lead to changes in aquatic biomass, fish migration, fish populations, and aquatic diversity. It will for instance increase the opportunity of establishment of fish populations by fish species that filter algae as for instance Pba Keo (*Clupeichthys aesarnensis*).

481. **Vectors.** In the few stagnant and sheltered parts of the reservoir water body proliferation of weeds might enable mosquitoes and snails to establish. This might again cause an increase in the risk of malaria and fluke infection. Except for the inhabitants in Ban Xiengdet, which are planned to be resettled, few people will be exposed for this increased risk.

482. **Weeds.** The occurrence of different aquatic weeds is prominent in the river system, especially in the dry season. A change from lotic to lentic conditions might favour the growth of such weeds. Aquatic weeds, and especially *Echornia* and *Pistia*, are known to have developed in many tropical reservoirs, especially in Africa and Asia. These weeds can form thick floating mats and thus block the penetration of light and atmospheric oxygen into water. They also constitute an obstacle to boat traffic and fishing.

483. The establishment of weed cover occurs most often in stagnant or slow moving water. The narrow NN3 reservoir with a constant mid reservoir current should therefore be less affected by weed formation than the wider downstream reservoirs like NN1 and NN2.

2. Upstream River Reaches

484. The upstream river reaches will experience some impacts on fish species composition and number because of the loss of the dry season refuge and spawning functions of the deep pools in the reservoir area (see above). The fish and aquatic ecology in upper Nam Ngum and Nam Ting will, however, be more fundamentally impacted by the NN5 and NN4 hydropower developments than by the NN3 reservoir.

3. Downstream River Reaches

485. Aquatic biodiversity in the reach downstream of the NN3 dam will be seriously disturbed due to substantial reduction in flow in the river channel. The first part downstream of the dam to the junction with the Nam Pha will lose all or most of its current aquatic life because of the diversion of the water. The intensity of the impacts downstream of the dam is higher because the project design does not

provide for any environmental flow releases[3] (see Chapter 3). Lao PDR presently does not have requirements for a minimum riparian release or environmental flow. The planned biodiversity study will include an assessment of effective measures to mitigate impacts on biodiversity (See Chapter 9).

486. The quarry downstream of the NN3 dam has also the potential to modify the surrounding aquatic habitats.

487. The reach downstream of the NN3 tailrace will be influenced by: changes in seasonal flow and daily flow variation, and by the releases of oxygen depleted and colder water from the reservoir. This will reduce fish populations and affect other aquatic organisms in this reach. The impact will be most serious in the first year after the commissioning of the power plant. It is during this time oxygen depletion problems will be at their peak. It is uncertain how the impact will be distributed in the downstream reach and into the NN2 reservoir, but the areas immediately downstream of the NN3 tailrace will be most affected.

488. Oxygen deficiency in the tailrace water is likely to have a severe impact on fish and other types of aquatic life. Aquatic organisms have different levels of tolerance and demands for dissolved oxygen. Low levels of dissolved oxygen can lead to substantial fish deaths some distance downstream. It is reasonable to expect that species with reduced tolerance to low oxygen levels will die or migrate to new areas if possible.

489. In addition to the oxygen problem, another impact will be caused by the intermittent release of water from the power plant. The turning on and off the turbines will have a flushing impact on the downstream reaches that might be difficult for fish and other aquatic organisms to manage.

490. It is expected that the aquatic habitats along the Nam Pha will be impacted by the fragmentation created by both the NN2 reservoir and the NN3 dam upstream, and that the Nam Phay, instead of the Nam Ngum, might attract short distance migrating fishes, if any migrating fish species do survive the NN2 reservoir conditions.

491. Fish species will be flushed out of the pools at downstream locations during the months of August and September when spills over NN3 dam occur. The flushing effect of spills will be exacerbated with the nitrogen super saturation of the spills released downstream of the dam.

4. Status of Aquatic Habitats

492. From the relative abundance of fish species found upstream and downstream of NN3 dam site by the CIA monitoring team it was concluded that at both locations (i) endemic fish species do not occur, (ii) no critically endangered or endangered fish species occur, and (iii) no long distance migrating fish species do occur upstream of NN3 damsite.

493. The relative abundance of fish species as found during the two-year monitoring period at locations downstream and upstream of NN3 dam site confirm that no critical aquatic habitat (a subset of both natural and modified aquatic habitats) for fish species deserves special attention other than for providing significant social and economic importance to the inhabitants of Ban Xiengdet.

5. Rare or Endangered Species

494. No fish collected in the surveys in the Nam Ngum after the construction of NN1 (Mekong Secretariat, 1984; Warren, 1998; Kottelat, 1997; Electrowatt, 1998; SMEC, 1996; and RMR, 2001) have been classed as endemic or very rare. The only species of conservation relevance recorded by RMR for the NN3 environmental assessment was the Featherback. This species has been given class 1 ("low risk of extinction") by IUCN.

[3] The concept of environmental flows refers to water provided within a river to maintain ecosystems, their functions and the benefits they provide to people. In addition to the volume, the quality of the water discharged has to be appropriate to qualify as an environmental flow.

495. Thus, the reservoir will probably not eliminate or endanger species known to be rare or endemic. Additional surveys of the aquatic fauna (especially fish) will be undertaken to confirm this.

G. Impacts of Climate Change

496. The impacts of climate change on the Nam Ngum River Basin were considered in the CIA, which indicates an anticipated increase in precipitation (up to 25% in the March-May period), with small changes (0-10%) throughout the rest of the year.

H. Impacts on Physical Cultural Resources

497. The reservoir will cause risk of flooding of the remains of the temples of Vat Vangsiang and Vat Xiengdet in Ban Xiengdet. Four spirit houses and a small part of the existing graveyard might be affected by periodic flooding. Flood protection, relocation and salvage initiatives will be undertaken.

498. Other sites of cultural and spiritual significance have been recorded only outside the direct impact area of the reservoir and construction lands. These might be impacted by the increased activity in the area but their presence could create opportunities for education and recreational purposes.

I. Impacts of Construction Activities

499. The main construction sites are (i) the dam site and (ii) the diversion tunnel site, (iii) the power station site, and (iv) the transmission line corridor. By their nature, construction activities have specific impacts on their surrounding environment, which are briefly presented here.

1. Soil Erosion and Land Slides

500. Soil erosion will result from direct project activities, like construction and improvement of roads, (opening and operation of quarries, disposal of spoil, and a number of other project related activities. As these sites will need to be cleared from their vegetation, the steep slopes and the heavy rainfall of the rainy season could contribute to serious erosion, which could, in addition to interrupting construction works, destroy further the natural vegetation cover and cause sedimentation in the rivers.

Figure 7.10: Construction work at the dam site access road

2. Air Quality and Noise

501. Increased exhaust emission and noise from works (stone crushing, blasting) and transport during the construction period will contribute to air and noise pollution, although these activities will be undertaken in areas with low density of population and wildlife, mainly the dam site, the powerhouse site, and the dedicated access roads.

3. Water Pollution

502. The sediment load downstream of the NN3 dam will increase during the construction of cofferdams and other river works. Since the river often experiences events of very high turbidity, it is not expected that the additional load from construction activities will have any considerable negative downstream consequence.

503. Pollution due to accidents during handling, disposal and use of oils, fuel and other chemicals, is a potential hazard to water quality. Such impacts will be more serious in the dry season as the higher wet season flows will have a strong dilution effect on this type of pollution.

504. The daily production of waste water and solid wastes from the population of workers and camp followers might result in serious water pollution from bacteria and other microbiological agents, in local streams and the main Nam Ngum.

4. Road Traffic & Traffic Accidents

505. Following the high volume of traffic expected during the construction phase, it is estimated that the traffic will return to almost pre-project levels upon completion of the construction. However a better infrastructure might encourage movements and higher speeds.

506. It is estimated that, over the main construction period, the traffic will increase by 50 vehicles/day on average up to 100 vehicles/day at peak times. This will cause nuisance in the forms of dust, noise , and accidents
.
507. The power house and dam site access roads will open up areas that have not previously encountered car traffic. Increased traffic and in particular traffic in areas close to settlements unused to heavy traffic will increase risk of accidents.

5. Biodiversity and Wildlife

508. The most likely negative impact would be the pressure on natural resources caused by the influx of up to 4,000 construction workers and their followers to the area. There is a risk that some of these will engage in the collection of NTFP and poaching. In the process of clearing sites for infrastructure, there is a risk that contractors will harvest timber and bamboo from the nearby forest for construction material. If not properly discouraged and controlled this would have significant negative impacts on the limited forest resources in the area.

6. Aquatic Life and Fish

509. The coffer dam will block the Nam Ngum River at the dam site and the water will be diverted through a diversion tunnel that will accommodate the Nam Ngum River discharge without much influencing water velocity, at the exception of the end of the rainy season when water velocities in the diversion tunnel may be too high for fish to swim upstream, blocking then fish migration.

J. Transmission Line Impacts

1. Introduction

510. The initial assessment of the transmission line impacts was undertaken for the original alignment of the Transmission Line, which was later on modified to minimise the impact such a

corridor would have had on the Phou Khao Khouay National Protected Area (see above). The exact alignment has not been finalised yet and will be done on technical, environmental and social grounds. A detailed EIA for the Transmission Line will be undertaken to update the information presented below.

2. Accident Risks and Electromagnetic Field Impacts

511. For the people living in the vicinity of the transmission line there is a risk of accidents involving children and young people, unaware of the dangers of electrocution, being fatally or seriously injured from climbing in the transmission towers.

512. Concerns have been raised about the health impacts of electromagnetic fields from transmission lines and substations. In several countries a maximum exposure level of 0.4 micro Thesla (μT) is considered within populated areas. This level matches well the 50 m safety zone used for 230 kV lines in Lao PDR. The line will, for most of its length, pass through land with very low population density, reducing further the significance of this potential impact.

3. UXO Risks

513. UXO are only present in the northern 49 km of the line. Some increased risk may exist in the Nam Bak valley. There are no risks along the southern 50 km of the Transmission Line.

4. Air Traffic Obstructions

514. Transmission line conductors might create a risk for collision of helicopters and other small aircrafts. The risk is at its highest when the corridor crosses deep valleys or water bodies, such as the arm of the NN1 reservoir.

5. Erosion and Silting

515. In most of its distance the Transmission Line runs through land categorised as "very hilly", and or "moderately hilly" land (RMR 2001). Tower foundation work and transport might cause erosion and induce soil slips. Access tracks and temporary stream crossings might in particular cause problems.

6. Land Use Impacts

516. 9 villages are found within a distance of 5 km of the planned transmission line. Within a distance of 600 m only 5 villages are found which might have paddy, hill rice, gardens, grazing land and some residential lands in the Transmission Line corridor. Except at the foundations of the towers this production can continue unhindered after the construction of the transmission line. Tree plantations will not be allowed. In the construction phase however, some interference might occur during the transport of materials and stretching of the conductors.

7. Habitat and Biodiversity Impacts

517. About half of the line corridor transverses land heavily impacted by human activities and thus of limited value from a biodiversity perspective. The section passing through the Phou Khao Khouay National Protected Area (34 km of the transmission line corridor) is, however, of high biodiversity significance. Even though the new selected corridor crosses the western part of the NPA which is the part most modified by swidden agriculture the impacts on biodiversity are likely to be significant due to forest loss, fragmentation and increased accessibility (Vattenfall 2008).

518. One small section on the western border of the NPA – north of the Ban Nakhay - is the only area within PKK NPA which has a formally higher status than the rest. It is designated a "Species Protection Zone" due to its birdlife (Vattenfall 2008). This area lies close to populated areas and about 4 km away from the planned transmission line corridor.

519. Some species of National Biodiversity Priority known to be found in the PKK NPA are: White-cheeked Crested Gibbon, Yellow-cheeked Crested Gibbon, Phayre's Langur, Dhole, Clouded Leopard, Asiatic Elephant, Green Peafowl, Water cock, Purple Swamp hen. However the presence of these species in the transmission line corridor has yet to be confirmed.

520. The transmission line itself could slightly impair the habitats of these species and have some effects on vulnerable populations directly. However the most serious potential impact would come as a result of the improved access and opening up of the areas to hunters and loggers, caused by the construction and maintenance activities.

521. For certain wildlife species, the transmission line and the cleared corridor might act as a barrier for migration and utilisation of their habitats. Particularly arboreal species are vulnerable for this impact. Such species could be: Slow Loris, Gibbon, Black Gibbon, Phayre's Langur, Rhesus and Stump-tailed Macaque, Northern Tree Shrew, Giant Black Squirrel, Variable Squirrel, Burmese Striped Tree Squirrel, and Binturong. Their presence will have to be confirmed.

522. Larger birds will experience the risk of death from colliding with the conductors. This risk is highest where the line crosses wetlands, rivers, and in this cases the area of the NN1 reservoir.

8. Affected Villages

523. Nine villages have been identified as potentially affected by the new proposed transmission line. Two of these villages are located north of the junction of the NN2 Transmission Line and the NN3 Transmission Line. Seven villages have been identified as being affected by the joint NN3 and NN2 TL.

Table 7.11: Villages potentially affected by NN3 TL (5 km distance).

Villages north of NN2 TL and NN3 TL junction	Villages affected by joint corridor
Na Tou	Houay Nam Nyen
Nam Ngone	Keo Saam Mi
	Phou Pha Dang
	Vang Heua
	Na Ngom Kao
	Tha Kok Hai
	Na Bong

524. Several other villages are found within a distance of 5 km from the TL route.[4] The detailed planning and assessments will identify if any of these might be significantly affected by the transmission line itself or related construction activities.

K. Impacts on Greenhouse Gasses

525. Studies show that dams and reservoirs might release significant amounts of gasses that contribute to global warming, in particular carbon dioxide (CO_2) and methane (CH_4) discharges. Higher emissions emanate from reservoirs with very high initial content of organic materials (in particular wetlands and swamps) and which have a very high annual inflow of degradable substances. Since the inundated area of the NN3 reservoir is small compared to the storage volume, the biomass and organic material present in the future NN3 reservoir area will be relatively modest.

526. Most hydropower projects will, however, release less GHG per produced energy unit than comparable thermal power plants. Under certain conditions hydropower plants are therefore eligible

[4] The villages South of Na Bong are: Phu Huat, Nam Moung, Houay Nam Nyen, Keo Saam Mi, Na Mon, Phone Savat, Phou Pha Dang, San Paa Thong, Houay Saen, Tao Tai, Paak Tou, Vang Heua, Na Khai, Na Ngom Mai, Na Ngom Kao, Na Tan, None, Tha Kok Hai, Na Bong, Nong Dong, Phone Kham, and Houa Na Thong,

for “Carbon Credits”. The UN Clean Development Mechanism (CDM) uses the “power density” index (Watt installed capacity divided by the flooded surface area) as an indicator of eligibility for emissions credits. The CDM Executive Board has set 10 W/m^2 as the threshold value for allowing full carbon credit.[5] As can be seen from Table 7.12, NN3 has an index value of about 16 and thus is expected to have very low greenhouse gas emissions compared to the power output.

Table 7.12: Power density indexes for some Lao PDR Hydropower Projects.

Hydropower Project	Installed capacity (MW)	Reservoir (km2)	Index W/m2
Nam Ngum 3	440	27	16.3
Nam Ngum 2	615	122	5.0
Nam Ngum 1	155	371	0.4
Nam Theun 2	1074	450	2.3

527. The use of 74 million liters of fuel and 77,000 MWh of electric power during the construction of the project will generate approximately 180,000 ton CO_2 eq. and 54,000 ton CO_2 eq. respectively, i.e. a total of approximately 234,000 ton CO_2 eq. over the 5 years of the construction, or 46,800 ton CO_2 eq. per year.

L. Cumulative Impacts

528. As mentioned earlier the NN3 will be one in a cascade of several existing and planned hydropower projects on the Nam Ngum River and its tributaries. This will result in an artificial hydrological situation where some of the impacts are cumulative or combined and difficult to strictly attribute to a specific project.

529. The cumulative impacts of the cascade of existing, under construction and planned hydropower projects and other developments in the Nam Ngum catchment have been assessed in a separate CIA study. In this study the impacts of the NN3 Project, are seen in conjunction with the other development projects and development trends in the region in a medium and long term perspective.

530. A Cumulative Impact Assessment (CIA) study was conducted for the project under ADB TA4921 by Vattenfall Power Consultant. The CIA study was implemented from mid-2007 until early 2010 in two distinct phases, with actual field work running until late 2009. Part 1 was the actual Impact Assessment, implemented in May 2007 until early 2008. The Final CIA Report was approved by the ADB in March 2008 and posted to the ADB website. The study was implemented as a strategic impact assessment as it dealt with the basin-wide socio-environmental implications of the then existing and proposed plans for further hydropower development in the Nam Ngum basin. Part 2 was a monitoring programme from early 2008 through November 2009. The monitoring programme focused on water quality and fish catch monitoring in the basin. The sampling sites included in the water quality monitoring programme were selected to be complementary to monitoring efforts already in place and run by either the Government of Lao PDR agencies or by private hydropower projects already in place in the basin. The idea was to fill the gaps during the monitoring period and for the Government to take over the programme. The sites for the fish catch monitoring were chosen based on the perceived key sites in terms of fish reproduction and potential clashes between the continued ecological viability of these and the hydropower development plans.

531. Hydropower generation and mining are among the main development activities that, in combination, are expected to generate long term environmental impacts in the NNRB. Other activities include increase in human population and construction of roads that may also create cumulative effects. The likely impacts could be on water quality and water use such as fishery, hydrology, biodiversity value, livelihood, and health, among others. And these require careful and comprehensive assessment on a basin-wide level.

[5] CDM – Executive Board: Approved consolidated baseline and monitoring methodology, ACM0002

532. The following sections summarise some of the impacts of cumulative nature expected to be experienced in the Basin.

1. Mining

533. Mining activities in the Nam Ngum 3 catchment, through industrial and artisanal operations and exploration (in particular Phu Bia Mining) have already significantly marked the area.[6]

534. Mine activities normally use large quantities of water for the milling and concentrating operations. Unless recycled and reused, the mines use a large proportion of the dry weather flow of rivers potentially affecting the water quality of the reservoirs downstream and of the rivers. Mining activities also have significant impact on the landform from the quarrying and disposal of tailings and overburden. Access roads for the mining equipment and trucks to haul supplies and the concentrates to staging areas need to be built, extended and shared with other projects. These roads present the risk to open the upstream areas for logging and poaching, and to fragment habitats. Some controls are needed and it is beyond the authority of each individual project proponent to carry these activities out.

535. The development of hydropower projects will affect the current and future mining activities in the river basin, and vice-versa. Cumulative impacts from both mining and hydropower development on socio-economy and the environment can be significant if project owners do not co-operate. To ensure sound development, mining and hydropower projects must work co-operatively to address potential impacts. Management and monitoring must be a central part of development for both the mining and the hydropower projects (Vattenfall 2008).

2. Hydropower

536. When all the hydropower plants included in the CIA development scenarios are in operation by 2020, the new reservoirs will cause an increase in the Nam Ngum dry-season flows in the Vientiane plains by approximately 10%, while the wet-season flows will be marginally reduced.

537. During the filling of each reservoir water will be withheld and the downstream located reservoirs and powerhouses will have less inflow and thus less energy production.

538. The filling-up of the dead-storage volumes in the new reservoirs will for a few years cause a total loss of energy production of just over 400 GWh in Nam Ngum 1 when NN2, NN3 and NN5 are filling up. Nam Ngum 2 will lose close to 150 GWh when NN3 and NN5 are filling in one wet season each. However, when all the plants/reservoirs are in operation, the energy production of NN1 and NN2 will increase by almost 100 GWh/year and just over 50 GWh/year respectively due to the regulation effect of the reservoirs that results in better allocation of water over the year.

539. An additional positive cumulative impact of the hydropower cascade development in the Nam Ngum River Basin is the increase of the lifetime of the downstream reservoirs, as less sedimentation will occur. Instead of having all sediments ending up in one reservoir, such sedimentation will be divided over several reservoirs, increasing the lifetime of downstream reservoirs.

540. Thus, the cumulative positive impacts of NN2, NN3, NN5 and NN4 will include:

(i) Increase of the life time of downstream located reservoirs;
(ii) Increases in power production (less spills);
(iii) Increase in value of power production (the value of 1 m^3 water stored in a hydropower reservoir depends on the depth where this 1 m^3 water is stored).

541. The NN1 power plant have already benefited of higher energy production as a consequence of the upstream constructions of Nam Xong diversion weir and Nam Leuk hydropower project. Nam Xong has diverted water from a tributary originally discharging downstream of the NN1 plant, and Nam Leuk

[6] There are more than 6000 km^2 of mining exploration area within the catchment.

from the Nam Mang Basin. Such type of diversion projects generally will have complicated environmental and social impacts downstream of the diversion point due to reduced flow. However, such type of water diversion projects do not cause negative impacts during their filling periods in recipient reservoirs (Nam Ngum 1).

3. Water Regulation

542. Operation of the various hydropower projects will contribute to a regulation of the discharges from the Nam Ngum River into the Mekong, with an increase of discharge in the dry seasons and reduced discharges during the rainy seasons.

543. In addition to reducing the occurrence of flooding downstream of NN1 dam, regulated flows can be used for irrigated agriculture downstream in the plain of Vientiane.

4. Irrigation

544. Positive impacts of the hydropower cascade will be the result of changes of river discharges in the Nam Ngum River Basin. Downstream of NN1 dam, the river discharges will be reduced during the rainy season and higher during the dry season. There will be less or no flooding at villages and agricultural lands along Nam Ngum downstream of NN1 dam in the Vientiane Plains provided a mechanism is set up to coordinate flood releases from all reservoirs.

545. This will give more opportunity for downstream dry season irrigation development. Irrigation at the Vientiane Plains that will require less pumping head and the already existing irrigation systems will require less pumping costs. With the currently increasing rice and energy prices, reduction of flooding during the rainy season and savings in pumping costs for dry season rice irrigation could contribute to rural development.

546. Vattenfall (2008) indicated that, due to expanded irrigation, there will be moderate dry-season rice-area increases. Water availability will not be a problem, but a potential lack of funds for maintenance, repairs and operation of pumping projects, siltation and control of irrigation canals, and difficulties with irrigation service fee collection pose risks to development.

5. Water Quality

547. Key impacts on water quality will likely include: localised increase in total suspended solids (TSS) and turbidity near the reservoir banks, thermal stratification, resulting in limited mixing of surface and deep reservoir waters, low dissolved oxygen content, and generation of hydrogen sulphide. It will be important for the owners/operators of the planned hydropower installation to address the expected impacts caused by intakes located only at deep levels of the reservoir.

548. If the various hydropower projects provide insufficient environmental measures to address poor water quality conditions at downstream locations during the rainy seasons, hydropower projects further downstream will possibly experience adverse cumulated impacts on water quality and consequently on fisheries at downstream reservoirs, exacerbating the poor water quality of subsequent downstream discharges.

549. A combination of aeration structures, airlift pumps and variable-level water intake structures are recommended by the CIA study. A comprehensive basin-wide monitoring programme for water quality should be developed and managed, in the long term, by the appropriate GoL body. The NN3 project has looked into these issues during the design phase as presented in the chapter 3 of this document.

550. It is equally important that mining projects, aquaculture activities and domestic waste water discharges in the Nam Ngum River Basin comply with the environmental regulations and implement mitigation measures to avoid the discharge of poor water quality. The quantity and quality of Nam Pha flows are also likely to play an important role. Any hydropower projects conceived on the Nam Pha in the future should take into account its cumulative impacts on the Nam Ngum River together with NN3.

6. Aquatic ecology

551. Despite all the economic and socio-economic benefits of the Nam Ngum River Basin hydropower cascade in general, each hydropower project will cause environmental and social impacts that are inherent to hydropower development in the climatic conditions experienced in Lao PDR. Changes in hydrology will cause major and, sometimes permanent, changes in water quality, aquatic life and habitats that in turn will impact on human use values as water supply and related human health, household fish catch, and collection of aquatic products such as snails, molluscs, shrimps, aquatic insects, and aquatic vegetation. Ineluctably, any new development in the NNRB will increase the fragmentation and modifications of the aquatic habitats of the Basin.

552. Table 7.16 gives an illustration of the environmental and social impacts of the changed aquatic ecological conditions following from the sequence of progress in hydropower development in the Nam Ngum River Basin.

7. Terrestrial ecology

553. The total area of the reservoir-inundated land is 23 000 ha out of which 7 000 ha are forests. This represents only approximately 1% of the river basin forests. Power transmission lines will affect the PKK National Protected Area over a total distance of less than 70 km. The impact is predicted to be moderate, but exacerbates the fragmentation of PKK.

554. It is recommended (Vattenfall 2008) to raise the required standard of the terrestrial ecological surveys carried out in connection with major projects and to make sure that key government staff are consulted and invited to learn from the work – as a capacity-building effort. Developer of transmission lines and roads should coordinate their projects with the purpose of minimising negative impacts on forests and biodiversity and maximising positive impacts. Developer of hydropower projects should contribute to the financing of conservation and watershed protection efforts in the river basin.

8. Resettlement and livelihood development

555. Resettlement planning and implementation in the basin have, until now, suffered from a lack of clear criteria for the assessment of losses of livelihoods and assets for the project-affected population.

9. Health issues

556. The most serious threats to long-term health status are malnutrition and HIV/AIDS/STI.

10. Policy and planning

557. Vattenfall (2008) recommends that the standards for benefit-sharing between hydropower project sponsors and affected communities should be improved. The legal framework needs to be strengthened. A clear focus on regional and local beneficiaries is recommended.

11. Update of the Cumulative Impact Assessment

558. It is recognised that the 2008 CIA and its recommendations will have to be updated for a more effective assessment and management of the cumulative impact of present and foreseeable development in the NNRB. This is because the contexts in which those scenarios considered in the CIA in terms of hydropower generation have significantly changed since. The scenario C of the CIA (Nam Ngum 1, Nam Leuk, Nam Mang 3, Nam Ngum2, Nam Ngum3, Nam Ngum5, Nam Lik 1 and Nam Lik 2 as well as Nam Bak 1 and Nam Bak 2) is the only one relevant as of today. The status of Nam Ngum 4 may have also changed.

559. Some recommended actions for the CIA update are presented below:

(i) Preparation of a map showing all hydropower and mining projects along with existing and proposed roads, with key environmental features – catchment of tributaries to the Nam Ngum river, national parks, areas of high ecotourism potential, areas under forest (primary and secondary forests), major inhabitations, major irrigated areas and areas rich in minerals and route of existing and proposed transmission line; as well as showing overlap of catchment areas of reservoirs and mining exploration and concession – highlighting likely points for water abstraction and tailing discharges. This map can mark the catchment areas of various tributaries with fractions of catchments for reservoirs - useful to assess which reservoirs are likely to be affected more by which mines. Data on water quality (only heavy metals and CN) in mining effluents will need to be collected and estimated (and be compared against both Lao and international standards).

(ii) Comparison of satellite images (current and 5 years old) to show the areas under pressure that may not be otherwise obvious (such as illegal logging), and areas with large settlement basins, or mining operations that do not implement appropriate sedimentation controls.

(iii) Survey and/or images analysis to show how and if the vegetation has been affected by the transmission lines, roads, and expansion of human inhabitation.

(iv) Basin-wide monitoring such as for water quality and fish catch monitoring should consider collaboration with MoNRE and the Mekong River Commission. The Fisheries Programme of the Mekong River Commission has been collating and analyzing the records of fish monitoring in several basins around the Mekong River and they could publish regular consolidated reports highlighting the impacts of hydropower dams on fisheries. Additional funding from donors and developers will be required to maintain such an on-going analysis.

560. Further update in CIA and basin-wide approach will require the following:

(i) Analysis of downstream flows in various tributaries and comparison with the existing flows.

(ii) Predict and monitor water quality in the NN2 reservoir based on the submergence of vegetation and its impacts on NN1 fishing and livelihood. For other reservoirs provide norm for clearance of vegetation to ensure that the reservoir water quality improves soon (a few years) after impoundment.

(iii) Assess typical water requirement, sediment generation, and heavy metal contamination based on existing mining activities. Dry months are more important as the river flow and the water volume in the reservoirs are limited. The 2008 CIA or recent monitoring reports has no information on heavy metal concentrations in river water, though during current monitoring a lot of incidences of artisanal mining (using mercury) were witnessed.

(iv) Assess additional impacts of mining qualitatively, including risks of biomagnifications if relevant based on above item.

(v) Assess the impacts of overall development on vegetation and impacts on biodiversity based on satellite data and field surveys. Many species are likely to be lost due to change in water regime and quality. For terrestrial wildlife see how the critical areas are affected by the inundation and greater access.

(vi) Ensure sustainable development and preservation of key natural habitats considering the rapidly evolving situation in terms of land take by the numerous hydropower projects, transmission lines, access and public roads, and village development.

(vii) Review the mine claims and mining operation upstream of the dam site, estimate their water consumption and their impacts on the land, water quality and on the aquatic flora and fauna. Typically with most cumulative impacts the control and responsibility for mitigating and managing these impacts are beyond the control and responsibility of the project proponent and thus will require joint management and monitoring along the basin with GOL.

(viii) Select relevant recommendations from the 2008 CIA that need to be implemented at the level of Nam Ngum River Basin Committee under MoNRE, or through interministerial coordination; including standards for benefit-sharing among projects sponsors and affected community, with clear focus on regional and local beneficiaries, and with a strengthened legal framework.

(ix) Suggest a separate study to develop the structure and powers responsible to manage all development issues in the river basin, including strengthening, but possibly beyond NNRBC.

(x) NN3PC will work closely with the NNRBC in water quality monitoring, biodiversity and natural resources conservation and management, fish monitoring and livelihood enhancement programs, among others to help manage the cumulative impacts on a basin-wide scale and share information and resources as necessary.

(xi) It is noted that ADB and other donors have, and will continue to have technical assistance to NNRBC and other agencies that may substantially strengthen the basin-wide management capability and experiences on cumulative impact management. A comprehensive basin-wide monitoring programme for water quality should be developed and be managed, in the long term, by NNRBC and MoNRE. Initially, a pilot project involving three sub-basins to be affected by the project will be used by NNRBC in cooperation with ADB in formulating sub-basin water quality monitoring and management framework and protocols. The objectives would be to monitor and evaluate the medium to long-term impact of the very extensive developments planned for the basin in order to assist future mitigation and adaptive management programmes. Ongoing work on a water quality monitoring network is a good starting point supported by the monitoring that has been carried out during 2008- 2009 as a part of the CIA study.

(xii) From ADB, another technical assistance TA 7780: LAO on National Integrated Water Resources Management Support Project (Cofinanced by the Government of Australia and the Spanish Cooperation Fund for Technical Assistance) has been approved in February 2011 for $3.9 million for 4 years. The TA will contribute to the implementation of the National Integrated Water Resources Management Support Program to support capacity building in MoNRE and the new Nam Ngum River Basin Committee (NNRBC) and its secretariat. It will assist the government to: (i) establish gender-responsive professional development programs for MoNRE staff; (ii) implement appropriate governance systems for project management, monitoring, and evaluation; (iii) establish institutional arrangements for river basin management; (iv) provide updates on the inventory of water resources and their utilization; and (v) assist the development of formal university education in IWRM at the National University of Laos (NUOL).

(xiii) To follow through the recently completed Nam Ngum Basin Development Sector Project, which included Integrated Water Resources Management, reservoir management and river basin modeling, and watershed management, additional financing for $5M for 5 years is being sought for (i) the support and upgrading of the Nam Ngum River Basin Secretariat for sub-basin river management, (ii) watershed management at provincial and district level with agricultural extension system for crop, livestock, and forest sustainability, and (iii) effective project management.

M. Summary of Potential Impacts

561. Table 7.13 to Table 7.16 below summarises potential project impacts. These potential impacts are ranked according to severity/magnitude without taking into account the possibilities for reducing or avoiding the impacts by mitigation measures. The mitigation or compensation measures are discussed in the Environmental Monitoring and Management Plans (EMMPs) section of this report.

562. In the ranking the impacts the following categories and symbols have been used:

(i) High negative – – –
(ii) Medium negative – –
(iii) Small negative –
(iv) Insignificant 0
(v) Small positive +
(vi) Medium positive + +

(vii) High positive + + +
(viii) Uncertain ?

Table 7.13: Summary of NN3 operational impacts

Permanent and operational impacts	
Potential impact	**Impact ranking**
Reservoir Impact Zone	
Eutrophication and algae bloom	– –
Periods of oxygen deficiency and anoxic deep water	– – –
Loss of agriculture land	–
Loss of forest land	– –
Loss of biodiversity	–
Loss of riverine fauna and flora	– –
Loss of river aquatic habitats and fish biodiversity	– –
Risk of introduction of invasive water plants	– –
Improved boat transport opportunities	+
Loss of traditional fisheries	–
New fisheries opportunities	?
Loss of cultural heritage sites	–
Nam Ngum Upstream Impact Zone	
Initial increase in fisheries	+ +
Long term reduction in fisheries	– ?
Nam Ngum Downstream Impact Zone	
River bank erosion	–
Periods of oxygen deficiency in water	– –
Loss of fauna and fish species	– –
Safety risk by flushing	–
Risk of dam failure	–
Construction Sites and Access Roads Impact Zone	
Loss of land for permanent facilities	–
Improved infrastructure	+
Loss of valuable forest	–
Loss of biodiversity	–

Table 7.14: Summary of NN3 construction impacts

Construction Phase Impacts	
Potential impact	**Impact ranking***
Increased fisheries in upstream reaches and tributaries	+
Risk of traffic accidents	–
Noise and dust problems	– –
Sediment flow downstream caused by construction and spoil disposal	– –
Discharge of oil components or other hazardous chemicals to water	– –
Spreading of hazardous and domestic solid waste	– –
Soil erosion from vegetation clearance and road construction	–
Increased pressure on wildlife and NTFP from workers and followers	– –
Drowning of animals during reservoir filling	–

Table 7.15: Summary of NN3 transmission line impacts

Transmission line Impacts	
Potential impact	Impact ranking*
Increased erosion, oil pollution, etc	–
Loss of valuable forest to line ROW	– –
Loss of wildlife	– –
Loss of agriculture land	–
Disturbance of Elephant management area	–
Health impacts, electrocution accidents	–
Visual impact and loss of tourist value	–

Table 7.16: Potential environmental and social impacts following changes in aquatic ecology caused by the sequence of Nam Ngum Hydropower Developments

Time and Sequence of Occurrence of Impacts at NN3 Impact Zones	Environmental Impacts at NN3 Impact Zones		Social Impacts at NN3 Impact Zones	
	Type of Environmental Impacts and Location	Severity of Environmental Impacts	Type of Impacts and Communities Impacted	Severity of Social Impacts
During operation of NN1 reservoir, after 1971	Occurrence of fish species as *Mekongina erythrospila* belonging to the family Pangasiidae at upstream locations of NN1 dam in Nam Ngum River Basin.	---	Opportunities by households to catch fish at villages along Nam Ngum upstream of NN1 reservoir	-
During operation of NN2 reservoir, current	Changes in fish migration from NN2 reservoir inundation area upstream into Nam Ngum River	-	Changes in household fish catch upstream in Nam Ngum and its tributaries	0
During construction of NN5 dam, current	Changes in turbidity in Nam Ting downstream NN5 dam	-	Opportunities by households along Nam Ting for water uses, including use of Nam Ting for drinking water at Ban Xiengdet	---
	Changes in aquatic life biomass and relative abundance of species in Nam Ting River downstream NN5 dam	-	Changes in household fish catch in Nam Ting at Ban Xiengdet	--
During construction of NN3 dam, 2011	Changes in turbidity in Nam Ngum downstream NN3 dam	-	Changes in water uses along Nam Ngum downstream NN3 dam	0
	Changes in fish migration in Nam Ngum River	-	Opportunities by households to catch fish at villages along Nam Ngum upstream of NN 3 reservoir	(0)
During filling of NN5 reservoir	Changes in Nam Ting and Nam Ngum River discharges, water levels, sediment load, and water quality downstream NN5 dam	--	Changes in water uses by households living at Ban Xiengdet along Nam Ting; water uses include drinking water and opportunities for gravity fed irrigation	---
	Changes in aquatic life biomass and relative abundance of species in Nam Ting and Nam Ngum River downstream NN5 dam	--	Changes in household fish catch in Nam Ting at Ban Xiengdet	--
During operation of NN 5 reservoir	Changes in Nam Ting and Nam Ngum river discharges (particularly occasional spills over NN5 dam), water levels, sediment load, and water quality downstream NN5 dam	---	Changes in water uses by households living at Ban Xiengdet along Nam Ting; water uses include drinking water and opportunities for gravity fed irrigation	---
	Changes in aquatic life downstream NN 5 dam in Nam Ting and Nam Ngum rivers by flushing effect of occasional spills over NN 5 dam	--	Changes in household fish catch along Nam Ting	---
	Changes of Nam Ngum River discharges and water quality downstream NN5 powerhouse	---	Changes in water uses along Nam Ngum River downstream of NN5 powerhouse	(-)

Time and Sequence of Occurrence of Impacts at NN3 Impact Zones	Environmental Impacts at NN3 Impact Zones		Social Impacts at NN3 Impact Zones	
	Type of Environmental Impacts and Location	**Severity of Environmental Impacts**	**Type of Impacts and Communities Impacted**	**Severity of Social Impacts**
During construction of NN4 A and B, (?)	Changes in aquatic life in Nam Ngum River downstream NN5 powerhouse by powerhouse discharges and water quality	---	Changes in household fish catch along Nam Ngum River downstream NN5 powerhouse	(-)
	Changes in turbidity in Nam Ngum River downstream NN4 dams	-	Changes in water uses along Nam Ngum downstream NN4 dams	(-)
	Changes in fish migration in Nam Ngum River	-	Opportunities by households to catch fish at villages along Nam Ngum downstream NN4 dams and upstream of NN3 reservoir	(0)
During filling of NN3 reservoir, 2016	Changes in fish biomass upstream of NN3 reservoir in Nam Ngum and tributaries as Nam Ting	++	Opportunities by households to catch fish in Nam Ngum and its tributaries such as Nam Ting, and Nam Chad upstream of NN3 reservoir	+++
During operation of NN3 reservoir, from 2017	Changes in water levels, water velocity, water retention time, stratification, and water quality in Nam Ngum River at NN3 reservoir area	---	Flooding and Resettlement Ban Xiengdet	---
	Changes in number of species and relative abundance of aquatic life in Nam Ngum River at NN3 reservoir area	---	Opportunities by households to catch fish at NN3 reservoir	+++
	Changes in Nam Ngum River discharges, water levels, sediment load, and water quality downstream NN3 dam	---	Changes in water uses along Nam Ngum downstream NN3 dam	(0)
	Changes in Nam Ngum River discharges, water levels, sediment load, and water quality downstream NN3 powerhouse	---	Changes in water uses along Nam Ngum downstream NN3 powerhouse	(0)
	Changes in aquatic life downstream NN5 dam and NN5 powerhouse in NN3 reservoir by flushing effect of occasional spills over NN5 dam and water quality from NN5 powerhouse discharges	---	Opportunities by households to catch fish downstream NN5 dam and downstream NN5 powerhouse in NN3 reservoir	--
	Changes in aquatic life in Nam Ngum River downstream NN3 powerhouse by flushing effect of occasional powerhouse discharges and water quality	---	Change in fish catch by households downstream of NN3 powerhouse	-
	Opportunity of development of large fish populations in NN2 reservoir	---	Opportunity of NN2 reservoir fisheries development	---

Time and Sequence of Occurrence of Impacts at NN3 Impact Zones	Environmental Impacts at NN3 Impact Zones		Social Impacts at NN3 Impact Zones	
	Type of Environmental Impacts and Location	**Severity of Environmental Impacts**	**Type of Impacts and Communities Impacted**	**Severity of Social Impacts**
During filling and operation of NN 4 A and B (?)	Changes of Nam Ngum River discharges and water quality downstream NN 4 powerhouse	---	Changes in water uses along Nam Ngum downstream of NN 4	(-)
	Changes in aquatic life in Nam Ngum downstream NN 4 powerhouse by powerhouse discharges and water quality	---	Changes in household fish catch along Nam Ngum downstream NN 4	--

VIII. PUBLIC CONSULTATION AND DISCLOSURE

A. Introduction

563. The NN3 Power Company recognises that meaningful public consultation is a process that (i) begins early in the project preparation stage and is carried out on an on going basis throughout the project cycle; (ii) provides timely disclosure of relevant and adequate information that is understandable and readily accessible to affected people; (iii) is undertaken in an atmosphere free of intimidation or coercion; (iv) is gender inclusive and responsive, and tailored to the needs of disadvantaged and vulnerable groups; and (v) enables the incorporation of all relevant views of affected people and other stakeholders into decision making such as mitigation measures, resettlement activities, livelihood restoration, compensation, the sharing of development benefits and opportunities, and implementation issues. The public consultation and disclosure process has been undertaken so far for the Nam Ngum 3 project in this spirit and will continue to be so.

564. As of the mid of 2011, there have been numerous public consultation and participation briefings, presentations and meetings, which have taken place at the local, regional and national levels (Table 8. 2). A dialogue has been established with the various stakeholders directly and indirectly involved in the Project and interested in the Project's public consultation programme (Table 8.1). This process has led to the consent of the affected households to the social and resettlement programme developed with them, including the dispute resolution mechanism should the plans be not implemented or be as successful as they are presented.

B. The Stakeholders

565. The main stakeholder groups have been identified during the development of the project and embrace: (1) the people directly and indirectly impacted by the Project; (2) government officials at the district, provincial and national levels; (3) the other hydropower projects upstream and downstream of the NN3 Project; (4) the other industrial projects operating in the area; (5) the broader interested national community; (6) the Civil Society present in Lao PDR, and ; (7) other regional and international groups and organisations.

566. These groups are presented in the following table:

Table 8.1: The NN3 Project Stakeholders

Local	• Individuals, households, village of Ban Xiengdet. • The 4 peri-reservoir villages and their communities. • The downstream villages and their communities. • The upstream villages and their communities. • The villages along the upgraded roads. • The villages and communities in and along the corridor of the transmission line from the power station to the Ban Nabong substation.
Regional	• Community leaders • District agencies • Provincial agencies • Businesses and contractors • Upstream and downstream hydropower projects (NN2, NN4, NN5) • Mining companies: Phu Bia Mining, and smaller operators
National	• GOL Ministries • MONRE NNRBCS • The Hydropower and Mining Forum • The People of Lao PDR • National NGOs • National media
International	• International contractors involved in the construction • Power utilities • Thai Government

	• Embassies • International and other Financial Institutions • NN3PC investors • International NGOs • International media • Hydroelectric dam developers

C. Public consultation & disclosure process

1. Approach

567. As usual for a project of this nature public consultation and disclosure has started and continue to be implemented through a three-phase process.

568. The first phase had the objective to collect and disseminate information on the human and physical characteristics of the current environment in order to foresee the Project impacts. During this phase, information about the project features and the implications on the social and physical environment was also disseminated to the stakeholders. This started when the first studies were undertaken by RMR in 1998, although the objective was not to achieve any consent from the population and the process is not documented. This was continued with the update of the E&S documentation of the project, when a detailed socio-economic profile was constituted for the Ban Xiengdet village (see Section 3 of the REMDP for example).

569. The second phase is the consultation with the various stakeholders, emanating from the comments sought from them in response to the information gathered in the first phase and the subsequent adjustments made to the proposed mitigation measures and alternatives. It is also the stage when the consent of affected ethnic minority households in Ban Xiengdet has been obtained. Data and information collected have then been disclosed at Ban Xiengdet and the four peri-reservoir reservoir villages Xieng Nga, Nam Sam, Xam Thong, and Long Cheng to formulate compensation and off setting measures, including resettlement planning.

570. This leads to a third phase of active and iterative involvement and participation in the project design and implementation, which is expected to continue during the project implementation. Livelihood restoration models will be developed in this way, such as the layout of the new village or the design of the most appropriate irrigation system for the replacement agricultural land.

2. Methodology

571. During the public consultation and disclosure process, it was felt important to take into consideration (1) the local power and authority structures, ensuring however that participation in consultations was not dominated by local authorities, (2) the need to enter into good faith negotiations with affected ethnic minority households, (3) the active participation of women and vulnerable groups, and (4) the proper documentation of the process.

572. The consultation techniques used involved, and will continue to involve, (1) the use of visual representations of the project, including pictures, diagrams, posters, (2) face-to-face communication in the form of general village meetings, interviews, small groups discussions, and site visits, (3) translation of key components of the Project documents in Lao language and verbal translations in the Khmu language when and where appropriate (the Khmu language has no written form), (4) dissemination of the project documentation (ESIA, REMDP, Environmental and Social Obligations of the Company, for example) through the Company and ADB websites, and in the future through various public information centres, and (5) site visits for international stakeholders.

573. A particular attention was given to secure the active participation of women in the consultations, as most women are less educated than men and have been less exposed to the outside world.

D. Consultation & participation activities

574. Several public consultation and disclosure events took place at local, regional and national levels since the beginning of the development of the project. They are presented in more details in Annex B of the REMDP and summarised in the following table.

Table 8.2: Consultations, Disclosures, and Public Meetings regarding Environmental and Social Issues

Stakeholder Group	Public Consultations and Disclosure, key information, timing and approaches taken
Central Level: Stakeholders including International Finance Institutes, MONRE, other GoL Organizations and Agencies, General Public, and NGOs.	• 16th January, 2008: National Consultation Workshop. • 8th February, 2008: Public Consultation Workshop. • NN3 Presentations to MONRE of Environmental and Social Project Impacts, 2010. • From November 2010: Collection by MONRE of comments by line Ministries and relevant GoL agencies on the October, 2010 versions of EIA Report and REMDP. • 8th December, 2010: Joint Consultation of Department of Environmental and Social Impact Assessment of MONRE and NN3PC. • December 2010: Joint Mission of representatives from International Finance Institutes (IFIs): Agence Française du Développement (AFD), Asian Development Bank (ADB), FMO, International Finance Corporation (IFC), and Proparco to discuss with representatives of GoL and NN3PC. • January 2011: Publication of NN3 EIA Report on ADB website. • 25 January, 2011: Technical Consultation Workshop by MONRE and NN3PC to present the revised Environmental and Social Impact Assessment Report in the presence of the Provincial Authorities of Xieng Khouang and Vientiane Provinces.
Provincial Level: Xieng Khouang & Vientiane Provinces and Vientiane Municipality. GoL Officials	• Oct – Nov 2007: Combined provincial and district workshops held in Phou Kout on the 30th October, in Hom on the 2nd of November and in Xaysomboun on the 20th November. • May 2009: Consultation at Xieng Khouang Province. • May 2009: Consultation at Vientiane Province. • May 2010: Consultation and Disclosure at Xieng Khouang Province. • July 2010: Consultation and Disclosure at Vientiane Province. • December 2010: Consultation at Xieng Khouang Province, with IFIs. • January, 2011: Technical Consultation Workshop with MONRE and Xieng Khouang and Vientiane Provinces.
District and Kum Ban Level: Phou Kout, Xaysomboun and Hom. GoL Officials	• 2007-2009: District and Kum Ban officials have been included in the survey team during fieldwork and village consultations. • May 2009: Consultation at Phou Kout District. • May 2010: Consultation and Disclosure Kum Ban and Phou Kout District. • June 2010: Consultation and Disclosure Kum Ban, Xaysomboun District. • December 2010: Consultation at Kum Ban Xaysomboun District (with the IFIs). • December 2010: Consultation at Kum Ban Phou Kout District (with the IFIs). • January, 2011: Consultation at Kum Ban Phou Kout District (with the Lenders).
Ban Xiengdet: Villagers, Village Authorities, Kum Ban Officials, District Officials	• March 2007: Household and village survey. • July 2007: Inventory of fixed assets carried out. • July 2007: Household Consultations carried out. • October 2007: Gender assessment study carried out. • Several field visits to Xiengdet for resettlement land identification,

Stakeholder Group	Public Consultations and Disclosure, key information, timing and approaches taken
	approval, and planning. • Village leadership participated in District Workshop. • December 2007: Village consultation on resettlement site.Disclosures, Consultations, and Informed Consent; Asset Registration; and October 2008, January 2009, May 2009: planning resettlement, livelihood and social development activities.2010: Additional planning meetings UXO clearance and resettlement site preparation, with Kum Ban. • December 2010: Consultation with IFIs. • January 2011: Start of (i) resettlement site preparation by villagers, (ii) UXO screening and clearance by UXO-LAO, and (iii) upgrading access road Nong Tang-Ban Xiengdet by GoL. • January 2011: Consultation, with Lenders. • June 1011: Consultation about relocation and entitlement, including for non-eligible households.
Peri-Reservoir Villages Xieng Nga, Nam Sam, Long Cheng (including Nam Ngua), and Xam Thong Villagers, Village Authorities, Kum Ban Officials, District Officials	• July and November 2007: Villages surveys and consultations. • May 2009: Consultation, disclosure, and informed consent at Xieng Nga and Nam Sam.June 2010: Consultation, disclosure, and informed consent at Long Cheng (including Nam Ngua) and Xam Thong.December 2010: Consultation at Long Cheng (including Nam Ngua), with IFIs • January 2011: Consultation at Long Cheng (including Nam Ngua), with Lenders
Downstream Villages (7) Villagers, Village Authorities	• November 2007: Village and fisheries surveys and village consultations, seven villages.
Upstream Villages (17) Villagers, Village Authorities	• December 2007: Fisheries and livelihood survey, two villages. • December 2007: Village consultations, six villages.
Project Construction Land Villages (roads & transmission line) Villagers, Village Authorities	• September – November 2007 : Village and sampled household surveys, and consultations, 12 villages.

E. The PCD process from the initial studies to now

575. Although the initial studies and surveys started in 1998 and included a presentation of the project conceived at that time, as indicated above, the field work undertaken did not aim at obtaining a formal endorsement of the project and proposed measures from the affected persons. It did however present the various components of the project and its environmental and social impacts, but these presentations have not been documented. Formal consultations started when the environmental and social studies were updated from 2007, as Table 8.2 above reveals it clearly and described in further details in Annex B of the REMDP.

576. A lot of focus was put on public consultation and disclosure activities at the village level (especially in obtaining the consent of affected ethnic minority households in Ban Xiengdet), in which the district, and sometimes the provincial, authorities have been associated.

577. The assessment of environmental impacts that will lead to impacts on assets, land ownership and land uses, therefore affecting livelihoods, have been disclosed at Ban Xiengdet, the four peri-reservoir reservoir villages, and the upstream and downstream villages to formulate compensation measures, including resettlement planning. To obtain approval to this approach, disclosures have also been held at Kum Ban, District and Provincial Levels. They are presented in details in Annex B of the REMDP.

578. Consultation workshops were held at the three districts of Phou Koot (Xieng Khouang Province), Hom and Xaysomboun (Vientiane Province). Consultations were also undertaken at several

occasions at the provinces of Xieng Khouang and Vientiane and the municipality of Vientiane, and whenever new staff was appointed.

579. Participants at these workshops were district officials from all line agencies related to the NN3 HPP activities, key provincial officers, villagers (in the case of Phou Koot District Workshop) and representatives from NGOs and other agencies involved in the project area.

580. The details of the consultation and disclosure process undertaken is presented in details in Annex B of the REMDP and summarised below.

581. In Phou Kout district the public consultation and disclosure workshop was held on the 30th of October 2007, in Hom district on the 2nd of November 2007, in Xaysomboun district, on the 20th of November 2007.

582. The main issues raised during these meetings were the following:

- (i) Need to clarify the roles of the various counterparts at the various levels.
- (ii) Need to put in place the infrastructure before people are moved in.
- (iii) The resettlement is to be done in close partnership with the villagers and should be done in kind, not in cash.
- (iv) Proper attention is to be given to spiritual and cultural artefacts, sites and practices.
- (v) Assistance is to be provided, in the form of rice for example, during the transition period from the old to the new village and fields.
- (vi) Support essential services: agriculture, health, education.
- (vii) Local labour should be given employment opportunities at construction sites.
- (viii) The rights of women, workers and ethnic minorities' people must be protected and promoted during the construction period.

583. Two national level consultation and disclosures workshops were organised in Vientiane, on the 16th of January 2008 and on the 8th of February 2008. The first one involved representatives from the central, provincial, district authorities and villages; the second involved in addition representatives from international financial institutions, non-governmental organisations and other relevant stakeholders. The objectives of the workshops, the list of participants, the topics raised and the responses provided by NN3PC are presented in details in Annex B of the REMDP.

584. The ESIA, in its December 2010 version, was distributed to MONRE and 15 Line Ministries and relevant Governmental Organizations for final comments at the same time it was made public on the ADB website in January 2011. On the 25th of January 2011, MONRE organised a Technical Consultation Workshop to present the latest revised ESIA report and the E&S compliance procedures for approval by the Provincial Authorities of Xieng Khouang and Vientiane provinces.

F. The PCD process in the future

585. To support and strengthen the PCD process, information centres will be established in Vientiane Capital, in Vientiane and Xiengkhouang provinces and at the project site offices. They will display the safeguard documents in their English and Lao language version, other public documents (progress report, entitlement matrices, environmental and social obligations of the Company), communication posters, photos and maps. These centres will be established after the completion of the next round of village consultations, during which the final draft of the EIA and the REMDP shall be presented.

586. A Company project website will be set up and it will serve as a way to disseminate information at the national and international level. In addition to the safeguards documents and other public document, the project website will be used to release updates on the progress of the project and provide a mean for interactions.

587. The PCD process will also be engaged with other important stakeholders in the Nam Ngum River Basin, in particular with the other hydropower projects (NN1, NN2, NN5 et NN4) and the mining

projects, in particular Phu Bia Mining. NN3PC intends to take an active and creative role in the Hydropower and Mining Forum and to support the activities of the NNRBCS both in terms of funding but also in terms in sharing the expertise available within the Company.

588. After the start of commercial operations, consultations and information disclosure should be gradually reduced. The grievance mechanism should however continue to be in place during the first 5 years of operation.

G. Stakeholder input into the project design

589. The long public consultation and disclosure process has enabled an exchange of opinions and experiences valuable during the planning phase of the project, improving both the quality of the planning and the decision making process. Whenever feasible, practical, and within the scope of the project, the feedback received from the various stakeholders has been taken into consideration. Table 8.3 summarises the influence that the stakeholders have had on the design of the Project.

Table 8.3: Stakeholders concerns and influence into the project planning

Topic	Stakeholder concerns	Influence on project planning
ESIA	Slow progress of project development	The project is developed in compliance with IFI safeguard policies, which takes time, but ensure sufficient attention is given to avoid, mitigate and compensate its impacts.
Fisheries	Impacts on the downstream families dependent on fisheries	The NN3 project is situated between a cascade of other hydropower projects, NN1 and NN2 downstream, and NN5 upstream, which have already seriously impacted the migration of fish in the Nam Ngum river. Nevertheless, the project has taken a proactive approach and shall establish a baseline and compensate the impacts that will be measured. In addition the potential of the fisheries in the reservoir shall be developed, although by its size, shape and hydrology, its potential looks less promising that NN1 or NN2.
Health	Health impacts during the construction period, mainly HIV/AIDS and STDs	The project shall implement various health programmes as part of its overall health action plan. These will target all the villages in the various project areas, the workforce, camp followers and sex workers. In addition, a dedicated health plan shall be prepared by the contractors to deal specifically with its workers and services providers.
	Impacts of camps & camp followers	A dedicated budget has been set aside to develop a plan to manage the camp followers, under the Construction Phase Social Management Plan.
Land issues	Compensation for loss of land and assets	The approach taken by the Company is to favour compensation in kind, i.e. land for land and to only resort to cash compensation if no alternatives are available. Entitlement matrices are very clear and transparent on the rates that shall be used in this case.
Natural habitats & wildlife	Natural habitats lost, and gained, as a result of the project	Consolidation of existing information was made in early 2011 to clarify the situation. The project will support the integrated watershed management through a funding of US$3.77M during a 9 year period, and part of this funding shall be used to conduct field surveys. This contribution shall be made to the NNRBC, which shall consolidate the various fundings to implement an integrated plan for the basin.
	Impacts of the TL crossing the Phou Kao Kouay NPA	The NN3 TL has been rerouted to follow the NN2 TL alignment, therefore avoiding the impacts of the crossing of the PKKNPA.

Topic	Stakeholder concerns	Influence on project planning
Public consultation & disclosure	Communities understanding fully the nature of the impacts and their entitlements	The PCD process endeavours and will continue to endeavour to use the most appropriate techniques to secure a full understanding of the impacts and the entitlements of the various impacted persons, including the particular needs of the vulnerable groups. Messages and materials are and will be developed specifically for target audiences.
PCR	Impacts on artifacts, historical places and spiritual and cultural assets	A survey was conducted to assess the presence of PCR within the project area. The contractors shall have the responsibility to develop PCR plans to ensure that PCR are properly dealt with during the construction period.
Water quality	Remaining biomass in the reservoir	A salvage logging and vegetation clearing programmes will be implemented during the construction period.
	Poor water quality downstream of the power station and responsibilities amongst the various projects	The project is actively looking at solutions at the scale of the NN Basin, considering the cascade of hydropower projects on the NN river. It considers involving the NNRBC to undertake its water quality monitoring programme.
	Poor water quality upstream due to the NN5 project	NN3PC will engage actively the NN5PC to ensure appropriate water quality downstream of its dam, with the support of the NNRBC.

590. Similarly, the consultations at the village and household levels have strongly influenced the selection of (1) the resettlement site, (2) some livelihood components to be strengthened, (3) infrastructure and housing styles.

H. Institutional arrangements for the PCD process

591. GoL will take the lead role in the public consultation and disclosure process, with NN3PC providing the required technical and managerial support, as required. At the level of the villages, dedicated teams will be put in place, with support from the district and training and support provided by NN3PC, in terms of methodology, of understanding of the range information relating to the Project, and of production of consultation materials (maps, posters, manuals, etc.).

IX. ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

592. Large scale construction activities and influx of construction workers and service providers are the primary causes of negative environmental impacts during the construction phase of the project. These impacts though significant in nature can be managed by adopting sound construction practices, health and safety measures; and careful management of the workforce and camp followers.

593. During the operation phase, the inundation of a river stretch by the creation of a permanent physical barrier (220 meter tall dam) and significantly reduced downstream flows, will cause significant and permanent negative environmental impacts. These impacts have been described in Chapter 7.

594. Table 9.1 summarizes the mitigation measures, implementation plans and the institutional responsibilities for the various impacts. Details are provided in the Environmental Monitoring and Management Plan (EMMP) and described in this chapter.

Table 9.1: Summary of NN3 Environmental Impacts and Mitigation Measures during the Operation Phase

Potential impact	Mitigation Measures	Implementation Plans	Responsible Entity
Reservoir Impact Zone			
Eutrophication and algae bloom	• Implement vegetation clearance prior to reservoir filling Prevent nutrient loading in the reservoir by ensuring adequate removal of the burnt ash and catchment area improvement measures	Biomass Clearance Plan Integrated Watershed Management Plan (IWMP) for catchment area improvement Water Quality Management and Monitoring Plan (WQMMP)	NN3PC and relevant GoL agencies
Periods of oxygen deficiency and anoxic deep water	• vegetation clearance prior to reservoir filling and prevention of nutrient loading • aeration devises if found effective	WQMMP	NN3PC
Seasonal inundation of 42 ha of rice paddy	• Replacement agricultural lands	REMDP	NN3PC and relevant GoL
Loss of forest land	• Update status of forest cover • Compensatory Reforestation & Biodiversity offset	IWMP	NN3PC and relevant GoL
Loss of biodiversity	• Update baseline biodiversity information; • Prepare appropriate and effective mitigation measures to achieve no net loss of biodiversity • Implement Biodiversity offset and conservation areas plan	IWMP Biodiversity Offset Plan	NN3PC and Relevant GoL Agencies
Risk of introduction of invasive water	• Monitoring and Removal	WQMMP	NN3PC

Potential impact	Mitigation Measures	Implementation Plans	Responsible Entity
plants		EMMP-OP	
Loss of traditional fishing expeditions on the NN river	• Reservoir fisheries	REMDP	NN3PC and relevant GoL
Nam Ngum Downstream Impact Zone			
River bank erosion	• Observations during operation to identify erosion prone areas • Design and implementation of erosion control measure in affected areas	EMMP-OP	NN3PC
oxygen deficiency in tailrace water affecting water quality in NN2 reservoir	• Implement vegetation clearance and nutrient control prior to reservoir filling • Monitor the extent of oxygen deficiency and if significant, and feasible, modify river morphology to increase aeration	IWMP WQMMP	NN3PC and relevant GoL agencies
Loss of fauna and fish species	• Update baseline biodiversity information; • Prepare appropriate and effective mitigation measures to achieve no net loss of biodiversity • Implement Biodiversity offset and conservation areas plan	Biodiversity Offset Plan	NN3PC and relevant GoL agencies
Safety risk by fluctuating water levels and increased velocities	• Fence along the bank of the river until the confluence with the Nam Phay • Warning signal and notices for sudden change of flow.	EMMP-OP	NN3PC
Risk of dam failure	• Apply state of the art dam safety design criteria. • Preparation of Emergency Plan	Project Design EMMP-OP	NN3PC
Construction Sites and Access Roads Impact Zone			
Loss of land for permanent facilities	• Compensation, when applicable.	REMDP	NN3PC and relevant GoL
Increased pressure on wildlife due to improved infrastructure	• Control access and enforce no hunting policy • Dismantle and restore all temporary construction roads to original vegetative state	EMMP-OP	NN3PC
Loss of forest	• Update status of forest cover • Compensatory Reforestation and biodiversity offset	IWMP	NN3PC and relevant GoL
Loss of biodiversity	• Update baseline biodiversity information; • Prepare appropriate and effective mitigation measures to achieve no net loss of biodiversity	IWMP	NN3PC and relevant GoL

Potential impact	Mitigation Measures	Implementation Plans	Responsible Entity
	• Implement Biodiversity offset and conservation areas plan		

595. The Environmental Management and Monitoring Plan (EMMP) provide a framework to ensure transparent and effective monitoring, prevention, minimization, mitigation, compensation, and off setting measures of the environmental impacts created by the NN3 project.

596. The Environmental Management and Monitoring Plan will be updated and/or revised, both for construction and operation phases, to adapt the measures to the prevailing conditions and monitored impacts during the construction period.

597. Three main sub-EMMPs have been identified:

(i) Sub-EMMP1: Integrated watershed management, targeting biodiversity conservation, biodiversity offset and compensatory reforestation;
(ii) Sub-EMMP2: Water quality monitoring and management (also includes the reservoir biomass clearance and reservoir impoundment plans);
(iii) Sub-EMMP 3: Construction Environmental Management and Monitoring Plan.

598. The 3 sub-EMMPs have been presented in details in this chapter. However, sub EMMPs 1 and 2 will be further updated based on the results of the base line biodiversity survey and additional field surveys. Sub-EMMP 3 will be prepared by the contractors 60 days before the start of construction activities

599. Six months before the start of the operations, NN3PC will submit a detailed environmental management and monitoring plan for the operation phase (Sub-EMMP 4 – Environmental Management and Monitoring Plan-Operation Phase).

A. Integrated Watershed Management Plan

1. Background

600. The NN3 project will undeniably be a factor contributing to the ongoing process of fragmentation, reduction of the natural forest cover and biodiversity values in the Nam Ngum River Basin. Large parts of the project impact area have already been impoverished (logging, mining, hydropower) but some parts of the Nam Ngum River Basin still contain values that are worth protecting.

601. Another valuable area in terms of forest and biodiversity value that will be impacted by the project, with its transmission line, is the Phou Khao Khouay National Protected Area. It contains, globally, mature forest eco systems with significant recordings of mammal and bird species classified as endangered or under threat. About 100 ha of forests will be permanently lost by the necessary ROW clearance. Additional indirect impacts will result from the fragmentation of the forest and the access roads and tracks that might result in illegal or unsustainable utilisation of forest products and wildlife.

602. During the analysis of the project impacts on terrestrial and aquatic biodiversity and natural habitats, and considering the numerous projects in preparation (hydropower and mining) in the NNRB, the Company thought that it would be more sustainable, to compensate for these impacts by inscribing the Company's activities within the overall framework to be provided by the NNRB. Targeted conservation and offset will only be effective if they are identified, confirmed, and implemented together with GoL relevant agencies, with NN3PC's financial support.

603. In this context the project will be supporting the NNRBC Integrated Watershed Management approach in the Nam Ngum River Basin aiming at the following objectives:

(i) improve the **conservation and protection of forest areas** that are important for **preserving biodiversity and protecting water resources**;
(ii) alleviate poverty and improve living standards by **improving sustainable livelihood opportunities** for households and communities whose needs are met from a **watershed's natural resources**;
(iii) improve the conservation and management of natural resources within watersheds for **sustainable economic productivity**, while maintaining and enhancing these resources' social and environmental functions;
(iv) improve water resource management within watersheds in order to (1) provide adequate quality water for all users within the watershed and downstream and (2) protect human settlements, lowland farms, power generation and transport infrastructure, and downstream fish ponds from flood and sedimentation damage; and
(v) increase the marginal productivity values of the natural resources of land, water and forests (i.e. increasing the productivity of one resource without decreasing the productivity of others).

604. It is believed that this approach undertaken in the framework of the Nam Ngum River Basin could guarantee some success and durability in the compensation and offsetting of the natural habitats and associated species that will be destroyed and/or degraded as a result of the NN3 project.

2. Objectives

605. The specific objectives of the NN3 interventions led by the NNRBC/MONRE[1] are to contribute to:

(i) Improve the knowledge of the various habitats and their biodiversity values;
(ii) Compensate for and increase the area covered with forest vegetation within the project influence zones (including the biodiversity offsets), and therefore increase and improve, in the long term, natural wildlife habitats;
(iii) Implement effective measures to ensure a no net loss of biodiversity affected by the inundation of a 64 km long river stretch and critically reduced flows in a downstream stretch of 15.7 km.
(iv) Reduce the risk of soil erosion and sedimentation in the catchment, particularly during flood events;
(v) Reduce the potential for hunting, collecting and trade of wildlife;
(vi) Maintain and improve the livelihoods of local people by maintaining and increasing the amount of available NTFP.

606. In addition to purely conservation activities, the project will support sustainable economic activities within the catchment enabling the improvement of livelihoods of villages impacted by the project. This could take the form of guaranteeing some access to some forested areas for the sustainable collection of NTFP.

607. The project will also support compensatory reforestation activities within the NNRB. A comprehensive compensatory reforestation plan as referred in the sub-EMMP shall be prepared by NN3PC subject to GOL approval and shall be implemented by GOL through appropriate government line agency. The area will be of a comparable size to the forests impacted by the project and will take into consideration the habitats that will be protected under the biodiversity conservation plan.

[1] Some activities to offset impacts of NN3 may be implemented outside of the NNRB. MONRE will be responsible for the implementation of such requirements.

608. Biodiversity offsets and compensatory reforestation for the project will be identified as (i) not to conflict with existing communities' uses or access, in a manner which cannot be resolved by compensation by NN3PC, (ii) not to conflict with existing mining concessions and (iii) and once identified will be declared by GoL as conservation areas.

609. NN3PC will prepare and implement a wildlife rescue plan acceptable to GOL, if recommended in the updated biodiversity study.

610. NN3PC shall make necessary provisions for biodiversity conservation measures, water holes, salt licks and any other measures recommended by the updated biodiversity study within the NN3 catchment and downstream down to backwaters of NN2.

3. Approach and Activities

611. NN3PC will undertake a biodiversity study that would include:

(i) update of the vegetation and forest cover of the areas impacted by the Project on the basis of the interpretation of satellite imagery and ground surveys;
(ii) collection, compilation and analysis of baseline data on aquatic and terrestrial flora, and fauna and their habitats;
(iii) classification of the habitats impacted by the project according to definitions of critical[2], natural[3] or modified habitats[4];
(iv) identification, assessment and recommendation of various measures to offset, enhance, protect and conserve the project affected biodiversity

612. NN3PC will need to collect baseline data mentioned above through field surveys and satellite image study in various project areas including (i) downstream of the dam and down to the NN2 backwaters including the areas earmarked for quarry and disposal sites, (ii) inundation area, (iii) NN3 catchment area excluding the catchments of upstream hydropower development (NN4 and NN5) for possible offsets and (iv) the transmission line corridor and adjoining areas (but excluding any areas impacted by the NN2 230 kV transmission line).

613. NN3PC will provide the necessary financial support to GOL to implement appropriate measures, consistent with the recommendations made in the biodiversity study, with respect to biodiversity offset and conservation initiatives. In particular GoL will identify viable and comparable host ecosystems, located either within the NN3 watershed, within the NNRB or outside.

4. Staff and resources

614. The role of NN3PC in the Biodiversity Conservation and Management Plan will be to support financially the NNRBC and the relevant GoL authorities involved (i.e Ministry of Agriculture and Forestry (MAF)) to implement the various activities. As necessary and considering that the NNRBC is still being established, NN3PC will provide technical support as it is required. It will also be involved in the decision and management processes (definition of the scope of the programmes and of the works, monitoring of

[2] **Critical Habitat.** A subset of both natural and modified natural habitat that includes areas with high biodiversity value, such as habitat required for the survival of critically endangered or endangered species;areas having special significance for endemic or restricted-range species; sites that are critical for the survival of migratory species; areas supporting globally significant concentrations or numbers of individuals of congregatory species; areas with unique assemblages or species or which are associated with key evolutionary processes or provide key ecosystem services; and areas having biodiversity of significant, social, economic or cultural importance to local communities.

[3] **Natural Habitat.** Land and water areas where the biological communities are formed largely by native plants and animal species, and where human activity has not essentially modified the area's primary ecological functions.

[4] **Modified Habitat**. Land and water areas where there has been an apparent alteration of the natural habitat, often with the introduction of alien species of plants and animals, such as agricultural areas.

progress). It is expected that the experience of the Forestry Division of MAF, of any other organisations and of independent experts will be sought for the implementation of the various components of the programme.

5. Budget and Schedule

615. A total budget of US$3.6M (US$1M before COD, US$2.6 after COD) has been set (Table 9.2) to support the biodiversity conservation and management plan. It will be broken down in details once the various components are known.

Table 9.2: Budget and Schedule for Integrated Watershed Management Plan

		pre COD (5 years) US$	post COD (4 years) US$	Total US$
2	**INTEGRATED WATERSHED MANAGEMENT PLAN**	**1,000,000**	**2,600,000**	**3,600,000**
	Support for compensatory reforestation and biodiversity conservation offsets and protection. Securing, in addition, the water quantity and quality on NN3 reservoir inflows and off-setting the NN3 impacts of the reservoir (flooding of forested area) and land take by the transmission line. Access to NTFP by peri-reservoir & downstream communities will be secured.			

616. Coordination with the NNRBC, and other partners including lenders, will be undertaken from the dry season 2011-12 to set the approach and the key milestones of the programme, and to prepare the update of the baseline data in the various project areas including: (i) downstream of the dam and up to the NN2 backwaters including the areas earmarked for quarry and disposal sites, (ii) inundation area, (iii) NN3 catchment area excluding the catchments of upstream hydropower development (NN4 and NN5) and (iv) transmission line corridor and adjoining areas, including the scope of work and the terms of reference for the biodiversity study and surveys. Some surveys will be undertaken immediately during the dry season 2011-12. The other activities identified above will be scheduled according to the plan and communicated to the various parties.

617. Following the NN3PC's baseline biodiversity update within the project area, NN3PC shall provide financial support to GOL sufficient through appropriate government line agency to undertake and complete all required additional surveys and studies to identify biodiversity offsets, in order to achieve no net loss of the affected biodiversity. With Company's financial support, the GOL shall take necessary actions to ensure that the recommended measures, including formalizing necessary biodiversity offset for both terrestrial and aquatic habitats, be effectively implemented in accordance with the timelines specified in the EMMP. The biodiversity offsets will be put in place before the commencement of impoundment of the NN3 reservoir.

B. Water Quality Monitoring and Management Plan

1. Background

618. Degradation of water quality resulting from the NN3 Hydropower Project can be divided into those resulting from the construction activities and those that are a consequence of the establishment of the reservoir and the operation of the power plant.

619. The main construction phase issues are:

(i) Risk of discharge of hazardous chemicals;
(ii) Discharge of domestic wastewater and sewage from construction sites and camps;

(iii) Sediment loads from construction activities;
(iv) Water quality changes caused by decomposition organic materials during filling of the reservoir.

620. The main operational water quality issues are:

(i) Permanent eutrophication and oxygen depletion in the reservoir and release of oxygen deficient water downstream;
(ii) Change in downstream water temperature;
(iii) Riverbed erosion and sediment transport downstream of tailrace and into NN2 reservoir;
(iv) Levels in iron (Fe) content in reservoir and downstream water.
(v) Management of domestic wastewater, and solid wastes

621. Water quality issues related to construction activities will be managed by the Contractors, under the monitoring of the Company, which will check on a regular basis, the water quality parameters measured by the Contractors by doing its own analysis.

622. Water quality issues resulting from the decomposition of the biomass in the reservoir will be addressed by (i) a dedicated biomass clearance programme aiming at the removal of the standing vegetation in the reservoir, and ensuring that the burnt material be managed to prevent nutrient loading in the reservoir and downstream, and (ii) the removal of floating debris and logs, estimated at 8,000 tonnes during the first three years of operation. Other Water quality issues resulting from project operation include management of domestic wastewater, and other wastes (including solid and industrial wastes such as used oil, chemicals, etc.)

2. Objectives

623. The water quality monitoring and management plan has two main components: the biomass clearance programme and the water quality monitoring.

624. The water quality monitoring objectives for the NN3 project are to:

(i) detect trends;
(ii) monitor critical conditions (annual maximum or minimum values of certain water quality parameters);
(iii) monitor any levels in excess of standards;
(iv) identify needs for mitigation.

625. The biomass clearance programme aims at reducing to the maximum the amount of biomass from the reservoir immediately before its impoundment in order to:

(i) Reduce the risks caused by oxygen depletion in the reservoir and discharges of oxygen deficient water in the downstream water reaches;
(ii) Reduce the amount of floating debris in the reservoir;
(iii) Improve the conditions for aquatic life and fisheries potential of the reservoir;
(iv) Adequately manage the material from the biomass clearance programme to prevent nutrient loading into the reservoir; and
(v) Clear the waterway for navigation.

3. Water Quality Monitoring Approach

a. Focus

626. The focus of the NN3 water quality monitoring programme will be to document the water quality

changes resulting from the construction and operation of NN3 and which might necessitate corrective actions or revision of existing mitigation measures or compensations. This is in particular the case in relation to the oxygen regime in the reservoir and the river reach downstream of the power plant. Monitoring in the first years of operation will be important for judging whether the natural aeration capacity of the downstream river rapids will be sufficient to recover acceptable water quality before discharging into the NN2 reservoir. If this is not the case additional aeration measures will be considered and provided.

627. The intention is to limit the monitoring strictly to the project area and to integrate some of its components into an integrated water monitoring system that might cover the whole of the Nam Ngum River Basin, but has yet to be constituted. A conventional water sampling and laboratory analysis approach is considered the most reliable monitoring method at this point in time.

628. Consideration will be given to joint hydrological and quality measurements when locating water quality monitoring stations. Flow data is integral to proper interpretation of the measured quality data and it is logistically advantageous to combine the functions of the monitoring stations.

629. A laboratory outfit will be established at the Ban Long Cheng field station, or in the location found the most appropriate. The monitoring system will primarily be based on a combination of field kit analysis for some of the water parameters and laboratory analysis. Sampling will be carried out by the Environment and Social Division (ESD) staff in Long Cheng and at the Phou Koot ESD unit.

630. If a basin-wide coordinated programme is initiated, technical specifications on sampling and analytic methods and procedures as well as the format of data storage and reporting format for the NN3 Monitoring Plan will have to be adjusted. Therefore only a preliminary outline of the technical details has been given at this stage.

b. Monitoring System Design

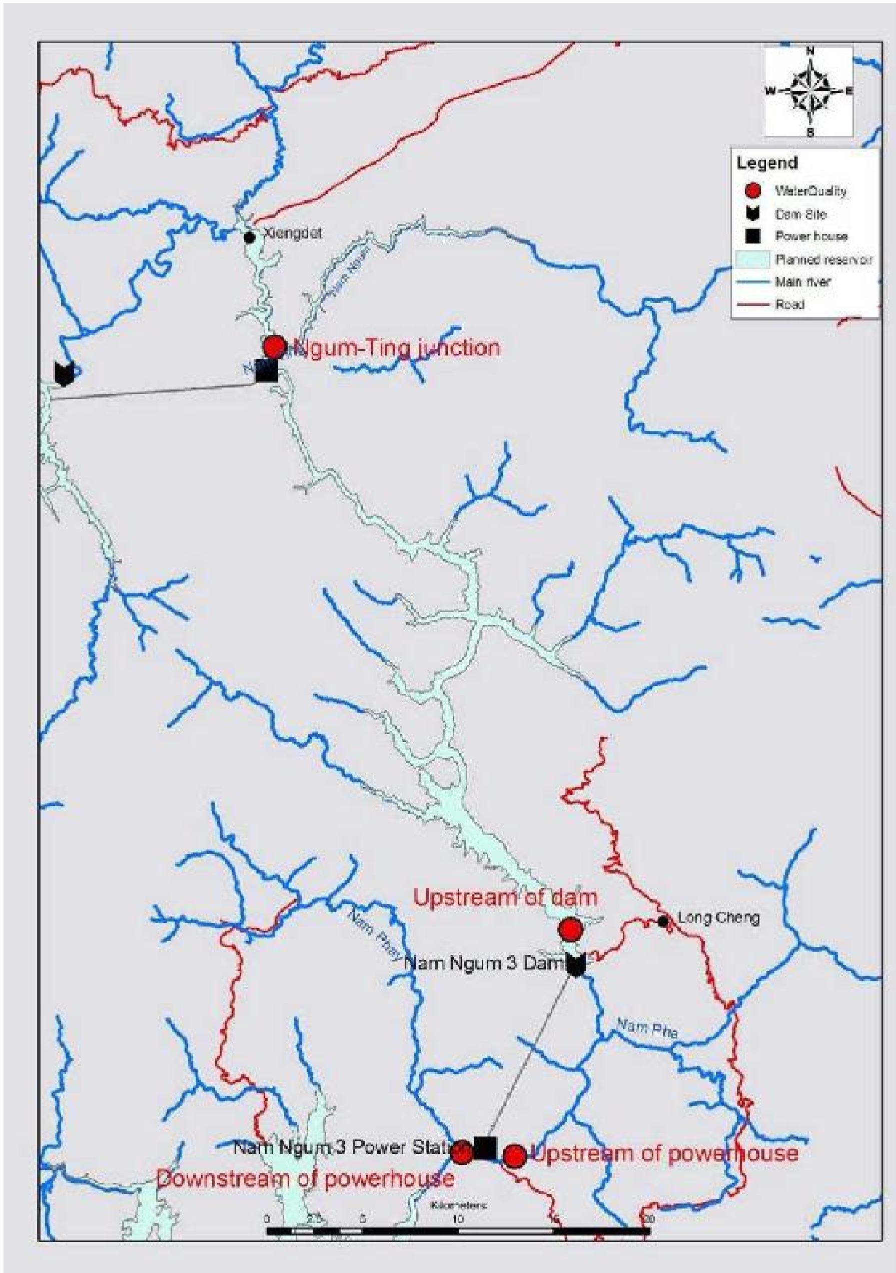
631. At this stage 5 different monitoring locations are proposed for the monitoring of the ambient water quality in the area of influence of the NN3. These are:

- (i) In the river/reservoir at the confluence between Nam Ngum and Nam Ting, upstream of the NN5 tailrace (one station).
- (ii) In the reservoir (several stations).
- (iii) In the Nam Ngum river 500 m upstream of the power house (for most of the year only fed by Nam Pha discharges) (one station),
- (iv) In the Nam Ngum river 500 m downstream of the tailrace outlet (one station), and
- (v) Near Ban Xiengdet (one station).

632. The stations are indicated in Figure 9.1. The number of stations and locations will be finally decided when more information about an integrated water monitoring programme is available.

633. The monitoring of construction work and potential water pollution from project activities inside the limits of the construction zone will be covered by site specific monitoring, which have to be specified by the Contractors in their Site Specific Environmental Management and Monitoring Plans. NN3 PC will undertake a separate monitoring at these points during the EHS inspections.

Figure 9.1: Proposed water quality monitoring stations



c. Parameters

634. Indicative water quality parameters are indicated in Table 9.3. Parameters relevant to the oxygen and the eutrophication situation have been given priority. The table also includes some parameters not relevant for the NN3 impacts, but which might be of interest for contributing to a more comprehensive picture of the water quality situation in the basin. The monitoring of heavy metals concentration, undertaken at various locations, will also be undertaken for fish tissues. Depth profiles (at least bottom, middle, top) will be done at one or several locations of the reservoir.

Table 9.3: List of proposed monitoring parameters

Parameter	Symbol	Unit	Measured
Temperature air	T_{air}	^oC	On site
Temperature water	T_{water}	^oC	On site
pH	pH		On site
Dissolved Oxygen	DO	mg/l	On site
Oxygen Saturation	Sat O_2	%	On site
Biological Oxygen Demand	BOD	(mg O_2/l)	In laboratory
Chemical Oxygen Demand	COD	(mg O_2/l)	In laboratory
Nitrite + Nitrate Concentration	$NO_2 + NO_3$	mg/l	In laboratory
Total Nitrogen Concentration	Tot – N	mg/l	In laboratory
Orthophosphate Concentration	PO_4 – P	mg/l	In laboratory
Total Phosphorus Concentration	Tot – P	mg/l	In laboratory
Faecal Coliform		no/ml	In laboratory
Alkalinity (as CaCO3)	Alk	mg/l	In laboratory
Calcium Concentration	Ca	mg/l	In laboratory
Magnesium Concentration	Mg	mg/l	In laboratory
Sodium Concentration	Na	mg/l	In laboratory
Potassium Concentration	K	mg/l	In laboratory
Chloride Concentration	Cl	mg/l	In laboratory
Lead	Pb	mg/l	In laboratory
Mercury	Hg	mg/l	In laboratory
Electric Conductivity		Ms/m	On site
Total Suspended Solids	TSS	mg/l	In laboratory
Chlorophyll	Ch-a	Ms/m	In laboratory
Planktonic algae	Algae	No./ml	In laboratory

d. Monitoring Frequency

635. A monthly monitoring frequency is recommended at this stage and might have to be adjusted to the overall river basin monitoring programme. Possibility will be given to undertake samplings at other frequencies to detect changes that might happen at smaller intervals (pulse of anoxic water for example) and to respond to emergency situations.

e. Reporting

636. The monthly report should present aggregate data in table and figure format, accompanied by narrative explanation and interpretation. A separate section should summarise the water quality situation and changes related to the project and project activities.

4. Biomass Clearance Programme Approach

a. Background

637. The logging of the commercially valuable timber in the area of the reservoir has already been undertaken by GoL and is considered to be completed. The biomass clearance programme will therefore focus on the reduction of the biodegradable biomass in the future reservoir area. It will follow the procedures set by GOL.

b. Organization

638. Logging activities have created access roads, which will facilitate the access and the removal of the biomass in the reservoir. Most of the clearance of the reservoir will be undertaken before filling and supplementary clearance in the drawdown zone could be undertaken during the first year of operation, facilitated by the visual marks left by the maximum flood level at the end of the previous wet season.

639. Priority will be given to the biomass clearance of the area that will be inundated by the construction of the cofferdam, at the beginning of the construction activities.

640. Just upstream the dam an arrangement for collection and removal of tree trunks and wooden debris will be installed and operated for the first years of dam operation.

641. The process of vegetation clearance and burning should be designed to encourage domestic and wild animals to move to adjacent lands.

c. Administrative and Contractual Arrangements

642. NN3PC will have the overall responsibility for the implementation of the Biomass Clearance Plan through the following:

- (i) Provision of management, planning and control through its Environment and Social Division.
- (ii) Engaging a Contractor with appropriate technical and management expertise to clear the reservoir.
- (iii) Provide training for clearance team staff in operations methods, health and safety, UXO surveys and management, PCR Chance Find Procedures, environmental awareness, etc.

643. Contract clauses will need to include procedures, schedules, and responsibilities for:

- (i) Demarcation of FSL;
- (ii) Providing “fire resistant corridors”;
- (iii) Description of removal procedures for soft biomass (to avoid haze);
- (iv) Description of procedures for removal of timber;
- (v) Description of procedures to avoid re-growth of vegetation;
- (vi) Removal of partially burnt biomass and ashes;
- (vii) Priority biomass removal between elevations of natural Nam Ngum River water levels and MOL of NN 3 reservoir;
- (viii) Secondary biomass removal in reservoir drawdown zone;
- (ix) Involvement of the local population;
- (x) Opportunities for procurement of type and quantities of hard wood logs for the construction of houses and public buildings at the relocation site of Ban Xiengdet;
- (xi) Responsibility and need of UXO clearance at certain areas within the drawdown zone of NN3 reservoir;
- (xii) Safety measures and procedures during UXO clearance;

(xiii) Reporting of compliance.

d. Activities

i. Detailed Planning

644. NN3PC's ESD will be responsible for the preparation of a work plan for all elements of the Biomass Clearance Plan. The detailed scheduling of specific tasks and responsibilities will be worked out jointly by the ESD and the contracted agency. This can only be done after field inspections, preparation of operational maps and consultations with villages and NN3PC.

645. It is important that the work programme is planned to match the reservoir filling and draw down schedule.

ii. Information and Training

646. Formal briefings and training will be necessary for contractors, supervisors and work teams in:

(i) Health and safety measures;
(ii) Environmental safety in work practices;
(iii) Clearance methods;
(iv) Burning techniques ;
(v) UXO surveys and management;
(vi) PCR Chance Find Procedures

iii. Demarcation

647. Some of the necessary demarcation of the reservoir perimeter has already been carried out in connection with the logging but additional demarcation will be needed. The area of second year clearing and burning (in the dry season after reservoir filling) will be easily identified by the sign of first year FSL inundation. It will be necessary to mark the limits of the water level behind the coffer dam for the first sequence of biomass removal in the deepest parts of the reservoir.

iv. Cutting and Burning

648. There will be a need to clear vegetation below the 550 masl contour prior to the inundation created by the construction of the coffer dam.

649. Two sequences of cutting and burning is planed covering:

(i) most of the reservoir inundation area in the dry season 2015-2016 and
(ii) reservoir drawdown zone between 660 masl and 723 masl in the dry season 2016-2017.

650. The second year cutting and burning process will start in the upper reaches of the reservoir. The cutting will follow the retiring water level and burning will start as soon as the organic material has dried up.

651. The work is to be controlled by creation of operational blocks. The size and limitation of the blocks will be determined as a part of Activity 1. Teams, to the largest extent possible consisting of local villagers, will be formed to carry out operations.

652. The biomass before burning will be piled away from the block edges to form narrow firebreaks and safe access and exit routes for burning teams. Each block is rapidly "back-burnt" by a large team to create a strong local wind effect to draw fire away from areas to be protected and inwards to obtain maximum

biomass fuel consumption. Alternative measures to biomass burning will be considered as ashes produced are nutrients either for the future reservoir and/or reservoirs located downstream.

653. During biomass clearance the burnt material shall be managed in accordance with MONRE draft guidelines on Biomass Removal from Hydropower Project reservoir dated August 2010 and to take necessary actions to prevent nutrient loading in the reservoir.

v. Logging and Timber Transport

654. Some supplementary logging activities might be necessary and will have to be contracted to competent agencies.

655. Logging teams will need to be instructed to minimise the amount of wood and larger branches that might be flushed downstream by the river or left floating in the future reservoir. The logging contractors should be instructed and required to avoid any spillage of fuel, oil products and other sources of environmental contamination.

vi. Domestic and Wild Animal Salvage

656. Wild animal losses are likely to be minimal as they can move voluntarily to safe surrounding habitats in three ways:

- (i) Rising water levels in the reservoir create pressure to move.
- (ii) The pattern of burning will force wild animals to move to safer land.
- (iii) The short distance between the shores will enable larger animals to cross the inundated area.

657. The planned biodiversity study will include an assessment of the applicability of a dedicated wildlife rescue plan.

658. A census will be completed of domestic animals in the inundation area. Owners of animals will be instructed to muster their herds and have them moved out of the area before the start of the inundation process.

vii. Residue Collection and Removal

659. Some large logs not completely consumed by fire will float as the water level rises. During initial and final reservoir filling a team will clear the water of logs and organic debris using booms placed upstream of the dam intake and spillway structures. A heavy- duty boat will be available to haul the material into collection ramps. A collection and disposal team will carry out reservoir material recovery at the dam site. After commissioning the removal of logs and other debris material at the dam site will be integrated in the normal routine hydropower dam operation.

viii. Monitoring, supervision and control

660. Activities iv - vii will be continuously monitored and controlled by NN3PC's ESD. The Contractor will prepare performance reports and ESD will ensure the objectives and results of the biomass clearance plan have been achieved. The monitoring should be frequent enough for the management to deal with departures from the specified plans. If technical or logistic problems are encountered, revised plans and strategies have to be developed.

661. The controllers should make regular reports on the progress of the relevant activities and make these reports available to NN3PC.

5. Staff and resources

a. Water quality monitoring

662. The water quality monitoring staff will be part of the ESD permanent staff. The sampling and analysis will be undertaken by the ESD environmental technician, who will be an experienced chemist. He will be assisted by EHS inspectors, in particular at the construction sites. The staff will be trained in sampling, storage and transportation techniques of water as well as calibration and effective operation and maintenance of laboratory equipment.

663. At the ESD office at Ban Long Cheng, a water quality facility will be established. The facility should be equipped with all means necessary to carry out the monitoring programmes. This includes:

(i) Sampling equipment,
(ii) Field measurements and field testing kits,
(iii) Materials for storage and transportation of water samples,
(iv) Laboratory equipments and chemicals,
(v) PC for data storage and processing,
(vi) Transport (car, boat, etc)

b. Biomass clearance

664. For the biomass clearance plan, a specialist will be engaged to manage and carry out the detailed planning, management and control necessary for implementing the Biomass Clearance Plan. The implementation of the plan will be done by a contracted company. The EHS inspectors will undertake the monitoring of these activities.

6. Budget

665. The cost of the overall water quality monitoring and management plan is presented in Table 9.4. US$500,000 have been budgeted for the monitoring and management of water quality, water level and water discharge for the 5 years of construction and US$300,000 for the first 4 years of operation. US$500,000 has been budgeted for the clearance of the soft vegetative biomass.

Table 9.4: Budget of Water Quality Monitoring and Management Plan

		pre COD (5 years) US$	post COD (4 years) US$	Total US$
3.0	**WATER QUALITY MONITORING AND MANAGEMENT PLAN**	**1,340,000**	**350,000**	**1,090,000**
3.1	Demarcation of the limits of the reservoir at Full Supply Level (FSL).	50,000	0	50,000
3.2	Inventory of commercial timber and of the soft vegetative biomass below FSL.	50,000	0	50,000
3.3	Preparation of a salvage logging management plan of the reservoir (below FSL)	90,000	0	90,000
3.4	Preparation of a soft vegetative biomass removal plan in the reservoir	50,000	0	50,000
3.5	Clearance of Soft Vegetative Biomass below FSL of Reservoir (including procurement of equipment required, necessary boat landings, access tracks).	500,000	0	500,000
3.6	Monitoring and management of Water Levels, Water Discharges, and Water Quality (including NN3PC set up of basic WQ monitoring).	500,000	300,000	800,000
3.7	Clearance of Debris from Reservoir.	100,000	50,000	150,000

7. Schedule

666. The water quality monitoring will be a permanent activity for the ESD. The programme will start before the beginning of the main construction activities.

667. The first activities of biomass clearance will be undertaken at the start of construction activities to clear the area that will be inundated by the construction of the coffer dam. Most of the biomass clearance will be undertaken in the dry season of COD - 1 and additional clearance in the dry season of the COD.

C. Construction Environmental Management and Monitoring Plan

1. Background

668. To avoid, mitigate and minimise environmental and social impacts associated with construction activities (see the above impacts section), the contractors are required to strictly follow and comply with the general IFC Environmental, Health, and Safety Guidelines (EHS) during construction activities at all sites: dam, power station, underground works, quarry, contractor camps, access roads, operator village, transmission line corridor, and during transport at public roads, access roads, and access tracks.

669. The IFC guidelines are reproduced in extenso in Annex I. The IFC has also formulated Environmental, Health, and Safety Guidelines for Electric Power Transmission and Distribution. These are applicable for the construction of the NN3 transmission line and are presented in Annex J.

670. The IFC EHS guidelines for construction activities are organized in four sections (i) Environment, (ii) Occupational Health and Safety, (iii) Community Health and Safety, (iv) Construction and Decommissioning. Table 9.5 presents the main topics by category of the IFC EHS guidelines.

Table 9.5: Main topics by category of the IFC EHS guidelines

Category	Main topics
Environmental	Air emissions and ambient air quality Energy conservation Wastewater and ambient water quality Water conservation Hazardous materials management Waste management Noise Contaminated land
Occupational health and safety	General facility design and operation Communication and training Physical hazards Chemical hazards Biological hazards Radiological hazards Personal Protective Equipment Special Hazard Environments Monitoring
Community Health and Safety	Water quality and availability Structural safety of project infrastructure Life and fire safety Traffic safety Transport of hazardous materials Disease prevention Emergency preparedness and response

Category	Main topics
Construction and decommissioning	Environment (i) Noise and vibration (ii) Soil erosion (iii) Air quality (iv) Solid waste (v) Hazardous materials (vi) Wastewater discharges (vii) Contaminated lands Occupational health and safety Community health and safety

671. NN3PC is responsible for the compensation of any construction-affected households. This will require a strong coordination between GoL Authorities, NN3PC and the contractors to implement the compensation measures in time. NN3PC will formulate Resettlement Action Plans for approval by MONRE, IFIs and the lenders for the transmission line and public road, and will subsequently implement these resettlement plans after approval. These are presented in details in the REMDP.

2. Objective

672. The overall objective of the Construction Environmental and Social Management Plan is to ensure that the environmental and social impacts of construction activities are managed according to the best practices of the industry.

3. Approach

a. Preparation by the Contractors of a CEMMP

673. The various construction contractors will be required to prepare a Contractor Environmental Management and Monitoring Plan, compliant with the requirements set by GOL, and structured along the following parts:

(i) A **Master ESMMP**, providing organizational and operational procedures for the implementation of the various measures;

(ii) **Technical Sub-plans** describing in details the environmental measures by themes and indicating the responsibility for implementation, technical details and how implementation will be monitored. Table 9.6 lists the main thematic sub-plans expected to properly manage the construction activities and to be in compliance with the IFC EHS guidelines.

(iii) **Site Specific Environmental Plans** providing for each construction site and for each phase of construction activities at each site, a description of the area and listing the relevant environmental measures adapted to the site.

674. The content of the expected Contractor EMMP and the applicable guidelines and standards are defined by GOL in Annex C of the Concession Agreement and the Company will impose this content, guidelines and standards to the Contractors. As indicated above, each construction contractor will be required to prepare Site Specific Environmental Management and Monitoring Plans, specifying pertinent concrete actions to be implemented at each constructions site and these will include performance indicators.

Table 9.6: List of Thematic Sub-plans

Thematic Sub-plans
1. Erosion and sediment control sub-plan
2. Spoil disposal planning and management sub-plan
3. Quarry management sub-plan
4. Water quality monitoring sub-plan
5. Chemical waste and spillage management sub-plan
6. Emergency sub-plan for hazardous materials
7. Emission and dust control sub-plan
8. Noise control sub-plan
9. Physical Cultural Resources sub-plan
10. Landscaping and re-vegetation sub-plan
11. Vegetation clearing sub-plan
12. Waste management sub-plan
13. Reservoir impoundment management sub-plan
14. Environmental training for construction workers sub-plan
15. On-site traffic and access management sub-plan
16. Explosive ordnance survey and disposal sub-plan
17. Construction work sub-plans
18. Manual of best practices in site management of environmental matters
19. Project construction staff health programme

675. The Contractor's EMMP documentation has the following objectives:

(i) Provide the environmental and social policy of the construction contractors;
(ii) Provide operational and emergency procedures, developed to address the environmental aspects and risks associated with the construction activities;
(iii) Clarify the implementation and operation of the EMMP to ensure that structure and responsibilities are assigned, staff is trained, aware and competent, and that there is proper communication, documentation, operational control and emergency preparedness and response;
(iv) Provide organisational and technical procedures for implementation of the EMMP which ensure that construction activities associated with potential environmental and social impacts are carried out in a controlled and responsible way;
(v) Provide checking and corrective action through monitoring and measurement;
(vi) Provide records collection and storage.

676. The various plans need to be approved by NN3PC's ESD. They will be submitted to MONRE, IFIs and the lenders as part of the annual implementation plans.

b. Monitoring by the Contractors of the implementation of the CEMMP

677. The various contractors will be responsible for the implementation of these plans and for monitoring and assessing how environmental and social management at each site is undertaken. This monitoring will include the activities undertaken by their sub-contractors. This will be done through the monitoring of environmental controls at each site and for the overall construction activities in general.

678. Routine monitoring of construction sites and construction activities will be undertaken by the Contractor in order to ensure that the requirements and measures specified in the EMMP are properly implemented and that the impacts are minimised or mitigated. This will be undertaken on a site-by-site basis.

679. The Contractor will employ specialist environmental, health and safety staff to undertake this monitoring.

680. The Contractor will report their inspections and ensure that corrective actions are taken when necessary and to track environmental performance.

c. NN3PC Monitoring and Auditing

681. Similarly NN3PC will employ a number of specialist environmental, health and safety staff to undertake the monitoring of each construction site and assess compliance with the IFC EHS guidelines. A system of non-conformance, using three levels of non-conformance, will be put in place to prioritise action according to importance and severity.

682. The non-compliance procedure will allow for the following safeguards:

- (i) Work can be stopped in the event of a serious non-compliance situation;
- (ii) Follow-up visits will be required to verify that the situation has been appropriately rectified by the Contractor;
- (iii) Investigations will determine the causes of incidents and evaluate if changes need to be made to the documentation to prevent similar incidents from occurring in the future.

683. Periodic auditing will also take place, two months after construction has commenced at each site and six-monthly audit after that, to verify conformance and that the proper procedures are in place.

684. Together, monitoring, non-conformance systems and auditing will allow evaluation of environmental performance, analysis of causes of problems, assessment of compliance with contractual and legal requirements, and enable identification of required corrective actions.

4. Activities

a. Environment

685. As per the IFC EHS guidelines, the contractors are obliged to implement all reasonable measures with regards to noise and vibration, soil erosion, air quality, solid waste, hazardous materials, wastewater discharges, and contaminated land. These are presented in details in Annex I.

b. Occupational Health & Safety

686. As per the IFC EHS guidelines, the contractors are obliged to implement all reasonable precautions to protect the health and safety of workers. Annex I list the various aspects to take into consideration such as: the integrity of workplace structures, severe weather and facility shutdown, workspace and exit, fire precautions, lavatories and showers, potable water supply, clean eating area, lighting, safe access, first aid, disease prevention, communication and training, over exertion, slips and falls, work in heights, struck by objects, moving machinery, dust, confined spaces and excavations, protective equipments, etc.

c. Community Health & Safety

687. In a similar way, as per the IFC EHS guidelines, the contractors are obliged to implement risk management strategies to protect the community from (1) physical, chemical, or other hazards associated with sites under construction, (2) hazards associated with the increased traffic, (3) communicable and vector-borne diseases associated with the population of workers. Risks and proposed management strategies are presented in details in Annex I.

d. Public Health Action Plan

688. A dedicated Public Health Action Plan, presented in the REMDP and targeting the local population, will be implemented during the periods of construction and operation. There will be obvious linkages and a need for coordination with the health components described above.

e. Construction Social Management Plan

689. Similarly, a dedicated Construction Social Management Plan, also presented in the REMDP, will be implemented to deal with the social issues associated with construction activities. This will include the preparation of a Workers Code of Conduct and a framework to guarantee the proper management of camp followers. Coordination between the various parties (workers, contractors, company, GoL authorities) will also be required for this component.

5. Staff and resources

690. As indicated above, the preparation, approval, implementation, and monitoring of the various activities will require specialist environmental, health and safety staff both from the side of the Company and from the side of the various contractors and sub-contractors.

691. Dedicated equipment will also be required to undertake the monitoring of the various parameters.

692. As the respect of the IFC guidelines is a contractual obligation for the Contractors, it will be up to each contractor to staff its EHS divisions appropriately to be able to comply with these obligations.

693. To undertake this function, NN3PC intends to have a dedicated EHS senior Manager, assisted by at least one environmental engineer, 4 EHS inspectors and at least one environmental technician, all permanent staff of the ESD. The Company will contract specialists to support its activities in this field, on an as-required basis.

6. Budget and Schedule

694. The cost of implementing the various measures, including the preparation of the various plans and their monitoring, by the Contractors is incorporated into the overall cost of the Construction Contracts and is not mentioned here.

695. The cost of reviewing and monitoring these measures by the Company is presented in Table 9.7. It amounts to US$2M pre-COD and to US$0.8M post COD. It does not include the cost of the associated programmes: the Construction Social Management Plan (US$310,000) and the Public Health Action Plan (US$1.23M).

Table 9.7: Budget of EMO Monitoring of Construction Activities

		pre COD (5 years) US$	**post COD (4 years) US$**	**Total US$**
1	ESD OVERALL MANAGEMENT, COORDINATION & COMMUNICATION			
1.1.2	Health, Safety & Environmental Protection (all HSE programmes) (personnel, offices, transport)	2,019,000	836,000	2,855,000

696. All these activities will be implemented from the start of the construction activities until the COD+4 years.

D. Other sub-Environmental and Social Management and Monitoring Plans

697. In addition to the impacts directly associated with the construction of the dam, the power house and directly associated infrastructure, potential environmental and social impacts of construction works are expected (i) along the NN3 transmission line, (ii) along the public road between Nam Ngone and Long Cheng and (iii) during reservoir impoundment. To address these impacts, sub-plans have been prepared and are discussed in the REMDP. They include (i) the Fisheries Management Plan, based on baseline survey and monitoring household fish catch, in Section 2.2 Social Impacts from Impoundment and Operations of the REMDP; (ii) Public Roads Environment Management Plan (see Section 2.1.3 of the REMDP discussion on the environmental impacts and mitigating measures for road construction and influx of camp followers/service providers); and (iii) Transmission Line Impact Assessment and Environmental Management Plan (see REMDP, Section 2.1.5, discussion on the environmental and social impacts and mitigating measures for Transmission Line).

698. For the portions of the NN3 transmission line corridor that run through the Phou Khao Khouay (PKK) National Protected Area, the project will: (i) act in a manner consistent with the existing protected area management plans, (ii) consult with the NPA management, local communities, and other key stakeholders, and (iii) implement additional programs, as appropriate, to promote and enhance the conservation aims of the protected area (See Chapter 9).

699. Impacts that will occur during the operation phase will start in January, 2017. They were assessed in the EIA. An Environmental Management and Monitoring Plan for the Operation Period (EMMP-OP) shall be prepared not later than 6 months the start of the operations and will address issues that require attention and monitoring. All these sub-EMMPs will be updated when the detailed Environmental and Social Impacts Assessments for the project components are completed at later stages of the project.

X. GRIEVANCE REDRESS MECHANISM

700. Due to different perceptions, values, objectives and responsibilities among different stakeholders, a range of conflicts may occur among and between affected people, civil society, government authorities and the Company. This is even more the case where different development projects have adverse environmental and/or social impacts at the same locations on the same people. In addition, when impacts are felt as a consequence of illegal and/or unsustainable land and water uses in the area of the Project, the situation is even more complex as it is then difficult either to assign one responsible party, or to compensate at full replacement cost to the satisfaction of the land and water users.

701. The Company has taken the approach to have one single grievance redress mechanism covering both environmental and social issues. This was arranged like that to avoid unnecessary duplication of procedures, offices and efforts, and also because it might be difficult in some instances to differentiate a purely environmental impact to an environmental impact having social implication. For these reasons, the project will be following the procedures and mechanisms to redress grievances as these are presented in the GoL's Technical Guidelines on Compensation and Resettlement of People Affected by Development Projects of March 2010, as no guidelines specific to purely environmental issues are immediately available.

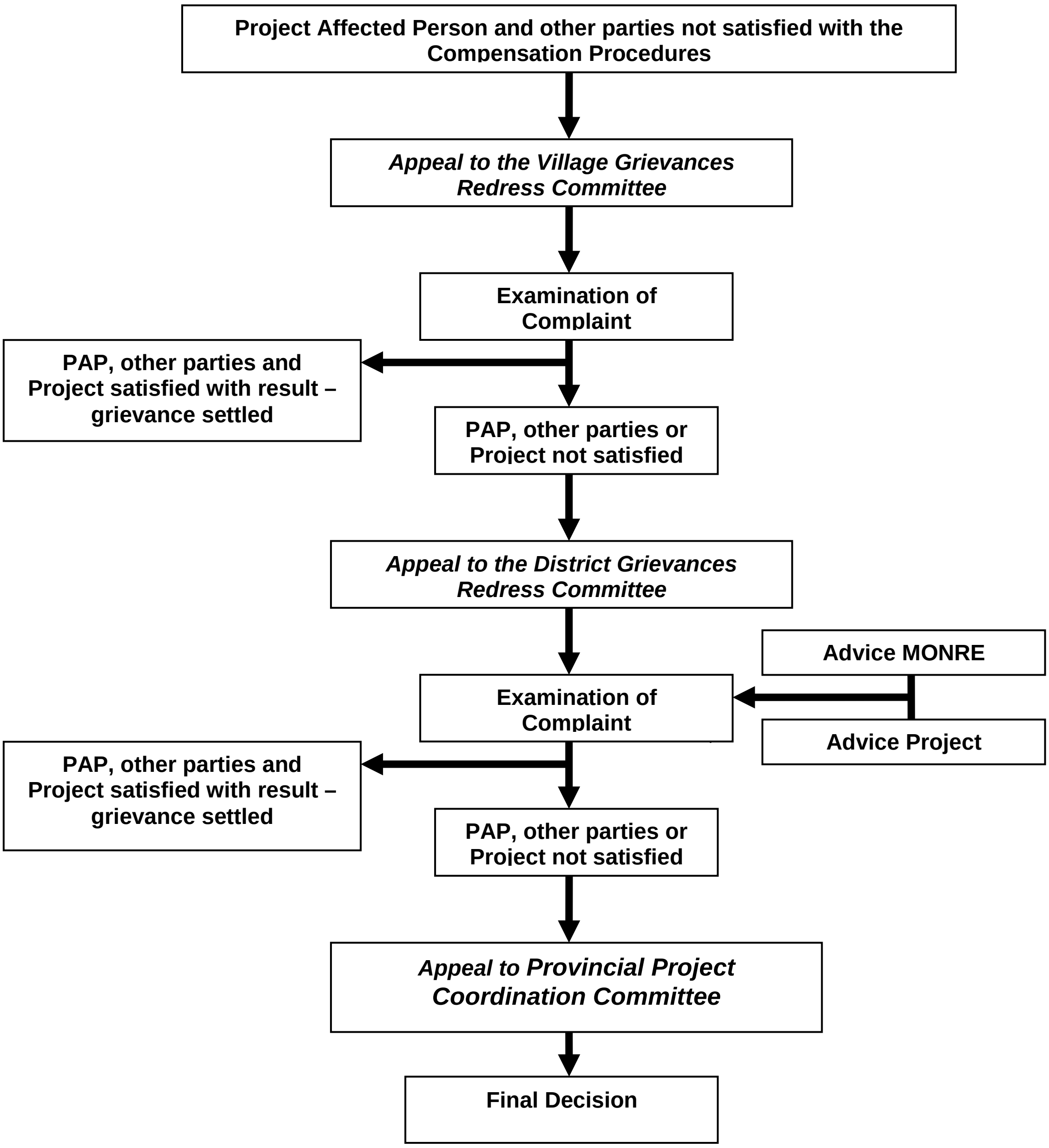
702. The phases of conflict development and appropriate interventions can be summarized as follows and are outlined in the flow chart on the next page (Figure 10.1):

- (i) Conflict avoidance Consultations, disclosures, participation in planning and decision making;
- (ii) Simple disagreements Informal negotiation, discussion and mediation;
- (iii) Early conflict development Reference to Village Grievance Redress Committee;
- (iv) Conflicting positions taken Reference to District Grievance Redress Committee; and
- (v) Conflicting positions hardened Reference to Provincial Grievance Redress Committee; and
- (vi) Intractable conflict Refer conflict to the Lao Court of Law.

703. To ensure that the basic rights and interests of project affected people and the civil society are protected, that their concerns are adequately addressed and that entitlements, when applicable, are delivered, a grievance procedure is outlined below. If an affected person or group is not satisfied with the resolution proposed, in some cases involving compensation, or if, for any reason, the compensation does not materialize, he or she has the right to make a claim.

704. The Environmental and Social Division (ESD) of NN3PC, through its EMO and SMO, should make every effort to find an amicable settlement to complaints or grievances brought by Project Affected Persons, and other parties. To pre-empt disagreements being referred to the Grievances Redress Committees at Village, District, and Provincial Levels, and ultimately to the Court of Law, the Project shall address complaints by Project Affected Persons, and other parties, through consultations conducted in a transparent manner to reach consensus at the project level.

Figure 10.1: Schedule whereby Grievances Redress Mechanism will be Applicable



705. All complaints and grievances relating to any aspects of the Project or sub project should be properly documented by ESD's EMO and/or SMO. If, the Project Affected Person or other another party is not satisfied with the decision at project level, the affected persons, other party can submit a formal complaint. The Grievances Redress Procedures will comprise the following steps.

706. The formal complaint will be examined by the Village Grievances Redress Committee, comprising village head, representatives of village authorities, village elders and/or representatives of mass organization, including Lao Women's Union. The meeting by the Village Grievances Redress Committee will be held in a public place allowing attendance by representatives of Project Affected Persons, local non-for-profit organizations, and Project representatives.

707. If the Village Grievances Redress Committee cannot resolve the complaint to the satisfaction of the Project Affected Person, other parties and/or the Project during the public meeting to be held within 15 days after formal receipt of the grievance, the next step can be taken, either by the claimant or the Village Grievances Redress Committee on his/her behalf. Representatives of affected people,

local non-for-profit organizations, and mass organizations may ensure that the complaints are forwarded to the Grievance Redress Committee at District Level.

708. Upon approval of the Project by the GoL and prior to start of the start of project activities, the project authorities will make a formal request to establish District Grievance Redress Committees in each District covered by the Project to address any complaints and grievances. The Grievances Redress Committees shall comprise the following representatives: (i) a local government representative, (ii) village head(s), (iii) representatives of the affected persons other than village heads, (iv) village elders or local representatives of mass organization, (v) representatives of local non-for-profit organizations, (vi) project owner representatives.

709. The GRC at village, district or provincial level as the case may be will conduct its own investigations and arrange to meet with responsible agencies including the Company, the claimant, and RMU and EMU as the case may be. NN3PC representatives will provide essential information to the committee members on inventories, entitlements, compensation, and prior activities undertaken for review of a particular complaint. Upon making its decision the GRC at village, district or provincial level as the case may be shall promptly inform the RMU and NN3PC of its decision. The Committees must maintain a public book showing all claims received and the decisions made.

710. If the affected people or party do not receive any response from the Grievances Redress Committee at District Level within 20 days of filing the complaint, or if the matter is not resolved to the satisfaction of the affected people and/or the Company representatives, the representatives of the affected people, local non-for-profit organizations, or mass organization on behalf of the affected persons will submit the complaint to the Provincial Resettlement and Livelihood Restoration Committee for examination and judgement in consultation with representatives of MONRE and NN3PC.

711. If the matter still remains unresolved within 20 days after filing the complaint to the Provincial Coordination Committee, the complaint will be forwarded to the Court of Law at the request of the affected people and/or at the request of the representatives of local non-for-profit organizations and mass organization on behalf of the affected people/parties. The Court of Law will follow up with relevant authorities to make the final and binding decision.

712. All administrative and legal costs incurred pursuant to the grievance redress procedures by affected persons or their representatives at Grievances Redress Committees at District Level, Project Head Office and MONRE, and the Court of Law will be covered by the Project in the cases that the Project has been found responsible for negligence. Claims of all such costs are to be submitted to the project authorities by the affected people. A copy of the claims should also be submitted to MONRE for record and information.

713. The independent monitoring agency will ensure that the grievances redress procedures is implemented appropriately and timely.

Table 10.1: Schedule whereby Grievances Redress Mechanism will be Applicable

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Grievances Related to Project Impacts during Construction	X	X	X	X	X	X				
Grievances Related to Project Impacts during Operation						X	X	X	X	X

XI. INSTITUTIONAL ARRANGEMENTS AND IMPLEMENTATION

A. Overall E&S organisation of the NN3PC

714. The NN3 Power Company will establish the Environmental and Social Division (ESD) responsible for implementing and coordinating all the environmental and social measures. The ESD will be headed by an E&S Manager who will report to the Project Manager, and at the same authority level as the Engineering and Construction Manager and the Administrative and Financial Manager. This person shall be responsible for the overall implementation of all environmental and social obligations set in the Concession Agreement, the Common Terms Agreement, the EIA, the REMDP and Action Plans describe therein, and the necessary interactions and coordination with the various parties, as shown on the overview of the institutional framework on Figure 11.1.

Figure 11.1: Overview of the institutional framework (environmental and social)

Coordination, Monitoring and Inspections, Grievances Redress	**NN3PC**	**GOL/Company shared implementation**	**GoL Responsible Parties**
1. Monitoring and Inspections 2. Capacity Building 3. Grievance Redress Procedures at district level and above 4. Nam Ngum River Basin Coordination, Including with Nam Ngum River Basin Committee, and/or Nam Ngum Basin Hydropower & Mining Forum 5. Coordination of Monitoring Outputs relating to other development projects in operation, under construction or in the planning phase, such as NN2, NN5, Phu Bia Mining, and NN4 A and B. 6. Coordination with GoL Line Ministries, involved in Integrated Watershed Management Planning and/or Implementation of NN3's Environmental and Social Measures: 7. Coordination with Line Ministries in Allocation of Concession Areas and Enforcement of Lao laws, rules, and regulations, particularly of sustainable use of natural resources, including water resources at Project Impact Areas	**ESD** (Environmental and Social Division) - **Environment Management Office** Implementing Environmental Programmes - **Social Management Office** Implementing Resettlement & relocation, infrastructure, livelihood, and social programmes and community liaison - **Administration, Information, Communication, Monitoring, Reporting, and Logistics Unit**	1. Clearance of Commercial Timber at NN3 Transmission Line Corridor 2. Vegetation Clearance of NN3 Reservoir 3. Integrated Watershed Management, Including (Re) Forestation and Biodiversity Conservation/ Protection 4. Upgrading and Maintenance Public Access Road from Xieng Nga to Ban Xiengdet Relocation Site 5. Upgrading and Maintenance Public Road from Nam Ngone to Long Cheng 6. Electricity Connection to Ban Xiengdet Houses, Public Buildings and Irrigation Pump Station 7. Public Health Centers at Nam Sam and Long Cheng 8. Education at Ban Xiengdet 9. Land Acquisition, Land Allocation, Land Titling 10. NN3 Reservoir Fisheries Management 11. Grievances Redress Procedures	**PROVINCES** **Provincial Resettlement and Livelihood Restoration Committee (PRLRC) by Provincial Authorities and MONRE** - Xieng Khouang Province- Vientiane Province -Vientiane Capital **DISTRICTS** **District Coordination & Grievances Redress Committees (DCC)** - Phou Kout, Xaysomboun Districts **PROJECT AFFECTED VILLAGES** Village Development Coordination & Grievances Redress Committees (VDCCs) & Village Focus Groups (VFC)

715. The ESD will consist of:

(i) the **Environmental Management Office**, dealing with all environmental issues, including in particular (i) the construction sites environmental, health and safety compliance, (ii) the UXO clearance, (iii) the water quality monitoring and management programme, including the biomass clearance programme, (iv) the integrated watershed management programme, and (v) an environmental monitoring laboratory and

(ii) the **Social Management Office**, dealing with (i) the resettlement and relocation programme, (ii) the infrastructure programme, (iii) the livelihood restoration programme, (iv) the social programme, and (v) community liaison.

716. There will be interactions between the EMO and the SMO.

717. The ESD will have three offices: (i) at the NN3 project office in Vientiane, (ii) in Xaysomboun District, and (iii) in Phou Kout District or Xiengdet village.

718. Table 11.1 presents the anticipated key staffing of the ESD. It does not include supporting consultants and staff, who will be provided under the various thematic programmes, and work under the supervision of the key ESD staff.

Table 11.1: Anticipated staffing of the ESD

Positions	# pre COD	# post COD
E&S Manager	1	1
Senior administrative assistant & GoL liaison officer	1	1
Administrative assistant	1	1
GIS Officer	1	1
HSE Manager	1	1
Administrative assistant	1	1
Environmental engineer	1	1
HSE inspectors	4	1
Environmental monitoring laboratory (WQ)	1	1
UXO Clearance supervision & coordination	1	0
Reservoir Biomass Clearance supervision & coordination	1	0
Social & Resettlement Manager	1	1
Deputy Social & Resettlement Manager & GoL liaison officer	1	0
Administrative assistant	2	1
Resettlement and relocation officers	4	2
Infrastructure officer (team leader)	1	0
Irrigation engineer (team leader)	1	0
Agriculture support & coordination officer (team leader)	1	1
Livelihoods support officer (team leader)	1	1
Fisheries support officer (team leader)	1	1
Social programme officer (team leader)	1	1
Health officer (team leader)	1	1
Community liaison & grievance officer	2	2

719. The Vientiane project office and the two field offices in Phou Kout and Xaysomboun Districts will also function as public information offices.

1. ESD Vientiane Office

720. In anticipation of the environmental and social impacts of the NN3 hydropower project within the Nam Ngum River Basin, GMS Lao, as one of the project sponsors, has recruited consulting firms to prepare, in compliance with the Safeguard Policy Statement of ADB, the EIA report and the REMDP, and to guide project E&S implementation activities and processes in line with these safeguards documents. The required consultations and information disclosures regarding the project involving key stakeholders held so far have been discussed in section 6 and in Annex B of the REMDP.

721. Key stakeholder engagement activities presently in the process include (i) the signing of the concession agreement between NN3PC and GoL, including the environmental and social obligations, (ii) the loan agreements by IFIs and other lenders, (iii) the awarding by NN3PC of the three main construction contracts, (iv) the opening of the NN3PC project office in Vientiane, and (v) the recruitment of project and ESD staff to monitor and supervise construction and implement the environmental and social measures, including surveying, monitoring, implementation, consultations, information disclosure, reporting, and stakeholder liaison to avoid, mitigate, minimize, compensate, and off set environmental and social impacts.

722. All five mentioned activities are presently in progress and are expected to be completed before main construction activities commence in October 2011. Key stakeholders include Design Engineers, Lenders, Lender s Technical Advisors, GoL, MONRE, Line Ministries, Provincial Officials, Project Steering Committee, villagers, shareholders of NN3PC, Board of Directors, Contractors, and NN3PC Project Management Staff.

723. From NN3PC Vientiane office, the overall E&S activities will be managed, including the recruitment of the ESD staff and consultants, human resource management, finance and administration. ESD will coordinate surveys, monitoring, consultations, information disclosure, GoL liaison, and report to stakeholders.

724. In addition, ESD Vientiane office will supervise and coordinate field activities to ensure that primary stakeholders, namely project affected households, are compensated in a meaningful, adequate, and transparent manner.

725. The ESD of NN3PC will open field offices at Xaysomboun and Phou Kout District from which the environmental and social measures on the ground, including participatory surveys, consultations and information disclosures will be implemented by staff to be recruited in 2011-12.

2. ESD Xaysomboun Field Office

726. From the field office at Xaysomboun District, ESD will monitor and supervise the environmental measures to be implemented by the contractors, monitor and supervise their occupational health and safety performance, monitor and implement the required community health and safety measures in coordination with the contractors, avoiding, mitigating, and minimizing project impacts and if necessary offsetting impacts and/ or compensating households affected during construction works during the period from October 2011 to January 2017. These monitoring, supervision, and compensation activities are related to (i) construction sites, (ii) public road from Nam Ngone to Long Cheng, (iii) camp followers, (iv) transmission line, and (v) access roads to power station and dam sites.

727. Key stakeholders will be the NN3 Project Management Staff, including construction supervisors, Contractors, project affected households, village authorities, kum ban and Xaysomboun District officials, and Provincial officials, as well as monitoring agencies including MONRE, IFIs, Lenders, and an Independent Monitoring Agency, as appropriate.

728. From the ESD field office at Xaysomboun District the field surveys, the monitoring activities, and the required consultations and information disclosures regarding project impacts during operation of the project will be implemented, as presented in further details in the REDMP.

729. Results of the monitoring activities by ESD from the field office of Xaysomboun District will be reported to key stakeholders as Village, District, and Provincial Authorities, but also to MONRE, IFIs and Lenders on a quarterly basis. However, analysis, reporting, and disclosure of the survey and monitoring results may be on an immediate and/or periodic basis; such will depend on the monitoring and supervision activities. For instance monitoring by ESD of the occupational health and safety measures to be implemented by the contractors might require immediate action, including reporting and information disclosure, while analysis and information disclosure of field surveys and monitoring of household fish catch will only be meaningful on the longer term as for instance one rainy season or one dry season, or even after one year. Accidents during construction will be reported immediately to MONRE and relevant Districts.

3. ESD Phou Kout Field Office

730. From the ESD field office at Phou Kout District (or Xiengdet village) the activities will be coordinated for Ban Xiengdet, and the peri-reservoir village of Nam Sam (See REMDP).

B. GoL Organisation

1. The various actors

731. MONRE is the GoL agency responsible for the administration of integrated water resource management and for regulating the sustainable development of water resources within the NNRB. The Nam Ngum River Basin Committee (NNRBC) with representatives of all relevant line ministries and provinces and the NNRB Secretariat run by MONRE's water resources department will be responsible to coordinate actual water resource management and integrated watershed management within the Basin. MONRE will establish an Environmental Management Unit (EMU). The EMU will monitor the Company's compliance with the Environmental Measures, Standards, Permits, and the various obligations of the Company under the Concession Agreement.

732. The Ministry of Agriculture and Forestry (MAF) is responsible for watershed management, through its Integrated Watershed Management Unit (IWMU). The IWMU under MAF, however, focuses more on forestry, agriculture (including irrigation), and fisheries within watersheds while the responsibility for sustainable water resources management and sustainable economic development in general is more a combined task that is the responsibility of different Line Ministries and GoL agencies.

733. Within the Nam Ngum River Basin, the Ministry of Defense has established military camps and provides security in special areas allowing limited public access. The Ministry of Transport and Public Works with Provinces and Districts have responsibilities for design, construction, and maintenance of public roads within the NNRB. The local area activities of both Line Ministries are related to water resources management through impacts by access to the use of natural resources, including water resources.

734. Within the NNRB most of the watersheds do cover concession and exploration areas of hydropower and mining projects issued by the Ministry of Energy and Mines.

735. The Nam Ngum River Basin Committee (NNRBC) has been set up and is the first River Basin Committee. NNRBC will facilitate integrated water resource management through its organizational structure involving representatives of all Line Ministries and relevant Departments, Provinces, Communities and relevant representatives of specific Development Sectors, as hydropower, mining, and agriculture. The NNRBC will have an important role in coordinating the interventions of the various projects, in resolving potential conflicts and sharing responsibilities.

2. GoL Responsibilities

736. Environmental and Social Measures, which are the responsibility of GoL include: (i) the removal of commercial timber from NN3 reservoir and the transmission line corridor, (ii) the management of a protected area or a biodiversity conservation area, (iii) the management of forestry

and fisheries, (iv) the development of institutional arrangements for coordination and cooperation with NN3, (v) providing secured land titles and certificates for replacement land, (vi) environmental and social monitoring and inspections, including endorsement, establishment, and management of grievance procedures, (vii) the arbitration and leading the process of conflict resolution, and (viii) securing water quantity and water quality of NN3 reservoir inflows.

737. A recently approved Prime Minister's Decree is the Decree on Environmental Impact Assessment, No 112/PM, dated 16 February, 2010 in which more attention has been given to social issues and where local and regional authorities, particularly Provinces, will obtain more responsibilities in environmental and social monitoring and inspections. The required increased involvement of the regional and local government agencies will allow NN3 to strengthen cooperation with the Provinces of Xieng Khouang and Vientiane, and the Districts of Phou Kout and Xaysomboun in coordination of environmental and social monitoring and inspections, including grievances redress procedures (see REMDP).

3. ADB Support to MONRE and NNRBC

738. The ADB has provided and continue to support MONRE and NNRBC in the field of building up the capacity of these institutions in their dealing of the integrated resources management, as detailed below, in particular in relation to hydropower development, construction and operation. It is expected that increased capacity will strengthen MONRE and NNRBC in their roles vis-à-vis the Nam Ngum 3 project in particular and the coordination of the hydropower projects in general, but also in their dealing of water quality monitoring and management issues.

739. Technical Assistance to the Lao PDR for Updating the National Water Resources Policy and Strategy. Manila (TA 7013-LAO, 12 December 2007, US$1.0M, including US$0.8M cofinanced by the Government of Australia).

740. Loan 1933-LAO ($ 17M ADF; 2004-Q1 2011; 7 years) Nam Ngum Basin Development Sector Project: The Nam Ngum Basin Development Sector Project had three main components: (i) Integrated Water Resources Management, (ii) reservoir management and river basin modelling, and (iii) watershed management.

741. Loan 1933-LAO, Nam Ngum Basin Development Sector Project (Additional Financing for $5M for 5 years). This project is still at the identification stage (concept review meeting, 13 May 2011). This additional financing is for (i) the support and upgrading of the Nam Ngum River Basin Secretariat for sub-basin river management, (ii) watershed management at provincial and district level with agricultural extension system for crop, livestock, and forest sustainability, and (iii) effective project management.

742. Technical Assistance (TA 7780), National Integrated Water Resources Management Support Project (Cofinanced by the Government of Australia and the Spanish Cooperation Fund for Technical Assistance). This project was approved in February 2011 for an amount of US$3.9M for 4 years. It will contribute to the implementation of the National Integrated Water Resources Management Support Program to support capacity building in MONRE and the new Nam Ngum River Basin Committee (NNRBC) and its secretariat. It will assist the government to: (i) establish gender-responsive professional development programs for MONRE staff; (ii) implement appropriate governance systems for project management, monitoring, and evaluation; (iii) establish institutional arrangements for river basin management; (iv) provide updates on the inventory of water resources and their utilization; and (v) assist the development of formal university education in IWRM at the National University of Lao (NUOL).

743. RETA 6498: Pilot demonstration activity for Building Private Sector Participation in River Basin Management – The Case of Nam Ngum River Basin, Lao PDR (Ongoing, September 2010, $38,000). This PDA has a specific focus on involving hydropower and mining concession operators in the preparations for the NNRBC meetings. The PDA is assisting the NNRBC to facilitate the participation of the private sector in river basin management through the formation of the Nam Ngum Hydropower and Mining Forum, which will have the following roles and functions:

(i) Serve as a mechanism for the Government to communicate policies, laws etc. on sustainable hydropower management to hydropower producers;
(ii) Facilitate communication by these producers to Government on a range of water and environment-related issues in the hydropower sector;
(iii) Exchange information and promote cooperation between hydropower producers;
(iv) Promote awareness of water, environment and hydropower among stakeholders;
(v) Promote implementation of government policies, laws etc.

744. **TA 7588: Strengthening Water Quality Management and Monitoring** in the three sub-basins of Nam Ngum 3 (Phai-Kamang, Nam Po- Nam Souy and Ting-Chat). The concept was approved and proposal will be developed in 2011 for submission to RSDD. Maximum budget is US$250,000 for 2012-2013. MONRE and NNRBC have agreed to develop the proposal jointly with ADB in 2011, starting with a concept note for submission to RSES for approval. The proposed country safeguards strengthening TA on Strengthening Water Quality Management and Monitoring in the three sub-basins will serve as a pilot program to develop a water quality monitoring and management framework and action plan including selection of parameters and sampling stations, frequency of monitoring, methods of water analyses, and a monitoring and surveillance water quality database. This will facilitate coordination of monitoring activities by government, various developers and stakeholders so that timely remedial measures could be provided for potential water pollution of water resources.

4. GoL Organisation at the local level

745. GoL organizational levels will consist of (1) the Provincial Resettlement and Livelihood Restoration Committee (PRLRC), (2) the District Coordination Committees (DCCs), (3) the Grievance Redress Committees at the Provincial, District and Village levels (GRCs), and (3) the Village Development Coordination Committees (VDCCs).

a. Provincial Resettlement and Livelihood Restoration Committee

746. The PRLRC shall be appointed by GoL as per the PM Decision on its establishment. Its responsibilities will be as follows:

(i) Overseeing and monitoring the planning and implementation of the Social Measures;
(ii) Controlling and supervising the planning and implementation of the Social Measures;
(iii) Giving instructions to RMU, DCCs, and VDCCs in relation to the implementation of Social Measures.
(iv) The PRLRC's geographical scope of work will include all areas impacted by the Project.

b. Resettlement Management Unit (RMU)

747. A single RMU will be established for the Project, by the PRLRC and in cooperation with MONRE. It will act as the Secretariat for the PRLRC and its implementing body.

c. District Coordination and Grievance Redress Committees

748. The DCCs and GRCs shall be established by the PRLRC and work under their supervision and the one of the Resettlement Management Unit of GOL. Their main responsibility will be the implementation of the resettlement and livelihood restoration activities.

d. Village Development Coordination Committees

749. The VDCCs shall be established by the DCC and their main function will be to implement the resettlement and livelihood restoration works under the supervision and instruction of the DCC and the RMU.

e. Central Environmental Management Unit

750. A central level Environmental Management Unit will be established within MONRE (Department of Environmental and Social Impact Assessment) to monitor the implementation of the EMMP (directly and /or with the assistance of the Independent Monitoring Agency), deal with the environmental grievances, review the various reports to be prepared by the Company and cooperate with the central and line ministries in relation to the proper implementation of the EMMP.

f. Provincial and District Environmental Units

751. Provincial and District Environmental Management Units will be established in both provinces and in the concerned districts with the responsibility to monitor, inspect, and report the implementation of the EMMP.

C. Construction Contractors

752. The three main contractors are required to establish their Environmental and Social Management and Monitoring Units with highly qualified staff ensuring compliance by the contractors and their sub contractors with the Environmental, Health, and Safety Guidelines of the International Finance Cooperation. The ESMMU's will also need to enforce the environmental and social regulations included in the contracts of their employees and sub contractors.

D. Coordination & roles of the various parties

753. The overview of the institutional framework is presented on figure 9.1 above. The activities of the various parties will need to be synchronised with important project milestones (signature of the Concession Agreement, Financial Close, start of Preliminary Construction Activities, award of main construction contracts) and the schedule, and progress, of construction activities. Detailed implementation schedules (Gantt charts) will be prepared in 2011, and other ad-hoc schedules will be developed for activities that will be implemented before this.

754. The actual fieldwork by ESD in the villages, including surveys, monitoring, and compensation activities will be reported during regular meetings with the Provincial Resettlement and Livelihood Restoration Committee (PRLRC), District Coordination Committees (DCC's), and Village Development Coordination Committees (VDCC's).

755. In the case of Xaysomboun District and Phou Kout District, NN3 is working presently with the District's Kum Ban representatives and Village authorities in the field during additional consultations and planning meetings. NN3 is reporting at Provincial and District Level regarding the outcome of these consultations and meetings.

756. MONRE at central and provincial levels and the Provincial Resettlement and Livelihood Restoration Committee (PCC) will coordinate the involvement of GoL's Line Ministries through the Nam Ngum River Basin Committee (NNRBC) and its Secretariat. The Integrated Watershed Management Activities, including reforestation and biodiversity protection/conservation to be implemented by the Ministry of Agriculture and Forestry will be overviewed by the NNRBC.

757. Other coordination activities by the NNRBC and its Hydropower and Mining Forum will be sought for:

- (i) Agreeing a common grievance framework to address multiple and overlapping impacts, or opportunistic claims to obtain compensation from several different parties;
- (ii) Agreeing common indicators and process for monitoring water quality and fisheries;
- (iii) Early flood warning system and emergency evacuation planning related to dam safety of the cascade of hydropower projects in Nam Ngum River Basin;
- (iv) Agreeing budget allocations to pay for these activities.

758. In addition to the grievances redress mechanism and procedures presented in section 11, a number of activities will be implemented by GoL agencies with support and in coordination by ESD: (i) salvage logging of commercial timber in the transmission line corridor, (ii) biomass clearance of the NN3 reservoir, (iii) upgrading and traffic management of the public access road from Xieng Nga to Ban Xiengdet, (iv) upgrading and traffic management of the public road from Nam Ngone to Long Cheng, (v) upgrading health centers and capacity building of health workers at Long Cheng and Nam Sam, (vi) education at Ban Xiengdet, (vii) land acquisition, land allocation, and land titling at Ban Xiengdet and for the transmission line corridor, (viii) NN3 reservoir fisheries management.

XII. BUDGETS

759. The environmental and social budgets of the NN3 project total US$22M before the commercial operation date (COD) and US$10.2M after COD, i.e. a total of US$32.2M.

A. The Environmental Budget

760. The environment budget is organized around the following programmes: (i) the monitoring of the health, safety and environmental protection undertaken by the construction contractors, (ii) the integrated watershed management, (iii) the water quality monitoring and management, and (iv) the construction social management plan.

761. Table 12.1 shows the distribution of the budget over the different programmes and provide some information on the nature of the activities involved. More details are provided in Section 10, and for the Construction Social Management Plan, in the REMDP. The environmental budget totals US$7.88M before COD and US$5.37M after COD, i.e a total of **US$13.2M**.

Table 12.1: Environmental Budget

		E & S Budget pre COD (5 years) US$	**E & S Budget post COD (4 years) US$**	**Total E & S Budget US$**
1	**ESD & EMU OVERALL MANAGEMENT, COORDINATION, AND COMMUNICATION**	**5,247,400**	**2,404,450**	**7,651,850**
1.1	Overall management of ESD & shared resources (personnel, offices, transport)	735,900	446,200	1,182,100
1.2	Health, Safety & Environmental Protection (all HSE programmes) (personnel, offices, transport)	2,019,000	817,000	2,836,000
1.3	Office, public information centers, accommodation, equipment, vehicles, boats, communication, food, …	1,262,500	631,250	1,893,750
1.4	EMU budget (central, provincial and district levels)	375,000	125,000	500,000
1.5	EMU monitoring and inspection	105,000	35,000	140,000
1.6	Annual contribution to the Environmental Protection Fund	250,000	200,000	450,000
1.7	Independent Monitoring Agency	500,000	150,000	650,000
2	**INTEGRATED WATERSHED MANAGEMENT**	**1,000,000**	**2,600,000**	**3,600,000**
2.1	Support for environmental improvement activities in the NN3 catchment area with emphasis on reforestation and biodiversity conservation and protection securing the water quantity and quality on NN3 reservoir inflows and off-setting the NN3 impacts of the reservoir (flooding of forested area) and land take by the transmission line. Access to NTFP by peri-reservoir & downstream communities will be secured.	1,000,000	2,600,000	3,600,000
3	**WATER QUALITY MONITORING AND MANAGEMENT PLAN**	**1,340,000**	**350,000**	**1,690,000**
3.1	Demarcation of the limits of the reservoir at Full Supply Level (FSL).	50,000	0	50,000
3.2	Inventory of the soft vegetative biomass below FSL.	50,000	0	50,000
3.3	Preparation of a salvage logging management plan of the reservoir (below FSL)	90,000	0	90,000
3.4	Preparation of a soft vegetative biomass removal plan in the reservoir	50,000	0	50,000
3.5	Clearance of Soft Vegetative Biomass below FSL of Reservoir (including procurement of equipment required, necessary boat landings, access tracks).	500,000	0	500,000

		E & S Budget pre COD (5 years) US$	E & S Budget post COD (4 years) US$	Total E & S Budget US$
3.6	Monitoring of Water Levels, Water Discharges, and Water Quality (including NN3PC set up of basic WQ monitoring).	500,000	300,000	800,000
3.7	Clearance of Debris from Reservoir.	100,000	50,000	150,000
4	**CONSTRUCTION SOCIAL MANAGEMENT PLAN**	**290,000**	**20,000**	**310,000**
4.1	Preparation of a camp service providers management plan (Objective is to regulate and control the influx of camp service providers to ensure proper health and hygiene conditions, guarantee proper water supply, management of liquid and solid wastes, prevent and forbid hunting, trade and consumption of wildlife, human trafficking)	80,000	0	80,000
4.2	Support to Vientiane Province and Xaysomboun District in managing the camp followers, health and human trafficking	80,000	20,000	100,000
4.3	Preparation & dissemination of a code of conduct applicable to all workers, camp followers, staff of the Company and contractors & visitors	30,000	0	30,000
4.4	Overall environmental and social awareness in the project areas (health, human trafficking, unsustainable use of natural resources, PCR)	100,000	0	100,000
	TOTAL BUDGET	**7,877,400**	**5,374,450**	**13,251,850**

B. The Social Budget

762. The social budget is organised around the following programmes: (i) the Public Health plan, (ii) the Ban Xiengdet resettlement and development plan, (iii) the peri-reservoir and downstream action plan, and (iv) the management of the social impacts of the transmission line and the new and upgraded public road and associated resettlement action plans.

763. The total social budget amounts to US$18.9M and is distributed for the programmes and over time as shown on Table 12. 2. The public health action plan will be coordinated with the health activities to be undertaken by the construction contractors.

Table 12.2: Overall Social Budget (in US$)

		pre COD (5 years)	post COD (4 years)	Total
1	ESD & RMU overall Management, Coordination and Communication	4,727,600	2,706,450	7,434,050
2	Public Health Action Plan	880,000	350,000	1,230,000
3	Ban Xiengdet Resettlement and Development Plan	7,128,000	906,000	8,034,000
4	Peri-Reservoir & downstream Action Plan	550,000	898,000	1,448,000
5	Management of the Social Impacts of the TL & New/Upgraded Public Roads	837,000	0	837,000
	Total Social Budget	**14,122,600**	**4,860,450**	**18,983,050**

C. Reallocation of Funds, Updates of Budgets and Disbursement of Funds

764. A number of costs have been estimated on the basis of the information available at the time of the preparation of the EIA. It is expected that the cost associated with some measures may change. Although a provision was always made when the budget was prepared, it is possible that budgets allocated prove to be either under-estimated or over-estimated. The Company will propose twice per

year an update of the overall environmental and social budget with suggestions on the way to reallocate funds. These suggestions will have to be approved by GoL and the IFIs.

765. For activities that will be implemented by GoL agencies, the Company shall disburse the funds in annual instalments in the first month of each fiscal year (i.e. after October 1) in accordance with a budget plan prepared and submitted by the GoL agency to the Company and in accordance with a mechanism to be advised. Payment shall be made by cheque or bank transfer in accordance with the written request for disbursement. No payments shall be made in cash or to the personal accounts of GoL agencies employees or on their behalf. The Company shall receive an official GoL receipt for the funds provided.

766. The GoL agencies having received the funds shall undertake internal audits of the implementation of the Annual Work Plan and management and use of the funds every 6 months. The non-personnel costs of these audits shall be included in the annual budget request to the Company. A copy of the internal audit report shall be made promptly available to the Company.

767. The GoL agencies shall also arrange for annual external auditing of the management and use of the funds in accordance with international auditing standards. The external audit shall be undertaken by the State Audit Agency at no additional cost to the project. Should the State Audit Agency be unable to undertake the audit, the GoL agencies shall arrange with the State Audit Agency for a local firm of auditors to undertake the audit, the cost of which shall be included in the annual budget request. A copy of the draft audit report shall be forwarded to the Company for comment prior to the final version being issued.

XIII. MONITORING AND REPORTING

A. Adaptive Management

1. Adaptive management approach

768. Adaptive management is a structured, iterative process of optimal decision making in the face of uncertainty, with an aim to reducing uncertainty over time via system monitoring.

769. In this way of system monitoring, decision making simultaneously maximizes one or more resource objectives and, either passively or actively, accrues information needed to improve future management. Adaptive management is a tool which should be used not only to change a system, but also to learn about the system. Because adaptive management is based on a learning process, it improves long - run management outcomes. The challenge in using adaptive management approach lies in finding the correct balance between gaining knowledge to improve management in the future and achieving the best short - term outcome based on current knowledge.

770. Adaptive management requires an open management process which seeks to include past, present and future stakeholders. Adaptive management needs to at least maintain political openness, but usually aims to create it. Adaptive management must therefore be a scientific and social process. It must focus on the development of new institutions and institutional strategies in balance with scientific hypothesis and experimental frameworks.

771. Key features of adaptive management are:

(i) Iterative decision-making (evaluating results and adjusting actions on the basis of what has been learned);
(ii) Feedback between monitoring and decisions (learning);
(iii) Explicit characterization of system uncertainty through multi-model inference;
(iv) Embracing risk and uncertainty as a way of building understanding.

772. Adaptive management initially applied in fishery management received more broad application in the 1990s and 2000s. Adaptive management functions as a systematic process for improving environmental management policies and practices. The adaptive management framework is also applied to other sectors seeking sustainability solutions such as community development. Adaptive management as a strategy emphasizes the need to change with the environment and to learn from doing. Adaptive management applied to natural resources, and the use of the natural resource base makes overt sense when considering ever changing environmental conditions caused by population growth, climate change, and development activities.

2. Adaptive management for the NN3 project

773. The flexibility and constant learning of an adaptive management approach is also a logical application for organizations seeking sustainability methodologies. Projects such as NN3, pursuing sustainability strategies employ an adaptive management framework to ensure that the organization is prepared for the unexpected and geared for change. During the development phase, consultants have set up the general environmental and social framework for the developer and later the Company based on the requirements and agreements by GoL and the IFIs will implement the various measures and programmes. By applying an adaptive management approach the projects begin to function as an integrated system adjusting and learning from a multi-faceted network of influences not just environmental but also economic and social. The goal of the Project guided by adaptive management principals is to engage in active learning to direct change towards sustainability.

774. Sustainable community development requires recognition of the relationship between environment, economics and social instruments within the community. An adaptive management approach to creating sustainable community policy and practice also emphasizes the connection and confluence of those elements. Looking into the cultural mechanisms which contribute to a community value system often highlights the parallel to adaptive management practices with an emphasis on

feedback learning, and its treatment of uncertainty and unpredictability. There are no such things as environmental or social baselines at communities that are relying much on use of natural resources due to population growth, climate change, and development activities.

775. By applying an adaptive management approach to community development the resulting systems can develop built-in sustainable practice. Active adaptive management views policy as a set of experiments designed to reveal processes that build or sustain resilience. It requires a social context with flexible and open institutions and multi-level governance systems that allow for learning and increase adaptive capacity without foreclosing future development options.

776. Changes in environmental and social policies are required to increase the opportunities for sustainable use of natural resources and to avoid the marginalization of project affected households, women, ethnic minorities, and vulnerable groups. Best environmental and social practices do change with the learning curve. Policies, standards, regulations, and compensation unit rates need regular updates.

777. This approach will be necessary to deal with unanticipated impacts.

3. Adaptive management for the integrated management of the Nam Ngum river basin

778. Environmental changes due to climate change, population growth, and cumulative impacts of different development projects within one watershed put pressure on the natural resource base generally utilized by the poor. Many uncoordinated development activities within one river basin may have significant impacts on the natural resource base utilized by many people in the Nam Ngum River Basin. Integrated watershed planning and river basin management planning do form an important part of sustainable management of water resources.

779. Adaptive management by the project recognizes and deals with risks and uncertainty through long term monitoring and regular analysis not only of the resettlement process itself, but also of the changes in environmental and social background resulting from overlap of environmental and social impacts by the Project and by neighboring hydropower and mining projects.

780. The Project's intention is to work closely with the Nam Ngum River Basin Committee (NNRBC), its Secretariat and its Hydropower and Mining Forum which are currently being established under the auspices of MONRE. Where impacts can unambiguously and directly be attributed to NN3, the developer will be fully responsible for compensation and mitigation measures. There are 5 areas where it is important for NN3 to work with other concessions holders (Hydropower and Mining Forum) and with the NNRBC and its Secretariat in the Nam Ngum River Basin:

- (i) Agreeing a common grievance framework to address multiple and overlapping impacts, or opportunistic claims to obtain compensation from several different quarters;
- (ii) Agreeing common indicators and process for monitoring water quality and fisheries;
- (iii) Nam Ngum River Basin Dam Safety Risk Assessment and Emergency Preparedness and Response;
- (iv) Cooperating on integrated watershed management for the long-term protection of the reservoirs against rapid sedimentation and potential pollution of reservoir inflows, and agreeing budget contributions for this purpose.
- (v) Agreeing budget allocations to pay for these activities.

781. Without adaptive management and coordination by multi-level governance systems that allow for learning and increase adaptive capacity, the environmental, resettlement, compensation, and social development activities by the many hydropower and mining projects within the Nam Ngum River Basin will be difficult to implement. Approaches to activities and allocation of budgets for the environmental and social measures to be implemented by each different development project in a watershed, sub-basin, and/or a river basin do need guidance and coordination, but may also need instructions and enforcement in many cases.

782. NN3 has allocated annual budgets to MONRE to increase its efforts in coordinating the multi-level governance systems within Nam Ngum River Basin by the Nam Ngum River Basin Committee, its Secretariat, and its Hydropower and Mining Forum. NN3 is embracing risk and uncertainty as a way of building understanding. However, through NNRBC's and NN3's adaptive management and system monitoring, risks and uncertainties will be reduced in time.

783. During monitoring and subsequent analysis it may turn out that the environmental and social impacts assessments of the project will require updating. It is therefore necessary that the environmental management plans and the social action plans contain confirmation surveys as well as different monitoring activities to better assess the actual adverse, but also the positive project impacts. Instead of marginalizing project-affected persons, the project aims to fully compensate project affected people, but also to implement development measures. Resulting from the updates of environmental and social impact assessments, the actual mitigation, offsetting, and compensation measures may need to be adjusted, which may need to be reflected in the presently allocated budgets and financing for these measures.

B. Monitoring and Reporting by NN3PC & other parties

784. Monitoring arrangements proposed for the NN3 projects have been discussed at several occasions in consultation with the various parties involved: the persons affected by the project, the Company, the GoL, IFIs and the lenders. The objective was to find the most efficient way to monitor and report progress and compliance with obligations, without burdening unnecessarily any of the parties, disrupting project activities and creating a counterproductive monitoring and reporting fatigue.

785. The proposed reporting arrangements related to environmental and social issues are presented in Table 13.1.

Table 13.1: Proposed reporting arrangements

Report & documents	Source	Frequency (times/year)	Disclosure
E&S Project Progress reports	NN3 PC	4 during construction, 2 during operation	Yes
Annual Implementation Plan	NN3 PC	1	Yes
Project specific reports	NN3 PC	As required	By request to NN3PC/GoL
	IFI funded TA	As required	Yes
Updated safeguard documents (i.e. REMDP for each project component)	NN3 PC	As required	Yes
Independent Monitoring Agency (IMA) Report	IMA	2[a]	Yes

[a] IMA will review the quarterly reports and other pertinent information, and submit semi-annual reports.

1. Monitoring by ADB and other Lenders

786. Representatives of ADB and lenders will be involved in regular field visits to monitor the project's progress in implementing environmental and social measures. Prior notice will be provided to the project before field visits. ESD's field staff will provide further information of specific local environmental and social activities and help to coordinate interviews with contractors' representatives, village authorities, and project affected households, if required.

2. Monitoring & inspections by MONRE

787. MONRE will have the possibility to carry out inspections at any time, by giving ESD at least one day notice prior to field visits and will be accompanied in the field by at least one representative of ESD.

788. MONRE and ESD will have meetings after the monitoring and inspections in the field to discuss the recommended improvements to be made in the implementation of environmental and social measures. The outcome of the discussions during these meetings will be reported by ESD in its monthly reports.

3. Other Monitoring and Visitors

789. Organizations and/or officials who want to monitor the project and /or project construction, rather than the environmental and social issues related to the project will be guided by the public relations division of NN3 Power Company, which might involve discussions from ESD staff.

790. These monitors and/or other visitors can make use of the public information centers to be set up by ESD at Vientiane and the Districts offices of Phou Kout and Xaysomboune, where environmental and social documents regarding NN3 can be reviewed. Annual monitoring and progress reports will be made available, as will be additional project information.

4. Coordination of all environmental and social site visits by the ESD

791. All field visits by any monitor, inspector and visitor shall be coordinated by ESD to minimise disturbance to households as well as disruption to project activities.

5. Internal monitoring and reporting by NN3PC

792. Starting from the beginning of construction phase in 2011, the Environmental and Social Division (ESD) of NN3PC will report to GOL, MONRE, ADB and other Lenders and to the Lender Technical Adviser on a monthly basis. This reporting will cover the various environmental and social activities undertaken during this period and related to the implementation of the active environmental and social programmes. It will present progress against the schedules and milestones set, identify potential difficulties and corrective measures taken, and present the results of its own monitoring against the obligations set in the Concession Agreement.

a. NN3PC monitoring of construction activities

793. NN3 ESD will undertake, on a daily basis, a compliance monitoring of the contractors' environmental and social activities *as per* the IFC Environmental, Health, and Safety guidelines, the approved Environmental Management and Monitoring Plan, sub-plans and Site Specific Environmental Plans to be prepared by the Contractors. The contractors are also required to report to the Company about their progress, their monitoring system, and their monitored data on a monthly basis.

b. NN3PC monitoring of operation activities

794. The environmental and social impacts that will occur during the operation phase have been assessed in the NN3 Environmental and Social Safeguards documents. These will be regularly updated, in particular before the start of the operations through confirmation surveys. An Environmental Management and Monitoring Plan specific to the operations phase shall also be prepared before the COD. It shall cover the issues that will require particular attention and monitoring.

c. NN3PC monitoring of water quality

795. The project's water quality monitoring program linked to the monitoring of reservoir water levels and water discharges by NN3 power station is described above. This water quality monitoring program takes into consideration the water quality of inflows into NN3 reservoir, the potential for fisheries in the NN3 reservoir, and opportunities for uses of water and aquatic resources at downstream locations. The water quality monitoring program starts in 2011 sampling water quality on a monthly basis. The program will continue till the rainy season of 2016, after which extra water quality sampling points in the reservoir and downstream locations will be added and the sampling frequency for crucial water

quality parameters will be increased. The monthly reports by ESD will include the measured water quality parameters and sampling points. Analysis of the water quality data will be on a bi-annual basis (dry and rainy seasons).

d. Fish catch monitoring programme

796. A participatory household fish catch monitoring program will be established in Ban Xiengdet, Long Cheng, and Xam Thong not only to be able to measure the project impacts on household fish catch, but also to identify the interest of project affected households in reservoir fisheries. This program is proposed to involve the 5 best fishers in each village administering their daily fish catch by filling in forms. During bi-annual group interviews in each of the 3 villages the obtained data will be discussed to confirm fishing grounds, fishing methodologies (including destructive fisheries), fishing efforts, and any changes that may occur in household fish catch. Additional household income surveys will be carried out, separating the project affected village areas and non-affected village areas where households do obtain cash and imputed income from fisheries, collection of NTFP's, and hunting. These monitoring activities and surveys will be carried out at least twice before the wet season of 2016, enabling appropriate cash compensation to affected households, if such appears to be required from information obtained during surveys and monitoring activities. The monthly ESD reports will include the outcome of household fish catch monitoring, bi-annual group meetings, and household income surveys starting in 2011.

797. At the downstream villages and the upstream villages surveys are required to confirm if any project impacts can be expected on household fish catch after the rainy season of 2016. If during the village surveys that will be held at all upstream and downstream villages starting in the dry season of 2012 – 2013 it can be concluded that households may be impacted in their household income (trade and consumption of fish) a household fish catch monitoring program will be set up at the villages that will be similar to that monitoring program proposed for Ban Xiengdet, Xam Thong, and Long Cheng. If, during monitoring activities it may turn out that the proposed monitoring schedule and/or targeted fishing households will need adjustments then this will be reported. These household fish catch monitoring activities and surveys will be carried out twice before the wet season of 2016, enabling appropriate cash compensation to affected fishing households, if such appears to be required from information obtained during surveys and monitoring activities.

e. Monitoring and reporting of water levels in the NN3 reservoir

798. By making available the water levels of NN3 reservoir as well as the Nam Ngum River water discharges downstream of the NN3 power station on a daily basis, the downstream hydropower projects of NN2 and NN1 will have the opportunity to anticipate inflows to their reservoirs and therefore optimize their reservoir management reducing spills over the dams and reducing adverse impacts by flooding at the Vientiane plains. This will be enhanced if other hydropower projects in Nam Ngum River Basin make available their downstream discharges allowing for strengthening the basin wide hydrological model to better anticipate and predict possible changes in reservoir inflows due to rainfall, potential natural disasters (especially caused by typhoons), and climate change. Reliable weather forecasts that include rainfall prediction on longer term than 1 or 2 days will also contribute much to reservoir management optimization, reducing spills over dams. Such reporting will be required after the COD and the Nam Ngum River Basin Committee has established their policy, including an early flood warning system at Vientiane plains and emergency evacuation planning related to dam safety of the cascade of hydropower projects in Nam Ngum River Basin.

C. Independent Monitoring

799. The Independent Monitoring Agency will include well qualified experts in environmental and social monitoring and will have the objective to ensure compliance of the Company activities with its environmental and social contractual obligations. This monitoring will be undertaken mainly for GOL agencies, IFIs, lenders, and the general public. Project affected people, however, do not need to fully rely on independent monitoring as they have opportunities to use the grievances redress mechanism presented above.

800. Independent monitors will not start their own field surveys or their own monitoring system in the field, but will focus on (i) improvement of the project monitoring activities, (ii) improvement of environmental and social measures to be implemented by ESD, (iii) improvement to be made in the grievances redress procedures to be implemented through the Project, and (iv) compliance with agreed entitlements and other obligations.

801. The independent monitors will receive the NN3PC monthly progress reports. The team will visit the different project sites during the construction and operation phase of the project on a bi-annual basis. ESD's field staff will provide further information of specific local environmental and social activities. The field visits should not interfere with ongoing construction activities or ongoing resettlement activities, and ESD will help to coordinate interviews with contractors' representatives, village authorities, and project affected households, as required.

802. After the field visits, joint meetings will be held with representatives of ESD, GoL agencies, including MONRE, IFIs and the lenders, during which the independent monitors will make presentations on their findings, including recommending meaningful improvements in the implementation process of environmental and social measures to be followed up by discussion between the parties involved in monitoring and implementation of activities. Minutes of the meetings will be made by ESD and included in the relevant monthly reports to the parties.

D. Disclosure of Monitoring Reports

803. Six-monthly monitoring reports of the Independent Monitoring Agency will be made available for public disclosure, either on the project's website, or that of MONRE, and on applicable IFIs website as indicated on Table 13.1. Other reports for public disclosure include Annual Project Implementation Reports and updated safeguards documents.

Annex A

LIST OF REPORTS PREPARED BY RESOURCE MANAGEMENT AND RESEARCH (RMR), 1999 - 2001

ANNEX A
LIST OF REPORTS PREPARED BY RESOURCE MANAGEMENT AND RESEARCH (RMR), 1999 - 2001

Nam Ngum 3 Draft Social Action Plan & Environmental Management Plan
Target Objectives & Recommended Modalities
Final Report – Part 1
SECTION 1 Introduction
SECTION 2 The Impact Analysis, the Work Programme
and an Outline of Study Findings
SECTION 3 Modifications of Project, Impact Events and Social and Environmental Consequences and Causes – an Overview

Nam Ngum 3 Draft Social Action Plan & Environmental Management Plan
Target Objectives & Recommended Modalities
Final Report – Part 2
SECTION 4 Catchment Impact Sector
SECTION 5 Reservoir Impact Sector
SECTION 6 Downstream River Impact Sector
ESSENTIAL INFORMATION
Essential Information about Catchment Impact Sector
Essential Information about Reservoir Impact Sector
Essential Information about Downstream River Impact Sector

Nam Ngum 3 Draft Social Action Plan & Environmental Management Plan
Target Objectives & Recommended Modalities
Final Report – Part 3
SECTION 7 Access Road Impact Sector
SECTION 8 Power Transmission Line Impact Sector
SECTION 9 Construction Sites Impact Sector
ESSENTIAL INFORMATION
Essential Information about Access Road Impact Sector
Essential Information about Power Transmission Line Impact Sector
Essential Information about Construction Sites Impact Sector

Nam Ngum 3 Draft Social Action Plan & Environmental Management Plan
Target Objectives & Recommended Modalities
Final Report – Part 4
SECTION 10 NN3D's Obligations and Interests
SECTION 11 Participation by Affected Stakeholders
SECTION 12 Interests of Concerned Stakeholders
SECTION 13 Positive Consequences

NAM NGUM 3 SOCIAL ACTION PLAN ENVIRONMENTAL MANAGEMENT PLANS
Chapters in separate volumes.

No.	Chapter Title
1	Work Programme For Critical Information Investigations, Social Action Plan & Environmental Management Plan
3	NN3 Reservoir Silt & Catchment Erosion Master Plan
4	Bed Degradation & Bank Erosion Monitoring Plan
5	Evaluation of Silt Control Benefits
6	NN River Water Quality Management Master Plan, Water Quality Model
7	Final Evaluation of the Riparian Release Option
8	Final Evaluation of Re-Regulating Reservoir Option
9	Downstream River Substitute Habitat Conservation Plan
10	Downstream River Rare Species Preservation Plan
11	NN Reservoir & River Transport Waterway Plan
12	NN River Assessment of Irrigation Potential
14	Final Evaluation of the Bottom Outlet Option
15	Final Evaluation of the Variable Level Intake Option
16	Access Road Timber Removal Plan
17	Access Road Animal Migration Mitigation Plan
18	Access Road Rural Development Programme
19	Access Road Village Impact Mitigation Plan with Specific Traffic Management plans for each village
20	Ban Pakmai Water Use Mitigation Plan
21	Fishery Monitoring & Mitigation Programme
22	Ban Pakmai Riverbank Garden Mitigation & Compensation Plan
23	Ban Pakmai Public Health Improvement Plan
24	Alluvial Mining Mitigation & Compensation Plan
25	Access Road Newly Accessible Resources & Habitats Protection Plan
27/46/63	A Generic Site Erosion Prevention, Control and Rehabilitation Plan
28/47/68	A Generic Personal and Property Accident/Damage Advisory Notice
29/48/69	A Generic Accidental Environmental Damage Compensation and Restoration Plan
30/49/71	A Generic Public Health & Infectious Disease Management Plan
31	Reservoir Filling Compensation & Management Plan
32	Reservoir Substitute Habitat Conservation Plan
33	Reservoir Rare Species Preservation Plan & RFCMP
34	Reservoir Biomass & Timber Management Plan
35	Floating Debris Removal & Filling Management Plan
36	Reservoir Fishery Development & Management Plan
37	Reservoir Drawdown Zone Management Plan
38	NN3 Drawdown Zone & Bed Erosion at Reservoir Intakes Management Plan
39	Reservoir Macrophyte Monitoring & Management Plan
40	Reservoir Long-Term Estate Development Plan
41/51	Access Road and PTL Maintenance & Integrated Road Development Plan

No.	Chapter Title
43	PTL Land Acquisition Mitigation & Compensation Plan
44	PTL Timber Removal Plan
45	PTL Animal Migration Mitigation Plan
50	PTL Village Impact Mitigation Plan and Specific Line Construction Management Plans for Each Village
53	PTL Rural Development Programme
54	PTL Newly Accessible Resources & Habitats Protection Plan
55	PTL Fire Risk Reduction Plan
56	PTL Safety & Education Plan
57/58/61	Xiengdet Village Relocation and Cropping Re-Organisation Plan
59	Xiengdet Pest Control Plan
60	Xiengdet Public Health Plan
64	Construction Sites Land Acquisition Mitigation & Compensation Plan
65	Construction Sites Timber Removal Plan
66/80/86	Worker Welfare Management Plan
67	Construction Sites Pollution & Contamination Monitoring & Control Plan
73	Diversion Tunnel Power Conduit Tunnel and Spillway Debris Management Plan
76	Diversion Tunnel Intake Power Conduit Tunnel Intake & Tailrace and Spillway Safety Plan
78/79/89	Local Community Harmonisation Plan
88 95	Access Road Land Acquisition Mitigation & Compensation Plan Access Road Fire Risk Reduction Plan
96	Construction Sites Fire Risk Reduction Plan

Annex B

ENVIRONMENTAL AND SOCIAL SAFEGUARDS COMPLIANCE AUDIT OF PRELIMINARY CONSTRUCTION WORKS AND RELATED ACTIVITIES

TABLE OF CONTENTS

1. INTRODUCTION

The main NN3 construction activities are planned to start in October 2011. In advance of these activities, the Company has awarded construction contracts to implement preliminary construction works. The preliminary construction works allowed (A) access for survey teams to provide necessary information and data for appropriate design of the (i) dam, (ii) power station, and the (iii) tunnel connecting the reservoir to the power station, and (B) from mid-April 2011 for securing all-weather access to the various construction sites and preparing work camps at these sites.

At the dam site an extensive geological survey, including core sampling was held for appropriate dam design and for determining quarry sites. At the power station site an exploratory adit has been constructed for appropriate design of the underground power station and the diversion tunnel from the dam to the power station. Apart from the access related works, facilities for accommodation and offices for the survey teams and construction workers involved in the preliminary works have been provided at the Nam Gnone camp site and the power station site.

The preliminary construction activities instigated by NN3PC consisted of (i) access road to the power station site, (ii) bridge over the Nam Ngum as part of the access road to power station site, (iii) exploratory adit at power station site, (iv) camp at power station site, (v) Nam Gnone camp, and (vi) access road to dam site. This work was completed in December 2010. Preliminary Construction Activities restarted in April 2011, mainly to secure the access to all construction sites, to prepare construction camps and to prepare offices facilities. Their scope is as follows:

- Installation of preliminary temporary camp,
- Installation of preliminary telecommunication facilities,
- Installation of preliminary office facilities.

- Construction of solid waste and hazardous material storage and management facility for PCA works,
- Bridges reinforcement of the public road from Ban Huay Kham to Ban Longcheng,
- Construction of an access track from Ban Longcheng to the Dam left abutment,
- UXO clearance of all areas to be impacted by PCA works.

- Road survey control points arrangement from Ban Longcheng to Dam left abutment,
- Intensified points arrangement of survey control grid in dam area,
- R1 road construction from dam left abutment to No.1 Bailey bridge,
- Placement of piers of No.1 Bailey bridge and assembly and installation of deck surface,
- R3 road construction from No.1 Bailey bridge to the portal of the diversion tunnel,
- No.1 Camp ground leveling and housing construction,
- Dam site lab,
- Dam site magazine ground leveling and building,
- Dam site fuel bay ground leveling and building.

- Intensified points arrangement of survey control grid in powerhouse area,
- Temporary road P2 construction from public road to switchyard,
- Temporary access road P3 construction to headrace tunnel adit #3,
- Temporary access road construction to headrace tunnel adit #2,
- Temporary road P5 construction in the powerhouse area,
- Camp #2, ground leveling and housing construction,
- Powerhouse area magazine ground leveling and building
- Powerhouse area fuel bay ground leveling and building

In addition to the construction activities instigated by NN3PC, GoL contracted three logging companies to complete the salvage logging within the NN3 reservoir area.

Furthermore Ban Xiengdet village took the initiative to build a new primary school at higher elevation than NN3 reservoir flood levels and requested financial support from NN3PC.

The part of the Nabong substation related to NN2 is completed, but NN3's part of Nabong substation still needs to be constructed. Presently, no actual field activities by NN3PC as construction works or land occupation at Nabong substation have started.

Following is a description of the construction works and NN3 related activities that have been implemented so far. The section concludes with the present site-specific status of the construction related activities.

1.1 Construction activities related to securing the access to the Power Station Site

During 2007-2008, the project developer hired the services of a construction contractor to construct a bridge over the Nam Ngum River close to the NN3 power station. The bridge was completed in 2008.

During 2007-2009, the developer hired the services of a second construction company to upgrade the existing access track to the power station site into an access road. The developer terminated the contract with the contractors before completion of the access road due to expiration of the NN3 construction permit and due to the occurrence of slope failures along the access road.

While the NN3 developer undertook construction activities for access to the power station site, the following activities took place along the access road:

- Contractors hired by the Ministry of Defence extended the access road to the power station site to construct a public road from Nam Gnone to Vang Vieng;
- The contractors hired by the Ministry of Defence use the access road to the power station site for construction of a separate access road to a bridge to be built over the Nam Phay that will form part of the public road from Nam Gnone to Vang Vieng;
- The contractors hired by the Ministry of Defence involved in the construction of the new public road from Nam Gnone to Vang Vieng have established a construction camp near the bridge over the Nam Ngum to the power station site;
- A Chinese company involved in the processing of NTFP products has established processing facilities and a camp along the access road to the power station site;
- A checkpoint has been established by the Ministry of Defence at the beginning of the access road to the power station site, while also some military housing is located along the access road;
- Nam Gnone villagers are allowed access along the access road after receiving approval at the military checkpoint (Nam Gnone is located about 6 km distance from the entrance of the access road to the power station);
- No villagers have established houses or field huts along the access road to the power station site. But, at the entrance at the public road from Nam Gnone to Long Cheng rice paddies and field huts occupied during each rainy season by 2 households based at Nam Gnone have been established well before construction of the access road took place.

1.1.1 Access Road to Power Station Site

Figure 1 shows the location of the access road to the power station site.

As a result of the construction of the NN2 dam, located downstream of NN3 power station site, the existing public road from Nam Gnone to Vang Vieng became inundated with the filling of the NN2 reservoir. The villages of Hom Xay, Nong Pou, and Phoun, located within Xaysomboun District became isolated with the inundation of the public road from Nam Gnone to Vang Vieng (see Figure 2). GoL decided to use the access road to the NN3 power station and the NN3 bridge over the Nam Ngum as part of a new public road from Nam Gnone to Vang Vieng. The new public road to Vang Vieng enables access to the three villages of Hom Xay, Nong Pou, and Phoun (see Figure2) and also provides Phou Bia Mining access for their copper and gold mining activities at Ban Houayxai (see Figure 3). The public road from Nam Gnone to Vang Vieng is still under construction under the responsibility of the Ministry of Defence.

The former existing access track to the power station site was about 3 meters wide. The upgraded, but not completed access road to the power station site that will become part of the public road from Nam Gnone to Vang Vieng has a total length of 12 kilometers and is 8.5 meter wide. The length of the access road to the bridge over the Nam Ngum is 11 kilometers, and the length of the access road from the bridge to the power station site is 1 kilometer.

During upgrading of the access track, the road was paved with crushed rock. The road is provided with side drains and cross drains, including box culverts (see pictures below).

All pictures shown below were taken in December 2010, after the construction activities were terminated, but not necessarily completed.

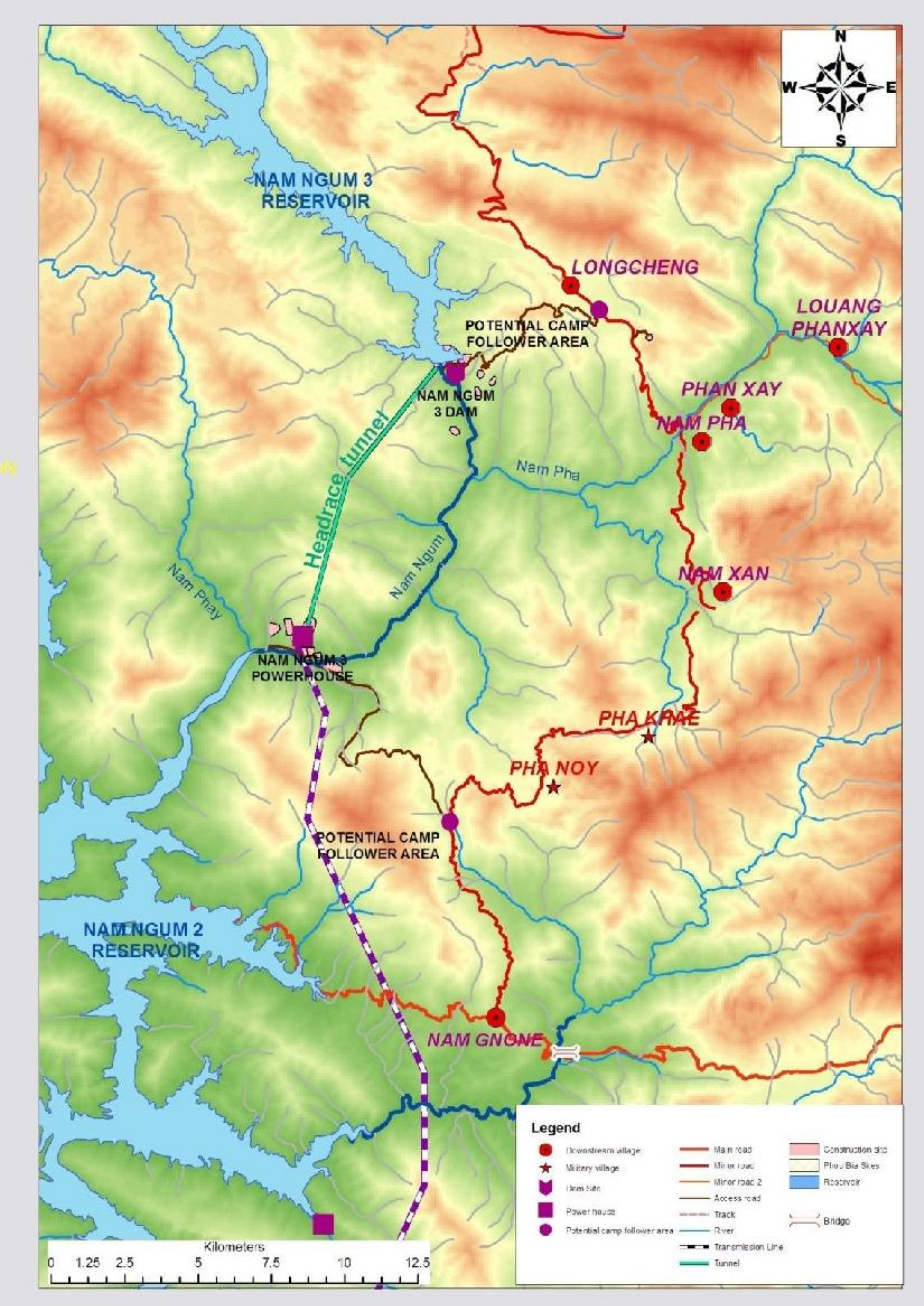


Figure 1 - Access Roads to Power Station and Dam Sites

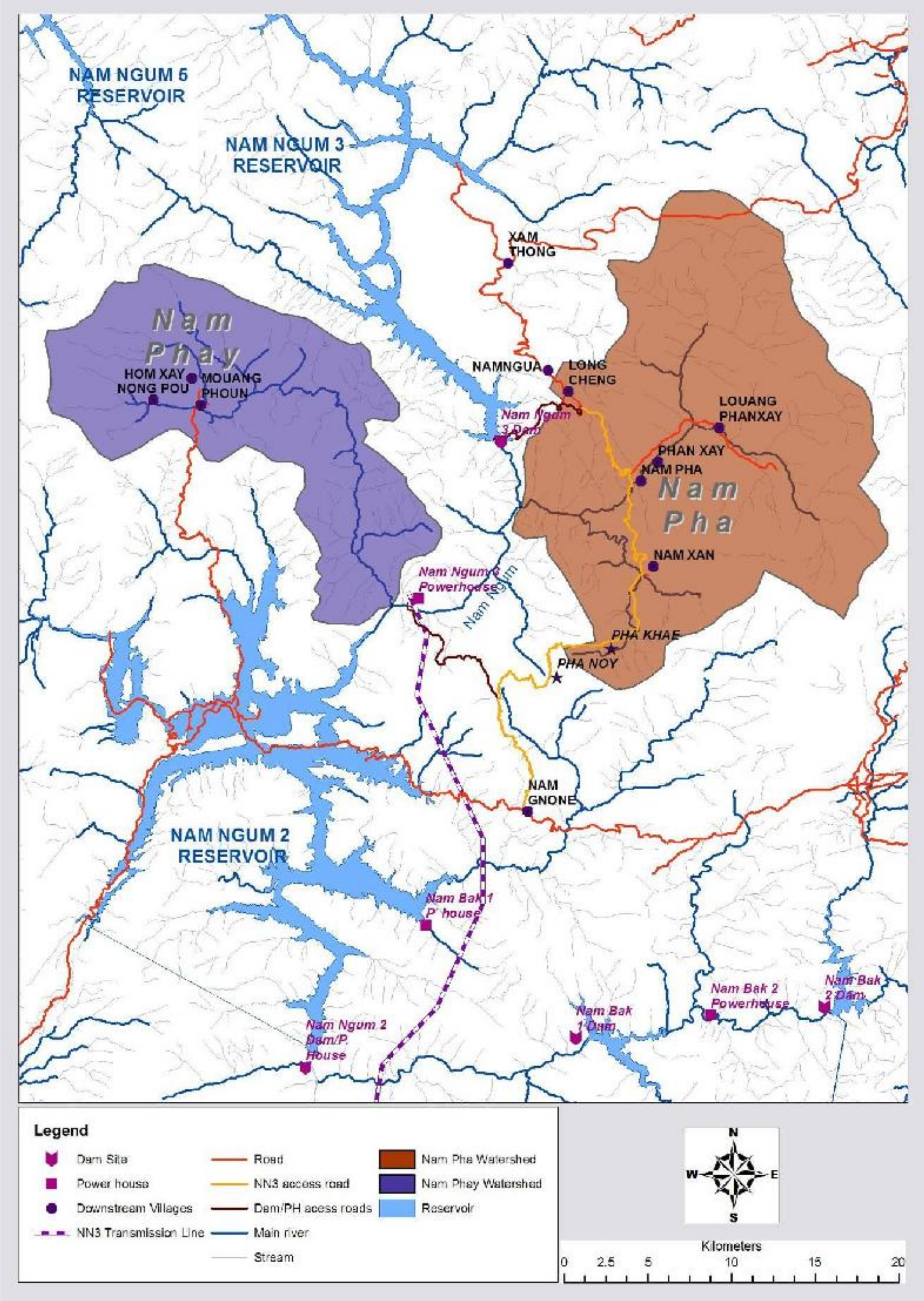


Figure 2 - (i) the inundation of the existing public road from Nam Gnone to Vang Vieng by NN2 reservoir and isolation of the villages Hom Xay, Nong Pou, and Mouang Phoun, and (ii) the access roads to NN3 power station and dam sites.

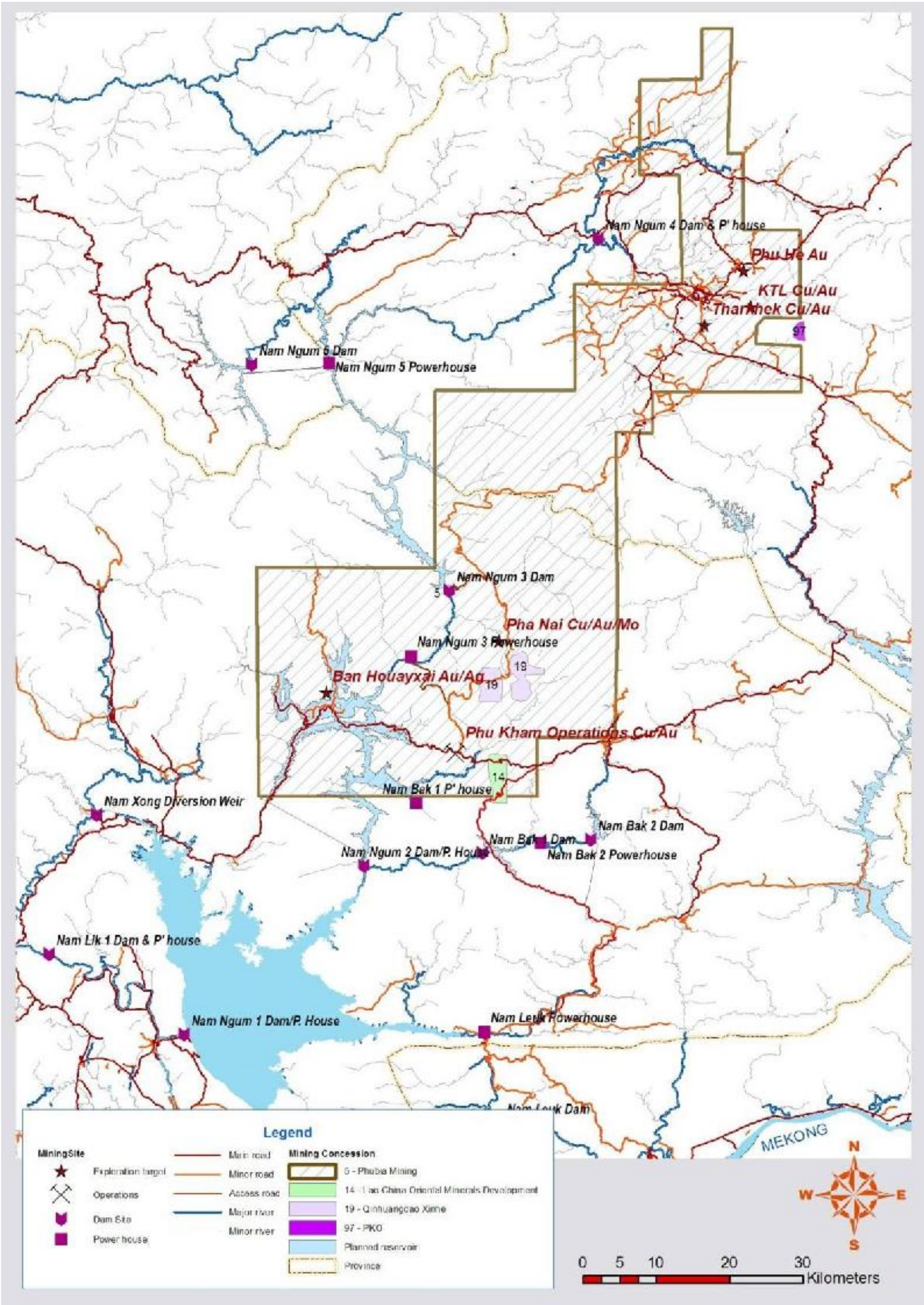


Figure 3 - Inundation of the existing public road from Nam Gnone to Vang Vieng by NN2 reservoir and the isolation of mining activities at Ban Houayxai.

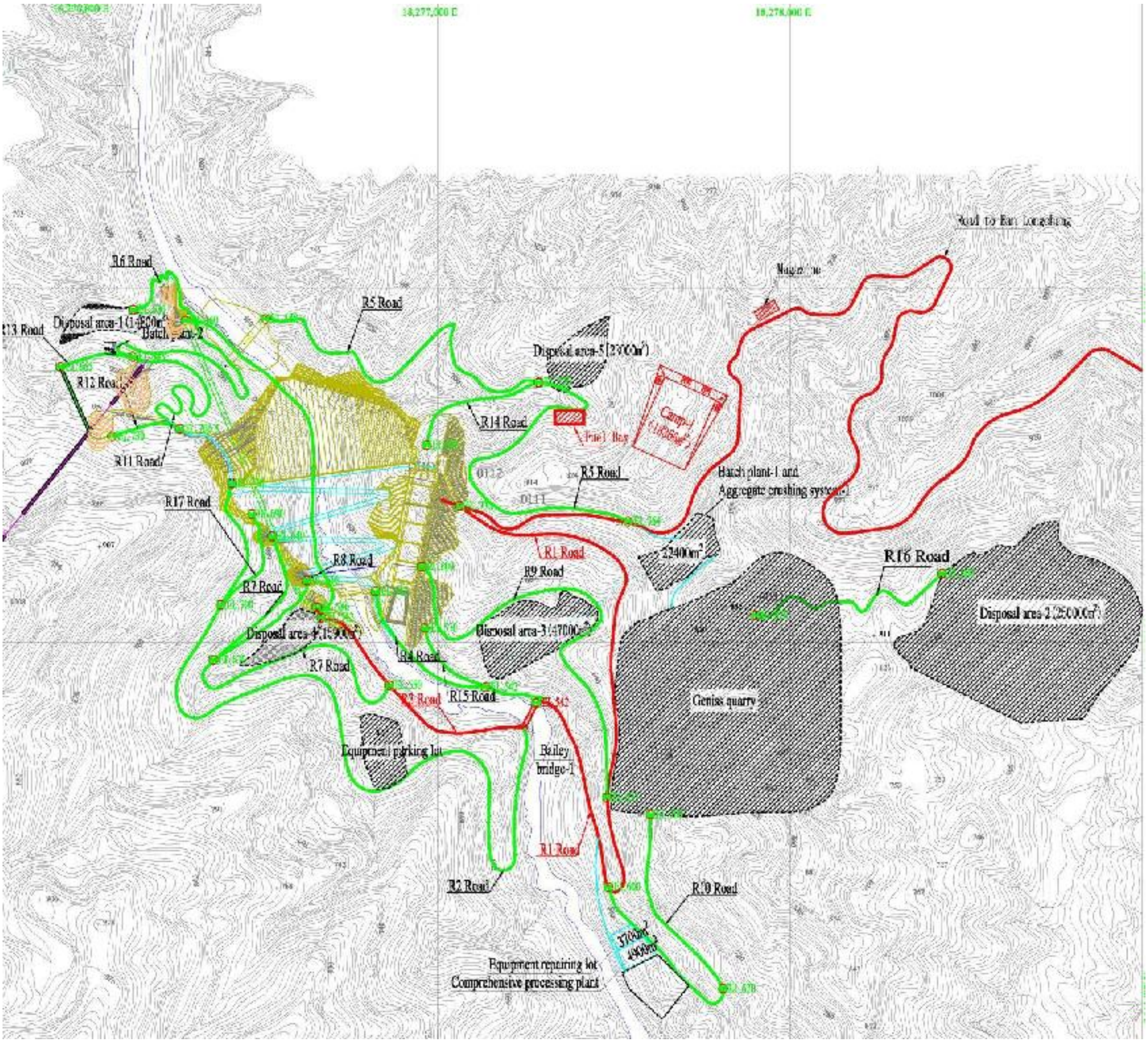


Figure 4 - Site layout at the dam site PCA, April 2011.

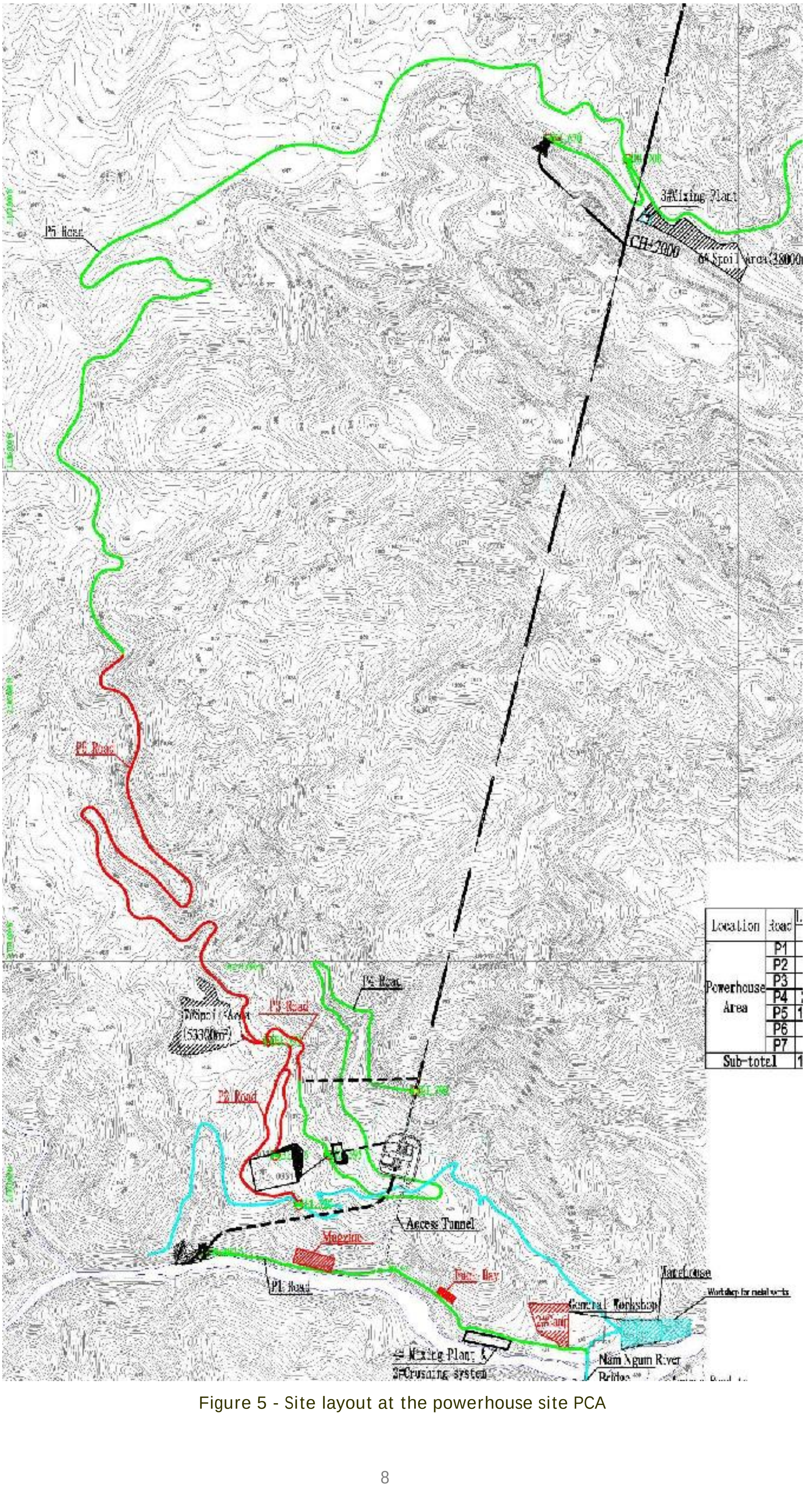


Figure 5 - Site layout at the powerhouse site PCA

Check point at the beginning of the access road to Power Station

Processing of NTFP's along the access road

Nam Gnone villagers on hand tractor at access road

NN3PC completed construction of access road downwards to the Nam Ngum and ongoing construction by GoL of public road to Vang Vieng and separate access road to Nam Phay bridge after crossing Nam Ngum upwards

Box culvert at the access road

Rice paddies close to the entrance of the access road

Natural re-vegetation of slopes of the road

Side drains and crushed stone pavement of access road

Slope failure along access road, crushed stone pavement

Former stone crushing site along access road

Slope failure and natural re-vegetation at former borrow site

1.1.2 Bridge over the Nam Ngum to the Power Station Site

The bridge over the Nam Ngum located 1 kilometer from the power station site was completed in 2008. The bridge is 110 meter long and 7 meter wide. The bridge has a maximum weight allowance for passing traffic of 32.4 tonnes. The bridge will become part of the public access road from Nam Gnone to Vang Vieng.


Completed bridge over Nam Ngum close to NN3 power station and public road to Vang Vieng under construction, December 2010

1.2 Exploratory Adit at the Power Station Site

Construction of the exploratory adit has been stopped in 2010. It had a diameter of 3 meters and a length of 450 meters. The disposal site of rocks from the exploratory adit is located immediately along the access road and has experienced a rapid natural re-vegetation.


Entrance of exploratory adit (Dec 2010)

Revegetation of rock disposal site of exploratory adit (Dec 2010)

1.3 Camp at Power Station Site

At the power station site, accommodation and offices for the construction workers working at the bridge and the exploratory adit has been built. The 12 camp buildings include water supply and sanitation. The camp site, including the constructed buildings, occupies 2 hectares of land that was not in use by villagers. All buildings have been constructed immediately near the access road to the power station site (see picture below). Water supply is provided from a stream, while the toilets, showers, and kitchen facilities are provided with drains to several septic tanks. The use of bottled drinking water is required at the camp site. All buildings at the power station site have been abandoned in 2010.

Camp at power station site, December 2010

1.4 *Nam Gnone Camp*

At an abandoned village area consisting of grass lands along the public road from Nam Gnone to Long Cheng, close to the junction with the access road to the power station site, a temporarily camp has been built with 21 rooms, office, kitchen, and canteen, that serve presently for guards, surveyors, and visitors and serve for construction supervisors and monitoring staff during the first two years of construction, starting from April 2011 (PCA).

The area of Nam Gnone camp site is 1.5 hectares. The camp site area has been selected in cooperation with Nam Gnone village chief ensuring that its use will not impact households living at Nam Gnone. Water supply is provided from a 10 meter deep ground water well, while the toilets, showers, and kitchen facilities are provided with pipe drains to several septic tanks. Bottled drinking water is provided separately. There are procedures for the collection of solid waste, but no disposal site has been identified.

Nam Gnone camp site, December 2010

1.5 *Construction activities related to access to Dam Site*

The former access track to the dam site was about 3 meters wide. It was upgraded in 2009–10 to an access road having a total length of 10.5 kilometers and being 4 meters wide.

During upgrading of the access track, the road was paved with lateritic soil as a sub base layer. The road is provided with small wooden bridges at locations were streams cross the road alignment. A temporary wooden bridge across a small stream collapsed in the rainy season of 2010 during a flash flood, while others survived the rainy season of 2010. This temporary bridge was rebuilt in April 2011.

The NN3 Developer had its site office in Long Cheng, renting a building from the military. The rental contract for this site office was terminated when the geological surveys were completed and the construction contract for upgrading the access road to the dam site was terminated.

At the termination of construction activities, the following activities were recorded along the access road:

- A military check point has been established along the public road to Long Cheng, just before the junction with the access road to dam site, well before preliminary construction activities started.
- Presently, battalion 584 is raising cattle at the area surrounding the upgraded access track.
- No Long Cheng villagers have established houses or field huts along the access road.


Access road to dam site at the public road (Dec 2010)

Access road to dam site (Dec 2010)


Access road to dam site and temporary bridge at access road after flash flood, December 2010


Access road Long Cheng – Left abutment to the dam, sta.7+900, May 2011

Contractor Camp at Dam Site, May 2011

Dam Site: Road quarry to Bridge #1, Road slope improvement at curve sta.0+300 (May 2011)

Dam Site: Road quarry to Bridge #1, road widening from sta. 0+000 to 0+200 (May 2011)

Dam Site: Road quarry to Bridge #1Road widening and slope improvement (May 2011)

Road R18 to dam site (May 2011)

Dam Site: Road quarry to Bridge #1 (May 2011)

Dam Site: Temporary cofferdam construction for pier no.#2 of Bridge #1 (May 2011)

1.6 Salvage Logging

The Ministry of Defence with assistance from the Ministry of Agriculture and Forestry carried out the demarcation of the reservoir full supply levels and undertook a timber survey. The volume of commercial valuable timber that will be inundated by the NN3 reservoir has been estimated by GoL at about 86,000 m^3.

Subsequently, GoL hired the services of three logging companies for the actual removal of commercial timber from the NN3 reservoir area. The NN3 reservoir area includes a small part of Phou Pha Phieng Production Forest Area that is located at the south west corner of NN3 catchment. Villagers do not own any trees within Phou Pha Phieng Production Forest, nor within the area to be inundated by the NN3 reservoir, with the exception of villagers at Ban Xiengdet located at the upper end of NN3 reservoir in Xieng Khouang Province. Villagers at Ban Xiengdet do own fruit trees within the area that will be seasonally inundated by NN3 reservoir during reservoir filling in the rainy season of 2016.

Salvage logging by the three logging companies is now completed.

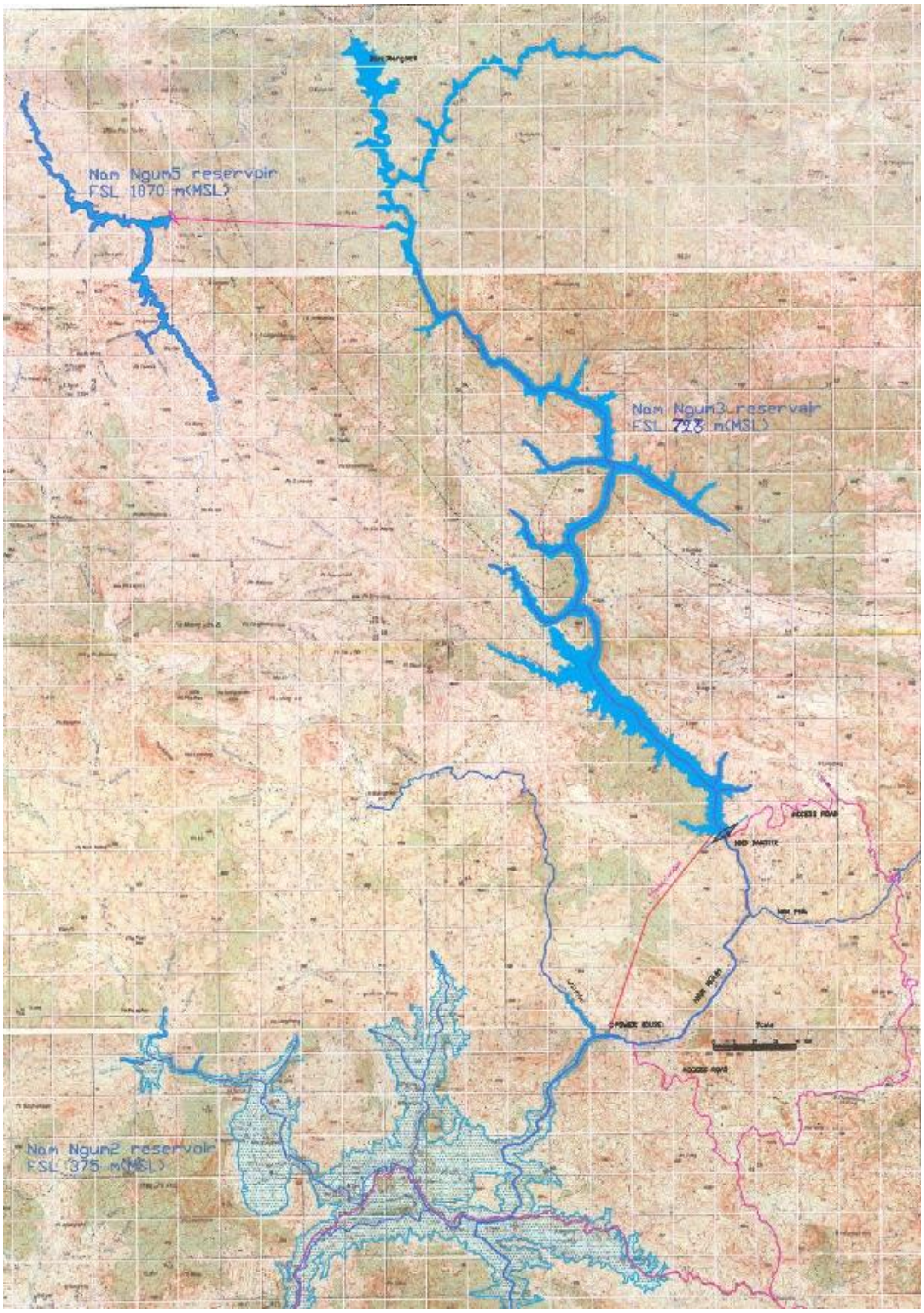


Figure 6 - NN3 reservoir water surface at Full Supply Level of 723 masl and the seasonally to be inundated part of Xiengdet village area

1.7 Ban Xiengdet

Villagers of Xiengdet have constructed a primary school with 5 class rooms at a location not more than 1 kilometer distance from their previous primary school within the village area boundaries. The former primary school had only two class rooms, requiring many children at Ban Xiengdet to walk 4 hours per day up and down to the primary school at the neighboring village of Nam Sam. The new primary school with additional teachers facilitates education at primary school level of all children of Ban Xiengdet.

While the former primary school was too small, it was also located at an area that will be seasonally flooded by the NN3 reservoir. The new primary school has been constructed by the villagers above FSL. Ban Xiengdet authorities requested financial support from NN3PC during the construction of the school to obtain lacking construction and education materials, new school furniture, and to provide water supply and sanitation.

While all school construction works have been implemented by the villagers of Ban Xiengdet with support and approval of Phou Kout District, NN3PC provided additional financial support on request (see Appendix 3).

The new school and school furniture at Ban Xiengdet, December 2010

In addition to the construction of the new primary school, many new houses have been constructed at the residential area of Ban Xiengdet that will be seasonally inundated by NN3 reservoir. These new houses have been constructed mainly by people who are not part of the population of Ban Xiengdet. These new houses also have been built without agreement by the village and district authorities and without support by the NN3 Power Company.

The Phou Kout District authorities have written a letter to Ban Xiengdet village authorities in which village authorities are instructed not to allow any construction of new houses or any trade in land by persons who are not part of the village population. A copy of this letter by the governor of Phou Kout District to Xiengdet village authorities is reproduced in Appendix 4.

1.8 Nabong Substation

The Nabong substation has been originally designed to be owned and operated by GoL to connect the incoming electricity from 4 hydropower projects, including NN2, NN3, NT1, and Nam Ngiep for export to Thailand using the same 500 kV transmission line. Both Nam Ngiep and NT1 hydropower projects have been delayed. The NN2 transmission line to the Nabong substation has been constructed and connected to the Nabong Substation.

No works have started for the NN3 transmission line and its connection to the Nabong substation. A land and asset ownership and land use survey within the NN3 transmission line corridor, including the connection area at Nabong substation will be undertaken to identify the land to be acquired and identify persons who will be physically displaced by loss of houses and/or land ownership or economically displaced by losses in land use and related structures. Also potential loss of community buildings will be determined.

2. Compliance Audit

2.1 Objectives and Scope

The proposed assistance by International Finance Institutions to the Nam Ngum 3 Power Company involves (i) existing facilities that will form part of the future project proposed for ADB financing and (ii) use of land or sites that have been acquired prior to ADB consideration of the Project. This report is being prepared to comply with the 2009 ADB

Safeguards Policy Statement (SPS) Safeguard Requirements 4 covering Special Requirements for Different Finance Modalities (SPS, SR 4, para 12). [1]

This compliance audit, undertaken by NN3PC, aims at (i) identifying past or present concerns related to impacts on involuntary resettlement (physical or economic displacement) and ethnic minorities/indigenous peoples; (ii) determining whether actions were in accordance with ADB's SR 2 and SR 3 principles and requirements and; (iii) determining whether a corrective action plan containing remedial actions is required.

2.2 Methodology

During the environmental and social safeguards compliance audit held in December 2010, the following activities have been undertaken:

- a review of available design drawings,
- meetings with former surveyors and construction supervisors to determine status of project construction activities,
- site inspection of completed and terminated construction works,
- consultations with households and village and Kum Ban authorities at Long Cheng and Xiengdet,
- onsite assessment of acquired lands/replacement lands,
- review and collection of available documents regarding past compensation procedures of persons affected by the preliminary construction works whether entitlement provided to affected people were in accordance with ADB's Safeguard Policy Statement and national requirements.

2.3 2010 Audit Findings

The following environmental and social related issues have been found during the compliance audit undertaken in December 2010.

- The completed or terminated civil works do not cross, traverse, or encroach environmental sensitive areas such as protected areas or buffer zones of protected areas. The completed or terminated civil works also do not cross, traverse, or encroach historical/cultural areas, except for four graves that were found during the upgrade of the access track to the power station site (see section 6).
- The locations of borrow, dump, and stone crushing areas can still be identified along the access roads to the power station and at the power station site and will be reused when access roads will be completed. A stone crushing site is located along the access road to the power station site, but no crushing sites have been established along the access road to the dam site. No equipment yard sites have been established, as not much heavy equipment was required during construction works. Compared to the other preliminary construction works, upgrading of the access track to the power station site required most of the heavy equipment used. Heavy equipment used during the upgrade of the access track to the power station site consisted of 5 large trucks for soil and rock transportation, 4 backhoes, 1 grader, 1 compactor roller, and 1 stone crushing equipment.
- Streams crossing the access roads to the power station and dam sites have been used as sources for water. Concrete pipe and box culverts have been constructed at the access road to the power station site, while temporary wooden bridges have been built over the small streams crossing the access track to the dam site.
- No animal paths (underpasses and overpasses) have been constructed at the two access roads, as the upgrading of the existing access tracks did not change the existing access opportunities of wild life.
- The required road embankment cuts during upgrading of the access road to the power station site have led to slope failures at two locations. Additional repair at these two locations is required. The existing vegetation along the access road to the power station consists mainly of bamboo, while the existing vegetation along the access track to the dam site consists mainly of *Imperata sp.* Both are considered to be pioneers occupying disturbed areas. However, both areas along the existing access tracks to the power station site and the dam site have been disturbed well before upgrading of the access tracks began.
- No residential areas are located close to the completed and/or terminated construction works. As village residential areas are located at safe and long distance from the preliminary construction works, air and water quality, noise and vibration levels have not been monitored during preliminary construction works by the

[1] The ADB Safeguards Policy Statement is available from http://www.adb.org/Documents/Policies/Safeguards/default.asp

developer and/or contractors. Environmental risks related to the preliminary construction works potentially affecting quality of life and land uses at communities have not been considered to be a significant issue. However, during upgrading of the access track to the power station site, the developer and contractor have compensated one affected farmer. To avoid the interruption of the water supply to a rainy season rice paddy located close to the junction of the public road from Nam Gnone to Long Cheng with the access road to the power station site, the paddy owner was provided by an uninterrupted water supply system (see section 6).

- In advance of upgrading the access track to the dam site, Unexploded Ordnances (UXOs) have been screened and detected. The military has subsequently removed several UXOs. At other construction sites, the risk for encountering UXOs during construction has also been screened. Only along the access track to the power station site a box with grenades has been found. The UXO screening, detection, and removal procedures during preliminary construction activities have been successful as no accidents occurred during the first phase of preliminary construction works.
- Apart from UXOs screening, detection, and removal procedures during preliminary construction works, the contractors have been required to implement and enforce other Environmental, Health, and Safety (EHS) procedures. Health and safety programs have been implemented by the contractors during construction works by establishing a small clinic at the power station site attended by nurses for first aid purposes mainly. To reduce risks of occupational health, personal protective equipment as dust masks, hearing, head and foot protection have been supplied to construction workers. The exploratory adit was provided by an adequate ventilation system. No human accidents are reported to have occurred during preliminary construction works.
- The main environmental measures required to be taken by the contractors during preliminary construction works included prevention of soil erosion. However, due to slope failures that occurred during the upgrading of the access track to the power station site, soil erosion occurred, particularly at two specific locations. Disposal sites for solid waste could not be identified during the time of audit. But, a rock disposal site has been established close to the exploratory adit at the power station site that experiences a rapid natural re-vegetation.
- All the preliminary construction sites experienced little or no use of access by local people during construction activities. No existing land ownership and/or land uses by local people have been impacted. The preliminary construction activities have not caused limitations in access by local people to Non Timber Forest Products. Two cases occurred during construction works that could have led to adverse impacts. However, the contractors have implemented adequate measures to avoid and compensate these impacts: (i) finding four graves during construction works, followed by traditional local ceremonies and compensation of families of buried persons as per the local customs, and (ii) providing one rice farmer with a water supply system avoiding interruption of water supply by the upgraded access track to the power station.
- Local communities have not been adversely impacted by the preliminary construction works resulting from occupation of land.
- No complaints or grievances from local communities and/or local persons have reached the contractors and/or the developer.

3. Stakeholder Engagement

At the preliminary construction sites, no land ownership or any land use by local communities could be identified during the meetings held at local communities and interviews held with key informants, including Hmong indigenous people. These interviews and meetings have been held during the project concept stage and during environmental and social impact studies. The sites of preliminary construction activities were not in use by local communities. Therefore, the preliminary construction works can be considered as projects with minimal risks and limited stakeholder issues. They were undertaken after reception of the construction permit by the Water Resources and Environment Administration (WREA).

During preliminary construction works, GoL, the developer, and contractors have been the major stakeholders. As required within Xaysomboun District, the developer has involved the Ministry of Defence to provide security services for the workforce in the field that consisted of surveyors, construction workers, and construction supervisors.

During occupation of land and construction of preliminary works, stakeholder issues have focused on meetings between the developer, governmental officials, including representatives of WREA, line ministries, District, Kum Ban, and village authorities, and the contractors.

A national consultation workshop was held in Vientiane on the 16th January 2008, attended by representatives of WREA and line ministries, the press, Xieng Khouang Province, Phou Kout District, 8 villagers of Ban Xiengdet, Vientiane Province, Xaysomboun District, 7 villagers from 7 different villages.

A public consultation workshop was held in Vientiane on the 8th February 2008, attended by representatives of WREA and line ministries, the press, Vientiane Province, Xaysomboun District, including representatives of International Financial Institutions and NGOs.

The developer and contractors have ensured that transport requirements made by Phou Bia Mining have been strictly followed during Phou Bia Mining's construction works at the public road passing Nam Gnone.

The field office at Nam Gnone camp site has been established with agreement and approval by Nam Gnone village authorities. The field office at Long Cheng was established after signing a temporarily rent agreement for an existing building owned by the military. The developer and the military terminated this rental contract at the end of 2009.

The established field offices of the developer at the Nam Gnone camp site and at Long Cheng have been functioning as open houses for required public information, complaints, and potential grievances during implementation of preliminary construction works. No outstanding complaints or grievances have been registered. Presently after completion and termination of preliminary construction works, in December 2010, the field offices are not in use other than functioning for accommodation of visitors. Upon the start of project main construction activities in October 2011, public information offices will be opened again both at Xaysomboun District and Phou Kout District, while the grievances redress mechanism will be strengthened.

The developer and the contractor have involved specifically the Nam Gnone village authorities of Hmong ethnic group, ensuring that the removal of graves of 4 Hmong persons and the ceremonies plus compensation of family members followed the Hmong traditions and customs. The timely compensation of the farmer of Hmong ethnicity whose paddy fields might have experienced interrupted water supply during the rainy season due to upgrading of the access track to the power station site was also witnessed and approved by Nam Gnone village authorities of Hmong ethnicity.

During consultations with communities during the environmental and social impacts studies, the upgrading of the existing access tracks was not considered to affect the daily lives of villagers. But, after the old public road from Nam Gnone to Vang Vieng has been inundated by NN2 reservoir, the access road to the power station site and the bridge over the Nam Ngum will become part of the new public road from Nam Gnone to Vang Vieng. Access for villagers will thus be improved after completion of the construction works. Also Phou Bia Mining's access to Ban Houayxai will be secured by the new public road, including the access road to the power station site and the bridge over the Nam Ngum.

4. Status of Land Occupation and Extent of Impacts

The following table shows the preliminary construction works and activities, either instigated by the developer, GoL or villagers with approval and support by GoL.

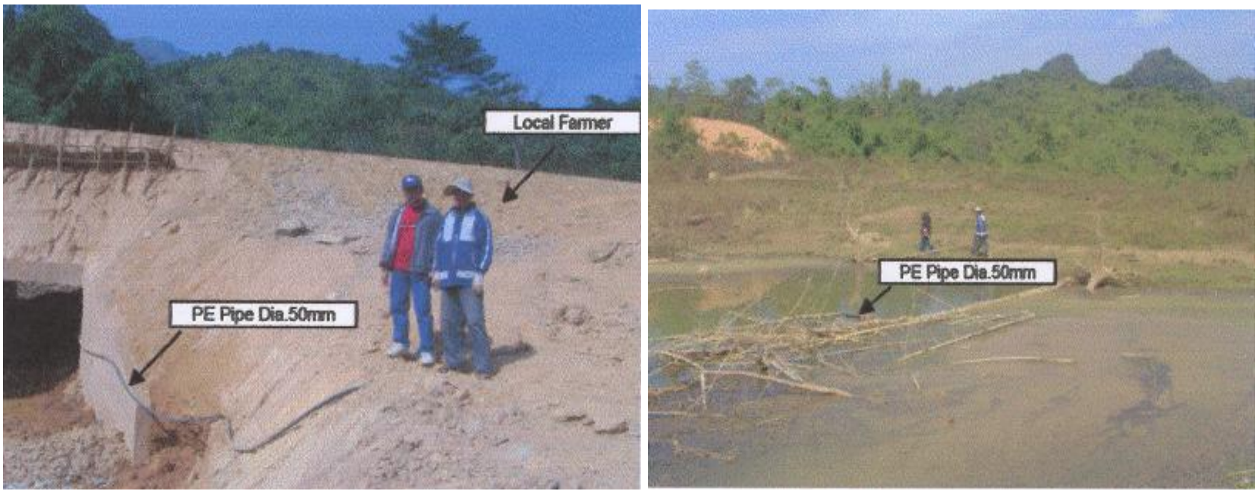
#	Preliminary Construction and Activities Related to NN3	Status	Land Area Occupied
1.	Upgrading Access to Power Station Site	Construction activities terminated in 2010, access currently being upgraded under PCA	Right of Way on Government owned land forming part of the ongoing construction of the public road from Nam Gnone to Vang Vieng.
2.	Bridge over the Nam Ngum	Construction Completed	Right of Way on Government owned land forming part of the ongoing construction of the public road from Nam Gnone to Vang Vieng
3.	Exploratory Adit at Power Station Site	Construction Completed	About 1.0 ha Government owned land for spoil site
4.	Camp at Power Station Site	Construction Completed, Additional Works Required	2.0 ha Government owned land
5.	Nam Gnone Camp Site	Additional Works Required	1.5 ha Government owned land consisting of abandoned village area
6.	Upgrading Access Track to Dam Site	Construction Activities Terminated,	Right of Way at Government Owned Land

		Additional Works Required, part of PCA scope	
7.	Salvage Logging	Completed	Government owned land within NN3 Concession Area
8.	Ban Xiengdet	Completed	Part of 10 ha allocated resettlement site within Village Area

No private land has been affected during constructions and activities related to NN3, at the exception of the site of the Long Cheng camp (see Annex 5) for which people have been compensated. No physical displacement from housing or economic displacement from land and other common property resources have occurred. No involuntary resettlement has taken place.

Two compensation measures have been implemented during upgrading of the access track to the power station.

(i) Installation of an uninterrupted water supply system close to the entrance of the access road to power station site. The water supply system provides uninterrupted water supply to the paddy fields of Mr. Law Toi of Hmong ethnicity who lives at Ban Nam Gnone. The piped water system consists of 192 meter polyethylene pipes of 50 mm diameter crossing the access road to the power station site. A copy of the signed document for hand over, ownership and maintenance of the water supply system is shown in Appendix 1. Witnesses of the hand over included village authorities of Nam Gnone. The two following pictures show the field survey by the potentially affected farmer in advance of signing the hand over document.



Inspection of water supply system by farmer and developer during upgrading of access track to power station site in 2009

(ii) Ceremonies and compensation of relatives of persons buried at 4 graves found during the upgrade of the access track to the power station site. The graves were about 35 years old (see pictures below).

Two of the four graves found during upgrading of access track to power station site in 2007

Ceremonies have been held by village authorities of Nam Gnone following Hmong traditional procedures before removal of the graves. Relatives of the persons buried in the four graves have received financial compensation witnessed by village authorities. The same procedures have been followed as earlier carried out at Nam Gnone when graves were encountered after land acquisition and/or during earth works by Phou Bia Mining. Copies of the relevant documents of removal ceremonies and support to family members are shown in Appendix 2.

5. Conclusions and Recommendations

During the concept stage of preliminary construction works, including design and environmental and social impact assessment studies it was predicted that preliminary construction works would have minimal environmental risks and stakeholder issues.

At the time of the audit, the monitoring data of air quality, noise, and water quality by the developer and the contractors was not available. Adequate air quality at the exploratory adit has been secured by installation of an appropriate air ventilation system. In addition to the ventilation system, also safety procedures have been implemented, including the use of gas masks and required guards, supervisors, and interdiction of access to the adit by individuals without being accompanied.

The developer has hired the services of surveyors and construction supervisors to ensure that the contractors followed design requirements, including avoidance and minimization of environmental and social impacts.

The developer has ensured that occupational health and safety measures have been implemented by the contractors by (i) screening, detection, and removal of UXOs, (ii) providing construction workers with protective equipment, (iii) mobilizing appropriate heavy equipment, (iv) installation of water supply and sanitation, including septic tanks, and (v) providing first aid services. No personal accidents or outbreak of contagious diseases have occurred during preliminary construction works.

During the audit no land fill area or disposal site for solid waste could be identified. Probably solid waste was collected and subsequently burned as is the custom in the villages nearest to project sites.

Slope failures, especially at two locations of the access road to the power station site, probably have caused turbidity at small streams during construction works, particularly during rainy seasons. Additional corrective actions, including erosion control, are required to avoid prolongation or extension of slope failures at these two locations. No re-vegetation activities have been implemented during upgrading of road works, but natural re-vegetation has been rapid.

The preliminary construction works have minimal stakeholder issues. Prior to occupation by the contractors and the developer, local communities, including Hmong indigenous people have been involved during the environmental and social impact assessments. Information obtained from key informants and from interviews and meetings at local communities made clear that that no private land ownership and no private ownership of structures, field huts, or trees could be expected at land to be occupied during preliminary construction works and activities. All land occupied is owned by the government. Community land uses as hunting, fishing, and collection of NTFPs were not practiced at occupied land.

The developer and contractor have timely compensated persons potentially impacted by preliminary construction works by (i) following traditional ceremonies and established procedures during removal of 4 Hmong graves, and (ii) securing a Hmong farmer uninterrupted water supply to paddy land.

At the end of the preliminary construction works, public services as electricity connection at Nam Gnone camp site and communication by mobile telephone have become available. Such has simplified communication procedures providing better opportunities to strengthen (i) monitoring of construction works, (ii) engagement of stakeholders, and (iii) grievances redress mechanism.

As the completed bridge over the Nam Ngum and the upgraded access track to the power station site will become part of the new public road from Nam Gnone to Vang Vieng, access for villagers to land owned by the government has improved, which may increase hunting, fishing, and collection of NTFPs by villagers in the areas along the public road. Improved access may also lead to occupation of land by villagers along the public road to Vang Vieng, including the access road to the power station site.

Already a wood processing plant producing base material for medicine and perfumes has been established along the upgraded road to the power station site. If the public road between Nam Gnone and Vang Vieng is opened during the implementation of NN3's main construction activities, more persons or companies may occupy land along the public road potentially affecting the maintenance of side drains and requiring stringent traffic management, including dust control, traffic signs, and speed/weight limitations to avoid traffic accidents, road damage, grievances, and complaints.

APPENDIX 1

Copy of letter of agreement for hand over and maintenance of water supply piping system to recipient Mr. Law Toi. This letter has been signed by (i) representative (Mr. Champa) of Nong Hai Construction, (ii) witness Mr Song Kue (Village Chief Ban Nam Gnone), and (iii) recipient (Mr. Law Toi).

ສາທາລະນະລັດ ປະຊາທິປະໄຕ ປະຊາຊົນລາວ

ສັນຕິພາບ ເອກະລາດ ປະຊາທິປະໄຕ ເອກະພາບ ວັດທະນາຖາວອນ

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ບໍລິສັດ ໜອງໄຮ ກໍ່ສ້າງ ຂົວທາງ ຈຳກັດ
ໂທລະສັບ: 021 351025-6

ເລກທີ 001... /ຂທບຮ, ບງ 3
ວັນທີ:... 23/01/2009

ໃບຢັ້ງຢືນການມອບສິດ ໃນການນຳໃຊ້ ແລະ ປົກປັກຮັກສາ

- ໃນວັນທີ 23/01/2009 ເວລາ 11.30 ໂມງ ບໍລິສັດ ໜອງໄຮ ກໍ່ສ້າງ ຂົວທາງ ຈຳກັດ ເຊິ່ງແມ່ນຜູ້ ຕິດຕັ້ງ ແລະ ວາງທໍ່ ຢາງດຳ (ທໍ່ PE) ຂະໜາດຜ່າສູນກາງ 50ມມ ແລະ ທ້າວ ລໍຕົວ ກີ ເຊິ່ງແມ່ນເຈົ້າຂອງນາ ຢູ່ຂ້າງທາງ ເຂົ້າຫາ ໂຮງຜະລິດ ໄຟຟ້າ ຂອງໂຄງການ ເຂື່ອນນ້ຳງື່ມ 3 ຢູ່ຈຸດ ກມ 0+750, ທັງສອງຝ່າຍ ໄດ້ ທຳການ ກວດກາ ສະພາບ ຂອງທໍ່ PE ທີ່ໄດ້ທຳການ ຕິດຕັ້ງແລ້ວ ເຊິ່ງເຫັນວ່າ ນ້ຳ ສາມາດໄຫລສົ່ງເຂົ້ານາ ເປັນທີ່ ເພິ່ງພໍໃຈ ຂອງ ເຈົ້າຂອງນາ ແລ້ວ.
- ທໍ່ດັ່ງກ່າວ ມີຄວາມຍາວທັງໝົດ 192ແມັດ ທີ່ບໍລິສັດ ໜອງໄຮ ກໍ່ສ້າງ ຂົວທາງ ເປັນຜູ້ ວາງໃຫ້ ໂດຍແມ່ນ ບໍລິສັດ GMS LAOS LIMITED ເປັນຜູ້ຈ່າຍໃນການ ມູນຄ່າ ທັງໝົດ ທີ່ໄດ້ ນຳໃຊ້ໃນການ ສົ່ງນ້ຳເຂົ້ານາ ນີ້, ການວາງທໍ່ ແມ່ນ ຕໍ່ໃສ່ ກັບທໍ່ ຂອງເຈົ້າຂອງນາ ທີ່ມີຢູ່ແລ້ວ ນັ້ນ ແລະ ວາງລອດພື້ນທາງ ເຂົ້າໃນທໍ່ເບຕົງ ສີ່ລ່ຽມ ຢູ່ ກມ 0+618 ແລ້ວສົ່ງຕໍ່ເຂົ້າຫານາ ຮອດຈຸດ ຕ່ຳ ສຸດ ຄືຈຸດໜອງປາ .

ດັ່ງນັ້ນ, ໃນມື້ນີ້ ທັງສອງຝ່າຍ ຈຶ່ງໄດ້ເຮັດໃບຢັ້ງຢືນ ການມອບກຳມະສິດ ສະບັບນີ້ ເພື່ອເປັນຫລັກຖານ ວ່າທໍ່ ທັງໝົດ ທີ່ກ່າວມາ ຂ້າງເທິງນັ້ນ ແມ່ນ ເປັນກຳມະສິດ ຂອງ ທ້າວ ລໍຕົວ ກີ້ ໃນການ ນຳໃຊ້ ໃຫ້ຖືກຕ້ອງ ແລະ ປົກປັກຮັກສາ, ຖືວ່າ ບໍລິສັດ ໜອງໄຮ ກໍ່ສ້າງ ຂົວທາງ ຈຳກັດ ຈະບໍ່ມີສ່ວນ ກ່ຽວຂ້ອງ ຫຍັງໝົດ ຖ້າຫາກ ທໍ່ດັ່ງກ່າວຫາກ ມີການຕົກເຮ່ຍ ຫລື ຫາກນ້ຳ ບໍ່ໄຫລເຂົ້າທໍ່ ໄດ້ ແມ່ນໃຫ້ ເຈົ້າຂອງນາ ຮັບຜິດ ຊອບເອງ ເພາະ ຕອນມອບກຳມະສິດນັ້ນ ນ້ຳໄດ້ໄຫລເຂົ້ານາ ຂອງຜູ້ກ່ຽວ ເປັນທີ່ເພິ່ງພໍໃຈ ແລ້ວ.

ບົດບັນທຶກສະບັບນີ້ ສ້າງຂຶ້ນໂດຍການເຫັນດີ ເປັນເອກະພາບກັນ ຂອງທັງສອງຝ່າຍ ເພື່ອເປັນການ ຢັ້ງຢືນ ໃຫ້ ເຈົ້າຂອງ ໂຄງການ ຄື: ບໍລິສັດ GMS LAOS LIMITED ເຊິ່ງເປັນຜູ້ ຈ່າຍຄ່າ ຕິດຕັ້ງ ແລະ ວາງທໍ່ PE ນີ້ ຮັບຊາບ.

ໃບຢັ້ງຢືນການມອບສິດ ໃນການນຳໃຊ້ ແລະ ປົກປັກຮັກສາ ສະບັບນີ້ ມີຜົນສັກສິດ ນັບແຕ່ມື້ ລົງລາຍເຊັນ ຂອງທັງສອງຝ່າຍ ເປັນຕົ້ນໄປ

ທີ່ ທາງເຂົ້າ ໂຮງຜະລິດ ໄຟຟ້າ ເຂື່ອນນ້ຳງື່ມ 3,

ວັນທີ 23/01/2009 ...... ວັນທີ 23/01/2009...

ຜູ້ມອບສິດ ຜູ້ຮັບສິດ

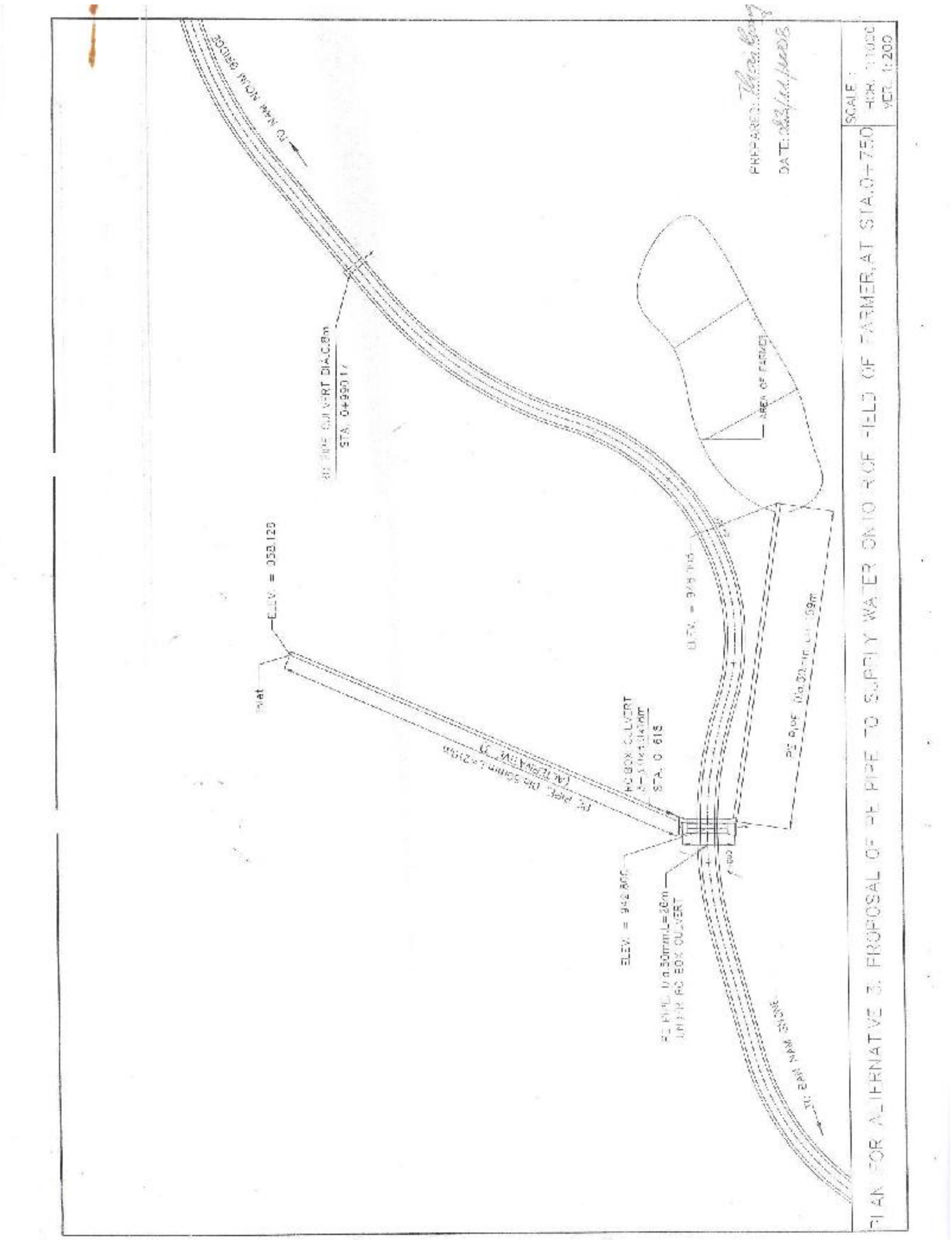
Champa

ວັນທີ 24/01/09

ຢັ້ງຢືນຈາກນາຍບ້ານ ບ້ານນ້ຳຢອນ

ນາຍບ້ານ ບ້ານ ນ້ຳຢອນ

Design drawing of water supply system.



APPENDIX 2

Ceremonies and compensation of the four graves found during the upgrading of the access road to the power station site.

GMS Lao Co., Ltd.
The Construction Supervision of Access Road-Portion 3
Nam Ngum 3 Hydropower Project

Burapha Development Consultants Co., Ltd.
P.O. Box 3144, Fax: (856-21) 451844, E-mail: bdcsm@laotel.com

Date: 23rd December 2007
Ref.: NN3 PM-07

MEMO TO : Mr. Sompak Sattayasoontorn, GMS's Representative
Senior Civil Engineer as Controller
GMS Lao Co., Ltd.
Nam Ngum 3 Hydropower Project

Subject : **Two More Graves Found Nearby the Center Line of the Proposed Road**
Construction of Access Road –Portion 3-
Nam Ngum 3 Hydropower Project

Cc. :

Dear Sir,

Further to the Contractor's letter Ref.: No. 053/NHC-R8CE, on 22nd December 2007 two more graves were found nearby the Center Line of the Proposed Road at Sta. 1+350 and Sta. 1+375 during the site clearing and grubbing. Please find herewith attached two photographs of the two graves.

It has been advised to the Contractor that firstly he is requested to inform the two graves found to the chief of Nam Gnone village to find the grave owners.

The grave issue will be also raised in Site Meeting No. 05 being held on Monday 24th December 2007 at 10:00 am in Engineer's Site Office in the Contractor's construction camp for more detailed discussion.

This is for your information and your comments on this issue will be highly appreciated.

Yours sincerely,

Mr. Khamsay Hongsouvanh
Team Leader of Construction Supervision Team

GMS Lao Co., Ltd.
The Construction Supervision of Access Road-Portion 3
Nam Ngum 3 Hydropower Project

Burapha Development Consultants Co., Ltd.
P.O. Box 3144, Fax: (856-21) 451844, E-mail: bdcsm@laotel.com

Date: 28th December 2007
Ref.: NN3 PM-10

MEMO TO : Mr. Sompak Sattayasoontorn, GMS's Representative
Senior Civil Engineer as Controller
GMS Lao Co., Ltd.
Nam Ngum 3 Hydropower Project

Subject : **Proposal of Remedial Action by Namgnone Village Governor**
Construction of Access Road –Portion 3-
Nam Ngum 3 Hydropower Project

Cc. :

Dear Sir,

Further to our discussion in the Site Meeting No. 05 held on 24th December 2007 regarding two graves found nearby the proposed road alignments at Sta. 1+350 and Sta. 1+375, on 26th December 2007 we, the engineer and contractor accompanied by Namgnone village governor and a patriot, inspected the graves found. After the inspection the engineer has informed that the graves are in cut sections with the depth of more than 1.60m and GMS's Site Representative would like to have your suggestions to simply to solve these problems at Village Level.

Namgnone Village Gorvernor, Mr. Kiaseulo, and the patriot, Mr. Kiatuyang has pointed out as followings:

1. The two graves are unknown, therefore they must be undisturbed.
2. Further to the experience done in Phoubia Mining Project, in practice for this case, an Agreement shall be made between the Employer and the Village Governor in witness of District Governor. The agreement is said that:
   - In case of unknown graves, the Employer shall reserve an amount of 3,000,000 (Three Millions) LKIP per grave within two years. Then regional ceremony can be arranged for removing the graves to temporary undisturbed areas at the expense of the employer.
   - If, within two years, Relative or Owners of graves are presented to the village governor, the Employer shall pay 3,000,000 LKIP per grave to them, otherwise (after two years) the first half of reserved amount (1,500,000 LKIP) will be paid to District Governor and another half will be paid to Village Governor.
3. Any action should not be done if no agreement is made.

These are for your information.

Yours sincerely,

Mr. Khamsay Hongsouvanh
Team Leader of Construction Supervision Team

Encl.

Mr. Kiaseulo and Mr. Kiatuyang have been performing the ceremonies in advance of removal of the graves and also witnessed the financial compensation in Nam Gnone village to relatives of the buried persons. Both Mr. Kiaseulo and Mr. Kiatuyang, who are still living at Nam Gnone village, can confirm the ceremonies held and the financial compensation provided to relatives of the persons buried in the 4 graves.

APPENDIX 3

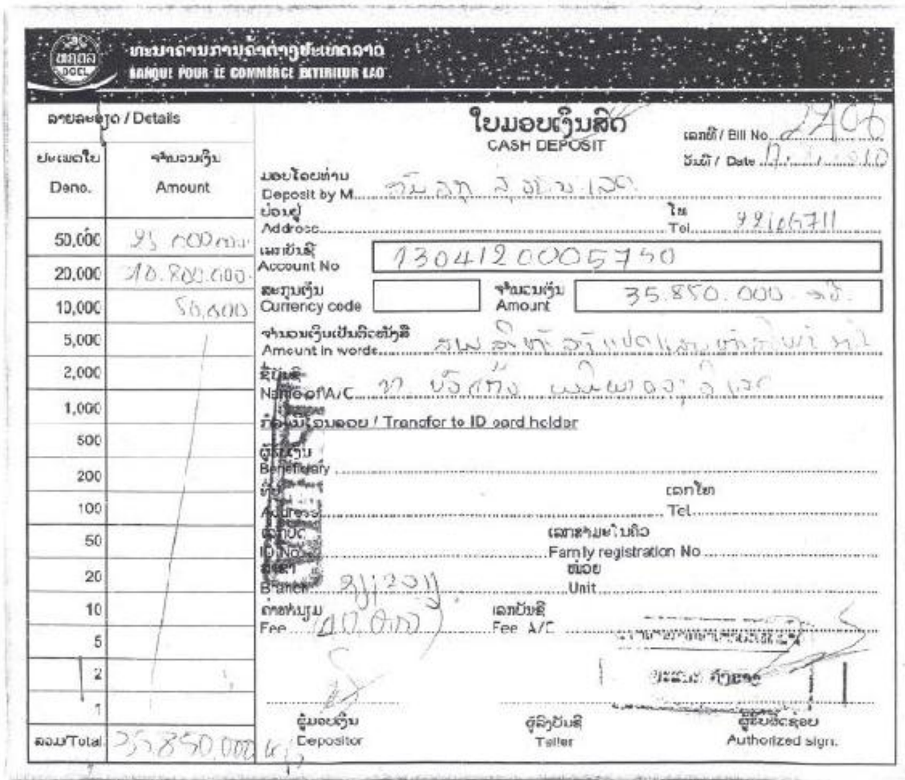
In July, 2010, the Xiengdet village authorities came with a request to the developer for financial support to the newly constructed primary school. The requested amount was Kip 35,850,000, equivalent to about USD 5,000, at the currency exchange rate at that time.

Following is the translated request by village authorities to the developer:

No.	List	Amount		Unit Cost	Total Cost	Currency	Note
1	Zinc	35	units	40,000	1,400,000	KIP	
2	Nail use with zinc	10	boxes	5,000	50,000	KIP	
3	Black board	5	units	50,000	250,000	KIP	
4	Table and chair of Student	120	suits	120,000	14,400,000	KIP	
5	Table and chair of Teacher	6	suits	110,000	660,000	KIP	
6	Textbooks	175	units	15,000	2,625,000	KIP	grade1- grade 5
7	Water pipe	1500	m	6,250	9,375,000	KIP	
8	faucet	3	units	20,000	60,000	KIP	
9	stool of toilet + concrete	3	units	110,000	330,000	KIP	
10	Timber	4	m3	850,000	3,400,000	KIP	
11	Sport equipment			600,000	600,000	KIP	Takor, volley ball, football
12	File cabinet	6	units	450,000	2,700,000	KIP	
	TOTAL				35,850,000	KIP	

After the developer received the above request for financial support, the Xiengdet village authorities opened a bank account at Xieng Khouang Province where the developer deposited 35,850,000.- Kip for assistance in (i) finalizing the construction of the school, (ii) obtaining furniture, (iii) providing water supply and sanitation, and (iv) procurement of text books.

Cash deposit by the developer at bank account of Ban Xiengdet village.


BANQUE POUR LE COMMERCE EXTERIEUR LAO

CASH DEPOSIT

Bill No. 2406

Date

Details

Deno.	Amount
50,000	25,000,000
20,000	10,800,000
10,000	50,000
5,000	
2,000	
1,000	
500	
200	
100	
50	
20	
10	
5	
2	
1	
Total	35,850,000

Deposit by M.

Address

Tel. 99106711

Account No 1304120005750

Currency code

Amount 35.850.000

Amount in words

Name of A/C

Transfer to ID card holder

Beneficiary

Address

Tel.

ID No.

Family registration No

Unit

Branch

Fee 10.000

Fee A/C

Depositor

Teller

Authorized sign.

APPENDIX 4

Letter of Governor of Phou Kou District (Mr. Vanthong Chantavong) to Village Authorities of Ban Xiengdet. This confirmation letter does not allow persons/households from outside the village to construct new houses or buying/establishing land plots within Ban Xiengdet village area as per the cut off date of 9 th October, 2009.

ສາທາລະນະລັດ ປະຊາທິປະໄຕ ປະຊາຊົນລາວ

ສັນຕິພາບ ເອກະລາດ ປະຊາທິປະໄຕ ເອກະພາບ ວັດທະນະຖາວອນ

ຫ້ອງວ່າການເມືອງພູກູດ

ເລກທີ 183 / ຈມ-ພກ

ວັນທີ 14 /07/2010

ຄຳສັ່ງແນະ

ຂອງທ່ານເຈົ້າເມືອງພູກູດ

ເຖິງ: ຄະນະຮັກສາການກຸ່ມຊູຍ-ຊຽງໃໝ ແລະ ນາຍບ້ານຊຽງແດດ, ບ້ານນ້ຳສານ

ເລື່ອງ: ຫ້າມບໍ່ໃຫ້ຮັບເອົາປະຊາຊົນບັນດາເຂົ້າໄປຕັ້ງຖິ່ນຖານຢູ່ໃນຂອບເຂດ ທີ່ຖືກຜົນກະທົບຈາກ ນ້ຳງື່ມສາມ

- ອີງຕາມການຕົກລົງຂອງກອງປະຊຸມ ກ່ຽວກັບການປະເມີນຜົນຂອງໂຄງການນ້ຳງື່ມສາມ ຢູ່ທີ່ນະຄອນຫຼວງວຽງຈັນທີ່ງ ວັນທີ 23/6/2008

- ອີງຕາມກອງປະຊຸມປຶກສາຫາລືກ່ຽວກັບການສືບຕໍ່ປະຕິບັດໂຄງການນ້ຳງື່ມ 3 ໃນແຕ່ປີ 2011-2017 ແລະ ຜົນກະທົບຕໍ່ພື້ນທີ່ ລົງວັນທີ 3/6/2010 ຢູ່ທີ່ພະແນກພະລັງງານບໍ່ແຮ່ແຂວງຊຽງຂວາງ

- ອີງຕາມການຕົກລົງຂອງເມືອງລົງວັນທີ 10/3/2008 ກ່ຽວກັບການປົກປ້ອງບ້ານຊຽງແດດທີ່ຖືກຜົນກະທົບ ຈາກ ໂຄງການນ້ຳງື່ມ 3 ບໍ່ໃຫ້ຮັບເອົາປະຊາຊົນນອກເຂົ້າມາຕັ້ງຖິ່ນຖານຢູ່ໃນເຂດຂອງໂຄງການ.

ເພື່ອເຮັດໃຫ້ໂຄງການໄດ້ສືບຕໍ່ຈັດຕັ້ງປະຕິບັດໄປໄດ້ດີນັ້ນ ເຈົ້າເມືອງພູກູດ ຂໍອອກຄຳສັ່ງແນະມາຍັງ ກຸ່ມບ້ານຊູຍ-ຊຽງໃໝ ແລະ ບັນດາບ້ານອ້ອມຂ້າງໄດ້ຮັບຊາບດັ່ງນີ້:

1. ຫ້າມບໍ່ໃຫ້ປະຊາຊົນບໍ່ວ່າຢູ່ໃນເມືອງ,ຕ່າງເມືອງ,ຕ່າງແຂວງ ເຂົ້າໄປຕັ້ງບ້ານເຮືອນ ທີ່ ເປັນພື້ນທີ່ເມືອງ ຂອງບ້ານຊຽງແດດ ທີ່ຖືກຜົນກະທົບຈາກໂຄງການ ເພາະຈະເປັນການສ້າງຄວາມຫຍຸ້ງຍາກໃຫ້ແກ່ໂຄງການ ແລະ ສັບສົນ ເນື່ອງຈາກວ່າທາງໂຄງການໄດ້ເກັບກຳຂໍ້ມູນຂອງຄົວເຮືອນທີ່ແລ້ວ.

2. ຄອບຄົວໃດທີ່ລູກຫຼານສ້າງຄອບຄົວໃໝ່ຈະອອກເຮືອນ ຕ້ອງໄດ້ມີໃບຢັ້ງຢືນຈາກການຈັດຕັ້ງບ້ານ, ຄະນະກຳມະການແກ້ໄຂສິ່ງກີດຂວາງ ແລະ ຄະນະພັກຮາກຖານກຸ່ມບ້ານຊັບສານ ເພື່ອນຳສະເໜີໂຄງການ ຄົ້ນຄວ້າພິຈາລະນາຕາມເງື່ອນໄຂຂອງໂຄງການວາງອອກ.
3. ເລຂາພັກບ້ານ, ນາຍບ້ານຕ້ອງໄດ້ຕິດຕາມກວດກາ ແລະ ບໍ່ອະນຸຍາດຊັບເອົາທີ່ນອກເຂດນາເປັນດິນ ລະເມືອງບ້ານຂອງຕົນສ່ວງໂດຍໂຄງການພວມນຳເປີນ, ສ່ວນປະຊາຊົນເຂົ້າມາ ນອກຈາກປະຊາຊົນເດີມທີ່ເຄີຍຕັ້ງຖິ່ນຖານແຕ່ວນັ້ນ ໃຫ້ນາຍບ້ານແກ້ໄຂຕາມລະບຽບການ ແລະ ປະຕິບັດຕາມສາທິດທີ່ໄດ້ເອກະພາບກັນໃນເມື່ອກ່ອນ, ສ່ວນທາງໂຄງການ ແລະ ທົ່ນເທົ່າຈະບໍ່ມີຈະຂອງນາ.
4. ຫ້າມເດັດຂາດບໍ່ໃຫ້ປະຊາຊົນຂາຍດິນໄຮ່,ດິນນາ(ເຖົ້າລວມເງິນທຸກປະເພດ) ໃຫ້ຄົນນອກເດັດຂາດ. ຜູ້ໃດຫາກບໍ່ປະຕິບັດຈະໄດ້ວ່າເປັນຄະດີ ແລະ ຖືກຍຶດຊັບທັງໝົດຕາມລະບຽບກົດໝາຍບ້ານເມືອງ.

ດັ່ງນັ້ນຈຶ່ງໄດ້ອອກຄຳສັ່ງແນະນຳມາໃຫ້ຄະນະຜູ້ນຳກຸ່ມບ້ານ, ນາຍບ້ານ ຈົ່ງນຳໄປເຜີຍແຜ່ໃຫ້ປະຊາຊົນຊາບຢ່າງ ແລະ ພ້ອມກັນຈັດຕັ້ງປະຕິບັດຢ່າງເຂັ້ມງວດ.

ເຈົ້າເມືອງ-ເມືອງພູກູດ

ວັນທອງ ຈັນທະລິງ

ບ່ອນສົ່ງ

1. ສົ່ງໃຫ້ໂຄງການ 1 ສະບັບ
2. ຫ້ອງວ່າການປົກຄອງແຂວງ 1 ສະບັບ
3. ຫ້ອງວ່າການປົກຄອງເມືອງພູກູດ 1 ສະບັບ
4. ກຸ່ມບ້ານພັດທະນາສູນ-ດຽງໃສ 1 ສະບັບ
5. ບ້ານຊຽງແດດ, ບ້ານນ້ຳງາມ ບ້ານລະ 1 ສະບັບ.

APPENDIX 5

Compensation for lands and crops impacted by construction activities at Longcheng camp site in March 2011.

ສາທາລະນະລັດ ປະຊາທິປະໄຕ ປະຊາຊົນລາວ

ສັນຕິພາບ ເອກະລາດ ປະຊາທິປະໄຕ ເອກະພາບ ວັດທະນະຖາວອນ

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ເມືອງໄຊສົມບູນ

ອົງການຄຸ້ມຄອງທີ່ດິນ,ນ້ຳ ແລະ ສິ່ງແວດລ້ອມເມືອງໄຊສົມບູນ

ເລກທີ 95 /ອຄດ.ນສບ.
ລົງວັນທີ 24/03/2011

ແຜນຄິດໄລ່ການຊົດເຊີຍ

ຜົນກະທົບ ຈາກໂຄງການ ໄຟຟ້ານ້ຳຕົກ ນ້ຳງືມIII (ບ້ານລ້ອງແຈ້ງ)

-ອີງຕາມ: ດຳລັດ ຂອງນາຍົກ ລັດຖະມົນຕີ ສະບັບເລກທີ 135/ນຍ ລົງວັນທີ 25/5/2009, ໃນມາດຕາ 43 ກ່ຽວກັບການ ຄິດໄລ່ໃນການ ທົດແທນ ທີ່ດິນຂອງປະຊາຊົນ ທີ່ຖືກເຂດເຊົ່າ ແລະ ສຳປະທານ.

- ອີງຕາມ: ຂໍ້ຕົກລົງຊົ່ວຄາວ ຂອງທ່ານເຈົ້າເມືອງໆ ໄຊສົມບູນ ສະບັບເລກທີ 268/ນຊບ, ລົງວັນທີ 26/8/2009, ວ່າດ້ວຍ ການກຳນົດອັດຕາດິນ ແຕ່ລະປະເພດ ທົ່ວເມືອງໄຊສົມບູນ.

ລຳດັບ	ປະເພດຜົນກະທົບ	ອັດຕາຊົດເຊີຍ	ຫົວໜ່ວຍ	ຈຳນວນ	ເປັນເງິນກີບ	ໝາຍເຫດ
I	ປະເພດພືດລະປູກ	-	-	-	-	
1	ມັນຕົ້ນ	8 000	ຕົ້ນ	1 275	10 200 000	
2	ຕົ້ນໝາກເຂືອ	5 000	ຕົ້ນ	06	30 000	
3	ຕົ້ນໝາກເພັດ	5 000	ຕົ້ນ	104	520 000	
4	ໝາກນັດ	8 000	ຕົ້ນ	13	104 000	
5	ຕົ້ນກ້ວຍ	50 000	ຂຸມ	66	3 300 000	
6	ມັນດ້າງ	5 000	ຂຸມ	300	1 500 000	
7	ຕົ້ນໝາກມີ້	15 000	ຕົ້ນ	02	30 000	
8	ໄມ້ໄຜ່	15 000	ຕົ້ນ	35	525 000	
9	ຕົ້ນໝາກກອກ	15 000	ຕົ້ນ	01	15 000	
10	ຕົ້ນໝາກຈອງ	15 000	ຕົ້ນ	01	15 000	
11	ມັນສະຄູ	5 000	ຂຸມ	15	75 000	
12	ຕົ້ນໝາກຫຸ່ງ	15 000	ຕົ້ນ	4	60 000	
13	ຕົ້ນໝາກໄຟ	15 000	ຕົ້ນ	3	45 000	
II	ປະເພດດິນ	-	-	-	-	
1	ດິນສວນ	15 00	ຕາແມັດ	50 000	75 000 000	M^2
ລວມຍອດ					91 419 000	

ຫົວໜ້າ ອົງການ ຄຸ້ມຄອງທີ່ດິນ, ນ້ຳ ແລະ ສິ່ງແວດລ້ອມ ເມືອງໄຊສົມບູນ

ອົງການ ຄຸ້ມຄອງທີ່ດິນ,ນ້ຳ ແລະສິ່ງແວດລ້ອມ

ບຣົງເຊີ ໄຊເລ່ຍວື

Xaysomboun District

Land ,Water and Environment Conservation Organization

No. 95/lweco……………………

Date…24/3/11……….

COMPENSATION PLAN FOR IMPACTS INDUCED BY NN3 HYDROPOWER PROJECT (Ban Long Cheng)

Based on : Decree of Prime Minister No.135/PM dated 25/5/09,Clause 43 on compensation cost for land of villagers affected by concession or lease

: Temporary agreement of chief of Xaysomboun district No.268/XD on price of land plot in Xaysomboun district area dated 26/8/09

NO.	Crops	Unit Rate	Unit	Quantity	Amount(kip)	Remark
I	Crops type	-	-	-	-	-
1	Cassava	8,000	ea	1,275	10,200,000	
2	Eggplant	5,000	ea	6	30,000	
3	Chillies	5,000	ea	104	520,000	
4	Pineapple	8,000	ea	13	104,000	
5	Banana	50,000	ea	66	3,300,000	
6	Sweet potato	5,000	ea	300	1,500,000	
7	Jackfruit	15,000	ea	2	30,000	
8	Bamboo	15,000	ea	35	525,000	
9	Hog plum	15,000	ea	1	15,000	
10	Wild fruit(Mak Jong)	15,000	ea	1	15,000	
11	Sago palm	5,000	ea	15	75,000	
12	Papaya	15,000	ea	4	60,000	
13	Wild fruit(Mak Fai)	15,000	ea	3	45,000	
II	Land plot	-	-	-	-	-
1	Garden land	1,500	M2	50,000	75,000,000	M2
Total					91,419,000	

Signed by the Chief of land, water and environment organization

Annex C

DAM SAFETY, SEISMICITY AND RESERVOIR FLUCTUATION

ANNEX C

DAM SAFETY, SEISMICITY AND RESERVOIR FLUCTUATION

The embankment foundation is divided into the following three principal areas:

Dam Type

A concrete face rock fill dam (CFRD) has been adopted, in preference over the option of a roller compacted concrete dam (RCCD), as consequence of the following considerations:

- Potential problematic foundation conditions for the RCCD option, including the depth of weathering of the foundation rock on both abutments, the characteristic of the alternating soft siltstone and mudstone on the right abutment, and the open fault zone just downstream of the location of the RCCD dam.
- Construction of RCCD is also more complicated and needs much better rock foundation than that needed for the CFRD option.
- The RCCD option requires greater excavation and larger area for the disposal of waste material than is needed for a CFRD.
- The RCCD option would also require importation of a very large volume of construction material, including cement, fly-ash and steel. Such importation would involve a large number of truck movements each day on the long and narrow access road from Ban Thabok to the dam site, thereby increasing road safety risks to the other users of the road, particularly on the public road between Ban Thabok and Ban Longcheng.
- The CFRD plinth slab can be located on moderately weathered rock foundation, and the CFRD dam embankment can be constructed on firm ground.
- Construction of the CFRD is simpler than for the RCCD option. Most of the construction material will be exploited near to the dam site.
- Following receipt and evaluation of tenders for both the CFRD and RCCD options, the CFRD option was shown to be significantly lower in cost than the RCCD alternative.

The CFRD option has more advantages in terms of geology and is inherently more stable in terms of resistance to seismic forces, but has some disadvantage compared with the RCCD option in the unlikely event of the dam being overtopped. Consequently, very careful review of the Nam Ngum hydrology and the spillway capacity has been undertaken to ensure the safety of the CFRD.

Dam Foundation and Dam Cross Section

Foundation conditions for the dam are complicated by the sub-vertical inclination of the inter-bedded strata and by the rapid alternation of different lithology with variable material properties. The steep orientation of the strata and discontinuities is generally favorable in reducing foundation seepage as they do not form a hydraulic connection from upstream to downstream.

- The upstream area adjacent to the plinth (i.e. the „plinth zone"), extending over a distance of 0.5 x Reservoir Head (minimum 10 m) downstream of the plinth reference line.
- The remainder of the upstream foundation area beneath the upstream shoulder.
- The downstream foundation area underneath the downstream shoulder.

The foundation quality requirements are most onerous in the plinth zone, and least stringent beneath the embankment zone.

- **Plinth foundation**

The dominating rock types along the plinth alignment are sandstone interbedded with phyllitic shale. Excavation for the plinth will involve the removal of all the completely weathered rock and the highly weathered rock material and possibly some local treatment. A moderately weathered rock foundation is considered as the minimum desirable profile for the plinth of a high CFRD.

Excavation depths will be less than 5 m in the river bed, averaging about 12 m on the lower slopes with a gradual deepening to more than 20 m in areas higher up the abutments.

- **Dam Foundation**

General stripping for the rock fill zones will involve the removal of completely weathered rock material and local slope modification to improve the foundation shape. Rock fill can be placed on highly weathered rock presenting firm conditions. Overburden removal is expected to involve an average of about 8 to 10 m of stripping.

- **Downstream Fault**

A geological fault is located below the downstream shoulder of the proposed CFRD; positioned on a transverse alignment approximately 20% of the overall dam width from the downstream toe. The results of plate loading tests indicate a low deformation modulus of 50 MPa for the sedimentary rock on the upstream side. The metamorphic rock on the downstream side of the fault is considerably stronger at a measured deformation modulus of 950 MPa. The measured value for the sedimentary rock is exceptionally low compared with the general magnitude of the foundation moduli measured on site.

Considering that the downstream fault is located well downstream of the dam axis, it is unlikely that it will have any adverse impact on the performance of the concrete face. Nevertheless, due consideration will be given to building this lineament into a FEM numerical model of the dam if the ou tcome o f a m ore de tailed g eological ap praisal du ring con struction shows this to b e necessary.

Dam Safety

The Nam Ngum hydrology and the design capacity of the spillway will directly impact the safety of the dam. The hydrology and the design flood of the project have been thoroughly reviewed by SMEC, Mr. Chidchop (an independent expert), Colenco and SWECO (the Lenders" Technical Advisor). The final design concept and criteria for dam safety is as follows:

- **Design Floods**

The criteria for selecting the design flood are based on the following, internationally recognised International Commission On Large Dam (ICOLD) publication:

- ICOLD Bulletin 125: Dams and Floods, Guidelines and Case Histories, ICOLD, 2003.

With regard to the ICOLD (2003) criteria and their application to the NN3 dam and spillway, the crest structure has to pass the PMF whilst providing the freeboard required for the CFRD type of dam (i.e. an embankment dam). Table above shows that there is scope to adopt a smaller design flood for determining the weir crest geometry and the optimum design for the energy dissipation works (i.e. spillway flip bucket and plunge pool). The optimum design of the spillway chute with regard to freeboard, etc. could also be based on the design flood, as long as the chute could still contain the water without jeopardizing the integrity of the dam during a PMF event.

ICOLD Criteria for Design Flood Selection

Dam Hazard Category	Loss of Life	Economic, Social, Environmental, Political Impacts	Design Flood	Safety Check Flood or Inflow Design Flood
High	N	Excessive	% PMF or 1,000-5,000 year	PMF or 5,000-10,000 year
Significant	0 to N	Significant	% PMF or 500-1,000 year	% PMF or 1,000-5,000 year
Low	0	Minimal	100 year	100-150 year

The 1,000 year flood is commonly used as the design flood for hydraulic design of spillways. The boundary between high hazard dams and significant hazard dams is established quantitatively according to the loss of lives being equal to or higher than N. The value of N varies between 1 and 10 lives. The NN3 dam is classified as a high hazard dam and the 10,000 year flood is considered to be more appropriate since even this is only 52 % of the PMF flow, in terms of reservoir inflow.

The following floods were adopted for the spillway design:

- Design Flood : $Q_{10,000}$
- Safety Check Flood : PMF (Probable Maximum Flood)

These flood events have the following magnitudes, in terms of peak reservoir inflow:

- $Q_{10,000}$ Design Flood : 6,316 m^3/s
- PMF : 12,137 m^3/s **Flood Routing**

A reservoir flood routing study was carried out to determine the maximum discharge and highest reservoir levels that would occur during the design floods. The „design flood" is the flood that has to be taken into account in the hydraulic design of spillways and energy dissipating structures, with a safety margin provided by the freeboard. The „safety check flood" represents the most extreme flood conditions to which the dam could be subjected without failure, but also with a lower safety margin (scenario limit). In this case, limited overtopping may be permitted for concrete dams, but not for embankment dams. For the 10,000 year flood, it was assumed that one spillway gate would be out of service, thus restricting the discharge to only two gate openings. The PMF analysis involved all three gates being available.

In reality, the gates would be fully opened before the inflow is equal to the spillway capacity at reservoir full supply level (FSL) since the gates can only regulate up to a certain opening height. The USACE (1992) suggest that the opening height at maximum regulation is 0.625 of the design head on the weir. So the assumption made in the model regarding gate operation is conservative.

Results of Flood Routing Analyses

Flood	Number of Gates in Operation	Q_{in} (m^3/s)	Q_{out} (m^3/s)	Max. Reservoir Level (m)
10,000-year	2	6,316	5,140	725.81
PMF	3	12,137	9,780	729.04

A possible method of operating the gates would involve opening the individual gates in sequence with „gate 1" being fully opened before „gate 2" starts regulating, etc. This staged operation would avoid all three gates from operating for prolonged periods at small openings, which would be undesirable from a hydraulics perspective, particularly with regard to cavitation.

- Survey monuments and deflection points.
- Electrical piezometers.
- Standpipe piezometers.
- Groundwater observation wells.

One important aspect of a gated spillway is that it should not discharge at a higher rate than the natural flow in the river before the dam was built. This condition applies to the rising limb of the hydrograph. The gate operation methodology must ensure that the amount of water released from the reservoir never exceeds the outflow from the natural basin for an equivalent storm.

The specific discharge through the 53 m wide spillway would be 97 m^3/s/m during a 10,000 year flood, and 185 m^3/s/m during a PMF event. These are satisfactory with regard to the normally accepted maxima for spillway design, which are 150 and 200 m^3/s/m for these respective floods.

- **Dam Instrumentation**

To monitor the safety of the dam during the construction and long-term operation, intensive dam instrumentation will be installed to record the behaviour and the performance of the dam. The instrumentation system is geared towards monitoring the following criteria:

- deformation of the concrete face slab;
- deformations within the dam body and on the surface of the rock fill;
- deformation along the dam crest;
- piezometric levels in the dam foundation and in the abutments;
- seepage quantities;
- earthquake response.

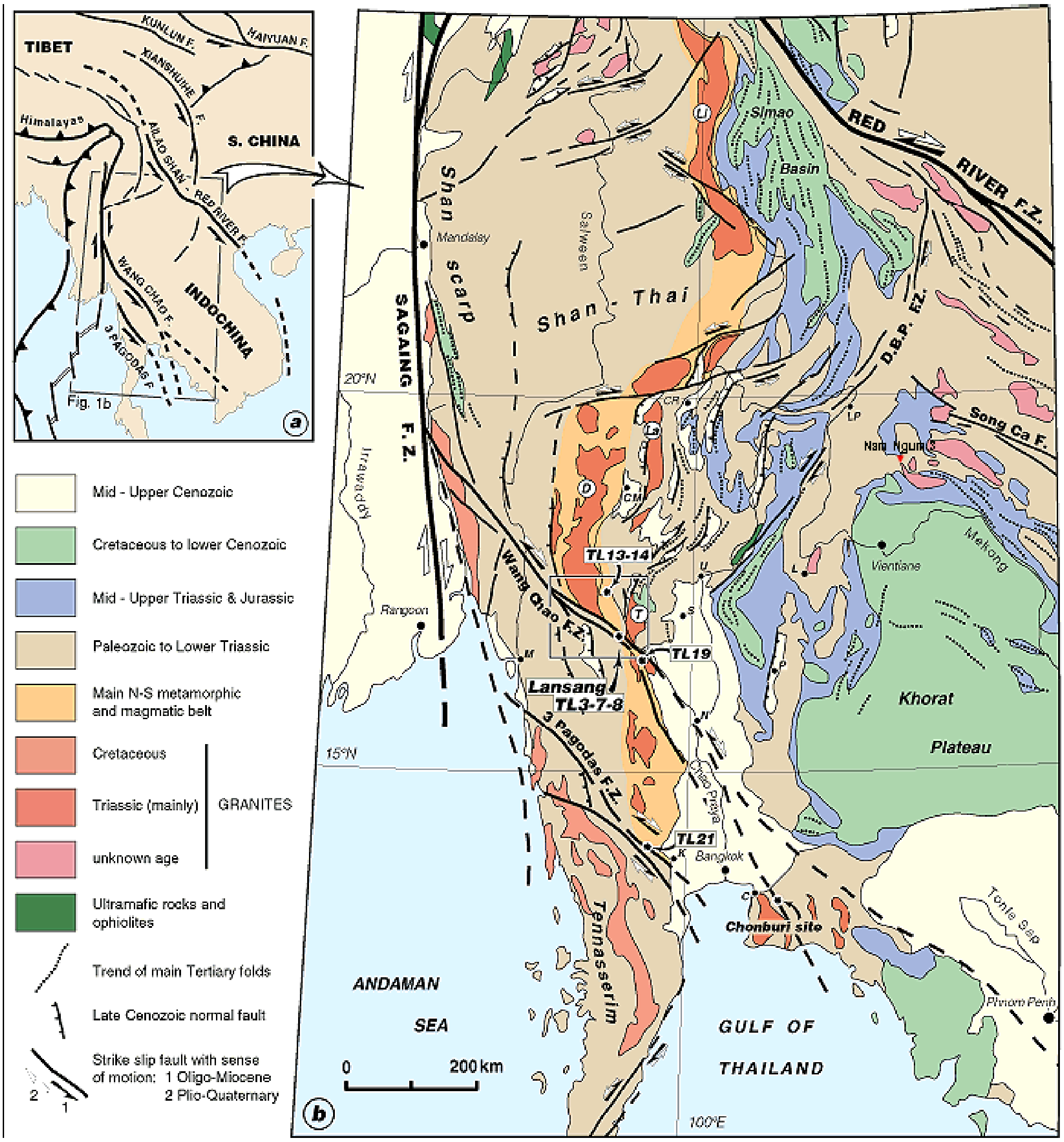
Three main instrumented sections will be provided in the dam. The instrumentation will include:

- Survey monuments and deflection points.
- Electrical piezometers.
- Standpipe piezometers.
- Groundwater observation wells.
- Hydrostatic settlement cells.
- Total pressure cells.
- Inclinometers.
- Strain gauges.
- Joint meters.
- Seepage measuring weir.
- Accelerograph /Seismograph.

Instruments will be installed as soon as practicable during construction so that data is available to verify the criteria used for designing the dam and monitoring its behaviour and long-term performance.

Earthquakes

The Project Area lies in what is called the "Indochina Platform", in a tectonically and seismically quiet context, and at substantial distances from regional major active faults and plate boundaries. The Cenozoic and Quarternary tectonics of the region is mainly developed at the boundaries, but locally also within the interior of the Indochina Platform.



The recorded seismic history within the region of largest influence to the earthquake hazard in the Project Area is rather short; 99% of the recorded data (updated to February 2007) relates to post-1972 earthquakes. An earthquake with magnitude 6.3 was recorded on 16 May 2007, with the epicenter located about 300 km from the Nam Ngum 3 Project Area.

The Maximum Credible Earthquake (MCE) of 0.22 g and the Operating Basis Earthquake (OBE) of 0.12 g were adopted as the design seismic parameter for the project.

No effect in the Project Area in excess of the MCE amplitude is expected to result from a reservoir induced earthquake (RIS) event of a size equivalent to the largest RIS earthquake so far recorded worldwide (M = 6.5). A RIS earthquake of this or smaller size at Nam Ngum 3 Reservoir is considered more likely than the MCE.

	Horizontal Peak Ground Acceleration PGA
Maximum credible earthquake – MCE	0.22 g = 220 cm/s^2
Operating basis earthquake – OBE Return period 475 years	0.12 g = 120 cm/s^2

Reservoir Fluctuation Levels

A serious degradation of the reservoir shores can be expected as a consequence of the large seasonal fluctuation of the water level in the reservoir (between EL 720 and EL 660 m). There is not much to be done in terms of design, but a survey of reservoir slopes will be carried out to make sure that possible slope instabilities will not impact on the safety of the project structures.

Review of surface features within the reservoir area was performed during the Feasibility Study by aerial photograph interpretation and inspection by helicopter in order to locate areas with slope instability. The review indicated that there are few areas of obvious local slope instability. Although some collapse structures were seen in the limestone areas, no evidence of large-scale land sliding was observed.

Annex D

BIODIVERSITY IN THE NAM NGUM RIVER VALLEY DOWNSTREAM NN3 DAM

ANNEX D

BIODIVERSITY IN THE NAM NGUM RIVER VALLEY DOWNSTREAM NN3 DAM

The following tables summarises the results of the RMR (Chapter 33, 2001) fauna surveys in the Nam Ngum reach from the NN3 dam site to the NN1 reservoir.

Classification of National Status

The column "IUCN National priority" status describes the risk level considered appropriate for the species' survival in Lao PDR. The classification of Duckworth *et al* has been simplified to show 4 categories of risk, namely:

Risk level for next ten years and Risk Index (0 – 3)		**Duckworth *et al* classification**
3	High Risk of National Extinction (or already nationally extinct)	"Acute National Priority Category" and some "Indeterminate National Priority spp." occurring in small populations in restricted areas & any new rare species.
2	Medium Risk of National Extinction	"High National Priority Category" and some "Indeterminate National Priority spp." occurring in small populations and reasonably distributed.
1	Low Risk of National Extinction	All listed "key" species except those in the Acute, High and Indeterminate Priority Groups and some "Indeterminate National Priority spp." with large and widespread populations
0	Negligible Risk of National Extinction	All common species not listed as key species

Classification of Global Status

The column "Global status of Lao population" is taken from Duckworth *et al*''s ranking of "Global significance of Lao populations". There are 5 categories of risk, as shown below:

Importance level for next ten years and Importance index (0 – 4)		Duckworth *et al* classification
4	Very High Risk of Global Extinction: Lao population critical	*Species close to global extinction. Lao population is a critical component**
3	High Risk of Global Extinction: Lao population is very significant	Species has small numbers and/or restricted range. Lao population is very significant component
2	Medium Risk of Global Extinction: Lao population is significant.	Species has a regionally concentrated distribution. Lao population is significant component.
1	Low Risk of Global Extinction: Lao population unimportant	Species numerous in the region. Lao population is an unimportant component.
0	Negligible Risk of Global Extinction: Lao population irrelevant	All common species not listed as key species. Lao population not a relevant component

Mammals

English Name	Family	Latin Name	No. of species	IUCN National Priority	No. of species	Global status of Lao population
Macaque	Cercopithecidae	*Macaca spp.*	1	1	3	2
			Several	0	2	1
Sambar	Cervidae	*Cervus unicolor*	1	1	1	1
Common Barking Deer	Cervidae	*Muntiacus muntjak*	1	0	1	0
Tomb Bat	Emballonuridae	*Taphozous theobaldi.*	1	1	1	1
Fishing Cat	Felidae	*Felis viverrina*	1	1	1	1
Leopard Cat	Felidae	*Felis bengalensis*	1	0	1	0
Crestless Himalayan Porcupine	Hystricidae	*Hystrix hodgsonii*	1	0	1	0
Pangolin	Manidae	*Manis sp.*	1	2	2	1
			1	1		
Vole	Muridae	*sp. or spp.*	1	0	1	0
Otter	Mustelidae	*Lutra spp.*	3	2	2	2
			1	1	2	1
Fruit Bat	Pteropodidae	*Several spp.*	1	1	1	1
Horseshoe Bat	Rhinolophidae	*Rhinolophus sp. or spp.*	1	1	12	1
					1	Unknown
Large Bamboo Rat	Rhizomyidae	*Rhizomys sumatrensis*	1	0	1	0
Variable Squirrel	Sciuridae	*Callosciurus finlaysoni*	1	0	1	0.
Water Shrews	Soricidae	*sp. or spp.*	1	0	1	0.
Common Wild Pig	Suidae	*Sus scrofa*	1	1	1	1
Lesser Mouse Deer	Tragulidae	*Tragulus javanicus*	1	0	1	0
Common Bat	Vespertilionidae	*Myotis sp. or spp.*	5	1	5	1
			Several	0	Several	0
Three Striped Palm Civet	Viverridae	*Arctogalida trivirgataFelidae*	1	0	1	0
Civet	Viverridae	*Several spp.*	1	3	1	3
			1	2	1	2
			Several	0	Several	0
Crab-Eating Mongoose	Viverridae	*Herpestes urva*	1	0	1	0

Reptiles

English Name	Family	Latin Name	No. of species	IUCN National Priority	No. of species	Global status of Lao population
Asian Water Dragon	Agamidae	*Physignathus cocincinus*	1	0	1	0
Python	Boidae	*Morelia reticulatus*	2	1	1	2
Colubrine Snake	Colubridae	*sp. or spp.*	2	1	2	1
			Many	0	Many	0
Terrapin	Emydidae	*sp. or spp.*	1 or several	0	1 or several	0
Stripe-Necked Terrapin	Emydidae	*Geomyda tcheponensis*	1	0	1	0
Skink	Scincidae	*Mabuya spp.*	Several	0	Several	0
Malayan Soft shelled Turtle	Tronycheidae	*Dogania subplana*	1	0	1	0
Big Headed Turtle	Tronycheidae	*Platysternon megacephalum*	1	2	1	2
Yellow Tree Monitor	Varanidae	*Varanus bengalensis*	1	0	1	0
Water Monitor	Varanidae	*Varanus salvato*	1	1	1	1

Amphibia

English Name	Family	Latin Name	No. of species	IUCN National Priority	No. of species	Global status of Lao population
Toad	Buffanidae	*Bufo melanostictus*	Several	0	Several	0
Frog	Ranidae	*Rana sp. or spp.*	Several	0	Several	0

Birds

English Name	Family	*Latin Name*	No. of species	IUCN National Priority	No. of species	Global status of Lao population
Fish Eagle	Accipitridae	*Ichthyophaga sp.*	1	0	1	0
Bat Hawk	Accipitridae	*Macheiramphus alcinus*	1	0	1	0
Common Kingfisher	Alcedinidae	*Alcedo atthis*	1	0	1	0
Pied Kingfisher	Alcedinidae	*Ceryle rudis*	1	2	1	0
Rufous-Backed Kingfisher	Alcedinidae	*Ceyx erithacus*	1	0	1	0
Stork-Billed Kingfisher	Alcedinidae	*Halcyon capensis*	1	0	1	0
Black-Capped Kingfisher	Alcedinidae	*Halcyon pileata*	1	0	1	0
			3	1	1	2
			Several	0	2	1
Geese	Anatidae	*sp. or spp.*			Several	0
			1	3	1	3
			3	1	3	1
Duck	Anatidae	*Anas spp.*	0	0	0	0
Grey Heron	Ardeidae	*Ardea cinerea*	1	1	1	0
Chinese Pond Heron	Ardeidae	*Ardeola bacchus*	1	0	1	0
Little Egret	Ardeidae	*Egretta garzetta*	1	0	1	0
Cinamon Bittern	Ardeidae	*Ixobrychus Cinnamostomus*	1	0	1	0
Frogmouth	Batrachostomidae	Batrachostomus sp	1	0	1	0
Thick-Knee	Burhinida	*Burhinus sp.*	2	1	2	1
Grey Nightjar	Caprimulgidae	*Caprimulgus indicus*	1	0	1	0
Lapwing	Charadriidae	*Vanellus sp. Ssp.*	Several	2	Several	1
Brown Dipper	Cinclidae	*Cinclus pallasii*	1	1	1	1
Rock Pigeon	Columba	*Columba punicea*	1	0	1	0
Coucal	Cuculidae	*Centropus spp.*	1	0	1	0
Black Drongo	Dicruridae	*Dicrurus macrocercus*	1	0	1	0
Banded Broadbill	Eurylaimidae	*Eurylaimus javanicus*	1	0	1	0
Jacanas	Jacanidae	*Hydrophasiaus chirurgus*	1	0	1	0
White Wagtail	Motacillidae	*Motacilla alba*	1	0	1	0
Grey Wagtail	Motacillidae	*Motacilla cinerea*	1	0	1	0
Litle Grebe	Podicipedidae	*Tachybaptus*	1	0	1	0
Moorhen	Rallidae	*Gallinula chlorpus*	1	0	1	0
Stit	Scolopacidae	*Calidris sp. or spp.*	1	0	1	0
Sandpiper	Scolopacidae	*Tringa sp. or spp.*	1	0	1	0
BarnOwl	Strigiformes	*Tyto alba*	1	1	1	1
Puff-Throated Babbler	Timaliidae	*Pellorneum ruficeps*	1	0	1	0
Forktail	Turdidae	*Enicurus spp.*	1	0	1	0
Blue Whistling Thrush	Turdidae	*Myiophoneus caeruleus*	1	0	1	0
Hoopoe	Upupidae	*Upupa epops*	1	0	1	0

Annex E

PHYSICAL CULTURAL RESOURCES (PCR) STUDY

ANNEX E
PHYSICAL CULTURAL RESOURCES (PCR) STUDY

1. Results of the Site Survey

Site ID.:	PK-1
Site Name:	Vat Vangsiang (¸ñ©¸ñ¤¦È¼¤)
Village Name:	Ban Xieng Daet (Phou Kout district, Xiengkhuang province)
Location:	Below NN3 Reservoir Full Supply Level
Coordinates:	N 19° 25.177′ E 102° 42.759′
Site Description:	The date of construction of the Vat is unknown but by examining the style of the Buddha statue and the construction technique of the sanctuary we could date it to the 18th c. AD. In 1970, most of the main sanctuary was destroyed as the temple together with the village was air bombed. The site was abandoned as the inhabitants fled the village. In 1982, the migrants originating from Muong Kham of Xiengkhuang province settled down and re-created the village which was re-named ‚Ban Xieng Daet' (the history of the village is accounted at previous paragraph). In plan the sanctuary is made of a rectangular hall connected at east to a smaller rectangular cell that houses the main statue of Buddha. The sanctuary is oriented E-W facing east; it is parallel to the Nam Ting river and is approximately 25m distant to the left bank of this river. The dimensions of the hall are 13.40 x 10.20m. The cell, main statue of Buddha with its altar have partly survived; the rest of the sanctuary is in ruins. The building was a masonry structure supporting wooden roofing that was covered with tiles. The roof has completely disappeared. Some walls have survived; the wall is 2.60m high from the floor inside the main hall. The floor is approximately 1.40m higher than ground surface. The pillars are cylindrical, two of them have survived and their diameter is 57cm. It is to note that the construction of the pillar is of great interest as it shows some degree of engineering. It is mounted with alternate layers; the first one is made of two semi-circular bricks while the second one is made of four quarters of bricks; these types of bricks were intentionally made with this design before they were fired in the kiln. This particular vertical arrangement could have been a device to resist earthquake; experimentation could be a rewarding exercise. Lime mortar was used for masonry as well as for plastering the walls and the pillars. Within the courtyard of the temple, two ancient kilns are still visible, distant 5m and 12 m to the east of the main sanctuary, respectively. They are constructed with bricks, with a cylindrical shape and thus belong to the updraft type with a diameter of 1.50m. Lime stone was

fired in these kilns to obtain lime that was needed for the construction of the temple. The main statue of Buddha was named Phra Inpeng; is it related to Phra Inpeng of Vientiane which dates back to the 16th c. and was one of the most worshipped. There is no evidence of such connection.

Significance: This temple evidenced the practice of Buddhism at this place during the 18th c. AD; this demonstrates the vitality of the ancient kingdom of Xiengkhuang whose inhabitants managed to reach such an area that is still renowned and feared for its remoteness and wildness. At the same time it demonstrates that the art style known as the school of art of the Xiengkhuang kingdom centred at Muong Khune, the then capital of the kingdom has reached such a far location, approximately 50 km away by bird's eye view. The temple represents a source of knowledge in particular the techniques of construction including that of the pillars and the production of lime at the construction site; these were probably undertaken by local craftsmen and labour with the support of the villagers who engaged the construction with faith and devotion to Buddhism.

Figure 30. The location of Vat Vangsiang is cultivated by villagers as corn plantation. On the background is Ban Xiengdaet.

Figure 31. Vat Vangsiang temple. Main Buddha statue damaged by the air bombingduring 1970s

Figure 32. Trying restitute the past through the discarded remains

Figure 33. Survived wall of the Buddha cell

Figure 34. Remains of 2 lime kilns

Figure 35. Updraft kiln constructed of bricks

Figure 36. Recording of the evidences

Figure 37. Architectural features

Site ID.:	PK-2
Site Name:	Vat Xieng Daet (¸ñ©§¼¤Á©©)
Village Name:	Ban Xieng Daet (Phou Kout district, Xiengkhuang province)
Location:	Below NN3 Reservoir Full Supply Level
Coordinates:	N 19° 25.299′ E 102° 42.714′
Site Description:	In 1964, there were rumours about the abbot of Vat Vangsiang. It was said that the abbot died after he had violated a monastic rule but he was reincarnated under the form of a big snake and continued to live at the same temple. The two ancient kilns inside the courtyard of the temple were said to be the trap made by the people to catch and confine the snake. Vat Vangsiang was feared by the villagers who then decided to collect the bricks that were available in the temple and transport them to the actual site of Vat Xieng Daet. Therefore Vat Xieng Daet temple was built with bricks that originate from Vat Vangsiang. However the temple was never completed; only its basement was constructed as it still visible. This basement is a rectangular platform, 5 x 10m of earth work raised at 1.60m higher than the ground surface. It is oriented SE-NW; a stair flight made of brick is found at its SE side. This unfinished sanctuary is parallel to the Nam Ting river and is 30m distant from its left bank. In 2005, 4 small silver plated statues of Buddha were unearthed from the courtyard of this temple by local villagers; but these statues were subsequently re-buried at the same place.
Significance:	This structure has never functioned as a religious site because its construction was not completed. The land of this ‘temple’ has now been encroached by modern housing.

Figure 38. The remains of Vat Xiengdaet temple

Figure 39. Cutting bushes of the temple

Figure 40. Pavement of the re-used bricks

Figure 41. Unfinished brick structure

Site ID.:	PK-3
Site Name:	airfield (À©†-¨ö-)
Village Name:	Ban Xieng Daet (Phou Kout district, Xiengkhuang province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	not recorded (opposite bank of Ban Xieng Daet)
Site Description:	The airfield was built during the 1960s; its runway is 4 km. It served as an air bridge with other military bases and also to fly out the local people accordingly to the stratagem of removing the population from Pathet Lao forces. It is built across the Nam Ting river exactly opposite to Ban Xieng Daet. Associated constructions such as offices, passenger facilities and fences have all disappeared.
Significance:	Vestige of recent history, in particular the period of the special war conducted by US Army in Laos.

Site ID.:	PK-4
Site Name:	Dongmuang (spiritual site) (©ö¤À´õº¤)
Village Name:	Ban Xieng Daet (Phou Kout district, Xiengkhuang province)
Location:	At NN3 Reservoir Full Supply Level
Coordinates:	N 19° 25.619′ E 102° 42.699′
Site Description:	The tall tree, approximately 15m high, emerging from the flat land along the Huay Hok river has been object of worship by the local people who believe in the spirit of natural features including the trees.
Significance:	Spiritual site.

Figure 42. Huay Hok, a tributary of Nam Ting. It flows beside Dongmuang, so it is also considered as sacred place.

Figure 43. Sacred tree which indicates Dongmuang is considered as spiritual place of Ban Xiengdaet.

Site ID.:	PK-5
Site Name:	Tham Phra Cave («Õ²ë½À´õº¤¦÷É¨)
Village Name:	Ban Xieng Nga (Phou Kout district, Xiengkhuang province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	N 19° 30.045′ E 102° 52.346′
Site Description:	A local oral tradition says that once upon the time two brothers took a long journey by elephants from Vientiane to Xiengkhuang in order to propagate Buddhism. On their way they made a stop at Ban Khang Lat. To locate the best site for a future construction of a Buddhist temple the two brothers ordered Bak Xieng, one of their elephants to hit the ground with its tusks; as an old practice of oracle. At one place the tusks were stuck in the ground and the elephant had to leave them behind. The place became a sacred site and received the construction of a sanctuary. Thus the name of the village changed from Ban Khang Lat to Ban Xieng Nga with reference to the tusk of the elephant as ‘nga’ means tusk, in Lao and ‘Xieng’ refers to the elephant’s name. The tusks of the elephant were carved into a statue of Buddha. One kilometre from Ban Xieng Nga, at Tham Nong Tao, the two brothers went to construct a big statue of Buddha, more than 3m tall. It was made in masonry and plastered. An inscription found on the wall of the cave next to the statue of Buddha indicates the date of 1779 AD. Thus the cave changed its name from Tham Nong Tao to Tham Phra Cave as Phra means the statue of Buddha. There are four other caves surrounding Tham Phra Cave *i.e* Tham Nam, Tham That, Tham Baolor and an un-named one. In April 2000, an important collection of statues of Buddha was discovered by Acharn Buakham, a monk from Vat Xieng Nga. Acharn Buakham went inside the un-named cave for a simple visit. A lizard captured his attention as it was running away and entered a hole in the cave wall. The monk removed the rock to uncover the lizard but he suddenly discovered a huge cavity that housed an important collection of antiquities that could be considered as a real treasure. This treasure is made of a collection of statues of Buddha and a set of utensils commonly used in a Buddhist temple. There were 289 statues which were made of different materials such as gold, silver, bronze and glass. One inscription indicating the date of 1779 AD was found on a bronze statue. One statue was made of ivory and it is since then believed that this was the tusk of the legendary Xieng, the elephant of the two mythical brothers. The set of utensils consisted of a series of gongs, cymbals, water jug, plates, alms bowl, cups, kettle, lime container, tobacco box, etc. The two concurrent dates, one on the

cave wall and the other on the statue of Buddha, and the statue of Buddha made of ivory seem to provide the legend with some historicity. This invaluable collection of antiquities has been transferred to the temple of Ban Xieng Nga where it is conserved and displayed for public viewing.

Significance: Archaeological site with an important collection of objects that evidenced Buddhism practice and associated ritual usage. This treasure was probably taken to the cave and hidden for its safety as a war was about to break out or at the eve of some critical event. Similar practice was found at Tham Phra Nongpafa in Khammuan province.

Figure 44. Main Buddha statue (Phra Ongteu) at Tham Phra Cave, made of bricks and plaster

Figure 45 (top) and 46 (down). Many bronze and wooden Buddha statues still be preserved in the cave

Figure 47. Basement of Xieng Nga temple. Remains of war destruction during 1970s

Figure 48. Layout of the temple

together with the village was all bombed.

There is a short earthen wall around the temple as to mark its boundary. Inside there are some constructions e.g. brick remains of the main sanctuary, an offering hall, a monk's residence (*kuti*) and a future community museum, which is under construction.

The Buddha collection that has been found at Tham Phra Cave (see Site ID PK-5) is now kept in this temple. In order to house this valuable cultural heritage and safely display for the public viewing the local people have an idea to set up a modest museum inside the temple. The funding comes from the generosity of villagers and other donors.

Significance:

The temple has cultural and tourist potential. It is located close to Tham Phra Cave which is already opened to the wider public and promoted as touristic site of Phou Kout district. This temple evidenced the practice of Buddhism at this place during the 18th c. AD.

Figure 49. Future community based museum under construction, it aims to house the Buddha collection discovered in Tham Phra Cave

Figure 50. Small Buddha statues so called *Phra keson dokmai*, covered with gold sheet

Figure 51. Buddha statue made of ivory that local people supposed to refer to *'Bak Xieng's* tusk

Figure 52. 18th century's bronze Buddha statue

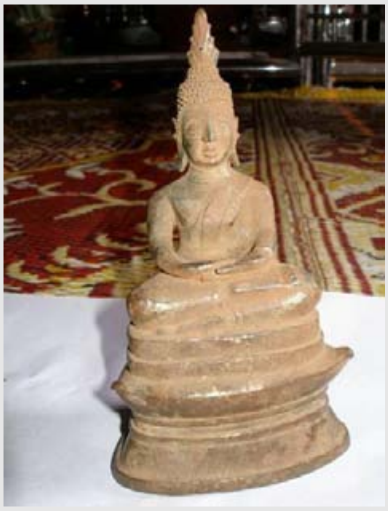


Figure 53. Bronze Buddha statue that contains inscription on the pedestal

Figure 54. Water jug, local manufacture found in the same collection

Figure 55. Imported Chinese painted ceramic found in the same collection

Figure 56. Bronze gong found in the same collection

Site ID.:	PK-7
Site Name:	airfield (À©†-®ò-)
Village Name:	Dernbin quarter, Ban Namsam (Phou Kout district, Xiengkhuang province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	N 19° 25.569′ E 102° 44.601′
Site Description:	The runway was approximately 2 km long and 8 m wide; it was unsealed. It could accommodate air planes of small size carrying less than 6 passengers.
Significance:	recent history of special war in Laos

Figure 57. Dernbin quarter; the houses were built along both sides of the runway of an abandoned military airfield. This is the reason for its name.

Figure 58. Dernbin quarter; some houses seen on one side of the old runway.

Site ID.:	PK-8
Site Name:	Tham Sok Cave («Õ§ö¡)
Village Name:	Dernbin quarter, Ban Namsam (Phou Kout district, Xiengkhuang province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	N 19° 25.627′ E 102° 45.169′

Site Description: Tham Sok or *Mortar Cave* is located about 2 km south-east of Dernbin quarter. This is a natural cavity found nearly on half way on a steep slope on the north-western facade of a lime stone outcrop which is called Phu Tham Sok. Its entrance is approximately 1 m wide by 1.80 m high. From the entrance a tunnel of 7 m long leads to an interior chamber which is oblong in plan, 4 x 5 m with a dome ceiling that is approximately 5-6 m high above the cave floor. The interior is quite dark as day light can reach only the entrance area. The floor is flat and nearby the back wall, there is a circular hole that looks like a dwell of 0.70 m of diameter and 50 cm deep. This ‚dwell' is surprisingly mirrored on the ceiling as a similar feature (this time upside down) is found on the ceiling exactly above the dwell, at the approximate height of 1.50 m. This ‚dwell' has provided with the cave the name and the legend on the use of this ‚dwell'. It is locally believed that this was a mortar where rice grain was pounded with a pestle. Some said that remains of husk were still visible at the corner of this cave chamber. During our visit evidence of ancient human occupation has not been observed.

Significance: Site of spiritual significance for the local people

Figure 59. Front view of Tham Sok

Figure 60. Entrance of Tham Sok, oriented north-west

Figure 61. Inside of the cave chamber; the arrow indicates location of circular hole.

Figure 62. Circular hole that the local people believes to be a stone mortar.

Site ID.:	SB-9
Site Name:	Vat Chomcheng (¸ñ©¥º´Á¥É¤)
Village Name:	Ban Longcheng (Saysomboun district, Vientiane province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	N 19° 06.379′ E 102° 55.798′
Site Description:	Within the ‘Special Forces’ and just under General Vang Pao the deputy Commander in chief was Chao Manivong, a nobleman from Luang Prabang. In 1963, Chao Manivong and Chao Vannaseng, another high ranking army officer and also nobleman from Luang Prabang decided to patronize the construction of a Buddhist temple since they realised that there was no temple for the whole Xamthong-Long Cheng area. The temple was built atop of a small hill and was named Vat Chomcheng; meaning the top of a hill that is illuminated as to refer to the legend of Khune Cheuang (see Long Cheng village). The temple was abandoned since 1973 and is still unoccupied. The main sanctuary is still in a fairly good state of conservation but unused as there is no monk living at this temple. The main sanctuary is a rectangular hall in plan, constructed with a reinforced concrete structure on a raised basement supporting wooden roofing that is covered with tiles. The hall is unusually oriented N-S, with the altar at South and the entrance at North. On the altar there are five statues of Buddha of which one is the presiding piece which is made of bronze and is taller then 2m and four small ones (approximately 1m tall). Out of these four, three are made of bronze and one is a gilt wood; two are in standing posture and two like the main statue are seated. The premises of the temple built in light materials have all disappeared. Until now this temple is still the only one that exists within a radius of about 100 km. The local inhabitants are currently enthusiastic to revive this temple as such religious edifice is necessary for the observation of Buddhist faith.
Significance:	This is the first religious building that has been ever been built in this remote region; it is significant in terms of recent history but also as a unique and rare religious establishment for this wide area. Despite absence of maintenance for more than three decades, the sanctuary is still in a fairly good state of conservation and would not need heavy means for its revitalisation. This temple would become the spiritual centre as the local Buddhist community is now considering the process of its revival.

Figure 63. Chomcheng buddhist temple at Ban Longcheng

Figure 64. Altar inside the temple where Buddha statues still be preserved.

Site ID.:	SB-10
Site Name:	Tham Nam Lod Cave or Nam Ork-hoo («Õ- Õìº©, - Õºº¡»ø)
Village Name:	Ban Nam Ngua (Saysomboun district, Vientiane province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	N 19° 09.185′ E 102° 53.330′
Site Description:	The site is of remarkable scenic beauty. Tham Nam Lod Cave is a huge cave (the entrance is 15m high by 6m wide) that is located at the edge of a limes stone massif; its entrance faces Northwest. The main chamber is 6m deep; the wall at the back of this chamber is impressive as it contains many small platforms that are arranged in terraces at different levels which resemble the landscape of rice field terraces. These platforms resulted from continuous accumulation of water that percolates out of the rock and gradual deposition of calcite and other salts. Successive terraces are formed over time at different levels as water slowly seeps from the rock and flows by gravity from one level to the next. At the bottom of these formations, springs out water that gives birth to the rivulet. Several meters downwards, two cascades are formed as the rivulet flows through boulders and rocks. Seen from front view, the rivulet with the double cascade form an impressive scene as they are framed by the huge cave and have the terraced walls settings at the backdrop. Big fish is found in an abundant quantity. This rivulet is named Nam Cha in the map of the Lao National Geographic Department but it is called by local villagers ‘Nam Lau’. This place where the rivulet starts is called Nam Ork-hoo (come out from a whole).
Significance:	Scenic beauty and geological site as it illustrates the formation of a rivulet within lime stone formation. It has a potential for tourism as it is easily accessible (15 mn of walk from the main road) and located along the main road that links Long Cheng to Xamthong.

Figure 65. Tham Nam Lod Cave (arrow indicates underground rivulet)

Figure 66. Inside the cave. Dark spot in the bottom of photo is the underground rivulet

Figure 67. Rice terrace shaped calcite formation in the cave

Figure 68. Outlet of Tham Nam Lod Cave which forms a kind of cascade

Site ID.:	SB-11
Site Name:	Tham Tintok Cave («Õ-ªó- -ªö¡)
Village Name:	Ban Nam Ngua (Saysomboun district, Vientiane province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	N 19° 07.686′ E 102° 53.684′
Site Description:	Tham Tintok Cave is a small cave of karstic formation; it is located 2 km from the village. The cave floor is sloping down inwards and ends where a small rivulet flows. It is situated right along the main road that links Long Cheng to Xamthong.
Significance:	An example of geological formation within a karstic environment. It is a place for recreation without any particular significance.

Figure 69. Tham Tintok Cave

Site ID.:	SB-12
Site Name:	Tham Phra Cavechao («Õ-²ë½-À¥í¾)
Village Name:	Ban Nam Ngua (Saysomboun district, Vientiane province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	N 19° 07.238′ E 102° 54.395′
Site Description:	Tham Phra Cavechao is a small and shallow grotto within a karstic formation; it is situated at the foot of a vertical cliff of approximately 15 m high. It is said that once in a time a collection of statues of Buddha was placed in fracture that is found on the cliff; this explains its name of ‚the cave of the statues of Buddha'. The grotto looks more like a tunnel that is less than 1.50 high and 1.20 m of width at the entrance; it has a dead end after mm of depth, During 1960s, under the overhang of the cliff and at the entrance of the grotto, a reversed U shaped low wall (1.50m tall) was constructed so that a kind of cell was created. This undoubtedly served military purpose as it could provide with occupants some safety against gun fire. This was made of metal sheets filled out with soil; it could have been covered with metallic sheets but this roofing has disappeared; only the low wall has survived.
Significance:	Remains of the war time (1960-72).

Figure 70. Front view of Tham Phrachao Cave

Figure 71. A tunnel shape grotto

Figure 72. U-shaped protection wall in front of the cave, remains of the war time

Site ID.:	SB-13
Site Name:	Tham Phadork Cave («Õ-°¾©-º¡)
Village Name:	Ban Xamthong (Saysomboun district, Vientiane province)
Location:	Above NN3 Reservoir Full Supply Level
Coordinates:	N 19° 10.965′ E 102° 53.216′
Site Description:	Tham Phadork Cave is a huge cave of 50m wide by 25m of height at the entrance; it is approximately 35m deep. The cavity is located on an independent lime stone outcrop; it starts from the bottom of the cliff and goes in the dark oblique ‘tunnel’ inside the outcrop. A large quantity of boulders and rocks are found on the floor which is sloping inwards with an acute angle. Inside the cave at the very bottom of the floor a rivulet flows but nobody knows where it emerges as it is not seen within area of 10 km of radius around the cave. It is renowned as a sacred place although no one can provide the exact explanation or the reason; it is said that it was a residence of spirits. At the left of the entrance a log coffin was found lying on the rock. The log coffin has a trough shape and is left open; its lid has disappeared. It has been emptied. Its dimensions are: 1.80m long, diameter 0.35m; the hole that has been dug out is 1.60m long, 0.21m wide and 0. 25m deep. The wood has gone through weathering but still remains intact as it has not been exposed to rain water; its age cannot be ascertained. These kinds of coffins are not unusual as they have been found in other cave sites of Laos as well as in northern Thailand.
Significance:	This is a spiritual site as it is related to the belief that it has housed spirits. Hence a guardian spirit hut has been built and is still active. The site has an archaeological and historical significance by the presence of the log coffin. The cave is also of interest in terms of geological formation.

Figure 73. Phadork limestone outcrop at Ban Xamthong

Figure 74. Log coffin (on the left) and spirit hut (on the right) at Tham Phadork Cave

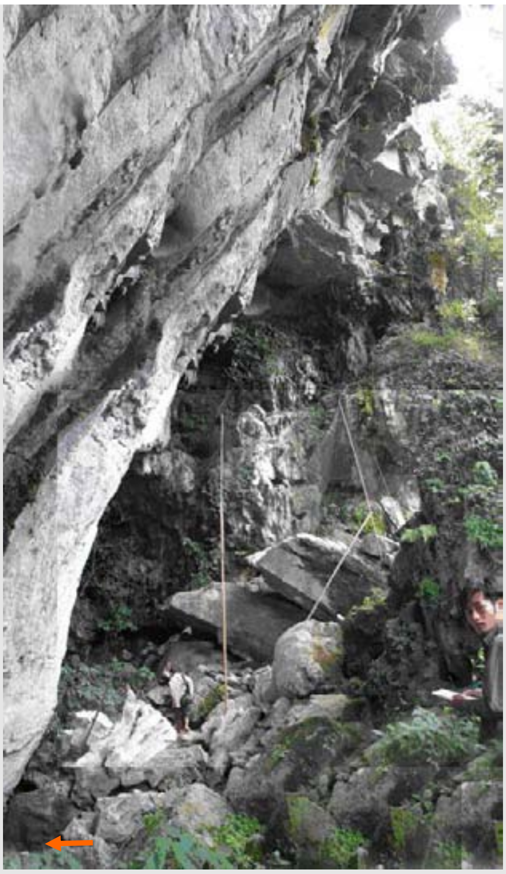


Figure 75. Entrance of the cave. Arrow indicates the location of the log coffin

2. Archaeological objects

Object Inventory No. 1: ground stone adze/axe without shoulders, found in Ban Xieng Daet

Dimensions (cm)	
height:	7.2
width at top:	2.9
width at middle:	3.1
width at base:	3.2
thick:	1.8
weight (gr):	69.3

<u>Provenance</u>: Mr. Iengthong, 53, deputy chief of Xieng Daet village owns this stone tool after he found it in 2007, during earthwork for the construction of a new access track to the village, at 3-4 km to the village.

<u>Significance</u>: evidences human occupation during the late Stone Age.

<u>Date</u>: Neolithic Period

Object Inventory No. 2: ground stone adze/axe without shoulders, found in Ban Longcheng.

Dimensions (cm)	
height:	7.8
width at top:	4.3
width at middle:	4.3
width at base:	4.4
thick:	1.6
weight (gr)	90

<u>Provenance</u>: Mr. Khamsen Oundala, 73, found in his farm near the temple of Vat Chomcheng (Longcheng) in 1980, when ploughing for the corn plantation. It was buried 20 cm depth.

<u>Significance</u>: evidences human occupation during the late stone Age.

<u>Date</u>: Neolithic Period

 *Object Inventory No. 3: ground stone adze/axe without shoulders, found in Ban Longcheng.*	Dimensions (cm) height: 12 width at top: 3.5 width at middle: 3.9 width at base: 4.2 thick: 2 weight (gr) 182 Provenance: Mr. Khamsen Oundala, 73, found in his farm near the Vat Chomcheng temple (Longcheng) in 1993, when ploughing for the corn plantation (on the same land parcel as item inventoried No.2). Significance: evidences human occupation during the late stone Age. Date: Neolithic Period

 *Object Inventory No. 4: ground stone adze/axe without shoulders, found in Ban Longcheng.*	Dimensions (cm) height: 9.7 width at top: 3 width at middle: 3.6 width at base: 3.8 thick: 1.3 weight (gr): 92 Provenance: Mr. Khamsen Oundala, 73, found this stone tool in 1984, some where in the forest on the west of Ban Longcheng, about 3-4 hours of walking. He was then digging for tubers at the depth of about 60 cm. Significance: evidences human occupation during the late stone Age. Date: Neolithic Period

<table>
<tr>
<td>

Object Inventory No. 5: ground stone adze/axe without shoulders.</td>
<td>Dimensions (cm)
height: 7.9
width at top: 4.9
width at middle: 5.4
width at base: 5.7
thick: 2

weight (gr): 110</td>
<td><u>Provenance</u>:
In 2005, Mr. Silai Phimphaduangviset, now aged 44 years, found several ground stone tools in his shifting cultivation land located at approximately 4 km north of the village. It is also located nearby the cave called Tham Long or ‚Coffin Cave' as the cave is reported to house six log coffins. The stone tools were found lying on the ground. As Thao Silai believes that these objects are embedded with some mysterious magical power he refused to show them because the public viewing would impact on such power; upon our strong request he showed us only one item.

<u>Significance</u>: evidences human occupation during the late Stone Age.

<u>Date</u>: Neolithic Period</td>
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<td>

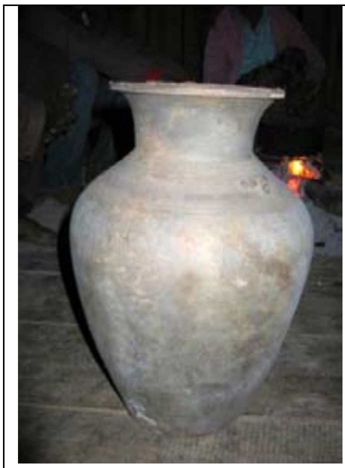
Object Inventory No.6: ground stone adze/axe without shoulders. The white stains (rice</td>
<td>Dimensions (cm)
height: 24
width at top: 5.4
width at middle: 6.2
width at base: 7.2
thick: 2.1

weight (gr): 550</td>
<td><u>Provenance</u>:
In 2005, Mr. Saykham, deputy village headman aged 42, found one large ground stone tool on the bed of the Huay Nam Khuang stream which is located at the foot hill of Tham Long, approximately 4 km north of the village. He reported that he found also pottery pipes but he did not collect them.

<u>Significance</u>: evidences human occupation during the late</td>
</tr>
</table>

powder) indicate its long storage inside a rice container.		Stone Age. Date: Neolithic Period

 *Object Inventory No. 7: ground stone adze/axe without shoulders.*	Dimensions (cm) height: width at top: width at middle: width at base: thick: weight (gr):	 21 3.5 3.7 3.9 2.8 380	Provenance: Mrs. Nong found in 2000 at the upper course of Huay Namkhuang Significance: evidences human occupation during the late Stone Age. Date: Neolithic Period

 *Object Inventory No. 8: stoneware jar found at Tham Tampor near Tham Long*	Dimensions (cm) total height: diameter at rim:	 40 19	Provenance: Mr. Boonthanom, found these 2 jars six month ago at Tham Tampor which is near to Tham Long where the villagers have reported that there are six log coffins kept in this cave. Significance: utilitarian object, used as food container. Despite it was deposited in the cave Tham Tampor, it was not used as an urn. The Tham Tampor cave is located outside the reservoir and was excluded from our study area. Date: early 20th AD

Object Inventory No. 9: stoneware jar found at ThamTampor near Tham Long

Dimensions (cm)	
total height:	30
diameter at top:	19

Provenance: see above

Significance: utilitarian object, used as food container. Despite it was deposited in the cave Tham Tampor, it was not used as an urn. The Tham Tampor cave is located outside the reservoir and was excluded from our study area.

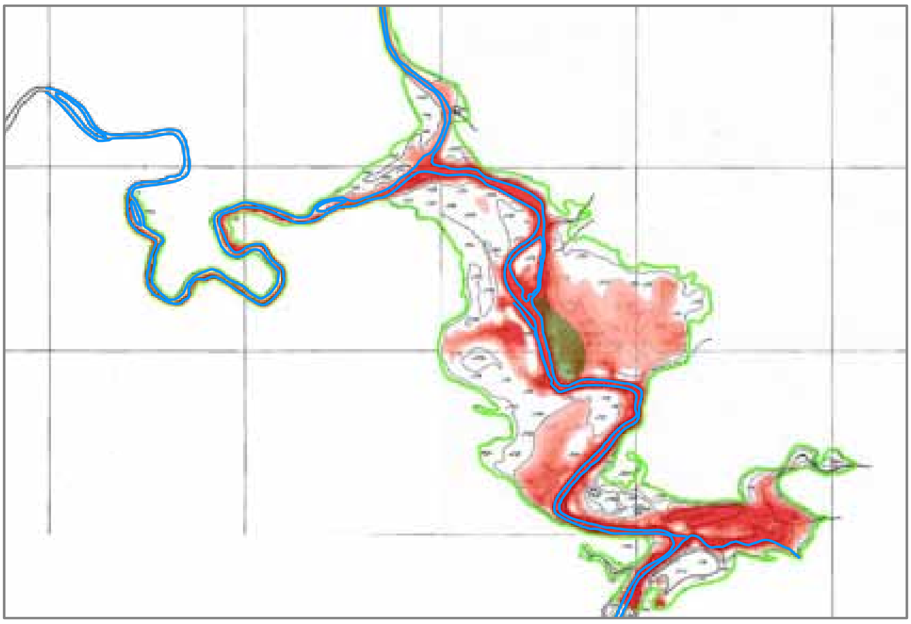
Date: early 20th AD

Annex F

BACKWATER EFFECT OF THE NAM NGUM 3 DAM

Nam Ngum3 Hydropower Project

Backwater Effect of Nam Ngum3 Dam



GMS POWER

November 2007

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Backwater Effect of Nam Ngum3 Dam

Executive Summary

The Nam Ngum3 dam will create a reservoir of about 1316 MCM in volume and 56 km in length. On the rim of the reservoir located Ban Xiengdet which eventually subjected to a backwater effect. In order to evaluate impacts, the backwater effect is investigated applying a HEC-RAS program to calculate water surface profiles along the Nam Ngum3 reservoir.

Major factors that affect the backwater effects are flood magnitudes and reservoir storage levels. Consequently, combination of the floods and storage levels are taken into account, namely; 5 yr, 10 yr, 50 yr, 100 yr, 500 yr and PMF; and storage level of 720 m(MSL) and 723 m(MSL) during the flood season and the end of flood season, respectively.

It is resulted that

1. The backwater effects, for almost every case, propagate up to Ban Xiengdet.
2. The backwater effects increase water levels at Ban Xiengdet from 5 to 10 m.
3. The higher the flood magnitudes occur, the lower the backwater effects and the higher the inundated area are.
4. The inundated areas mainly depend on the flood magnitudes rather than the backwater effects.
5. The 5 yr up to 500 yr flood would partially inundate Ban Xiengdet and inundated less than 30% of the Ban Xiengdet flood plain.
6. The PMF would almost entirely flood Ban Xiengdet and flood more than 50% of the Ban Xiengdet flood plain.

1 Introduction

The Nam Ngum3 Hydropower Project is located in Ban Longcheng, Xaisomboun. The dam, a rolled compact concrete dam of about 220 m in height, will impound water at a full supply level (FSL) of 720 m(MSL) creating a reservoir of 1,316 MCM in volume and 25.6 sq.km in surface area, stretching more or less 56 km upstream from the dam. At the end of rainy season (end of September) the water level will be raised up to 723 level to store more water and release through the turbine instead of spilling. At the uppermost brim of the reservoir on the Nam Ting tributary there is a large flood plain where Ban Xiengdet is situated. The plain lies about 4 km along Nam Ting covering an area of 2.7 sq.km while Ban Xiengdet, on the left bank, occupies an area of 45,161 sq. m (Resources Management and Research, October 2000) as shown in Figure 1. The population was about 71 households, which lies between 721- 734 m(MSL) (which crop land below this level).

2 Objective

The study is aimed to find out backwater effect and flood extent of Ban Xiengdet when the Nam Ngum3 dam is constructed. The main interesting are

1) Backwater effect

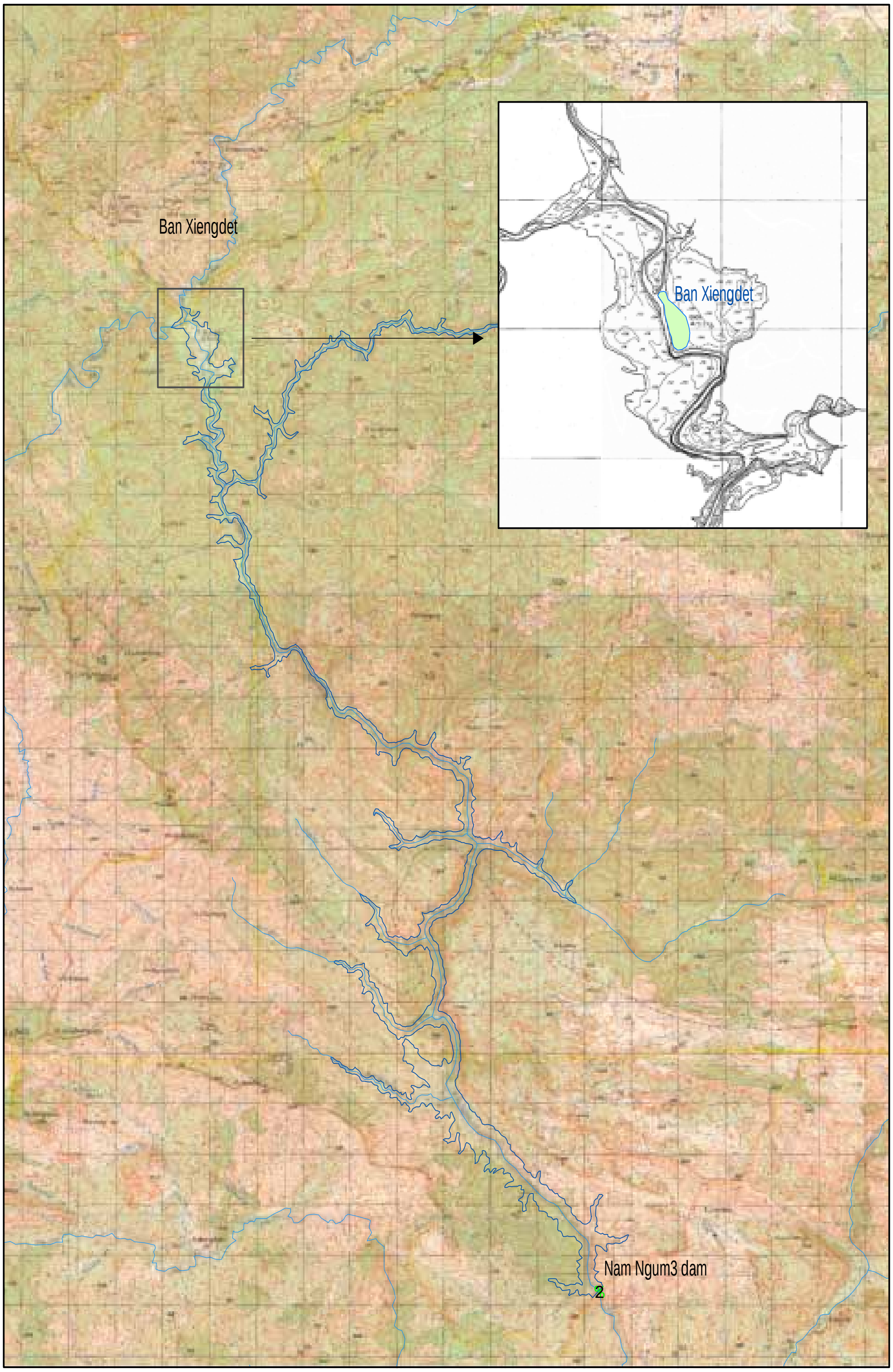
   To find out the extent of backwater effect induced by Nam Ngum3 dam. Water levels along Nam Ngum3 river before and after Nam Ngum3 is constructed, are computed and compared.

2) Flood extent at Ban Xiengdet

   To find out the extent of inundated area in the vicinity on Ban Xiengdet. Water levels, flood depths and flood maps in the neighbourhood of Ban Xiengdet are presented.

3 Mathematical Model

A HEC-RAS system is one-dimensional river analysis software, developed by US Army Corps of Engineers. A Steady Flow Water Surface Profiles component of the modeling system is intended for calculating water surface profiles for steady gradually varied flow. The HEC –RAS is then adopted to simulate water level profiles along the Nam Ngum river for various flood situations



\backwater\floodmap\fig1.mxd

Figure 1 Location of Ban Xiengdet on Nam Ting

4 Study Schemes

The Nam Ngum3 reservoir is planned to store water at full supply level of 720 m(MSL) and raise the storage level to 723 m(MSL) at the end of flood season to store extra water that would otherwise be spilled, thus increase the energy production. Backwater effects mainly depend on flood discharge as well as reservoir impounding levels. In the study the following factors are taken into consideration.

1) Normal flood discharge

   The flood of 5 yr, 10 yr, 50 yr, 100 yr, 500 yr and PMF are selected. The 5 yr, 10 yr and 50 yr floods are intended to represent general flood situations which likely to occur, while the rest represent extreme flood situations which rarely occur. Magnitudes of floods on Nam Ting at Ban Xiengdet are estimated according to the drainage area, which is 664 sq.km.

2) Reduced flood

   After the end of flood season, about 15 September, it is expected that floods with smaller peaks than those of the normal floods would occur, these floods is called "Reduced floods". The flood frequency analysis revealed that the peak flow of 1000 yr flood would become 2,400 m3/s, comparing to the normal 1000 yr flood of 5,000 m3/s peak flow. Because no reduced floods for the other return periods are analyzed, the normal floods of magnitude up to 100 yr return period or 2,200 m3/s are adopted.

3) Nam Ngum3 impounding level

   The reservoir water level of 720 m(MSL) and 723 m(MSL) are taken into account for the normal flood and the reduced flood situations, respectively. Moreover, maximum flood surcharges resulting from spillway routing are included, even though they would last for only a few days. These would give the upper limits of flood incidents. A summary of spillway routing calculation is presented in Appendix A.

In addition, an existing case, which represents the present water surface profiles before Nam Ngum3 is built, is also included.

Summary of parameters adopted in the analysis are presented in Table 1.

Table 1 Schemes and Parameters Applied in the Backwater Analysis

Return period	Flow m3/s		Water level at Nam Ngum3 damsite, m(MSL)				
			Existing	Flood season		End of flood season	
	Nam Ngum3	Nam Ting	Natural flow	720	720 + flood surcharge	723	723+ flood surcharge
				Case 720	Case 720+S	Case 723	Case 723+S
5 yr	1,230	305	528.4	720	720.3	723	723.03
10 yr	1,490	370	529.1	720	720.7	723	723.2
50 yr	2,000	496	530.4	720	721.5	723	723.8
100 yr	2,220	551	530.9	720	721.8	723	724.1
500 yr	3,050	757	532.5	720	723.1	-	-
PMF	7,900	1,960	539.5	720	731.9	-	-

5 Backwater Effect

A backwater model is introduced to compute water levels along Nam Ngum river from the Nam Ngum3 dam up to Ban Xiengdet for the existing situation (without Nam Ngum3 dam) and for the future situation (with Nam Ngum3 dam) for different floods and reservoir water levels.

5.1 Backwater Model

The model covers a Nam Ngum river reach from Nam Ngum3 dam up to Nam Ting, a total distance of 58 km. Model basic components are as follows:

1) Cross sections

   Cross sections data are obtained from a 1:10,000 scale topographic maps (1995) with a 5 m contour interval covering the reservoir area.

   The cross sections along the river, as show in Appendix B, are read from the map for every 2 km interval. Since the bed elevations of the sections are not known, it is estimated by extending the slope of both banks.

2) Downstream boundary

   The downstream boundary is water level at Nam Ngum3 damsite or Nam Ngum3 reservoir.

3) Roughness coefficient

A Manning roughness coefficient of 0.035 for a natural stream is applied.

5.2 Result of the backwater effect study

Output of water levels along the river are presented in Appendix C and summarized in Table 2 and Figure 2, which reveals that

1. Backwaters propagate up to Ban Xiengdet in almost every case, except that of PMF with the reservoir water level at 720 m(MSL).
2. Backwater effects at Ban Xiengdet (km56) range from 5 m to 10 m, which imply that impounding of Nam Ngum3 would increase flood levels at Ban Xiengdet.
3. On the flood season, flood levels are confined in the river main channel as long as the magnitude of flood is less than PMF.
4. For the end of flood season, floods levels are mainly confined in the river channel, except at km 54 where overbank flow occurs.
5. For PMF with the reservoir water level at 720 m(MSL), the backwater would extend up to km 52. Nevertheless, Ban Xiengdet is already flooded.
6. The backwater effects of PMF are smaller than those of small flood, and negligible for Case 720 ,i.e., reservoir water level at 720 m(MSL).

Table 2 Backwater Effect

Case	Flow m3/s	Water level on Ban Xiengdet m(MSL) Km 54	Km 55	Km 56	Km 57	Backwater effect, m Km 54	Km 55	Km 56	Km 57
Bank full , m (MSL)		720	725	730	730				
0 Existing water level									
	1,230	704.78	704.76	713.09	717.59				
	1,490	706.33	706.32	713.58	718.12				
	2,000	708.95	708.95	714.39	719.00				
	2,200	709.96	709.96	714.72	719.35				
	3,050	713.42	713.43	715.76	720.50				
	7,900	725.72	725.75	725.85	726.95				
1 Case 720 : Flood season, reservoir water level at 720 m(MSL)									
	1,230	720.18	720.18	720.16	720.36	15.40	15.42	7.07	2.77
	1,490	720.26	720.26	720.23	720.52	13.93	13.94	6.65	2.40
	2,000	720.46	720.46	720.42	720.88	11.51	11.51	6.03	1.88
	2,200	720.56	720.57	720.52	721.06	10.60	10.61	5.80	1.77
	3,050	721.05	721.05	720.98	721.80	7.63	7.63	5.22	1.30
	7,900	725.91	725.94	726.06	727.11	0.19	0.19	0.21	0.16
2 Case 720+S : Flood season, reservoir water level at 720 m(MSL) with flood surcharge									
	1,230	720.57	720.57	720.55	720.72	15.79	15.81	7.46	3.13
	1,490	720.94	720.94	720.92	721.13	14.61	14.62	7.34	3.01
	2,000	721.88	721.89	721.86	722.13	12.93	12.94	7.47	3.13
	2,200	722.25	722.26	722.23	722.52	12.29	12.30	7.51	3.17
	3,050	723.81	723.81	723.79	724.11	10.39	10.38	8.03	3.61
	7,900	733.31	733.33	733.36	733.39	7.59	7.58	7.51	6.44
3 Case 723 : End of flood season, reservoir water level at 723 m(MSL)									
	1,230	723.12	723.12	723.12	723.18	18.34	18.36	10.03	5.59
	1,490	723.18	723.18	723.17	723.26	16.85	16.86	9.59	5.14
	2,000	723.31	723.32	723.31	723.47	14.36	14.37	8.92	4.47
	2,200	723.39	723.39	723.38	723.57	13.43	13.43	8.66	4.22
4 Case 723+S : End of flood season, reservoir water level at 723 m(MSL) with flood surcharge									
	1,230	723.15	723.15	723.15	723.21	18.37	18.39	10.06	5.62
	1,490	723.37	723.37	723.37	723.45	17.04	17.05	9.79	5.33
	2,000	724.08	724.08	724.08	724.2	15.13	15.13	9.69	5.2
	2,200	724.43	724.43	724.43	724.57	14.47	14.47	9.71	5.22

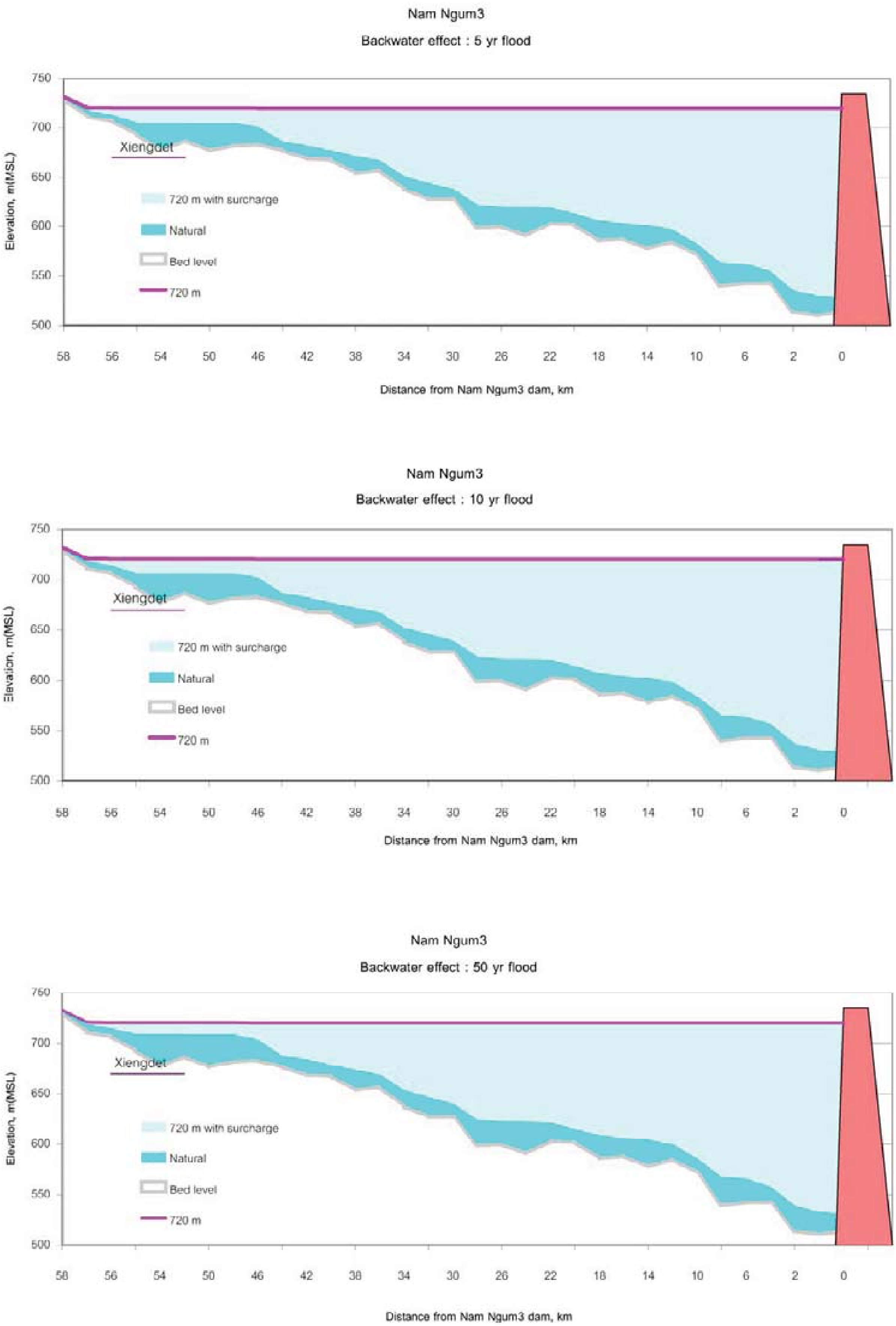


Figure 2 Backwater Effect During Flood Season

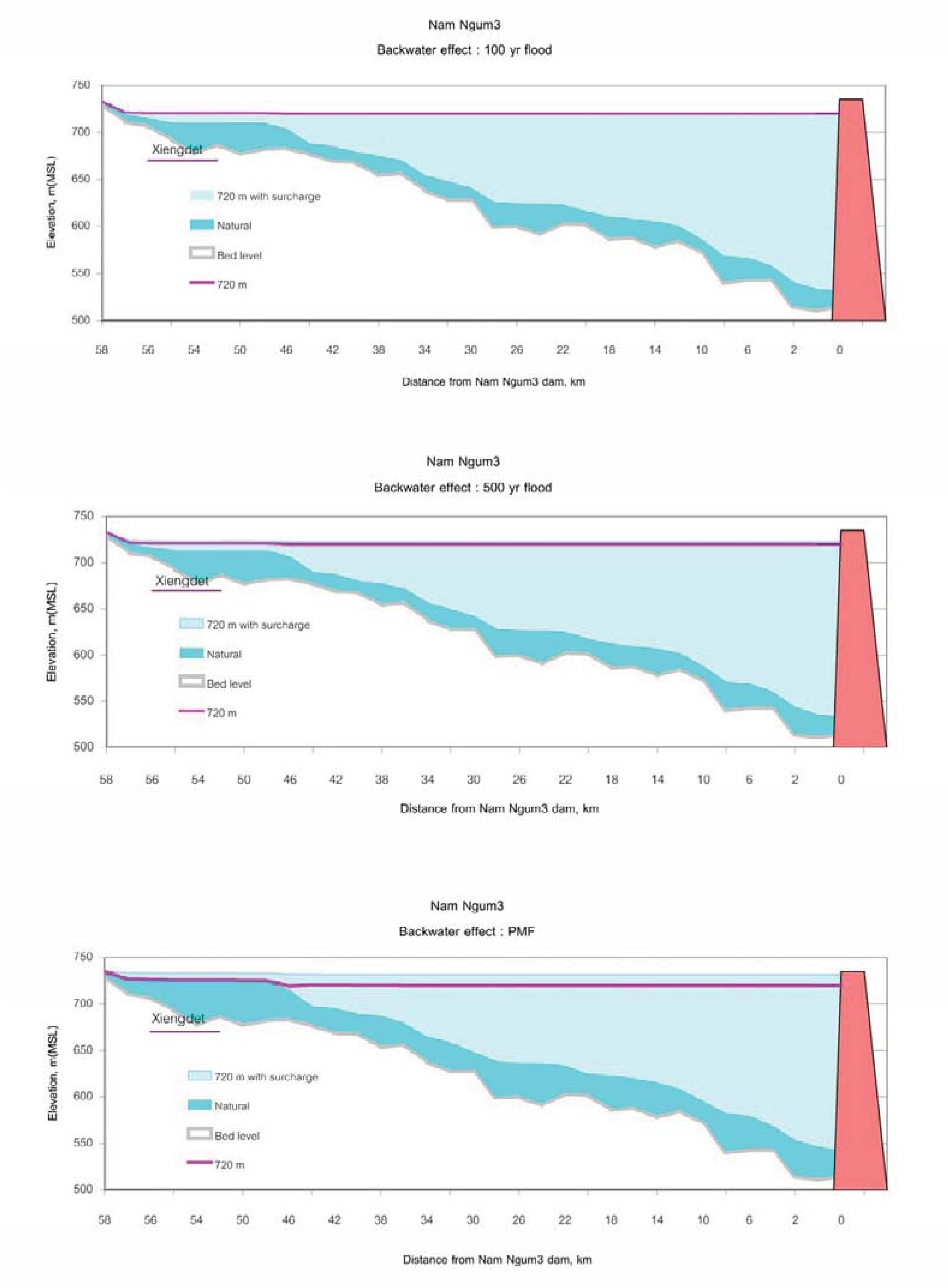


Figure 2 (Cont.) Backwater Effect During Flood Season

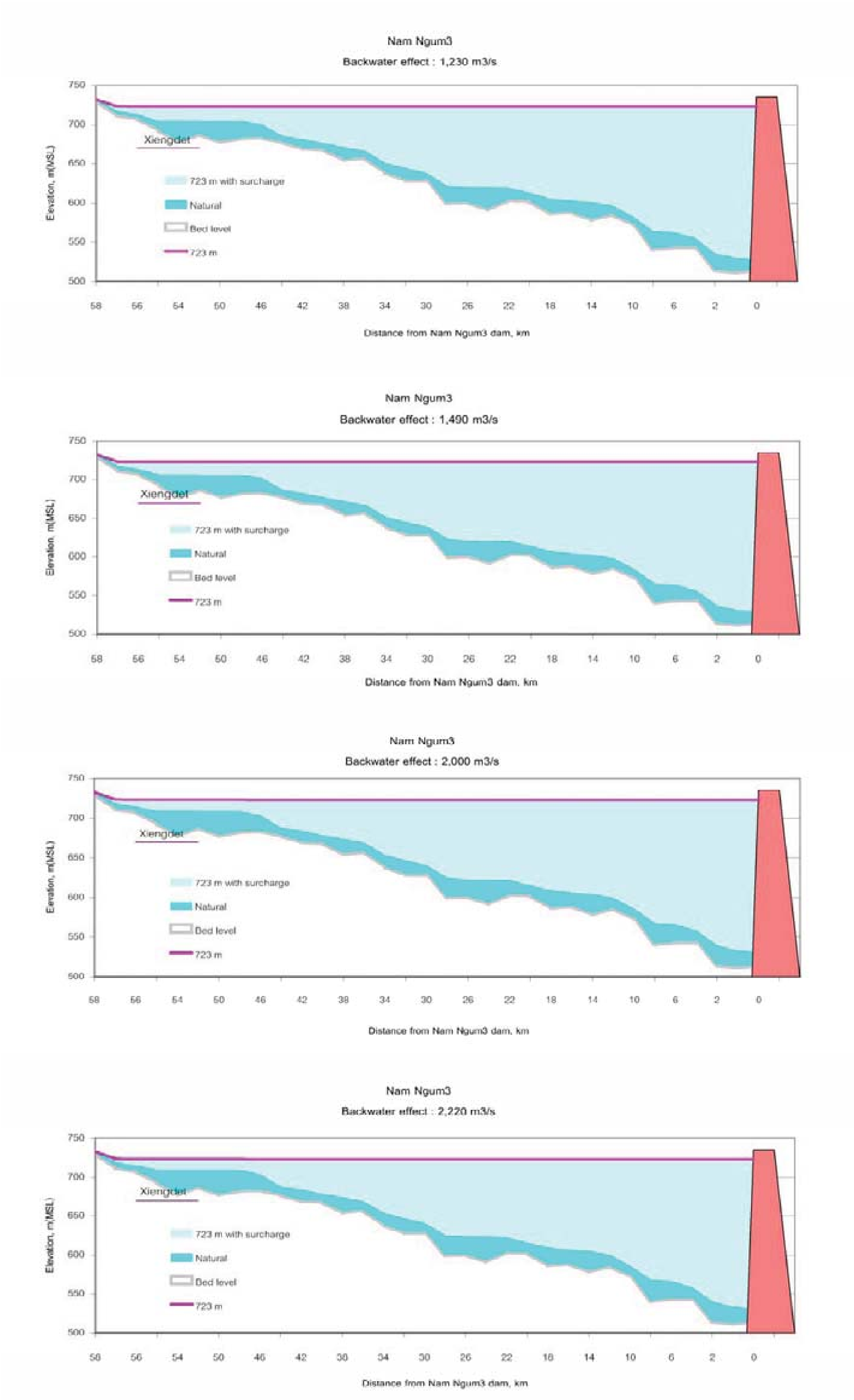


Figure 2 (Cont.) Backwater Effect During the End of Flood Season

6 Flood Boundary

As shown previously, the backwater effects intensify the flood levels around Ban Xiengdet. To investigate the flood extent, a more detailed flood model is established applying cross sections data from a ground survey of Ban Xiengdet. A boundary of flood plain of Ban Xiengdet is shown in Figure 3.

6.1 Flood model

The flood model represents a Nam Ting river reach along Ban Xiengdet, i.e., from station 52+000 to 58+000, totally 6 km (Figure 3)

Model configurations consist of

1) Cross section data

   There are 8 cross sections data, i.e. CR1 to CR8, in the neighbourhood of Ban Xiengdet which were surveyed in 2000 by HEC. The elevations of cross sections are compared at the same locations to those of 1:10,000 scale maps, as shown in Figure 4. It is concluded that the 1:10,000 topographic maps are more or less 7 m higher in elevation.

2) Downstream boundary

   The downstream boundary conditions are water levels at CR 8 which adapted from those of km 52+000 in the backwater study, with the adjustment in elevations, as shown in Table 3.

3) Roughness coefficient

   A Manning roughness coefficient of 0.035 for a natural stream is applied.

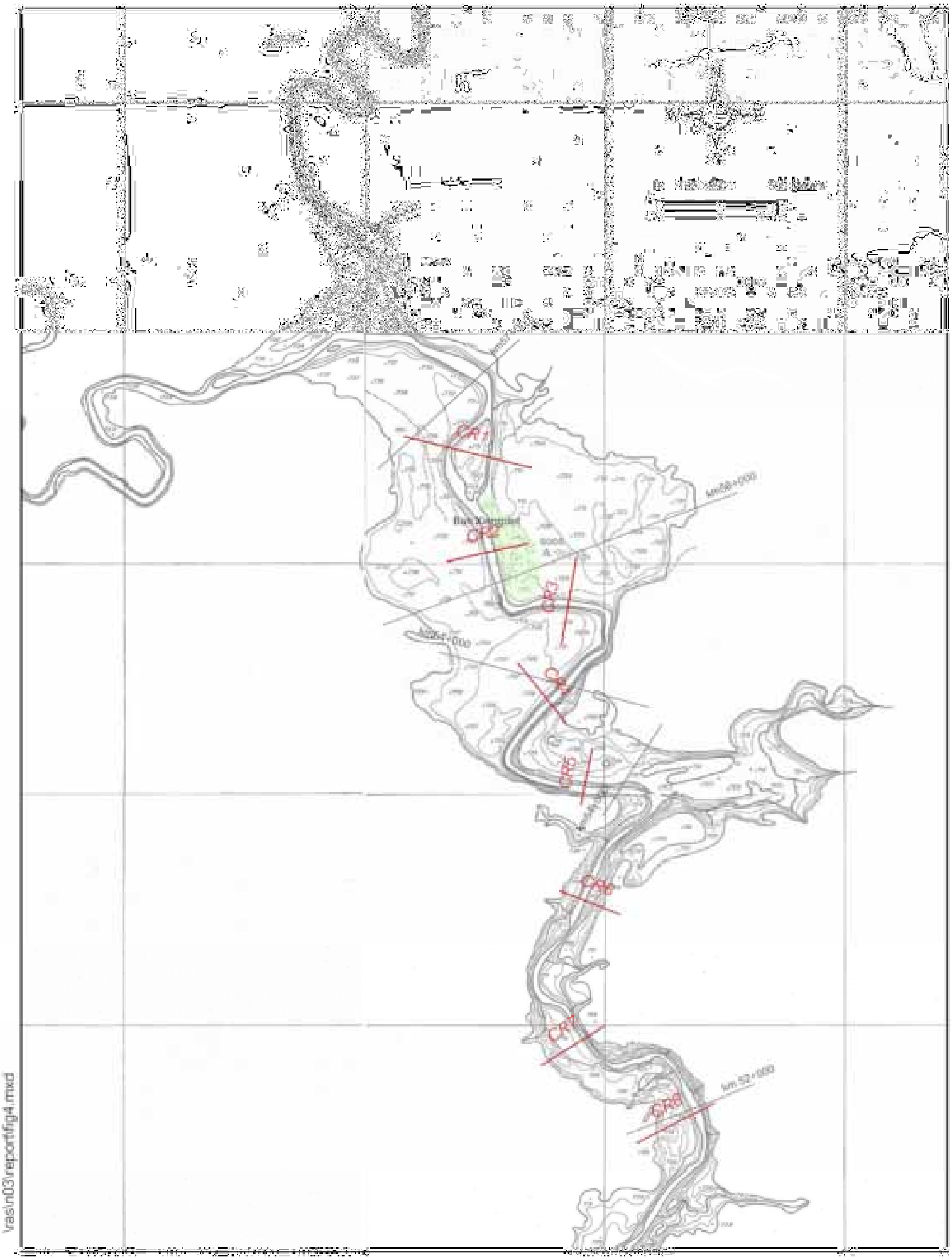


Figure 3 Plan of Flood Model on Ban Xiengdet

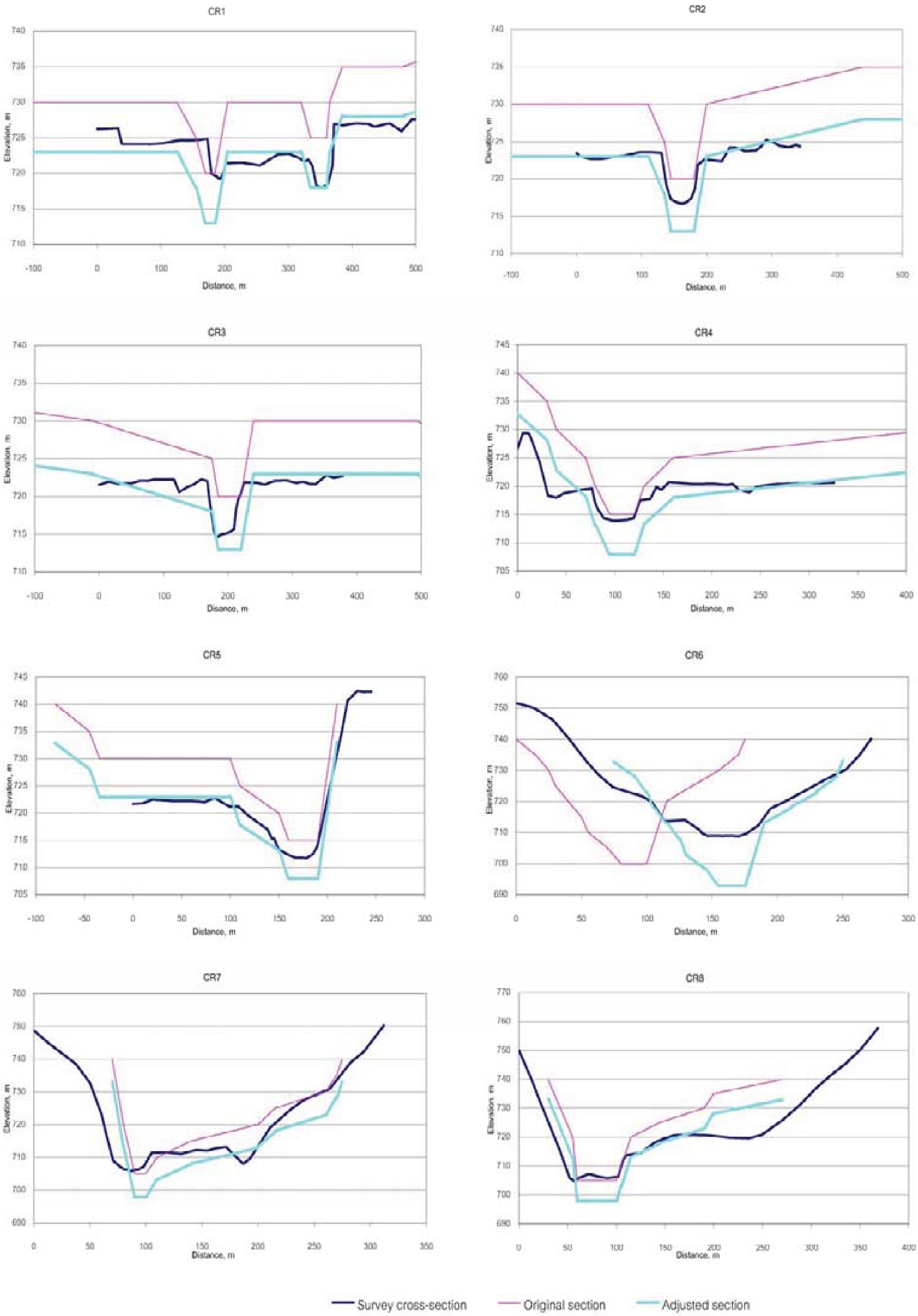


Figure 4 Comparison of Elevation

Table 3 Downstream Boundary Conditions

Return period	Nam Ting Flow m3/s	Flood season		End of flood season	
		Case 720 (1)	Case 720+S (2)	Case 723 (3)	Case 723+S (4)
5 yr	305	713.17	713.56	716.11	716.14
10 yr	370	713.25	720.93	716.17	716.36
50 yr	496	713.44	714.87	716.30	717.07
100 yr	551	713.54	715.23	716.37	717.42
500 yr	757	714.00	716.78	-	-
PMF	1960	718.77	726.27	-	-

(1) reservoir water level at 720 m(MSL)

(2) reservoir water level at 720 m(MSL) with flood surcharge

(3) reservoir water level at 723 m(MSL)

(4) reservoir water level at 723 m(MSL) with flood surcharge

6.2 Flood level

Results of flood model are presented in Appendix D, which are summarized as shown in Table 4 and Figure 5, and concluded as follows.

1. In most cases, except for PMF, flood water levels are confined in the main channel.
2. PMF would cause overbank flow and, to some extent, inundate Ban Xiengdet.
3. For the end of flood season situation, no overbank flow occurs.

Table 4 Flood Water Level

Flood		Water level at Ban Xiengdet, m(MSL)				
m3/s	(Return per.)	CR5	CR4	CR3	CR2	CR1
Bank full level, m(MSL)		721.25	719.61	721.85	722.53	724.86
1 Case 720 : Flood season, reservoir water level 720 m (MSL)						
305	(5 yr)	714.34	717.18	718.57	719.73	721.67
370	(10yr)	714.73	717.46	718.95	720.11	721.93
496	(50yr)	715.62	718.08	719.69	720.78	722.39
551	(100yr)	715.84	718.37	719.98	721.06	722.60
757	(500yr)	716.51	719.29	721.00	722.12	723.38
1960	(PMF)	720.00	722.17	723.26	724.71	725.67
2 Case 720+S : Flood season, reservoir water level 720 m (MSL) with flood surcharge						
305	(5 yr)	714.52	717.10	718.58	719.73	721.67
370	(10yr)	715.02	717.34	718.96	720.11	721.93
496	(50yr)	715.7	718.04	719.68	720.78	722.39
551	(100yr)	715.99	718.32	719.97	721.06	722.60
757	(500yr)	717.27	719.17	720.96	722.09	723.37
1960	(PMF)	726.40	726.51	726.56	726.63	726.85
3 Case 723 : End of flood season, reservoir water level 723 m (MSL)						
305		716.23	716.99	718.59	719.73	721.67
370		716.34	717.29	718.96	720.11	721.93
496		716.59	717.93	719.67	720.77	722.39
551		716.71	718.22	719.97	721.06	722.60
4 Case 723+S : End of flood season, reservoir water level 723 m (MSL) with flood surcharge						
305		716.26	717.00	718.59	719.73	721.67
370		716.51	717.34	718.96	720.11	721.93
496		717.25	718.15	719.70	720.78	722.39
551		717.60	718.50	719.99	721.06	722.60

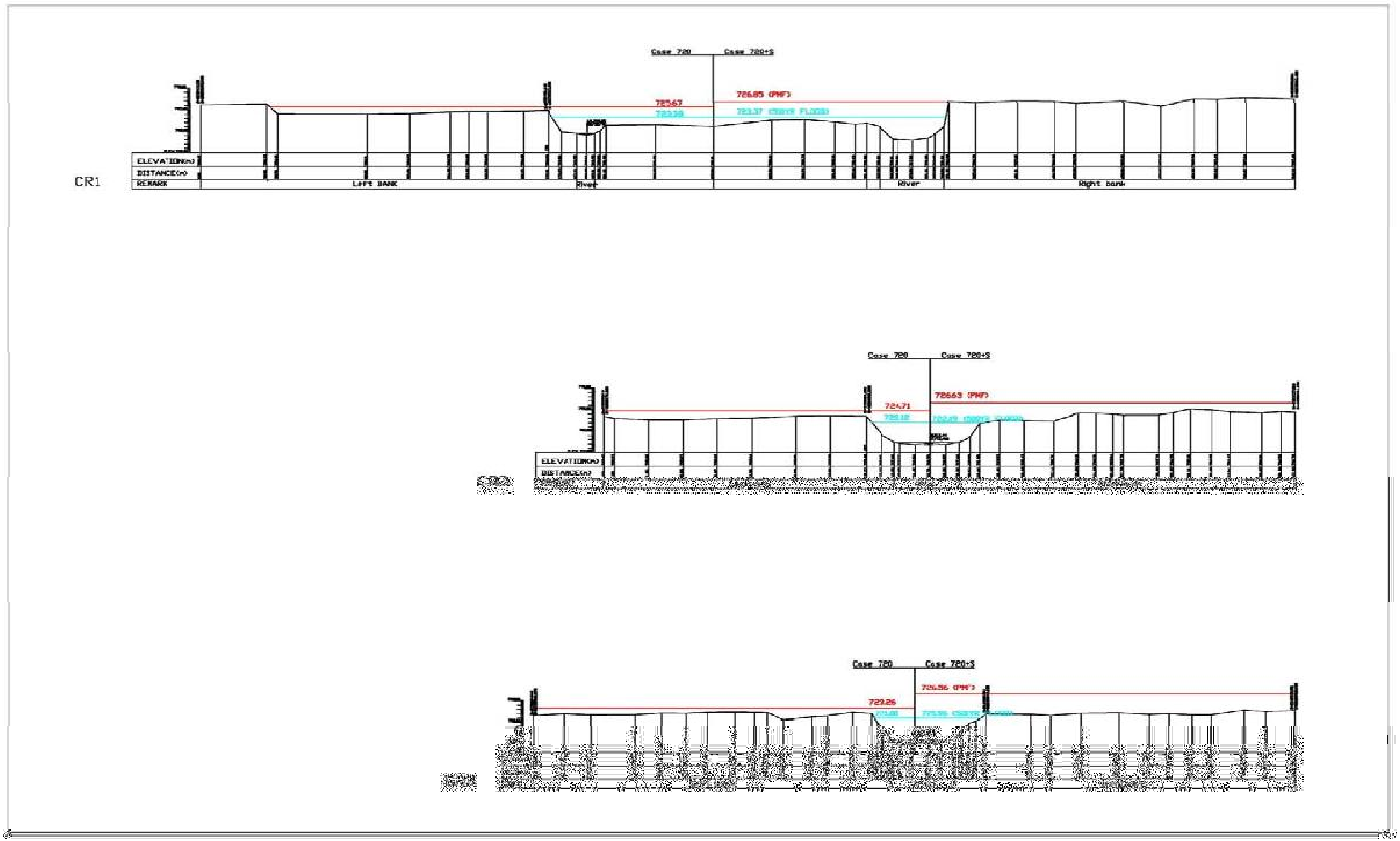


Figure 5 Flood Water Levels at the Ban Xiengdet

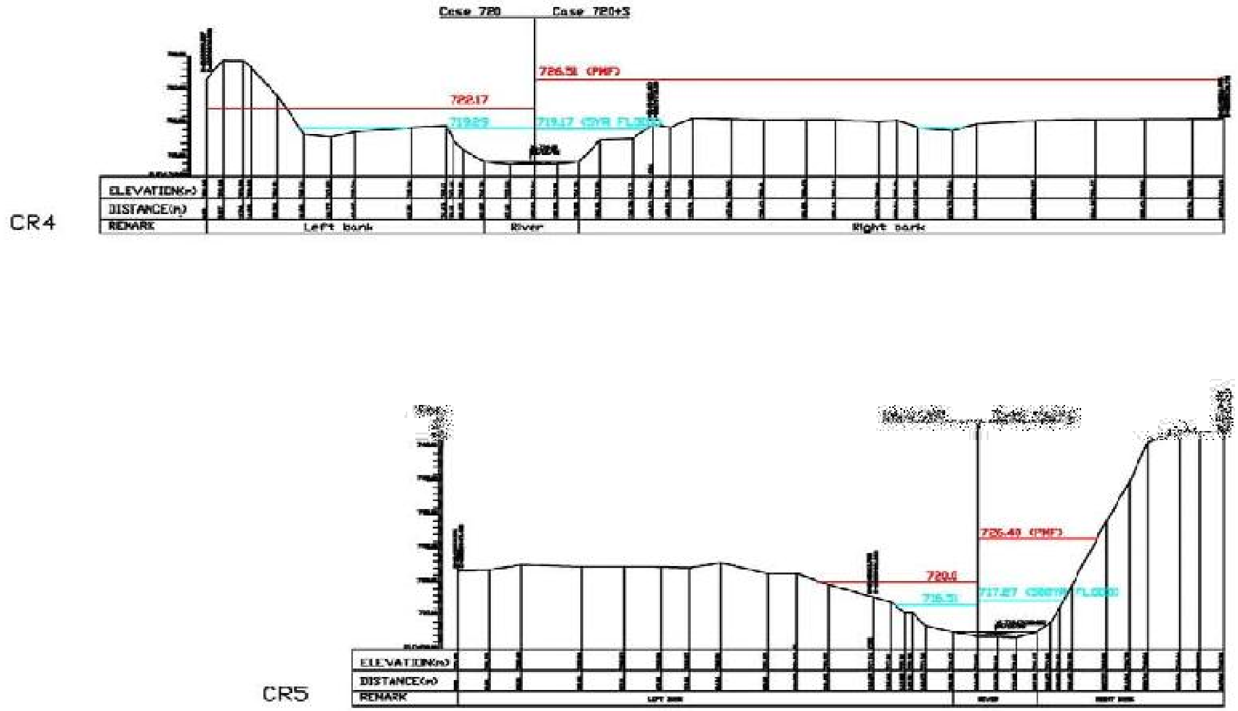


Figure 5 (Cont.) Flood Water Levels at the Ban Xiengdet

6.3 Flood map

To produce flood maps, flood depths are firstly calculated from flood levels and natural ground levels. The natural ground levels are derived from the 1:10,000 topographic map with correction in elevations mentioned earlier. A total area of Ban Xiengdet flood plain is 2.7 sq.km including surface area of Nam Ting, which is classified in the following Table.

Table 5 Classification of Flood Plain Area in Ban Xiengdet

Elevation	Area, sq.m
<705	110,400
705-715	299,000
715-725	1,040,300
725-735	1,243,600
>735	30,600
Total	2,723,900
River	316,900

Note that only flood maps of the flood season which give higher flood depths are presented.

Flood depths are shown in Table 6 while the flood maps are depicted in Figure 6. It is resulted that

1. For floods which smaller than that of PMF
    - Ban Xiengdet is partially inundated, while the flood plain of less than 30% is inundated.
    - Flood water is mainly restricted in the river channel.
    - A distinguish flooded area is a low land area between CR5 and CR6, which is located about 2 km downstream of Ban Xiengdet.
2. For PMF
    - Ban Xiengdet is almost totally inundated.
    - Overbank is widespread over the flood plain covering more or less 50% to 65% in case of without and with spillway routing, respectively.

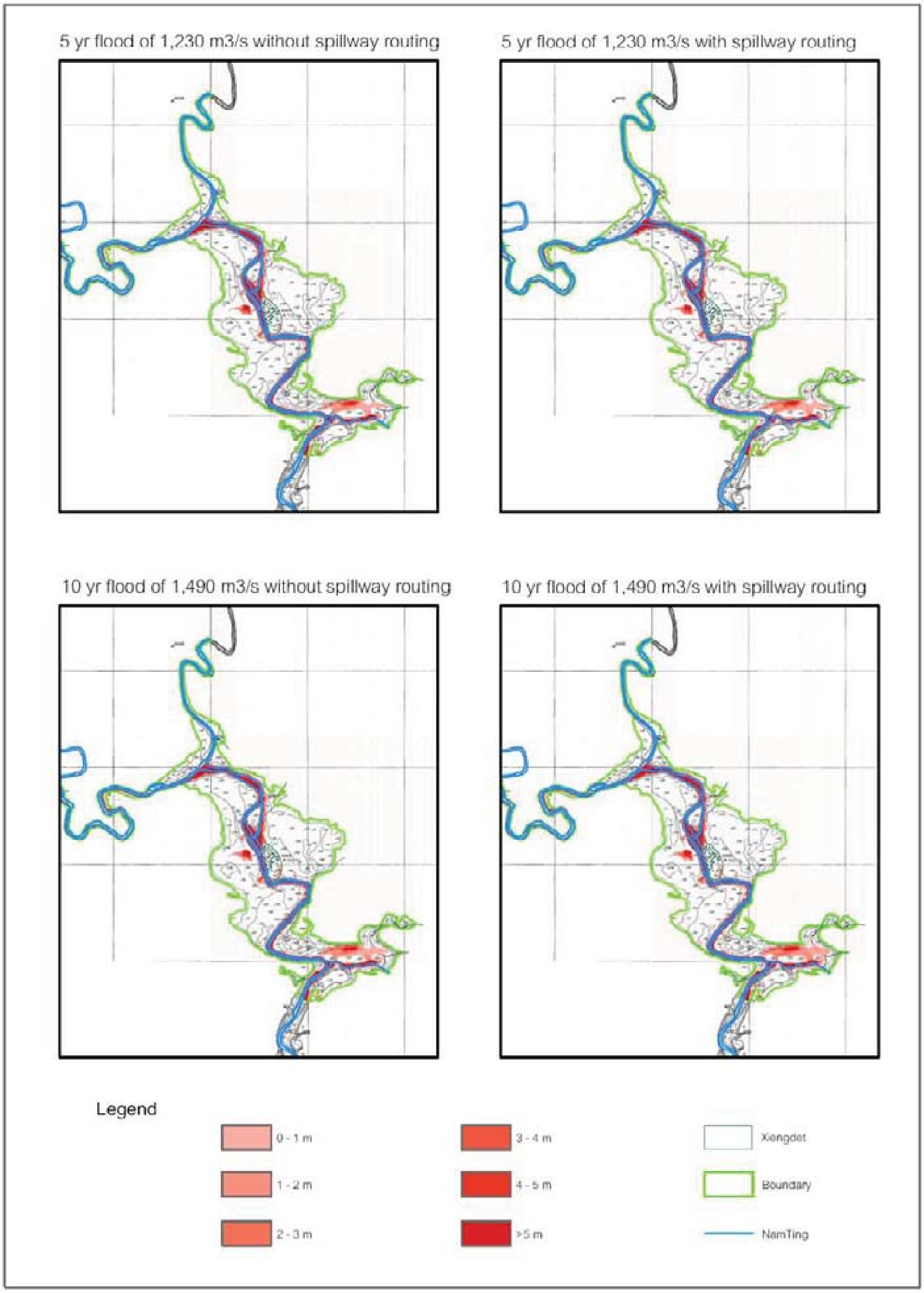


Figure 6 Flood Maps of Flood Plain at Ban Xiengdet

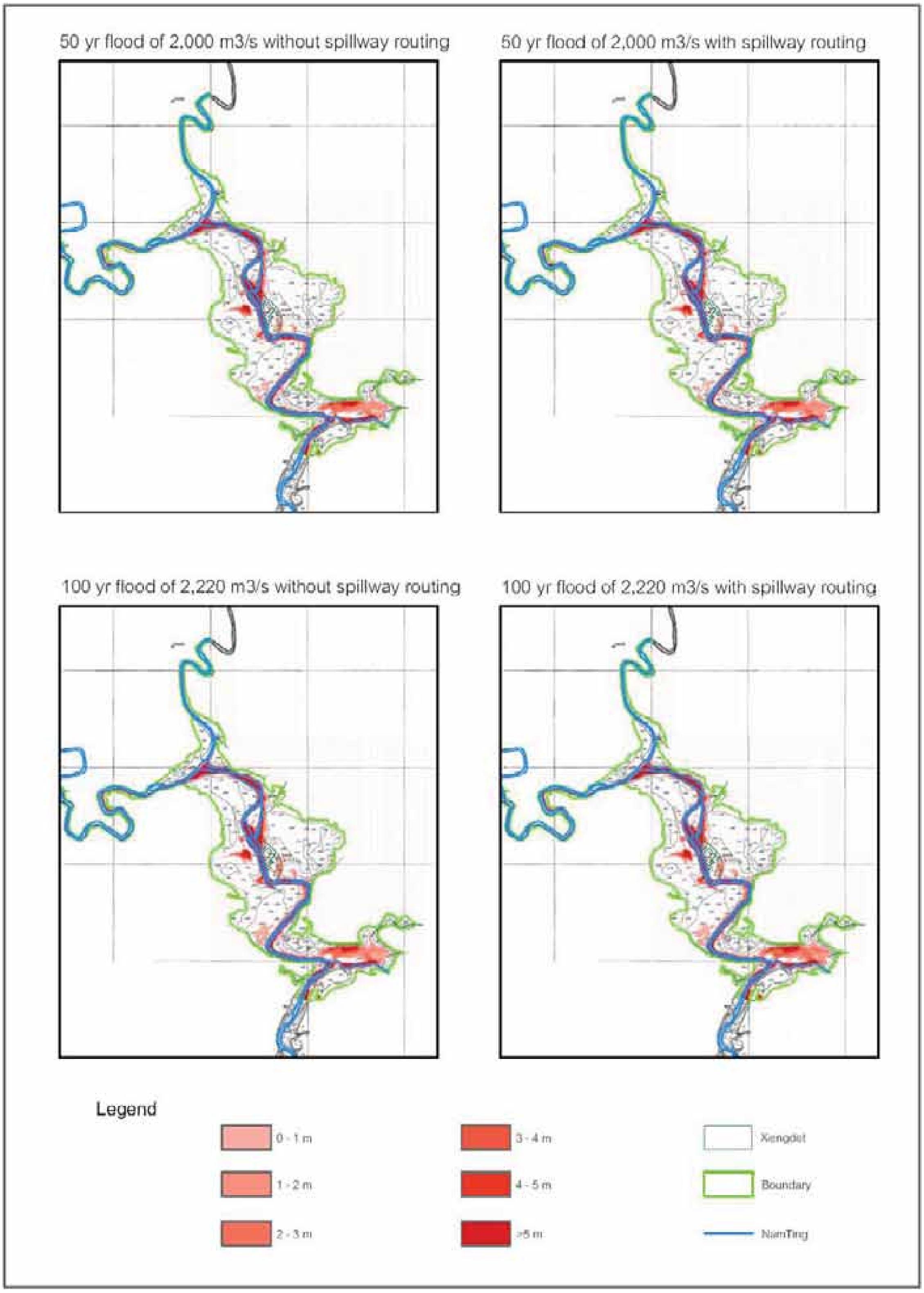


Figure 6 (Cont.) Flood Maps of Flood Plain at Ban Xiengdet

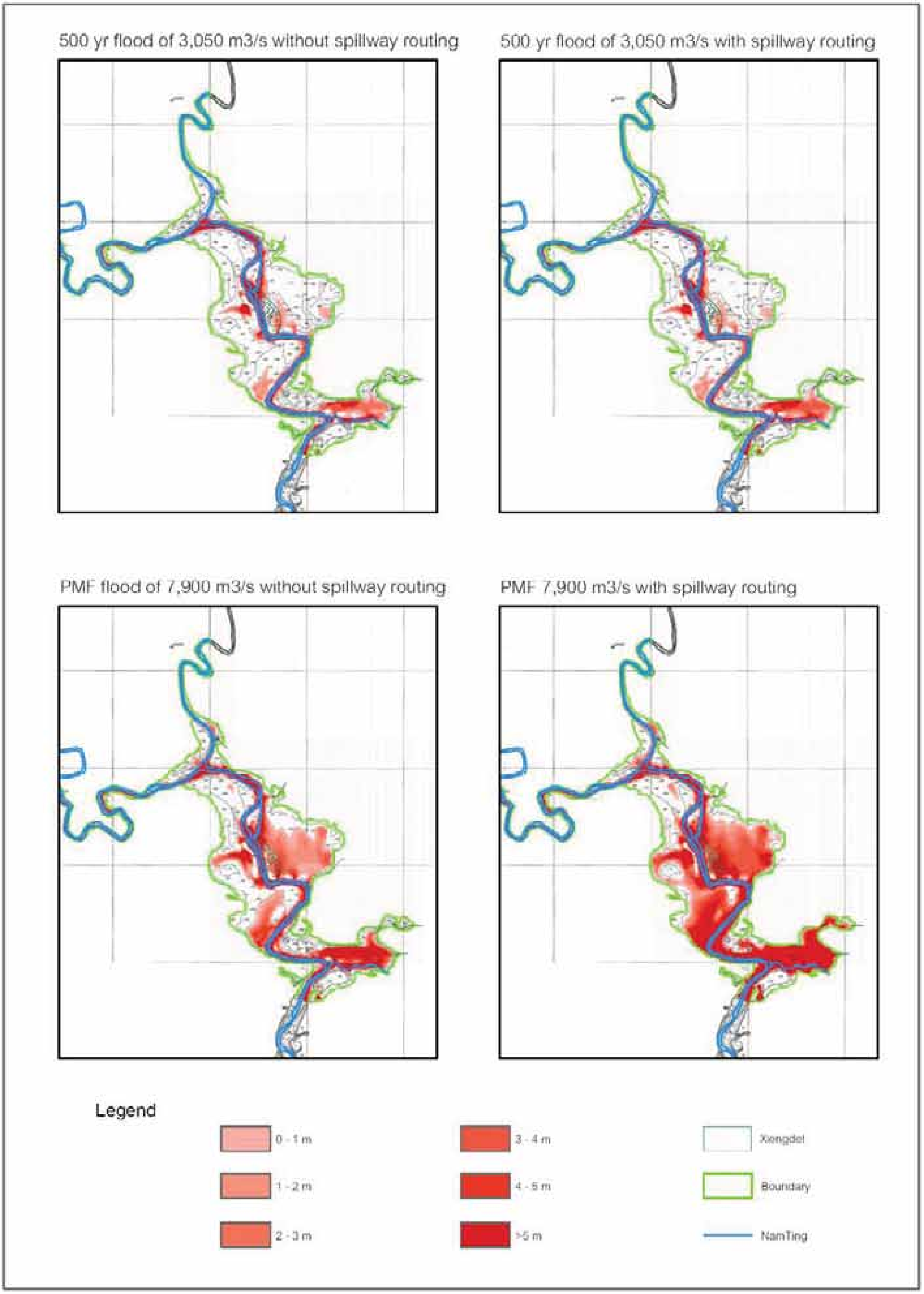


Figure 6 (Cont.) Flood Maps of Flood Plain at Ban Xiengdet

Table 6 Inundated Area on Ban Xiengdet Flood Plain

Return period Flow, m3/s	5yr 1,230	10yr 1,490	50yr 2,000	100yr 2,200	500yr 3,050	PMF 7,900
1) Case 720 Flood depth	Inundated area, sq.m					
No flood	2,205,900	2,181,400	2,118,500	2,054,200	1,924,800	1,394,800
0-1 m	71,800	73,400	83,600	131,800	181,300	186,600
1-2 m	48,100	58,600	72,600	71,900	93,900	226,700
2-3 m	32,100	35,800	51,000	59,300	73,300	167,200
3-4 m	30,100	27,800	32,000	34,500	50,300	138,300
4-5 m	29,400	32,500	37,700	33,600	32,900	84,900
> 5 m	306,500	314,400	328,600	338,600	367,400	525,400
Total	2,723,900	2,723,900	2,724,000	2,723,900	2,723,900	2,723,900
	% Inundated area					
No flood	81.0	80.1	77.8	75.4	70.7	51.2
0-1 m	2.6	2.7	3.1	4.8	6.7	6.9
1-2 m	1.8	2.2	2.7	2.6	3.4	8.3
2-3 m	1.2	1.3	1.9	2.2	2.7	6.1
3-4 m	1.1	1.0	1.2	1.3	1.8	5.1
4-5 m	1.1	1.2	1.4	1.2	1.2	3.1
> 5 m	11.3	11.5	12.1	12.4	13.5	19.3
Total	100	100	100	100	100	100
2) Case 720+S Flood depth	Inundated area, sq.m					
No flood	2,198,600	2,171,900	2,115,100	2,047,400	1,905,900	1,016,400
0-1 m	70,800	69,400	78,400	128,300	177,800	143,900
1-2 m	54,000	64,300	69,300	68,400	86,100	137,600
2-3 m	32,400	40,800	59,500	66,500	64,600	134,700
3-4 m	31,000	28,100	33,700	39,000	65,400	281,000
4-5 m	29,600	34,400	37,700	32,000	47,900	160,000
> 5 m	307,500	315,000	330,200	342,400	376,000	850,100
Total	2,723,900	2,723,900	2,723,900	2,724,000	2,723,700	2,723,700

Table 6 (Cont.) Inundated Area on Ban Xiengdet Flood Plain

Return period Flow, m3/s	5yr 1,230	10yr 1,490	50yr 2,000	100yr 2,200	500yr 3,050	PMF 7,900
Case 2) 720+S Flood depth	% Inundated area					
No flood	80.7	79.7	77.6	75.2	70.0	37.3
0-1 m	2.6	2.5	2.9	4.7	6.5	5.3
1-2 m	2.0	2.4	2.5	2.5	3.2	5.1
2-3 m	1.2	1.5	2.2	2.4	2.4	4.9
3-4 m	1.1	1.0	1.2	1.4	2.4	10.3
4-5 m	1.1	1.3	1.4	1.2	1.8	5.9
> 5 m	11.3	11.6	12.1	12.6	13.8	31.2
Total	100	100	100	100	100	100

7 Conclusion

- Nam Ngum3 reservoir induces backwater effects which have impacts on Ban Xiengdet.
- Flooding of Xiengdet is essentially depend on flood magnitude and intensified by backwater effect.
- The higher magnitude of flood occurs, the smaller the backwater effect is results.
- For floods are smaller than PMF, Ban Xiendet is partially flooded and up to 30% of the flood plain is flooded.
- For PMF, Ban Xiengdet is almost entirely flooded and up to 60% of the flood plain is flooded.

Appendix A

Spillway Routing Study

Spillway Routing of Nam Ngum3 (Draft Interim Design Report - Rev.0C)

1 Criteria

a) Spillway 3 gates (10m*15m)

b) Sill elevation 708 m

c) Initial water level 720 m(MSL) and 723 m(MSL)

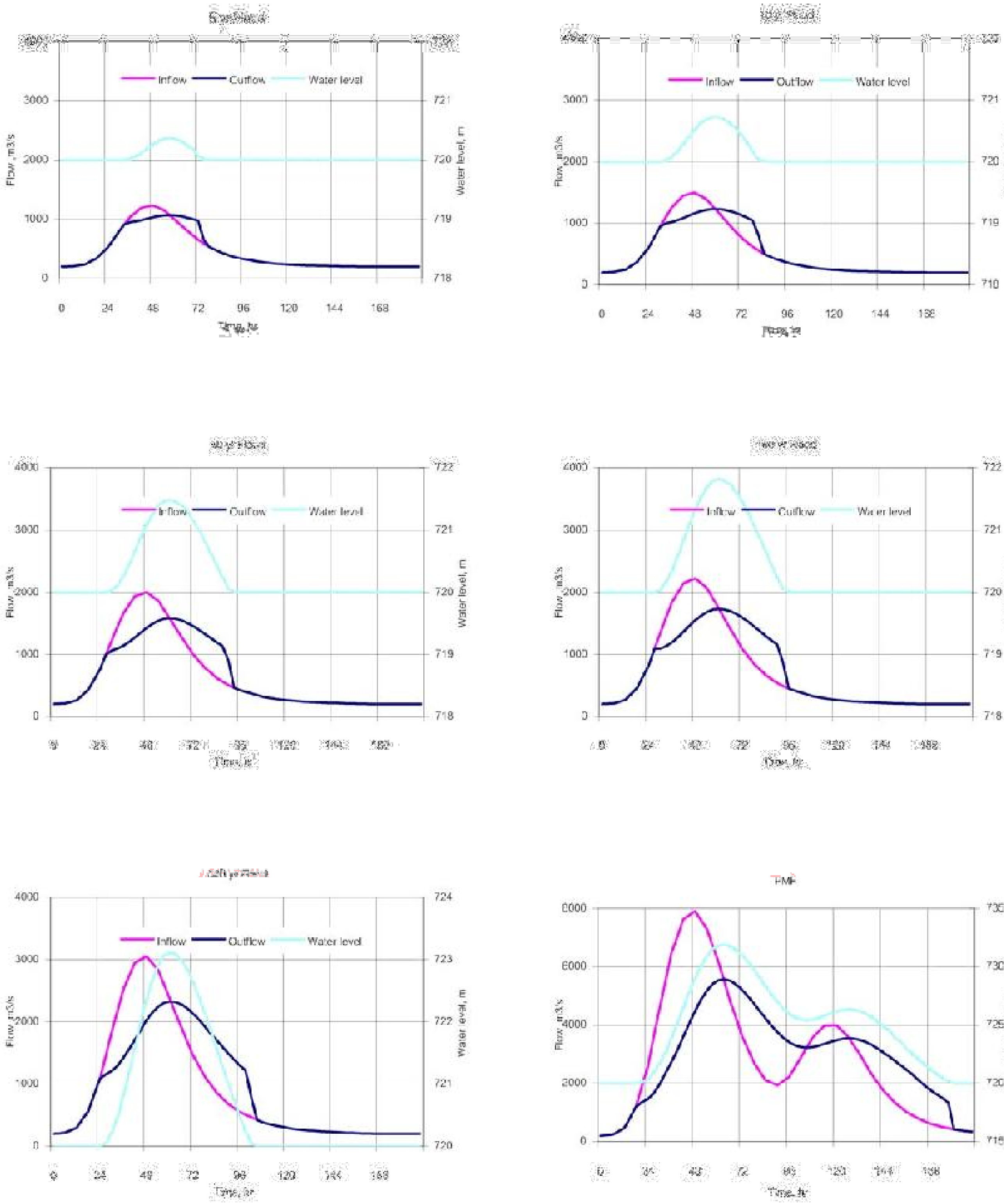
d) Spillway Outflow

$$Q = 1.9*L*H^{1.5}$$

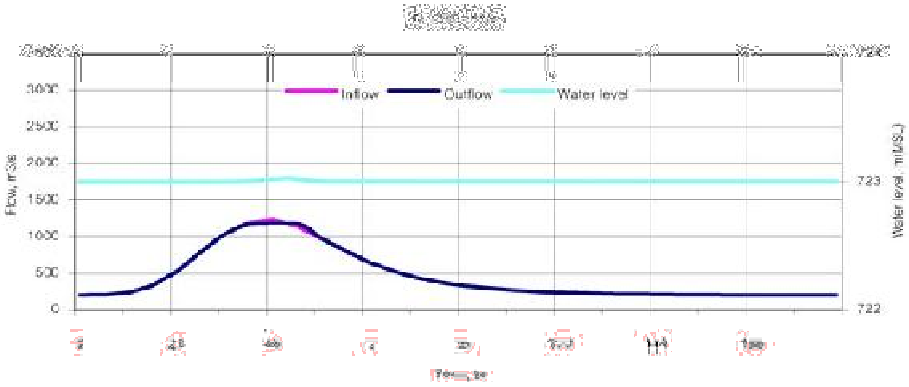
Where L = 30 m

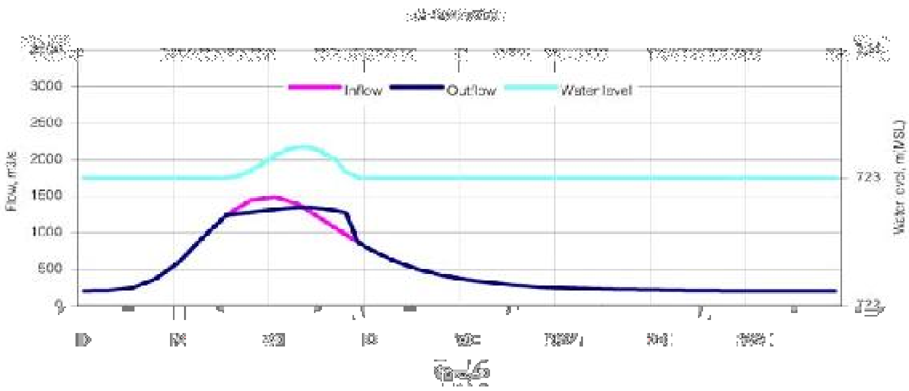
H = head above the sill

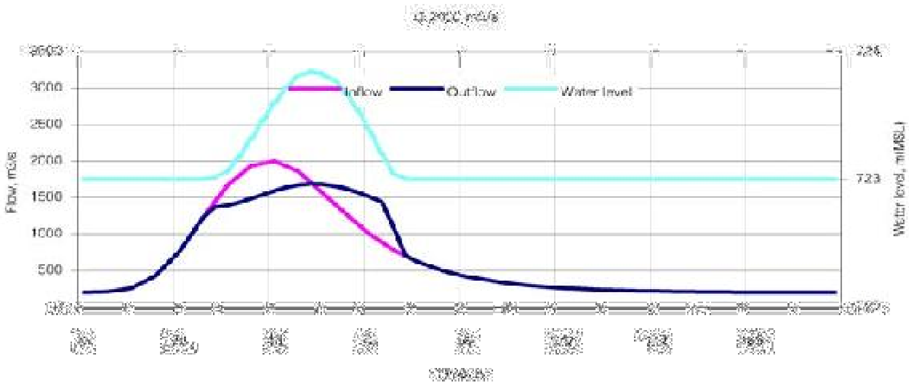
Return period	Peak inflow m3/s	Reservoir initial water level			
		720 m(MSL)		723 m(MSL)	
		Peak outflow m3/s	Max water level, m(MSL)	Peak outflow m3/s	Max water level, m(MSL)
5 yr	1,230	1065	720.3	1188	723.0
10 yr	1,490	1227	720.7	1345	723.2
50 yr	2,000	1577	721.5	1682	723.8
100 yr	2,220	1728	721.8	1831	724.1
500 yr	3,050	2327	723.1	-	-
PMF	7,900	5569	731.9	-	-

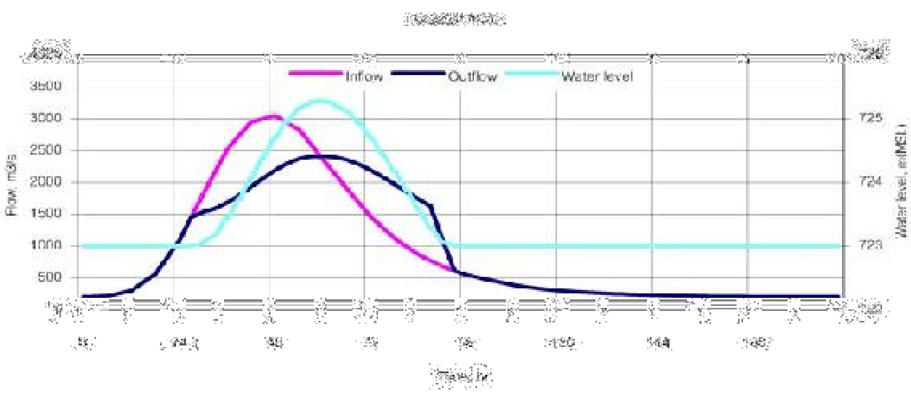


A.1 Spillway Routing for Reservoir Level at 720 m (MSL)





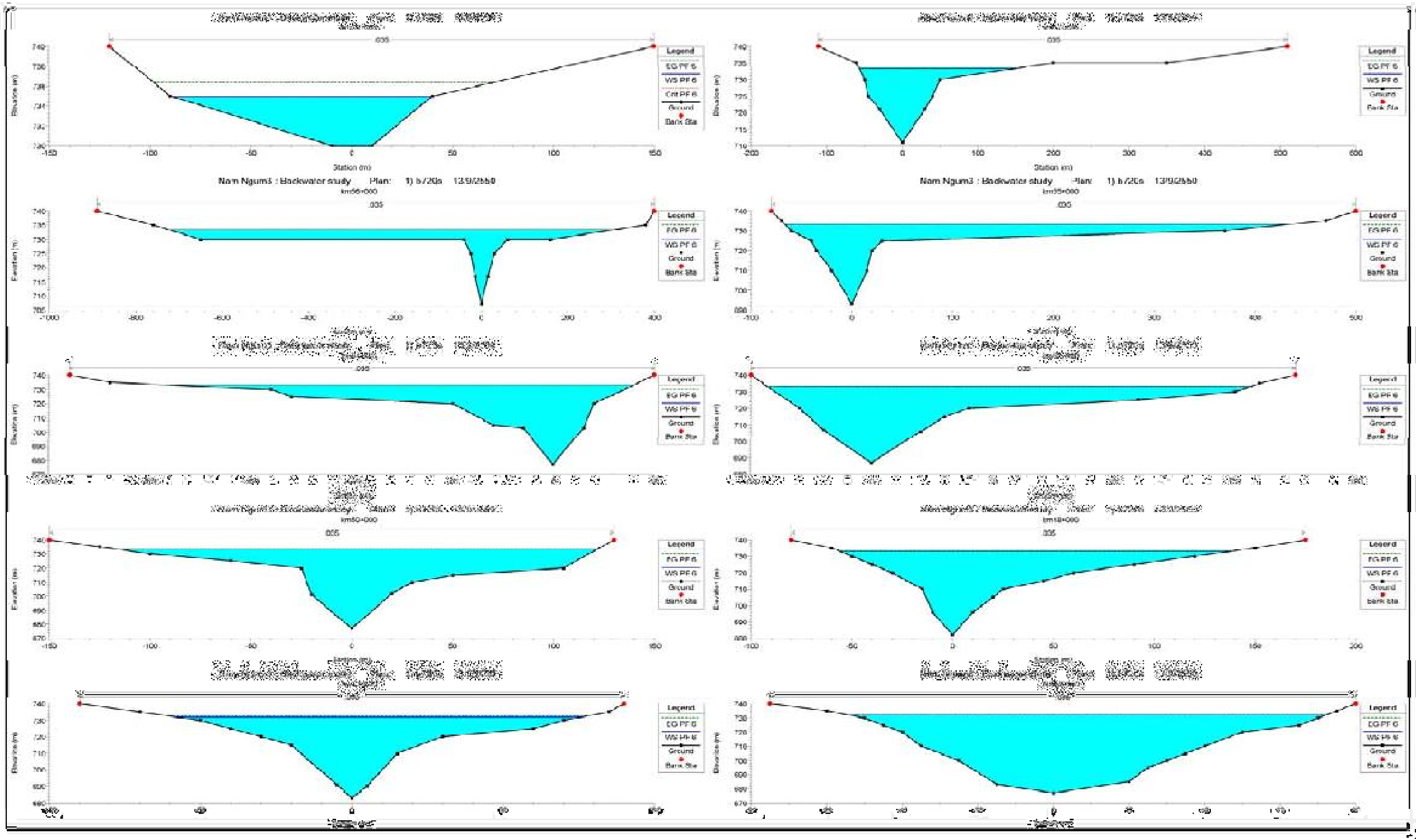




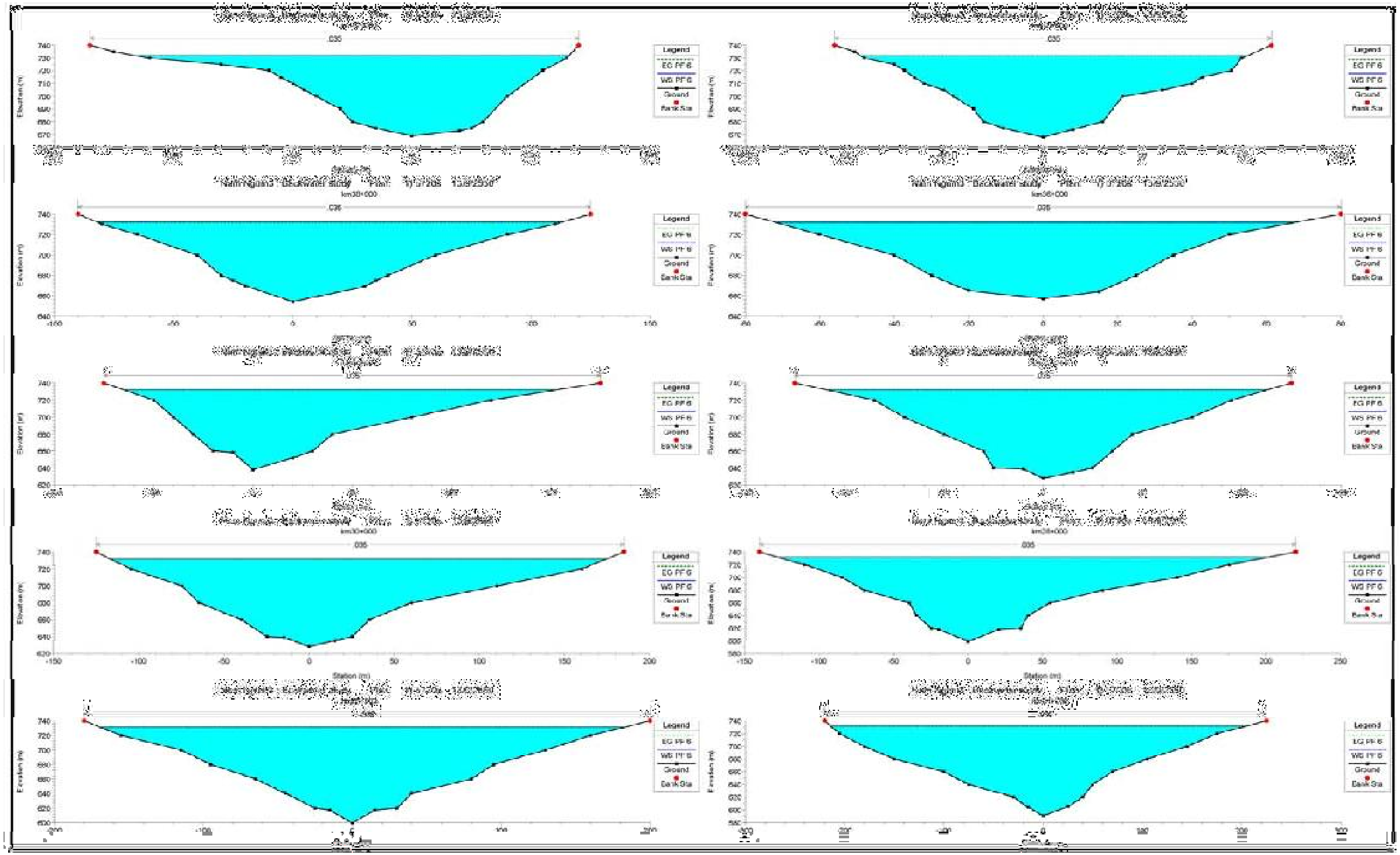
A.2 Spillway Routing for Reservoir Level at 723 m (MSL)

Appendix B

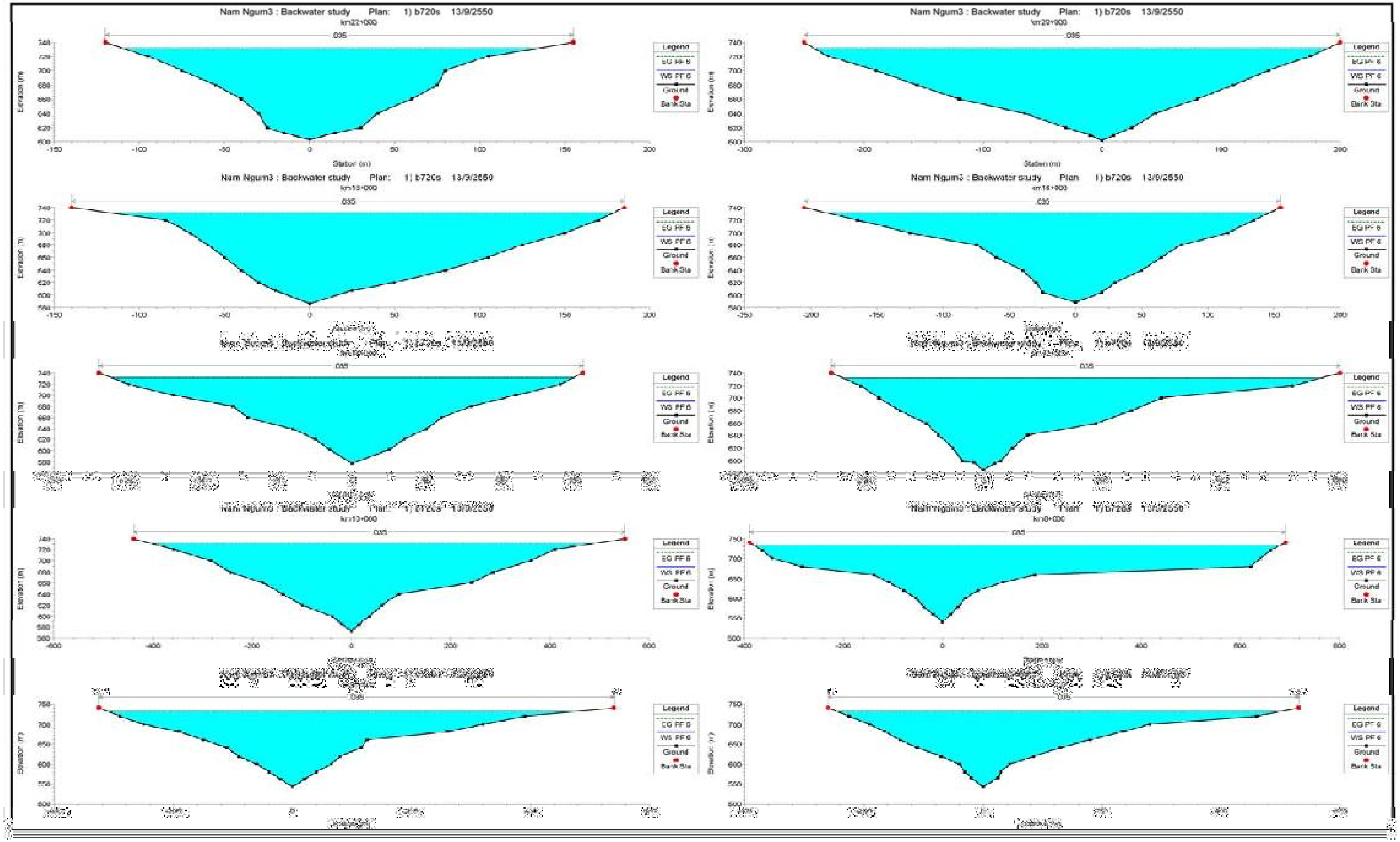
Cross Sections Along Nam Ngum River for the Backwater Model



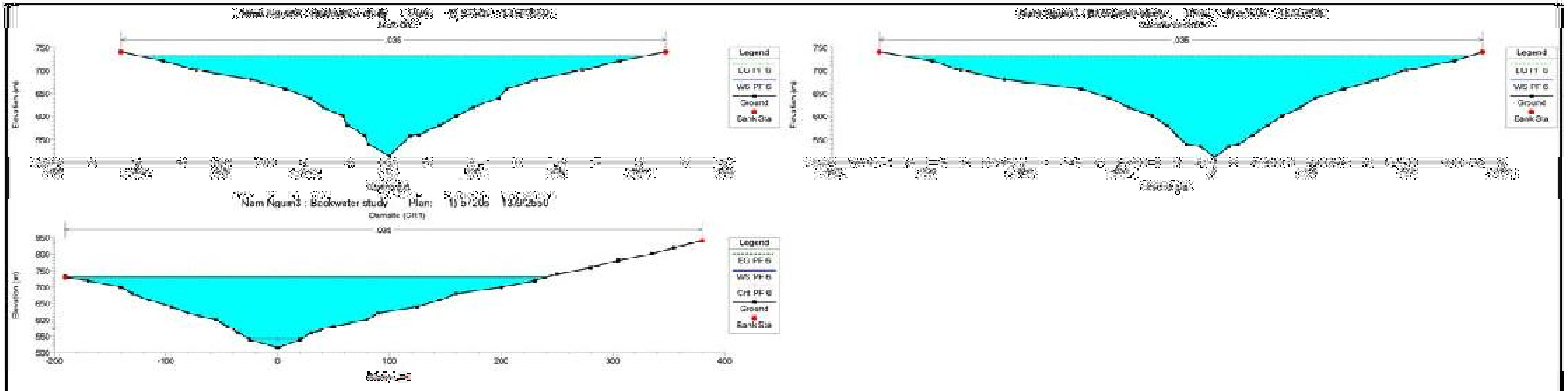
B.1 Cross Sections Along Nam Ngum River for the Backwater Model



B.1 (Cont.) Cross Sections Along Nam Ngum River for the Backwater Model



B.1 (Cont.) Cross Sections Along Nam Ngum River for the Backwater Model



B.1 (Cont.) Cross Sections Along Nam Ngum River for the Backwater Model

Appendix C

Water Surface Profiles Output for the Backwater Model

C1 Water surface profile for the existing condition (Without Nam Ngum3 dam)

C2 Water surface profile for flood season, reservoir water level at 720 m(MSL)

C3 Water surface profile for flood season, reservoir water level at 720 m(MSL) with flood surcharge

C4 Water surface profile at the end of flood season, reservoir water level at 723 m(MSL)

C5 Water surface profile at the end of flood season, reservoir water level at 723 m(MSL) with flood surcharge

C1 Water Surface Profile for the Existing Condition (Without Nam Ngum3 Dam)

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	309.00	730.00	732.50	732.00	732.87	0.011122	3.42	34.36	64.16	1.01
[illegible]	[illegible]	[illegible]	370.00	730.00	732.51	732.21	732.94	0.010847	3.77	40.33	64.72	1.01
[illegible]	[illegible]	[illegible]	436.00	730.00	732.57	732.57	733.39	0.011304	3.90	124.40	76.61	1.00
[illegible]	[illegible]	[illegible]	561.00	730.00	732.71	732.71	733.66	0.010144	4.09	135.30	79.53	1.09
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[illegible]	[illegible]	[illegible]	2230.00	677.00	698.02	698.02	701.43	0.007984	8.21	295.51	39.46	1.00
[illegible]	[illegible]	[illegible]	3250.00	677.00	699.71	699.71	703.64	0.007621	9.01	360.47	41.30	1.00
[illegible]	[illegible]	[illegible]	7500.00	677.00	697.24	697.24	704.05	0.007646	11.50	636.91	58.78	1.00
[illegible]	[illegible]	[illegible]	1250.00	560.00	651.56		651.93	0.000550	4.71	454.42	66.56	0.36
[illegible]	[illegible]	[illegible]	1490.00	555.00	663.40		662.53	0.001163	3.56	577.41	67.46	0.35
[illegible]	[illegible]	[illegible]	2000.00	460.00	664.08		664.65	0.001765	3.52	630.39	69.08	0.33
[illegible]	[illegible]	[illegible]	2230.00	460.00	665.36		665.31	0.001795	3.42	646.86	59.86	0.34
[illegible]	[illegible]	[illegible]	3250.00	535.00	586.74		587.60	0.002505	4.01	791.02	61.74	0.36
[illegible]	[illegible]	[illegible]	7500.00	560.00	594.61		596.76	0.001907	6.26	1037.15	78.21	0.48
[illegible]	[illegible]	[illegible]	1250.00	568.00	576.87	576.44	578.12	0.009162	5.53	130.95	43.65	1.09
[illegible]	[illegible]	[illegible]	1490.00	568.00	577.10	577.10	578.45	0.007098	5.70	310.61	46.04	1.00
[illegible]	[illegible]	[illegible]	2000.00	568.00	578.24	578.24	580.01	0.007517	7.30	271.23	52.10	1.00
[illegible]	[illegible]	[illegible]	2230.00	568.00	578.99	575.99	581.47	0.007320	7.40	306.35	54.10	1.09
[illegible]	[illegible]	[illegible]	3250.00	568.00	580.11	580.11	583.35	0.007764	8.00	351.56	60.11	1.01
[illegible]	[illegible]	[illegible]	7500.00	568.00	588.59		592.27	0.005537	5.96	474.82	68.56	0.74

C1(Cont.) Water Surface Profile for the Existing Condition (Without Nam Ngum3 Dam)

[illegible]	[illegible]	[illegible]	1230.00	664.00	673.81		674.27	0.000497	2.80	462.36	83.60	0.28
[illegible]	[illegible]	[illegible]	1490.00	664.00	671.97		672.39	0.000642	2.87	519.21	84.40	0.30
[illegible]	[illegible]	[illegible]	2000.00	664.00	673.52		674.31	0.000698	3.21	623.56	87.84	0.31
[illegible]	[illegible]	[illegible]	2220.00	664.00	674.64		675.11	0.000714	3.34	665.32	88.19	0.32
[illegible]	[illegible]	[illegible]	3050.00	664.00	677.00		677.71	0.000768	3.74	816.29	63.99	0.33
[illegible]	[illegible]	[illegible]	7900.00	664.00	687.02		688.28	0.000897	4.91	1646.60	80.93	0.27
[illegible]	[illegible]	[illegible]	1230.00	657.00	665.71	665.00	668.40	0.002073	5.84	210.57	37.84	0.79
[illegible]	[illegible]	[illegible]	1490.00	657.00	667.01	666.63	669.48	0.002085	6.17	241.46	38.87	0.79
[illegible]	[illegible]	[illegible]	2000.00	657.00	668.99	667.74	671.33	0.002502	6.70	298.57	40.72	0.79
[illegible]	[illegible]	[illegible]	2220.00	657.00	669.52	668.27	672.34	0.002672	6.90	321.88	41.46	0.79
[illegible]	[illegible]	[illegible]	3050.00	657.00	671.44		674.50	0.002617	7.63	414.91	43.57	0.80
[illegible]	[illegible]	[illegible]	7900.00	657.00	679.63	677.45	684.59	0.005278	10.19	777.45	52.01	0.85
[illegible]	[illegible]	[illegible]	1230.00	638.00	650.70	650.70	653.59	0.010044	7.91	155.40	24.42	1.00
[illegible]	[illegible]	[illegible]	1490.00	638.00	651.71	651.71	655.18	0.010765	8.22	181.40	28.44	1.00
[illegible]	[illegible]	[illegible]	2000.00	638.00	653.41	653.41	657.37	0.010356	8.74	228.76	28.48	1.00
[illegible]	[illegible]	[illegible]	2220.00	638.00	654.08	654.08	658.13	0.010233	8.94	248.58	30.09	1.00
[illegible]	[illegible]	[illegible]	3050.00	638.00	656.27	656.27	660.39	0.009753	9.62	380.21	34.48	1.00
[illegible]	[illegible]	[illegible]	7900.00	638.00	666.47	666.47	670.99	0.008477	11.73	750.63	50.47	1.00
[illegible]	[illegible]	[illegible]	1230.00	629.00	644.03		644.45	0.000797	2.82	435.34	53.56	0.31
[illegible]	[illegible]	[illegible]	1490.00	629.00	645.12		645.59	0.000816	3.03	491.85	53.84	0.32
[illegible]	[illegible]	[illegible]	2000.00	626.00	646.77		647.37	0.000908	3.46	580.40	55.67	0.34
[illegible]	[illegible]	[illegible]	2220.00	626.00	647.49		648.15	0.000937	2.61	616.86	56.66	0.35
[illegible]	[illegible]	[illegible]	3050.00	624.00	649.53		650.48	0.000948	4.13	739.24	57.13	0.37
[illegible]	[illegible]	[illegible]	7900.00	626.00	658.65		660.65	0.001466	6.34	1296.67	63.57	0.44
[illegible]	[illegible]	[illegible]	1230.00	626.00	637.99	637.99	640.62	0.006021	7.06	174.20	24.49	1.00
[illegible]	[illegible]	[illegible]	1490.00	626.00	638.72	638.72	641.59	0.009942	7.42	200.87	27.09	1.02
[illegible]	[illegible]	[illegible]	2000.00	628.00	640.36	640.36	643.09	0.006164	7.57	270.28	50.46	1.00
[illegible]	[illegible]	[illegible]	2220.00	628.00	640.79	640.79	643.58	0.006095	7.63	294.87	50.93	1.00
[illegible]	[illegible]	[illegible]	3050.00	623.00	642.90	642.90	645.70	0.007764	8.29	367.90	52.75	1.00
[illegible]	[illegible]	[illegible]	7900.00	626.00	648.65	648.65	654.65	0.007144	10.84	721.59	58.76	1.00
[illegible]	[illegible]	[illegible]	1230.00	608.00	621.48		621.69	0.000418	2.17	567.76	61.99	0.23
[illegible]	[illegible]	[illegible]	1490.00	608.00	622.64		622.81	0.000422	2.32	640.56	61.56	0.23
[illegible]	[illegible]	[illegible]	2000.00	608.00	624.64		624.96	0.000449	3.01	735.54	63.46	0.24
[illegible]	[illegible]	[illegible]	2220.00	608.00	625.48		625.81	0.000458	2.72	816.63	64.07	0.24
[illegible]	[illegible]	[illegible]	3050.00	603.00	628.67		628.96	0.000506	3.08	986.68	67.08	0.25
[illegible]	[illegible]	[illegible]	7900.00	603.00	633.81		639.64	0.000998	4.62	1728.56	73.96	0.30
[illegible]	[illegible]	[illegible]	1230.00	600.00	619.66		620.33	0.001186	3.86	862.77	52.08	0.41
[illegible]	[illegible]	[illegible]	1490.00	600.00	621.67		621.43	0.001373	3.40	431.04	56.81	0.40
[illegible]	[illegible]	[illegible]	2000.00	600.00	622.68		623.60	0.001227	3.86	547.05	59.52	0.39
[illegible]	[illegible]	[illegible]	2220.00	600.00	623.64		624.35	0.001144	3.74	594.09	60.60	0.38
[illegible]	[illegible]	[illegible]	3050.00	600.00	626.26		627.09	0.001113	4.03	755.45	64.49	0.38
[illegible]	[illegible]	[illegible]	7900.00	601.00	635.43		637.92	0.001026	6.29	1493.50	79.74	0.50
[illegible]	[illegible]	[illegible]	1230.00	591.00	619.74		619.80	0.000085	1.10	1121.63	69.48	0.09
[illegible]	[illegible]	[illegible]	1490.00	591.00	620.92		621.00	0.000067	1.26	1125.49	72.83	0.10
[illegible]	[illegible]	[illegible]	2000.00	591.00	622.60		622.39	0.000090	1.50	1302.60	77.91	0.12
[illegible]	[illegible]	[illegible]	2220.00	591.00	633.64		633.77	0.000094	1.59	1390.31	59.12	0.12
[illegible]	[illegible]	[illegible]	3050.00	591.00	625.92		625.99	0.000126	1.90	1595.59	87.64	0.14
[illegible]	[illegible]	[illegible]	7900.00	591.00	636.35		636.82	0.000242	3.00	2632.41	114.98	0.20
[illegible]	[illegible]	[illegible]	1230.00	603.00	618.03		619.46	0.000786	2.91	423.07	51.97	0.33
[illegible]	[illegible]	[illegible]	1490.00	603.00	620.17		620.60	0.000818	3.10	481.36	55.06	0.33
[illegible]	[illegible]	[illegible]	2000.00	603.00	621.83		622.40	0.000849	3.45	580.71	56.41	0.34
[illegible]	[illegible]	[illegible]	2220.00	603.00	622.58		623.24	0.000845	3.08	615.49	58.94	0.35
[illegible]	[illegible]	[illegible]	3050.00	603.00	623.67		626.71	0.000537	4.06	751.82	58.66	0.36
[illegible]	[illegible]	[illegible]	7900.00	600.00	635.75		636.92	0.000662	6.07	1508.11	69.21	0.43
[illegible]	[illegible]	[illegible]	1230.00	602.00	612.88	612.54	615.80	0.006618	7.25	190.30	32.27	1.00
[illegible]	[illegible]	[illegible]	1490.00	602.00	613.49	613.49	616.54	0.006905	7.69	198.83	34.03	1.00
[illegible]	[illegible]	[illegible]	2000.00	600.00	615.12	615.12	618.83	0.006223	7.97	252.04	38.48	1.00
[illegible]	[illegible]	[illegible]	2220.00	602.00	615.64	615.64	619.01	0.003292	8.13	273.00	41.14	1.01
[illegible]	[illegible]	[illegible]	3050.00	602.00	617.45	617.45	621.30	0.007021	8.56	357.72	48.68	1.01
[illegible]	[illegible]	[illegible]	7900.00	602.00	624.44	624.44	630.01	0.006675	10.48	754.04	57.32	1.00
[illegible]	[illegible]	[illegible]	1230.00	595.00	605.81		605.97	0.000814	2.62	470.78	41.50	0.31
[illegible]	[illegible]	[illegible]	1490.00	595.00	606.79		607.32	0.000860	3.22	460.96	44.85	0.32
[illegible]	[illegible]	[illegible]	2000.00	595.00	608.63		609.61	0.000927	2.88	563.29	50.11	0.41
[illegible]	[illegible]	[illegible]	2220.00	595.00	609.71		610.30	0.000968	3.67	604.36	52.23	0.35
[illegible]	[illegible]	[illegible]	3050.00	593.00	612.55		613.22	0.000926	4.08	770.80	59.58	0.38
[illegible]	[illegible]	[illegible]	7900.00	593.00	628.23		624.44	0.000993	5.09	1563.48	84.49	0.30
[illegible]	[illegible]	[illegible]	1230.00	589.00	602.61		605.52	0.001774	3.29	180.68	41.68	0.47
[illegible]	[illegible]	[illegible]	1490.00	589.00	604.18		604.99	0.001878	4.06	353.77	45.14	0.48
[illegible]	[illegible]	[illegible]	2000.00	586.00	606.35		607.19	0.001815	4.35	462.41	47.69	0.44
[illegible]	[illegible]	[illegible]	2220.00	589.00	605.95		603.90	0.001893	4.45	458.94	47.81	0.44
[illegible]	[illegible]	[illegible]	3050.00	589.00	608.49		610.72	0.001834	4.91	521.36	59.15	0.46

C1(Cont.) Water Surface Profile for the Existing Condition (Without Nam Ngum3 Dam)

C2 Water Surface Profile for Flood Season, Reservoir Water Level at 720 m(MSL)

HEC-RAS Plan: b720 River: [illegible] Reach: Main

[illegible]	[illegible]	[illegible]	305.00	730.00	732.04	732.01	732.67	0.011178	3.62	84.30	65.11	1.01
[illegible]	[illegible]	[illegible]	370.00	730.00	732.21	732.21	732.94	0.010689	3.77	98.06	65.67	1.01
[illegible]	[illegible]	[illegible]	496.00	730.00	732.57	732.57	733.38	0.010369	4.00	123.92	76.53	1.00
[illegible]	[illegible]	[illegible]	551.00	730.00	732.71	732.71	733.53	0.010155	4.00	134.82	73.67	1.00
[illegible]	[illegible]	[illegible]	757.00	730.00	733.18	733.18	734.13	0.009757	4.37	173.23	88.67	1.00
[illegible]	[illegible]	[illegible]	1990.00	730.00	734.94	734.94	736.32	0.009969	5.33	387.41	138.71	1.01
[illegible]	[illegible]	[illegible]	305.00	711.00	720.30		720.40	0.000298	1.18	262.74	50.13	0.17
[illegible]	[illegible]	[illegible]	370.00	711.00	720.52		720.61	0.000399	1.38	271.61	57.09	0.20
[illegible]	[illegible]	[illegible]	496.00	711.00	720.89		721.06	0.000448	1.69	292.80	58.27	0.23
[illegible]	[illegible]	[illegible]	551.00	711.00	721.00		721.20	0.000533	1.82	305.44	62.30	0.26
[illegible]	[illegible]	[illegible]	757.00	711.00	721.60		722.04	0.000632	2.18	349.82	64.99	0.30
[illegible]	[illegible]	[illegible]	1990.00	711.00	727.11		727.43	0.000480	2.95	775.60	91.39	0.29
[illegible]	[illegible]	[illegible]	305.00	707.00	720.18		720.28	0.000173	1.17	264.35	38.87	0.13
[illegible]	[illegible]	[illegible]	370.00	707.00	720.23		720.35	0.000254	1.41	263.31	40.10	0.18
[illegible]	[illegible]	[illegible]	496.00	707.00	720.42		720.52	0.000419	1.83	279.88	40.82	0.23
[illegible]	[illegible]	[illegible]	551.00	707.00	720.53		720.72	0.000408	2.06	274.86	40.89	0.25
[illegible]	[illegible]	[illegible]	757.00	707.00	720.98		721.57	0.000783	2.48	288.58	42.42	0.31
[illegible]	[illegible]	[illegible]	1990.00	707.00	726.08		728.70	0.001982	3.54	553.80	64.57	0.39
[illegible]	[illegible]	[illegible]	305.00	690.00	720.19		720.19	0.000015	0.40	757.24	53.65	0.03
[illegible]	[illegible]	[illegible]	370.00	690.00	720.28		720.27	0.000014	0.49	761.76	53.77	0.04
[illegible]	[illegible]	[illegible]	496.00	690.00	720.48		720.49	0.000024	0.64	773.14	56.34	0.05
[illegible]	[illegible]	[illegible]	551.00	690.00	720.57		720.58	0.000030	0.71	779.14	55.73	0.05
[illegible]	[illegible]	[illegible]	757.00	690.00	721.05		721.10	0.000051	0.94	806.90	55.15	0.08
[illegible]	[illegible]	[illegible]	1990.00	690.00	725.94		728.09	0.000260	1.86	1157.88	137.72	0.10
[illegible]	[illegible]	[illegible]	305.00	677.00	720.18		720.18	0.000003	0.23	1345.08	73.87	0.02
[illegible]	[illegible]	[illegible]	370.00	677.00	720.28		720.28	0.000004	0.27	1351.07	74.59	0.02
[illegible]	[illegible]	[illegible]	496.00	677.00	720.48		720.47	0.000007	0.36	1366.82	78.04	0.03
[illegible]	[illegible]	[illegible]	551.00	677.00	720.56		720.57	0.000008	0.40	1374.78	78.87	0.03
[illegible]	[illegible]	[illegible]	757.00	677.00	721.00		721.06	0.000018	0.53	1419.38	85.32	0.04
[illegible]	[illegible]	[illegible]	1990.00	677.00	725.94		725.95	0.000054	0.98	2049.66	190.88	0.06
[illegible]	[illegible]	[illegible]	305.00	687.00	720.17		720.17	0.000004	0.27	1127.01	77.43	0.02
[illegible]	[illegible]	[illegible]	370.00	687.00	720.25		720.25	0.000005	0.35	1132.71	73.73	0.03
[illegible]	[illegible]	[illegible]	496.00	687.00	720.44		720.45	0.000009	0.43	1147.30	73.81	0.04
[illegible]	[illegible]	[illegible]	551.00	687.00	720.54		720.55	0.000011	0.48	1155.66	75.12	0.04
[illegible]	[illegible]	[illegible]	757.00	687.00	721.00		721.02	0.000021	0.63	1193.65	85.06	0.05
[illegible]	[illegible]	[illegible]	1990.00	687.00	725.77		725.83	0.000073	1.11	1768.08	191.30	0.10
[illegible]	[illegible]	[illegible]	305.00	677.00	720.17		720.17	0.000002	0.18	1726.55	131.36	0.02
[illegible]	[illegible]	[illegible]	370.00	677.00	720.23		720.24	0.000003	0.21	1730.64	131.66	0.02
[illegible]	[illegible]	[illegible]	496.00	677.00	720.43		720.44	0.000004	0.28	1761.90	132.58	0.02
[illegible]	[illegible]	[illegible]	551.00	677.00	720.53		720.54	0.000005	0.31	1776.14	134.13	0.03
[illegible]	[illegible]	[illegible]	757.00	677.00	720.98		720.99	0.000009	0.41	1837.06	138.17	0.04
[illegible]	[illegible]	[illegible]	1990.00	677.00	725.71		725.74	0.000027	0.76	2501.26	177.78	0.05
[illegible]	[illegible]	[illegible]	305.00	682.00	720.16		720.16	0.000004	0.25	1238.38	91.27	0.02
[illegible]	[illegible]	[illegible]	370.00	682.00	720.23		720.24	0.000005	0.30	1248.10	91.88	0.03
[illegible]	[illegible]	[illegible]	496.00	682.00	720.42		720.42	0.000008	0.39	1265.08	93.25	0.03
[illegible]	[illegible]	[illegible]	551.00	682.00	720.51		720.52	0.000011	0.43	1272.06	94.08	0.04
[illegible]	[illegible]	[illegible]	757.00	682.00	720.95		720.97	0.000016	0.58	1314.14	97.60	0.05
[illegible]	[illegible]	[illegible]	1990.00	682.00	725.90		725.98	0.000057	1.06	1894.43	134.80	0.09
[illegible]	[illegible]	[illegible]	1250.00	695.30	719.98		720.06	0.000125	1.39	648.87	58.97	0.12
[illegible]	[illegible]	[illegible]	1490.00	693.00	719.99		720.13	0.000182	1.66	686.70	59.05	0.16
[illegible]	[illegible]	[illegible]	2000.00	693.00	719.98		720.24	0.000331	2.26	866.00	59.31	0.19
[illegible]	[illegible]	[illegible]	2220.00	693.00	719.97		720.29	0.000488	2.51	885.88	58.88	0.21
[illegible]	[illegible]	[illegible]	3080.00	693.00	719.94		720.38	0.000773	3.45	653.94	59.74	0.39
[illegible]	[illegible]	[illegible]	7900.00	693.00	719.38		728.73	0.002730	9.31	848.41	57.97	0.77
[illegible]	[illegible]	[illegible]	1250.00	677.00	720.04		720.06	0.000008	0.59	2203.48	90.04	0.03
[illegible]	[illegible]	[illegible]	1490.00	677.00	720.02		720.08	0.000011	0.65	2202.00	90.08	0.04
[illegible]	[illegible]	[illegible]	2000.00	677.00	720.03		720.07	0.000020	0.87	2204.09	90.11	0.05
[illegible]	[illegible]	[illegible]	2220.00	677.00	720.03		720.08	0.000024	0.98	2205.02	90.14	0.06
[illegible]	[illegible]	[illegible]	3080.00	677.00	720.07		720.13	0.000043	1.32	2208.38	90.26	0.09
[illegible]	[illegible]	[illegible]	7900.00	677.00	720.44		721.02	0.000280	3.37	2243.13	91.79	0.21
[illegible]	[illegible]	[illegible]	1250.00	669.00	720.00		720.02	0.000002	0.34	3643.30	115.05	0.02
[illegible]	[illegible]	[illegible]	1490.00	669.00	720.01		720.02	0.000004	0.41	3644.08	115.07	0.02
[illegible]	[illegible]	[illegible]	2000.00	669.00	720.02		720.04	0.000005	0.55	3645.55	115.12	0.03
[illegible]	[illegible]	[illegible]	2220.00	669.00	720.03		720.05	0.000007	0.61	3646.01	115.15	0.03
[illegible]	[illegible]	[illegible]	3080.00	669.00	720.05		720.09	0.000013	0.84	3648.10	115.29	0.03
[illegible]	[illegible]	[illegible]	7900.00	669.00	720.34		720.52	0.000065	2.14	3684.77	116.81	0.12
[illegible]	[illegible]	[illegible]	1250.00	668.00	720.04		720.04	0.000002	0.28	4376.15	165.01	0.02
[illegible]	[illegible]	[illegible]	1490.00	668.00	720.05		720.05	0.000002	0.34	4378.87	165.02	0.02
[illegible]	[illegible]	[illegible]	2000.00	668.00	720.02		720.06	0.000004	0.46	4377.09	165.03	0.03
[illegible]	[illegible]	[illegible]	2220.00	668.00	720.02		720.04	0.000005	0.51	4378.56	165.03	0.03
[illegible]	[illegible]	[illegible]	3080.00	668.00	720.04		720.07	0.000010	0.70	4381.93	165.06	0.04
[illegible]	[illegible]	[illegible]	7900.00	668.00	720.26		720.44	0.000065	1.76	4421.44	165.42	0.11

C2(Cont.) Water Surface Profile for Flood Season, Reservoir Water Level at 720 m(MSL)

HEC-RAS Plan: b720 River: Nam Ngum Reach: Main (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1230.00	564.00	720.01		720.01	0.000001	0.20	5269.38	155.62	0.01
[illegible]	[illegible]	[illegible]	1490.00	564.00	720.01		720.01	0.000001	0.28	5269.74	155.64	0.02
[illegible]	[illegible]	[illegible]	2000.00	564.00	720.01		720.02	0.000002	0.38	5269.78	155.65	0.02
[illegible]	[illegible]	[illegible]	2220.00	564.00	720.02		720.02	0.000003	0.42	5270.22	155.66	0.02
[illegible]	[illegible]	[illegible]	3050.00	564.00	720.03		720.05	0.000006	0.58	5272.61	155.12	0.03
[illegible]	[illegible]	[illegible]	7960.00	564.00	720.22		720.33	0.000036	1.45	5301.80	155.77	0.08
[illegible]	[illegible]	[illegible]	1230.00	557.00	720.00		720.01	0.000002	0.31	3677.58	110.60	0.02
[illegible]	[illegible]	[illegible]	1490.00	557.00	720.00		720.01	0.000003	0.37	3677.60	110.60	0.02
[illegible]	[illegible]	[illegible]	2000.00	557.00	720.00		720.01	0.000005	0.50	3677.67	110.60	0.03
[illegible]	[illegible]	[illegible]	2220.00	557.00	720.00		720.02	0.000006	0.56	3677.72	110.60	0.03
[illegible]	[illegible]	[illegible]	3050.00	557.00	720.00		720.02	0.000011	0.77	3677.89	110.61	0.04
[illegible]	[illegible]	[illegible]	7960.00	557.00	720.02		720.22	0.000074	1.98	3680.18	110.66	0.11
[illegible]	[illegible]	[illegible]	1230.00	526.00	720.00		720.00	0.000001	0.19	6470.17	170.00	0.01
[illegible]	[illegible]	[illegible]	1490.00	526.00	720.00		720.00	0.000002	0.23	6470.22	170.00	0.01
[illegible]	[illegible]	[illegible]	2000.00	526.00	720.00		720.01	0.000002	0.31	6470.29	170.01	0.02
[illegible]	[illegible]	[illegible]	2220.00	526.00	720.00		720.01	0.000002	0.34	6470.43	170.01	0.02
[illegible]	[illegible]	[illegible]	3050.00	526.00	720.01		720.02	0.000004	0.47	6470.86	170.02	0.02
[illegible]	[illegible]	[illegible]	7960.00	526.00	720.05		720.11	0.000024	1.23	6475.88	170.14	0.06
[illegible]	[illegible]	[illegible]	1230.00	528.00	720.00		720.00	0.000000	0.14	8625.15	183.00	0.01
[illegible]	[illegible]	[illegible]	1490.00	528.00	720.00		720.00	0.000000	0.17	8625.19	183.00	0.01
[illegible]	[illegible]	[illegible]	2000.00	528.00	720.00		720.00	0.000001	0.23	8625.34	183.01	0.01
[illegible]	[illegible]	[illegible]	2220.00	528.00	720.00		720.01	0.000001	0.26	8625.42	183.01	0.01
[illegible]	[illegible]	[illegible]	3050.00	528.00	720.00		720.01	0.000002	0.35	8625.17	183.01	0.02
[illegible]	[illegible]	[illegible]	7960.00	528.00	720.05		720.03	0.000010	0.90	8630.09	183.10	0.04
[illegible]	[illegible]	[illegible]	1230.00	526.00	720.00		720.00	0.000000	0.11	11165.21	205.00	0.01
[illegible]	[illegible]	[illegible]	1490.00	526.00	720.00		720.00	0.000000	0.13	11165.26	205.00	0.01
[illegible]	[illegible]	[illegible]	2000.00	526.00	720.00		720.00	0.000000	0.18	11165.44	205.00	0.01
[illegible]	[illegible]	[illegible]	2220.00	526.00	720.00		720.00	0.000000	0.20	11165.58	205.00	0.01
[illegible]	[illegible]	[illegible]	3050.00	526.00	720.00		720.01	0.000001	0.27	11166.01	205.01	0.01
[illegible]	[illegible]	[illegible]	7960.00	526.00	720.03		720.06	0.000005	0.71	11171.82	205.08	0.03
[illegible]	[illegible]	[illegible]	1230.00	520.00	720.00		720.00	0.000000	0.08	15030.23	285.00	0.00
[illegible]	[illegible]	[illegible]	1490.00	520.00	720.00		720.00	0.000000	0.10	15030.28	285.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	520.00	720.00		720.00	0.000000	0.13	15030.51	285.01	0.01
[illegible]	[illegible]	[illegible]	2220.00	520.00	720.00		720.00	0.000000	0.15	15030.63	285.01	0.01
[illegible]	[illegible]	[illegible]	3050.00	520.00	720.00		720.01	0.000000	0.20	15031.13	285.01	0.01
[illegible]	[illegible]	[illegible]	7960.00	520.00	720.05		720.06	0.000003	0.53	15037.36	285.10	0.02
[illegible]	[illegible]	[illegible]	1230.00	500.00	720.00		720.00	0.000000	0.07	17382.72	315.00	0.00
[illegible]	[illegible]	[illegible]	1490.00	500.00	720.00		720.00	0.000000	0.09	17382.80	315.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	500.00	720.00		720.00	0.000000	0.12	17383.03	315.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	500.00	720.00		720.00	0.000000	0.13	17383.15	315.01	0.01
[illegible]	[illegible]	[illegible]	3050.00	500.00	720.00		720.01	0.000000	0.18	17383.67	315.01	0.01
[illegible]	[illegible]	[illegible]	7960.00	500.00	720.02		720.03	0.000002	0.45	17390.11	315.05	0.02
[illegible]	[illegible]	[illegible]	1230.00	591.00	720.00		720.00	0.000000	0.05	25129.27	383.00	0.00
[illegible]	[illegible]	[illegible]	1490.00	591.00	720.00		720.00	0.000000	0.06	25129.39	383.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	591.00	720.00		720.00	0.000000	0.08	25129.67	383.01	0.00
[illegible]	[illegible]	[illegible]	2220.00	591.00	720.00		720.00	0.000000	0.09	25129.81	383.01	0.00
[illegible]	[illegible]	[illegible]	3050.00	591.00	720.00		720.00	0.000000	0.12	25130.46	383.01	0.01
[illegible]	[illegible]	[illegible]	7960.00	591.00	720.03		720.03	0.000001	0.34	25138.74	383.08	0.01
[illegible]	[illegible]	[illegible]	1230.00	503.00	720.00		720.00	0.000000	0.10	12125.04	203.00	0.00
[illegible]	[illegible]	[illegible]	1490.00	503.00	720.00		720.00	0.000000	0.12	12125.09	203.00	0.01
[illegible]	[illegible]	[illegible]	2000.00	503.00	720.00		720.00	0.000000	0.16	12125.28	203.00	0.01
[illegible]	[illegible]	[illegible]	2220.00	503.00	720.00		720.00	0.000000	0.18	12125.10	203.00	0.01
[illegible]	[illegible]	[illegible]	3050.00	503.00	720.00		720.00	0.000001	0.25	12126.15	203.00	0.01
[illegible]	[illegible]	[illegible]	7960.00	503.00	720.00		720.02	0.000004	0.65	12135.34	203.02	0.03
[illegible]	[illegible]	[illegible]	1230.00	502.00	720.00		720.00	0.000000	0.05	23182.00	405.00	0.00
[illegible]	[illegible]	[illegible]	1490.00	502.00	720.00		720.00	0.000000	0.06	23182.17	405.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	502.00	720.00		720.00	0.000000	0.09	23182.47	405.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	502.00	720.00		720.00	0.000000	0.10	23182.64	405.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	502.00	720.00		720.00	0.000000	0.13	23183.29	405.01	0.01
[illegible]	[illegible]	[illegible]	7960.00	502.00	720.01		720.02	0.000001	0.34	23187.63	405.05	0.01
[illegible]	[illegible]	[illegible]	1230.00	560.00	720.00		720.00	0.000000	0.07	16235.00	295.00	0.00
[illegible]	[illegible]	[illegible]	1490.00	560.00	720.00		720.00	0.000000	0.09	16235.06	295.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	560.00	720.00		720.00	0.000000	0.11	16235.13	295.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	560.00	720.00		720.00	0.000000	0.12	16235.15	295.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	560.00	720.00		720.00	0.000000	0.17	16235.27	295.00	0.01
[illegible]	[illegible]	[illegible]	7960.00	560.00	720.01		720.02	0.000001	0.45	16236.63	295.02	0.02
[illegible]	[illegible]	[illegible]	1230.00	586.00	720.00		720.00	0.000000	0.07	17000.01	300.00	0.00
[illegible]	[illegible]	[illegible]	1490.00	586.00	720.00		720.00	0.000000	0.09	17000.06	300.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	586.00	720.00		720.00	0.000000	0.12	17000.08	300.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	586.00	720.00		720.00	0.000000	0.13	17000.09	300.00	0.01
[illegible]	[illegible]	[illegible]	3050.00	586.00	720.00		720.00	0.000000	0.18	17000.13	300.00	0.01

C2(Cont.) Water Surface Profile for Flood Season, Reservoir Water Level at 720 m (MSL)

[illegible]

[illegible]	[illegible]	[illegible]	7900.00	555.00	720.00		721.01	0.000002	0.46	17060.58	300.01	0.01
[illegible]	[illegible]	[illegible]	1250.00	578.00	720.00		720.00	0.000000	0.07	17063.03	290.00	0.00
[illegible]	[illegible]	[illegible]	1450.00	578.00	720.00		720.00	0.000000	0.08	17060.03	290.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	578.00	720.00		720.00	0.000000	0.12	17063.00	290.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	578.00	720.00		720.00	0.000000	0.13	17073.98	290.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	578.00	720.00		720.00	0.000000	0.18	17073.03	290.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	578.00	720.00		720.01	0.000002	0.46	17073.61	290.39	0.02
[illegible]	[illegible]	[illegible]	1250.00	585.00	720.00		720.00	0.000000	0.03	36275.07	725.00	0.00
[illegible]	[illegible]	[illegible]	1450.00	585.00	720.00		720.00	0.000000	0.04	36275.13	725.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	585.00	720.00		720.00	0.000000	0.06	36275.36	725.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	585.00	720.00		720.00	0.000000	0.06	36275.24	725.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	585.00	720.00		720.00	0.000000	0.08	36275.47	725.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	585.00	720.00		720.01	0.000000	0.22	36277.97	725.02	0.01
[illegible]	[illegible]	[illegible]	1250.00	572.00	720.00		720.00	0.000000	0.02	49320.97	770.00	0.00
[illegible]	[illegible]	[illegible]	1450.00	572.00	720.00		720.00	0.000000	0.03	49320.15	770.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	572.00	720.00		720.00	0.000000	0.04	49320.25	770.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	572.00	720.00		720.00	0.000000	0.05	49320.25	770.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	572.00	720.00		720.00	0.000000	0.06	49320.47	770.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	572.00	720.00		720.00	0.000000	0.16	49322.45	770.00	0.01
[illegible]	[illegible]	[illegible]	1250.00	540.00	720.00		720.00	0.000000	0.02	68250.10	1025.00	0.00
[illegible]	[illegible]	[illegible]	1450.00	540.00	720.00		720.00	0.000000	0.02	68250.21	1025.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	540.00	720.00		720.00	0.000000	0.03	68250.36	1025.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	540.00	720.00		720.00	0.000000	0.03	68250.36	1025.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	540.00	720.00		720.00	0.000000	0.05	68250.65	1025.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	540.00	720.01		720.00	0.000000	0.12	68253.02	1025.01	0.00
[illegible]	[illegible]	[illegible]	1250.00	543.00	720.00		720.00	0.000000	0.03	45400.02	680.00	0.00
[illegible]	[illegible]	[illegible]	1450.00	543.00	720.00		720.00	0.000000	0.03	45400.03	690.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	543.00	720.00		720.00	0.000000	0.04	45400.11	690.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	543.00	720.00		720.00	0.000000	0.05	45400.19	690.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	543.00	720.00		720.00	0.000000	0.07	45400.34	690.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	543.00	720.00		720.00	0.000000	0.17	45401.21	[illegible]	0.01
[illegible]	[illegible]	[illegible]	1250.00	543.00	720.00		720.00	0.000000	0.03	42132.55	685.00	0.00
[illegible]	[illegible]	[illegible]	1450.00	543.00	720.00		720.00	0.000000	0.04	42132.60	685.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	543.00	720.00		720.00	0.000000	0.05	42132.81	685.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	543.00	720.00		720.00	0.000000	0.05	42132.91	685.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	543.00	720.00		720.00	0.000000	0.07	42133.13	685.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	543.00	720.00		720.00	0.000000	0.19	42133.83	685.01	0.01
[illegible]	[illegible]	[illegible]	1250.00	514.00	720.00		720.00	0.000000	0.03	41685.05	545.00	0.00
[illegible]	[illegible]	[illegible]	1450.00	514.00	720.00		720.00	0.000000	0.04	41685.05	545.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	514.00	720.00		720.00	0.000000	0.05	41685.10	545.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	514.00	720.00		720.00	0.000000	0.05	41685.10	545.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	514.00	720.00		720.00	0.000000	0.07	41685.18	545.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	514.00	720.00		720.01	0.000000	0.19	41685.65	545.01	0.01
[illegible]	[illegible]	[illegible]	1250.00	511.00	720.00		720.00	0.000000	0.03	43472.58	545.00	0.01
[illegible]	[illegible]	[illegible]	1450.00	511.00	720.00		720.00	0.000000	0.03	43472.63	545.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	511.00	720.00		720.00	0.000000	0.05	43472.62	545.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	511.00	720.00		720.00	0.000000	0.05	43472.52	545.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	511.00	720.00		720.00	0.000000	0.07	43472.06	545.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	511.00	720.00		720.00	0.000000	0.18	43473.03	545.00	0.01
[illegible]	[illegible]	[illegible]	1250.00	514.00	720.00	527.06	720.00	0.000000	0.03	36535.04	400.00	0.00
[illegible]	[illegible]	[illegible]	1450.00	514.00	720.00	528.28	720.00	0.000000	0.04	36535.04	400.00	0.00
[illegible]	[illegible]	[illegible]	2000.00	514.00	720.00	530.70	720.00	0.000000	0.05	36535.04	400.00	0.00
[illegible]	[illegible]	[illegible]	2220.00	514.00	720.00	530.79	720.00	0.000000	0.06	36535.04	400.00	0.00
[illegible]	[illegible]	[illegible]	3050.00	514.00	720.00	533.09	720.00	0.000000	0.08	36535.04	400.00	0.00
[illegible]	[illegible]	[illegible]	7900.00	514.00	720.00	541.82	720.00	0.000000	0.20	36535.34	400.00	0.01

C3 Water Surface Profile for Flood Season, Reservoir Water Level at 720 m(MSL) with Flood Surcharge

[illegible]

C3(Cont.) Water Surface Profile for Flood Season, Reservoir Water Level at 720 m(MSL) with Flood Surcharge

C3(Cont.) Water Surface Profile for Flood Season, Reservoir Water Level at 720 m(MSL) with Flood Surcharge

C4 Water Surface Profile at the End of Flood Season, Reservoir Water Level at 723 m(MSL)

HEC-RAS Plan: [illegible] River: [illegible] Reach: Main

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Main	[illegible]	PF 1	205.00	730.00	731.84	731.81	732.62	0.011173	3.92	84.93	54.11	1.01
Main	[illegible]	PF 2	270.00	730.00	732.24	732.24	732.84	0.010684	3.77	98.60	60.67	1.01
Main	[illegible]	PF 3	495.00	731.00	732.57	732.57	733.55	0.010058	4.00	123.36	75.60	1.00
Main	[illegible]	PF 4	551.00	730.00	732.79	732.71	733.06	0.010163	4.30	134.47	78.54	1.00
Main	[illegible]	PF 1	205.00	711.00	723.16		723.01	0.000068	0.55	443.75	73.02	0.07
Main	[illegible]	PF 2	270.00	711.00	723.25		723.30	0.000079	0.98	461.90	74.15	0.11
Main	[illegible]	PF 3	495.00	711.00	723.47		723.52	0.000130	1.09	467.80	75.82	0.14
Main	[illegible]	PF 4	551.00	711.00	723.50		723.74	0.000150	1.16	478.73	75.08	0.16
Main	[illegible]	PF 1	205.00	707.00	723.12		723.16	0.000063	0.76	391.35	48.11	0.07
Main	[illegible]	PF 2	270.00	707.00	723.17		723.22	0.000088	0.90	396.61	48.25	0.11
Main	[illegible]	PF 3	495.00	707.00	723.34		723.36	0.000147	1.24	401.21	48.71	0.14
Main	[illegible]	PF 4	551.00	707.00	723.39		723.41	0.000177	1.31	404.41	44.99	0.16
Main	[illegible]	PF 1	205.00	695.00	723.12		723.13	0.000002	0.26	906.76	64.86	0.02
Main	[illegible]	PF 2	270.00	695.00	723.18		723.19	0.000004	0.29	937.27	64.93	0.03
Main	[illegible]	PF 3	495.00	695.00	723.32		723.33	0.000013	0.37	940.47	64.93	0.04
Main	[illegible]	PF 4	551.00	695.00	723.38		723.41	0.000015	0.50	952.18	65.17	0.05
Main	[illegible]	PF 1	205.00	677.00	723.12		723.12	0.000000	0.18	1426.10	125.60	0.02
Main	[illegible]	PF 2	270.00	677.00	723.18		723.19	0.000003	0.22	1543.57	125.60	0.02
Main	[illegible]	PF 3	495.00	677.00	723.34		723.32	0.000006	0.30	1600.60	128.31	0.02
Main	[illegible]	PF 4	551.00	677.00	723.39		723.35	0.000007	0.32	1606.90	129.27	0.03
Main	[illegible]	PF 1	205.00	687.00	723.13		723.15	0.000004	0.22	1406.77	116.74	0.02
Main	[illegible]	PF 2	270.00	687.00	723.17		723.17	0.000004	0.26	1412.80	117.52	0.02
Main	[illegible]	PF 3	495.00	687.00	723.30		723.31	0.000007	0.35	1427.79	118.01	0.03
Main	[illegible]	PF 4	551.00	687.00	723.37		723.35	0.000009	0.38	1434.63	120.64	0.04
Main	[illegible]	PF 1	205.00	677.00	723.13		723.13	0.000001	0.10	2146.56	156.49	0.01
Main	[illegible]	PF 2	270.00	677.00	723.16		723.17	0.000002	0.12	2157.86	156.11	0.01
Main	[illegible]	PF 3	495.00	677.00	723.29		723.29	0.000004	0.22	2175.90	157.19	0.02
Main	[illegible]	PF 4	551.00	677.00	723.36		723.36	0.000005	0.25	2188.71	157.74	0.02
Main	[illegible]	PF 1	205.00	682.00	723.13		723.11	0.000004	0.20	1640.30	115.07	0.02
Main	[illegible]	PF 2	270.00	682.00	723.16		723.16	0.000009	0.24	1643.19	115.27	0.02
Main	[illegible]	PF 3	495.00	682.00	723.28		723.29	0.000005	0.35	1658.77	115.53	0.03
Main	[illegible]	PF 4	551.00	682.00	723.30		723.35	0.000007	0.35	1671.27	115.08	0.03
Main	[illegible]	PF 1	1220.00	682.00	723.00		723.06	0.000082	1.11	1105.41	95.01	0.10
Main	[illegible]	PF 2	1490.00	682.00	723.00		723.09	0.000130	1.35	1105.38	95.01	0.12
Main	[illegible]	PF 3	2000.00	682.00	723.00		723.17	0.000215	1.81	1103.72	95.01	0.16
Main	[illegible]	PF 4	2220.00	682.00	723.00		723.21	0.000265	2.01	1103.86	95.01	0.18
Main	[illegible]	PF 1	1220.00	673.00	723.01		723.02	0.000005	0.47	2581.38	102.94	0.03
Main	[illegible]	PF 2	1490.00	673.00	723.01		723.03	0.000009	0.57	2591.90	102.95	0.04
Main	[illegible]	PF 3	2000.00	673.00	723.02		723.06	0.000015	0.77	2592.84	102.93	0.05
Main	[illegible]	PF 4	2220.00	673.00	723.03		723.07	0.000012	0.86	2593.39	102.11	0.05
Main	[illegible]	PF 1	1220.00	665.00	723.01		723.01	0.000002	0.31	4010.86	150.04	0.02
Main	[illegible]	PF 2	1490.00	665.00	723.01		723.02	0.000003	0.37	4011.41	150.05	0.02
Main	[illegible]	PF 3	2000.00	665.00	723.03		723.03	0.000005	0.50	4012.85	150.10	0.03
Main	[illegible]	PF 4	2220.00	665.00	723.02		723.04	0.000006	0.55	4013.14	150.11	0.03
Main	[illegible]	PF 1	1220.00	668.00	723.00		723.01	0.000001	0.25	4977.70	166.61	0.02
Main	[illegible]	PF 2	1490.00	668.00	723.01		723.01	0.000002	0.31	4978.14	166.61	0.02
Main	[illegible]	PF 3	2000.00	668.00	723.01		723.02	0.000003	0.41	4979.27	166.62	0.02
Main	[illegible]	PF 4	2220.00	668.00	723.02		723.03	0.000004	0.45	4979.86	166.70	0.03
Main	[illegible]	PF 1	1220.00	654.00	723.00		723.01	0.000001	0.21	5748.93	186.53	0.01
Main	[illegible]	PF 2	1490.00	654.00	723.00		723.01	0.000001	0.26	5749.32	186.53	0.01
Main	[illegible]	PF 3	2000.00	654.00	723.01		723.02	0.000002	0.35	5750.10	186.54	0.02
Main	[illegible]	PF 4	2220.00	654.00	723.01		723.02	0.000002	0.39	5750.84	186.83	0.02
Main	[illegible]	PF 1	1220.00	657.00	723.00		723.00	0.000001	0.19	6318.60	177.57	0.01
Main	[illegible]	PF 2	1490.00	657.00	723.00		723.01	0.000002	0.35	6318.87	177.60	0.02
Main	[illegible]	PF 3	2000.00	657.00	723.00		723.01	0.000002	0.32	6319.50	177.60	0.02
Main	[illegible]	PF 4	2220.00	657.00	723.00		723.02	0.000010	0.51	6319.92	177.62	0.03
Main	[illegible]	PF 1	1220.00	658.00	723.00		723.00	0.000000	0.18	6998.13	192.00	0.01
Main	[illegible]	PF 2	1490.00	658.00	723.00		723.00	0.000001	0.21	6998.16	192.00	0.01
Main	[illegible]	PF 3	2000.00	658.00	723.00		723.01	0.000001	0.29	6998.26	192.01	0.01
Main	[illegible]	PF 4	2220.00	658.00	723.00		723.01	0.000002	0.32	6998.41	192.01	0.02
Main	[illegible]	PF 1	1220.00	628.00	723.00		723.00	0.000000	0.13	9193.80	180.60	0.01
Main	[illegible]	PF 2	1490.00	628.00	723.00		723.00	0.000000	0.16	9193.90	180.60	0.01
Main	[illegible]	PF 3	2000.00	628.00	723.00		723.00	0.000001	0.22	9193.90	180.60	0.01
Main	[illegible]	PF 4	2220.00	628.00	723.00		723.00	0.000001	0.24	9193.40	180.61	0.01
Main	[illegible]	PF 1	1220.00	602.00	723.00		723.00	0.000000	0.10	11610.55	271.75	0.00
Main	[illegible]	PF 2	1490.00	602.00	723.00		723.00	0.000000	0.13	11610.31	271.75	0.01
Main	[illegible]	PF 3	2000.00	602.00	723.00		723.00	0.000000	0.17	11610.50	271.75	0.01

C4(Cont.) Water Surface Profile at the End of Flood Season, Reservoir Water Level at 723 m(MSL)

HEC-RAS Plan: [illegible] River: [illegible] Reach: Main (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Main	[illegible]	PF 4	2220.00	626.00	723.00		723.03	0.000000	0.16	41910.[illegible]	271.75	0.01
Main	29.9	PF 1	1230.00	598.00	723.00		723.00	0.000000	0.08	15502.62	296.25	0.00
Main	29.9	PF 2	1490.00	598.00	723.00		723.00	0.000000	0.09	15502.60	296.25	0.00
Main	29.9	PF 3	2030.00	598.00	723.00		723.01	0.000000	0.13	15502.5[illegible]	296.25	0.01
Main	29.9	PF 4	2220.00	598.00	723.00		723.01	0.000000	0.14	15502.49	296.25	0.01
Main	26.9	PF 1	1230.00	600.00	723.00		723.00	0.000000	0.07	18342.29	324.75	0.00
Main	26.9	PF 2	1490.00	600.00	723.00		723.00	0.000000	0.08	18342.34	324.75	0.00
Main	26.9	PF 3	2030.00	600.00	723.00		723.00	0.000000	0.11	18342.65	324.75	0.00
Main	26.9	PF 4	2220.00	600.00	723.00		723.00	0.000000	0.12	18342.67	324.75	0.01
Main	24.2	PF 1	1230.00	581.00	723.00		723.00	0.000000	0.05	24274.32	389.75	0.00
Main	24.2	PF 2	1490.00	581.00	723.00		723.00	0.000000	0.06	24274.31	389.75	0.00
Main	24.2	PF 3	2030.00	581.00	723.00		723.00	0.000000	0.08	24273.17	389.75	0.00
Main	24.2	PF 4	2220.00	581.00	723.00		723.00	0.000000	0.09	24273.31	389.75	0.00
Main	22.5	PF 1	1230.00	603.00	723.00		723.00	0.000000	0.10	12741.88	211.25	0.00
Main	22.5	PF 2	1490.00	603.00	723.00		723.00	0.000000	0.12	12741.68	211.25	0.00
Main	22.5	PF 3	2030.00	603.00	723.00		723.00	0.000000	0.16	12741.56	211.25	0.01
Main	22.5	PF 4	2220.00	603.00	723.00		723.00	0.000000	0.17	12741.50	211.25	0.01
Main	20.8	PF 1	1230.00	602.00	723.00		723.00	0.000000	0.05	24487.79	411.75	0.00
Main	20.8	PF 2	1490.00	602.00	723.00		723.00	0.000000	0.06	24487.76	411.75	0.00
Main	20.8	PF 3	2030.00	602.00	723.00		723.00	0.000000	0.08	24487.58	411.75	0.00
Main	20.8	PF 4	2220.00	602.00	723.00		723.00	0.000000	0.09	24487.57	411.75	0.00
Main	18.9	PF 1	1230.00	588.00	723.00		723.00	0.000000	0.06	18015.78	265.50	0.00
Main	18.9	PF 2	1490.00	588.00	723.00		723.00	0.000000	0.08	18015.77	265.50	0.00
Main	18.9	PF 3	2030.00	588.00	723.00		723.00	0.000000	0.11	18015.31	265.50	0.00
Main	18.9	PF 4	2220.00	588.00	723.00		723.00	0.000000	0.12	18015.26	265.50	0.00
Main	16.8	PF 1	1230.00	588.00	723.00		723.00	0.000000	0.07	17913.46	309.00	0.00
Main	16.8	PF 2	1490.00	588.00	723.00		723.00	0.000000	0.08	17913.49	309.00	0.00
Main	16.8	PF 3	2030.00	588.00	723.00		723.00	0.000000	0.11	17913.51	309.00	0.00
Main	16.8	PF 4	2220.00	588.00	723.00		723.00	0.000000	0.12	17913.54	309.00	0.01
Main	14.8	PF 1	1230.00	578.00	723.00		723.00	0.000000	0.07	17957.84	296.25	0.00
Main	14.8	PF 2	1490.00	578.00	723.00		723.00	0.000000	0.08	17957.85	296.25	0.00
Main	14.8	PF 3	2030.00	578.00	723.00		723.00	0.000000	0.11	17957.62	296.25	0.00
Main	14.8	PF 4	2220.00	578.00	723.00		723.00	0.000000	0.12	17957.54	296.25	0.01
Main	12.8	PF 1	1230.00	585.00	723.00		723.00	0.000000	0.03	36479.31	744.50	0.00
Main	12.8	PF 2	1490.00	585.00	723.00		723.00	0.000000	0.04	36479.31	744.50	0.00
Main	12.8	PF 3	2030.00	585.00	723.00		723.00	0.000000	0.05	36479.33	744.50	0.00
Main	12.8	PF 4	2220.00	585.00	723.00		723.00	0.000000	0.06	36479.38	744.50	0.00
Main	10.9	PF 1	1230.00	572.00	723.00		723.00	0.000000	0.02	51879.48	803.00	0.00
Main	10.9	PF 2	1490.00	572.00	723.00		723.00	0.000000	0.03	51879.49	803.00	0.00
Main	10.9	PF 3	2030.00	572.00	723.00		723.00	0.000000	0.04	51879.57	803.00	0.00
Main	10.9	PF 4	2220.00	572.00	723.00		723.00	0.000000	0.04	51879.63	803.00	0.00
Main	8.5	PF 1	1230.00	540.00	723.00		723.00	0.000000	0.02	55537.34	1033.25	0.00
Main	8.5	PF 2	1490.00	540.00	723.00		723.00	0.000000	0.02	55537.34	1033.25	0.00
Main	8.5	PF 3	2030.00	540.00	723.00		723.00	0.000000	0.03	55537.51	1033.25	0.00
Main	8.5	PF 4	2220.00	540.00	723.00		723.00	0.000000	0.04	55577.40	1033.25	0.00
Main	6.5	PF 1	1230.00	543.00	723.00		723.00	0.000000	0.03	47481.32	797.75	0.00
Main	6.5	PF 2	1490.00	543.00	723.00		723.00	0.000000	0.03	47481.55	797.75	0.00
Main	6.5	PF 3	2030.00	543.00	723.00		723.00	0.000000	0.04	47481.67	797.75	0.00
Main	6.5	PF 4	2220.00	543.00	723.00		723.00	0.000000	0.05	47481.75	797.75	0.00
Main	4.5	PF 1	1230.00	543.00	723.00		723.00	0.000000	0.03	44211.08	790.75	0.00
Main	4.5	PF 2	1490.00	543.00	723.00		723.00	0.000000	0.04	44211.08	790.75	0.00
Main	4.5	PF 3	2030.00	543.00	723.00		723.00	0.000000	0.05	44211.13	790.75	0.00
Main	4.5	PF 4	2220.00	543.00	723.00		723.00	0.000000	0.05	44211.13	790.75	0.00
Main	2.5	PF 1	1230.00	514.00	723.00		723.00	0.000000	0.03	45549.88	960.75	0.00
Main	2.5	PF 2	1490.00	514.00	723.00		723.00	0.000000	0.03	45549.86	960.75	0.00
Main	2.5	PF 3	2030.00	514.00	723.00		723.00	0.000000	0.05	45548.83	960.75	0.00
Main	2.5	PF 4	2220.00	514.00	723.00		723.00	0.000000	0.05	45548.68	960.75	0.00
Main	0	PF 1	1230.00	511.00	723.00		723.00	0.000000	0.03	48126.62	557.75	0.00
Main	0	PF 2	1490.00	511.00	723.00		723.00	0.000000	0.03	48126.62	557.75	0.00
Main	0	PF 3	2030.00	511.00	723.00		723.00	0.000000	0.04	48126.63	557.75	0.00
Main	0	PF 4	2220.00	511.00	723.00		723.00	0.000000	0.05	48126.64	557.75	0.00
Main	0.1	PF 1	1230.00	514.00	723.00	527.25	723.00	0.000000	0.03	37748.47	409.00	0.00
Main	0.1	PF 2	1490.00	514.00	723.00	529.25	723.00	0.000000	0.04	37748.47	409.00	0.00
Main	0.1	PF 3	2030.00	514.00	723.00	530.19	723.00	0.000000	0.05	37748.47	409.00	0.00
Main	0.1	PF 4	2220.00	514.00	723.00	530.79	723.00	0.000000	0.06	37748.47	409.00	0.00

C5 Water Surface Profile at the End of Flood Season, Reservoir Water Level at 723 m(MSL) with Flood Surcharge

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	PF 1	365.00	730.00	732.31	732.31	732.87	0.011172	3.42	94.33	64.11	1.01
[illegible]	[illegible]	PF 2	370.00	730.00	732.21	732.21	732.94	0.010583	3.77	98.38	65.57	1.01
[illegible]	[illegible]	PF 3	496.00	730.00	732.57	732.57	733.30	0.010360	4.00	123.93	76.50	1.00
[illegible]	[illegible]	PF 4	661.00	730.00	732.91	732.91	733.80	0.010192	4.50	154.82	76.57	1.00
[illegible]	[illegible]	PF 1	365.00	711.00	723.21		723.29	0.000168	0.68	447.61	73.37	0.09
[illegible]	[illegible]	PF 2	370.00	711.00	723.46		723.49	0.000173	0.79	468.03	75.34	0.10
[illegible]	[illegible]	PF 3	496.00	711.00	724.20		724.25	0.000196	0.95	524.17	80.01	0.13
[illegible]	[illegible]	PF 4	661.00	711.00	724.57		724.62	0.000122	1.00	665.02	82.35	0.12
[illegible]	[illegible]	PF 1	365.00	707.00	723.15		723.19	0.000139	0.78	565.41	49.21	0.08
[illegible]	[illegible]	PF 2	370.00	707.00	723.37		723.41	0.000130	0.82	404.32	49.55	0.10
[illegible]	[illegible]	PF 3	496.00	707.00	724.05		724.14	0.000115	1.12	440.55	52.91	0.13
[illegible]	[illegible]	PF 4	661.00	707.00	724.48		724.50	0.000137	1.29	462.70	53.21	0.13
[illegible]	[illegible]	PF 1	365.00	693.00	723.15		723.15	0.000030	0.33	900.57	64.45	0.03
[illegible]	[illegible]	PF 2	370.00	693.00	723.37		723.37	0.000030	0.39	960.10	65.92	0.04
[illegible]	[illegible]	PF 3	496.00	693.00	724.08		724.10	0.000043	0.49	987.16	67.26	0.04
[illegible]	[illegible]	PF 4	661.00	693.00	724.43		724.45	0.000046	0.64	1020.92	68.30	0.04
[illegible]	[illegible]	PF 1	365.00	677.00	723.18		723.18	0.000002	0.18	1602.16	126.12	0.02
[illegible]	[illegible]	PF 2	370.00	677.00	723.37		723.37	0.000003	0.22	1657.92	128.06	0.02
[illegible]	[illegible]	PF 3	496.00	677.00	724.08		724.09	0.000006	0.28	1781.14	141.48	0.03
[illegible]	[illegible]	PF 4	661.00	677.00	724.42		724.44	0.000006	0.38	1864.75	147.56	0.03
[illegible]	[illegible]	PF 1	365.00	667.10	723.14		723.15	0.000003	0.22	1405.25	117.94	0.02
[illegible]	[illegible]	PF 2	370.00	667.00	723.36		723.37	0.000004	0.26	1420.26	123.45	0.02
[illegible]	[illegible]	PF 3	496.00	667.00	724.07		724.09	0.000005	0.30	1524.12	151.06	0.03
[illegible]	[illegible]	PF 4	661.00	667.00	724.42		724.42	0.000007	0.35	1570.36	155.27	0.03
[illegible]	[illegible]	PF 1	365.00	677.00	723.14		723.14	0.000001	0.14	2194.15	155.32	0.01
[illegible]	[illegible]	PF 2	370.00	677.00	723.36		723.36	0.000001	0.17	2196.35	161.72	0.01
[illegible]	[illegible]	PF 3	496.00	677.00	724.08		724.07	0.000002	0.22	2321.57	162.63	0.02
[illegible]	[illegible]	PF 4	661.00	677.00	724.41		724.42	0.000002	0.23	2365.41	168.40	0.02
[illegible]	[illegible]	PF 1	365.00	662.00	723.14		723.14	0.000002	0.20	1546.32	115.21	0.02
[illegible]	[illegible]	PF 2	370.00	662.00	723.36		723.36	0.000003	0.24	1571.51	118.84	0.02
[illegible]	[illegible]	PF 3	496.00	662.00	724.05		724.06	0.000005	0.30	1656.53	122.45	0.03
[illegible]	[illegible]	PF 4	661.00	662.00	724.40		724.41	0.000006	0.32	1686.70	125.22	0.03
[illegible]	[illegible]	PF 1	1230.00	663.00	723.05		723.08	0.000081	1.11	1109.16	84.26	0.10
[illegible]	[illegible]	PF 2	1490.00	663.00	723.25		723.29	0.000115	1.33	1120.66	86.62	0.12
[illegible]	[illegible]	PF 3	2000.00	663.00	723.91		723.99	0.000130	1.78	1124.92	90.47	0.15
[illegible]	[illegible]	PF 4	2220.00	663.00	724.21		724.39	0.000120	1.86	1201.25	92.66	0.15
[illegible]	[illegible]	PF 1	1230.00	677.00	723.04		723.05	0.000008	0.47	2604.06	155.94	0.02
[illegible]	[illegible]	PF 2	1490.00	677.00	723.27		723.28	0.000008	0.57	2606.36	159.24	0.04
[illegible]	[illegible]	PF 3	2000.00	677.00	723.92		723.95	0.000014	0.70	2820.90	165.29	0.05
[illegible]	[illegible]	PF 4	2220.00	677.00	724.13		724.16	0.000017	0.82	2707.90	168.51	0.05
[illegible]	[illegible]	PF 1	1230.00	669.00	723.04		723.04	0.000002	0.31	4044.57	126.18	0.02
[illegible]	[illegible]	PF 2	1490.00	670.00	723.25		723.25	0.000003	0.37	4037.45	131.06	0.02
[illegible]	[illegible]	PF 3	2000.00	669.00	723.92		723.93	0.000005	0.49	4100.05	134.02	0.03
[illegible]	[illegible]	PF 4	2220.00	669.00	724.12		724.14	0.000006	0.53	4159.35	135.51	0.03
[illegible]	[illegible]	PF 1	1230.00	666.00	723.04		723.04	0.000001	0.26	4680.21	160.56	0.01
[illegible]	[illegible]	PF 2	1490.00	666.00	723.21		723.21	0.000002	0.30	4842.04	169.21	0.02
[illegible]	[illegible]	PF 3	2000.00	666.00	723.81		723.82	0.000003	0.40	5095.26	170.22	0.02
[illegible]	[illegible]	PF 4	2220.00	666.00	724.12		724.13	0.000003	0.41	5394.04	171.36	0.03
[illegible]	[illegible]	PF 1	1230.00	654.00	723.02		723.04	0.000001	0.21	4752.57	166.53	0.01
[illegible]	[illegible]	PF 2	1490.00	654.00	723.21		723.21	0.000001	0.26	4752.47	166.82	0.01
[illegible]	[illegible]	PF 3	2000.00	654.00	723.80		723.87	0.000002	0.34	4973.16	169.94	0.02
[illegible]	[illegible]	PF 4	2220.00	654.00	724.12		724.13	0.000002	0.37	5024.72	169.92	0.02
[illegible]	[illegible]	PF 1	1230.00	657.00	723.02		723.02	0.000001	0.26	4326.34	117.56	0.01
[illegible]	[illegible]	PF 2	1490.00	657.00	723.20		723.21	0.000002	0.34	4542.38	118.03	0.02
[illegible]	[illegible]	PF 3	2000.00	657.00	723.80		723.81	0.000004	0.45	4443.63	118.90	0.02
[illegible]	[illegible]	PF 4	2220.00	657.00	724.10		724.11	0.000004	0.50	4496.87	120.28	0.03
[illegible]	[illegible]	PF 1	1230.00	638.00	723.03		723.03	0.000000	0.16	7208.92	182.12	0.01
[illegible]	[illegible]	PF 2	1490.00	638.00	723.20		723.20	0.000001	0.21	7024.55	167.80	0.01
[illegible]	[illegible]	PF 3	2000.00	638.00	723.82		723.81	0.000001	0.28	7108.24	168.21	0.01
[illegible]	[illegible]	PF 4	2220.00	638.00	724.10		724.11	0.000001	0.31	7228.93	186.41	0.02
[illegible]	[illegible]	PF 1	1230.00	628.00	723.02		723.02	0.000000	0.13	9106.31	180.61	0.01
[illegible]	[illegible]	PF 2	1490.00	628.00	723.20		723.20	0.000000	0.18	9293.75	181.30	0.01
[illegible]	[illegible]	PF 3	2000.00	628.00	723.80		723.80	0.000001	0.21	9394.57	183.31	0.01
[illegible]	[illegible]	PF 4	2220.00	628.00	724.10		724.19	0.000001	0.24	9462.78	184.35	0.01
[illegible]	[illegible]	PF 1	1230.00	626.00	723.03		723.03	0.000000	0.10	11916.42	271.63	0.00
[illegible]	[illegible]	PF 2	1490.00	626.00	723.20		723.20	0.000000	0.12	11934.73	272.20	0.01
[illegible]	[illegible]	PF 3	2000.00	626.00	723.80		723.80	0.000001	0.16	12126.59	273.56	0.01

C5(Cont.) Water Surface Profile at the End of Flood Season, Reservoir Water Level at 723 m(MSL) with Flood Surcharge

Appendix D

Water surface profiles output for the flood model

D1 Water surface profile for flood season, reservoir water level at 720 m(MSL)
D2 Water surface profile for flood season, reservoir water level at 720 m(MSL) with flood surcharge
D3 Water surface profile at the end of flood season, reservoir water level at 723 m(MSL)
D4 Water surface profile at the end of flood season, reservoir water level at 723 m(MSL) with flood surcharge

D1 Water Surface Profile for Flood Season, Reservoir Water Level at 720 m(MSL)

[illegible]

D2 Water Surface Profile for Flood Season, Reservoir Water Level at 720 m(MSL) with Flood Surcharge

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	365.00	717.82	721.07		721.46	0.002525	1.93	192.30	127.13	0.53
[illegible]	[illegible]	[illegible]	370.00	717.82	721.99		722.12	0.002125	1.60	198.00	144.24	0.53
[illegible]	[illegible]	[illegible]	414.00	717.82	722.20		722.67	0.002448	1.58	284.30	163.10	0.47
[illegible]	[illegible]	[illegible]	551.00	717.82	722.60		722.77	0.002076	1.84	296.97	113.00	0.46
[illegible]	[illegible]	[illegible]	757.00	717.82	723.27		723.51	0.001103	1.60	447.62	105.67	0.39
[illegible]	[illegible]	[illegible]	1960.00	717.82	725.03		726.43	0.002493	1.29	1511.69	146.24	0.32
[illegible]	[illegible]	[illegible]	365.00	716.70	718.83		720.13	0.023180	3.80	105.05	49.92	0.58
[illegible]	[illegible]	[illegible]	370.00	716.70	720.11		720.54	0.002037	2.52	20.77	47.72	0.51
[illegible]	[illegible]	[illegible]	414.00	716.20	720.78		724.27	0.002817	3.11	134.47	49.26	0.50
[illegible]	[illegible]	[illegible]	551.00	716.70	721.58		721.57	0.002303	3.57	173.62	50.46	0.52
[illegible]	[illegible]	[illegible]	757.00	716.20	722.08	720.41	722.66	0.002307	3.12	222.14	62.04	0.60
[illegible]	[illegible]	[illegible]	1960.00	716.20	726.03		726.73	0.002281	1.41	1389.63	243.08	0.22
[illegible]	[illegible]	[illegible]	365.00	714.52	712.59		718.83	0.001607	2.48	121.35	49.67	0.48
[illegible]	[illegible]	[illegible]	370.00	714.52	718.86		719.32	0.001918	2.67	133.75	42.20	0.42
[illegible]	[illegible]	[illegible]	414.00	714.52	719.49		720.11	0.002018	2.91	172.95	45.57	0.48
[illegible]	[illegible]	[illegible]	551.00	714.52	719.97		719.43	0.001942	3.01	183.98	47.40	0.49
[illegible]	[illegible]	[illegible]	757.00	714.52	720.89		721.43	0.002283	3.22	235.33	62.15	0.53
[illegible]	[illegible]	[illegible]	1960.00	714.52	725.66		725.81	0.000174	0.96	2045.72	378.55	0.10
[illegible]	[illegible]	[illegible]	365.00	713.83	717.40		717.25	0.002547	2.65	115.94	46.36	0.50
[illegible]	[illegible]	[illegible]	370.00	713.03	717.54		717.79	0.002642	2.52	128.51	48.41	0.54
[illegible]	[illegible]	[illegible]	414.00	713.52	718.04		718.51	0.002129	3.07	164.40	61.85	0.59
[illegible]	[illegible]	[illegible]	551.00	713.65	719.02		719.29	0.002209	3.02	182.47	71.44	0.59
[illegible]	[illegible]	[illegible]	757.00	713.85	719.17		719.83	0.002395	3.06	257.98	162.09	0.63
[illegible]	[illegible]	[illegible]	1960.00	713.83	726.21		726.54	0.000469	0.57	2,659.64	357.85	0.10
[illegible]	[illegible]	[illegible]	365.00	711.88	716.67		716.95	0.002548	2.37	95.83	40.25	0.45
[illegible]	[illegible]	[illegible]	370.00	711.88	716.02		716.57	0.002864	3.09	112.98	45.08	0.67
[illegible]	[illegible]	[illegible]	414.00	711.08	715.70		716.39	0.002923	3.48	146.71	50.05	0.64
[illegible]	[illegible]	[illegible]	551.00	711.88	716.49		716.68	0.002459	3.46	159.37	61.22	0.69
[illegible]	[illegible]	[illegible]	757.00	711.88	717.27		717.83	0.002568	3.52	225.50	67.13	0.13
[illegible]	[illegible]	[illegible]	1960.00	711.88	726.40		726.47	0.000160	1.21	1622.64	244.69	0.10
[illegible]	[illegible]	[illegible]	365.00	708.77	713.71		713.96	0.000981	1.15	239.60	63.08	0.28
[illegible]	[illegible]	[illegible]	370.00	708.27	714.14		714.29	0.000677	1.26	235.65	75.24	0.28
[illegible]	[illegible]	[illegible]	414.00	708.27	715.55		715.18	0.000543	1.71	267.68	76.50	0.30
[illegible]	[illegible]	[illegible]	551.00	708.27	715.61		715.54	0.000450	1.64	335.77	79.90	0.28
[illegible]	[illegible]	[illegible]	757.00	708.27	716.87		717.08	0.000967	1.66	480.40	64.56	0.25
[illegible]	[illegible]	[illegible]	1960.00	708.27	726.58		726.39	0.000094	1.25	1598.84	145.08	0.10
[illegible]	[illegible]	[illegible]	365.00	706.81	713.67		713.84	0.000158	0.71	454.36	152.08	0.13
[illegible]	[illegible]	[illegible]	370.00	706.81	714.58		714.65	0.000130	0.77	482.63	124.31	0.15
[illegible]	[illegible]	[illegible]	414.00	706.81	714.98		714.99	0.000117	0.67	611.83	136.02	0.12
[illegible]	[illegible]	[illegible]	551.00	706.81	715.55		714.96	0.000112	0.85	691.79	152.57	0.13
[illegible]	[illegible]	[illegible]	757.00	706.81	716.87		716.93	0.000156	0.66	873.06	147.36	0.13
[illegible]	[illegible]	[illegible]	1960.00	706.81	726.29		726.33	0.000050	0.85	2289.95	175.09	0.11
[illegible]	[illegible]	[illegible]	365.00	704.98	713.59	707.98	713.60	0.000054	0.21	437.53	63.50	0.05
[illegible]	[illegible]	[illegible]	370.00	704.00	713.96	707.08	713.96	0.000079	0.12	457.85	71.50	0.10
[illegible]	[illegible]	[illegible]	414.00	704.00	714.07	700.34	714.67	0.000105	0.64	579.15	64.60	0.12
[illegible]	[illegible]	[illegible]	551.00	704.50	716.24	708.30	716.24	0.000113	0.59	666.25	69.21	0.10
[illegible]	[illegible]	[illegible]	757.00	704.06	716.78	709.02	716.96	0.000144	1.06	630.99	97.56	0.13
[illegible]	[illegible]	[illegible]	1960.00	704.00	726.27	711.33	726.32	0.000149	0.81	2427.44	5407	0.06

D3 Water Surface Profile at the End of Flood Season, Reservoir Water Level at 723 m(MSL)

[illegible]

D4 Water Surface Profile at the End of Flood Season, Reservoir Water Level at 723 m(MSL) with Flood Surcharge

[illegible]

Annex G

WATER QUALITY IMPACTS OF EXISTING RESERVOIRS IN NAM NGUM RIVER BASIN

1 NN 1

In Nam Ngum River Basin, experiences with poor reservoir water quality just after filling of the reservoir have occurred at NN 1 in the beginning of the 1970's. At NN 1 no biomass was cleared before impoundment. The formation of toxic hydrogen sulfide and the associated smell of rotten eggs during the first few years after impoundment of NN 1 reservoir have been reported by Acres, 1974[1] and were described more explicitly by the Smithsonian Institute, 1975.[2]

NN 1 Reservoir is situated about 80 kilometers distance from the capital of Lao PDR, Vientiane. During the first few years after impoundment of the reservoir in the beginning of the 1970's, even the inhabitants of Vientiane could smell the stench of rotten eggs if the wind direction was from Nam Ngum 1 Reservoir.

Low water quality conditions of reservoirs and the formation of hydrogen sulfide occur in all Southeast Asian reservoirs during the first years after impoundment if too much biomass is left in the reservoir area before impoundment and/or if the reservoir filling procedure has taken too much time. The long term under-water tree logging operations in NN 1 reservoir after impoundment demonstrate that the reservoir area was not cleared of vegetation and trees before impoundment in the 1970's.

Most probably, NN 1 reservoir filling procedures were also not appropriate. The longer the period between filling of the reservoir and subsequent release of reservoir water, the worse the reservoir water quality. In the beginning of the period between reservoir filling and reservoir water release, aerobic bacteria consume the inundated biomass by using Dissolved Oxygen (DO). Over time, DO concentrations in the reservoir become so low that anaerobic bacteria replace aerobic bacteria. Anaerobic bacteria by reduce metals and decompose biomass producing methane, ammonium, and hydrogen sulfide. In the case of NN 1, the main factors that determined poor reservoir water quality were (i) the high amount of biomass left in the inundation zone and (ii) the long retention time of reservoir water.

The water quality problems in NN 1 reservoir occurred in the 1970's at the time of the Indo China war and civil strife. Hence, one can imagine that at that time more important things had to be taken care of than mere biomass clearance and filling procedures of a hydropower reservoir. By (i) appropriate biomass clearance in the impoundment area, and (ii) keeping reservoir filling period short, poor water quality conditions can be avoided.

Despite, obvious poor reservoir water quality conditions during impoundment, over the years NN 1 reservoir water quality conditions improved and supported healthy reservoir fisheries. See Figure 2.1

Due to the fact that the official fisheries statistics of NN 1 reservoir are not inluding all fish landing places around the reservoir and due to the fact that household fish consumption of villagers living around the reservoir is often under-reported, the official fisheries statistics give a too low estimate of annual fish landings. But, Matson et al estimated the annual NN 1 reservoir fish landing as shown for the year 1998 most probably too high.

Schouten[3] estimated the value of annual fish landings in 1998 as at least 0.8 Million USD and also estimated that annual sustainable fish yields of NN 1 reservoir would be around 30 kg/ha for the reservoir at Full Supply Level. With the devaluation of the US Dollar and with the increased price of fish, the value of annual NN 1 reservoir fish landings would now have a much higher value than 0.8 Million USD.

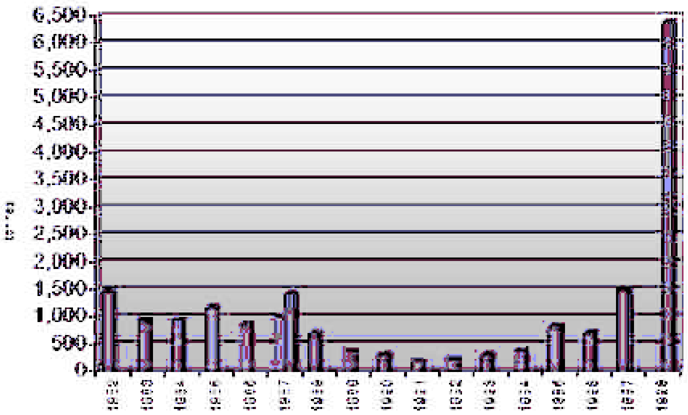
[1] Acres International Limited, 1974, Environmental Analyses of the Construction of the Nam Ngum, Laos, Hydro-Electric Project, IBRD.

[2] Smithsonian Institution, 1975, Post-Impoundment Assessment of the Ecological Effects of the Nam Ngum Dam and Reservoir, Laos, A Report Submitted to the Committee for Coordination of Investigations of the Lower Mekong Basin.

[3] Schouten R., 1998, Effects of Dams on Downstream Fisheries, Case of Nam Ngum. Catch and Culture – Mekong Fisheries Network Newsletter, MRC, Vol 5 No.2.

Such healthy fisheries in NN 1 reservoir indicate that poor reservoir water quality conditions during and after impoundment have been overcome during operation.

Figure 2.1 Annual Fish Landings of NN 1 Reservoir



light columns: official fisheries statistics (Bernascek, 1997)[4]
dark columns: MCR/ACIAR estimates (Mattson et al, 2001)[5]

2 Nam Leuk

Another example of poor reservoir water quality due to impoundment procedures in Nam Ngum River Basin is Nam Leuk. Nam Leuk reservoir gives a good example what can happen if reservoir filling procedures are not appropriate while much effort has been done to clear biomass.

The Nam Leuk Reservoir is located in Nam Leuk River Basin, but water from Nam Leuk is trans-basin diverted to Nam Xan, a tributary to NN 1 reservoir. Nam Leuk was impounded at the end of the 1990's. Before impoundment, the reservoir area was largely covered by primary forest. Trees have been logged and vegetation has been burned on site before the actual filling of Nam Leuk reservoir started. However, due to (i) re-growth of vegetation, (ii) biomass left in soils, and (iii) remaining ashes from burned vegetation left in the impoundment area, it was estimated by ADB consultants that not more than 70 % of the total biomass was removed. This way, most of the biomass in the Nam Leuk impoundment area was supposed to be cleared, but still reservoir water quality at Nam Leuk became a big issue after the reservoir was filled.

DO concentrations and other water quality parameters have been measured in Nam Leuk reservoir by the Environmental Office of Electricité de Lao (EdL) and by consultants hired by Asian Development Bank (ADB) from 1998 to 2002. In 2000, just after the reservoir reached Full Supply Level for the first time, water quality monitoring showed that only a thin reservoir surface water layer of approximately 30 centimeters contained DO concentrations higher than 5 mg/l. DO concentrations higher than 5 mg/l in the aquatic environment are considered to be favorable for aquatic life[6]. All water deeper than 30 centimeters from the surface was anaerobic. Under such poor water quality conditions at most of the water volume of the reservoir, fish kills in Nam Leuk reservoir occurred.

Subsequent water quality monitoring revealed that the depth of the surface water layer with high DO content substantially increased over years. Figure 2.2 shows the actual measured

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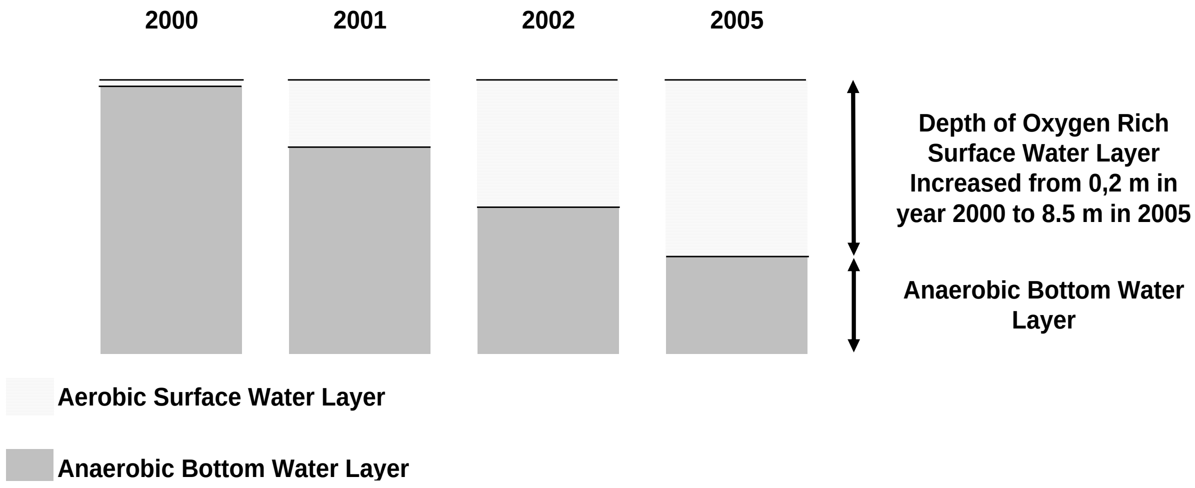
[4] Mattson et al., 2001, Changes in fish yield and catch composition at the Nam Ngum Reservoir, Lao PDR, MCR/ACIAR Proc. # 98.

[5] Bernacsek G., 1997, Large Dam Fisheries of the Lower Mekong Countries: Review and Assessment. Mekong River Commission Report 97023.

[6] Notification of the National Environmental Board of Thailand, 1994, No. 8, B.E 2537 issued under the Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E 2537.

depth of the reservoir water surface layer rich in Dissolved Oxygen (DO) concentrations in Nam Leuk reservoir during the first few years after impoundment.

Figure 2.2 **The Increasing Depth of the Oxygen Rich Surface Water Layer in Nam Leuk Reservoir over the Years 2000[7], 2001[8], 2002[9], 2005[10] after Impoundment.**



Despite the effort of biomass clearance, water quality in Nam Leuk reservoir became poor after impoundment. Low water quality in Nam Leuk reservoir after impoundment was mainly due to (i) the 30 % of estimated biomass left in the inundation area, especially the biomass left in wetlands/swamps and (ii) the long period between reservoir filling and the actual start of operation of the powerhouse.

When Nam Leuk reservoir was filled and reached its Full Supply Level (FSL), the transmission line was not ready and only during the subsequent year, the powerhouse could start operation. During this period, Nam Leuk reservoir water quality deteriorated rapidly as a result of long water retention time exacerbated by biomass that was left behind. After the powerhouse did start operation, water quality of the reservoir slowly improved and the reservoir nearly matured in 2005 (see figure 2.2). Hydreco states that over the years water quality in Nam Leuk reservoir has improved, for example methane concentrations have decreased considerably (from 17 mg/l at the reservoir bottom in April 2001 to 5 mg/l at the same location in April 2002).

In 2002, Hydreco sampled and measured water quality at different depths of Nam Leuk Reservoir (see table 2.3). The table shows clearly (i) the decrease of temperature, pH, and DO concentrations with reservoir depth and (ii) the increase with reservoir depth of conductivity, turbidity, and concentrations of nitrates, ferrous iron, sulphates, and methane. Such anaerobic water quality conditions of the hypolimnion are unfavorable for aquatic life.

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[7] Personal observation Roel Schouten during water quality monitoring activities implemented at Nam Leuk Reservoir as part the ADB funded TA: LAO- Environmental and Social Strengthening.

[8] Hydreco, NT2 Hydropower Project in Lao PDR, The Dissolved Oxygen Consumption Kinetics in the Water Turbined by the Nam Leuk Power Plant.

[9] Hydreco, NT2 Hydropower Project in Lao PDR, The Dissolved Oxygen Consumption Kinetics in the Water Turbined by the Nam Leuk Power Plant.

[10] National University of Laos and Garry Thorncraft, 2006, Final Report Nam Mang 3, Aquatic Ecology and Water Quality Monitoring Programme, Prepared for EDL.

Table 2.3 **Water Quality in Nam Leuk Reservoir at Different Depths on 05/04/2002.**[11]

Water Quality Parameter	Unit	Depth [m]					
		0.20	5.00	10.00	15.00	20.00	25.00
Temperature	(°C)	28.1	26.5	25.2	24.3	24.0	23.8
pH		6.95	6.80	5.70	5.70	5.80	5.85
Dissolved oxygen	(mg/l)	8.3	8.3	0.0	0.0	0.0	0.0
Dissolved oxygen	(%)	113	113	0	0	0	0
Conductivity	(µS/cm)	13.9	14.8	31.9	36.8	54.2	86.5
Turbidity	(FAU)	5	7	4	2	2	7
Ammonium	(mgN/l)	0.00	0.00	0.40	1.30	1.90	3.40
Nitrites	(mgN/l)	0.002	0.004	0.003	0.002	0.002	0.005
Nitrates	(mgN/l)	0.030	0.023	0.018	0.015	0.025	0.053
o.phosphates	(mgP/l)	0.01	0.02	0.02	0.02	0.03	0.05
Total Phosphorus	(mgP/l)	0.04	0.07	0.03	0.04	0.03	0.05
Chemical Oxygen Demand	(mg O_2/l)	14	14	10	10	14	14
Silicon	(mgSi/l)	1.3	1.5	2	4.7	6.6	4.6
Calcium	(mgCa/l)	1.15	1.19	1.03	0.91	0.86	0.73
Magnesium	(mgMg/l)	0	0	0	0	0	0
Ferrous iron	(mgFe/l)	0	0	2.07	3.19	5.32	8.60
Sulphates	(mgSO4/l)	0	0	1	1	2	3
Sulphides	(mgS2-/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chlorophyll a	(µg/l)	12.4	17.3	24.6			
Methane	(mgCH4/l)	0.04	0.02	0.23	0.92	2.20	0.90

Table 2.3 confirms figure 2.2 that in 2002 between depths of 5 to 10 meters from the surface of Nam Leuk reservoir, water quality conditions change dramatically from favorable to unfavorable conditions for aquatic life. Such is common at any water body deeper than 10 meters in Southeast Asia.

After initial fish kills in Nam Leuk reservoir during impoundment, over time Nam Leuk reservoir water quality conditions have turned to normal. Nam Leuk reservoir now has an epilimnion of 10 meters depth from the surface with high DO concentrations and supporting fish populations that potentially be of high human use values. Nam Leuk is located in Phou Khao Kuay protected area, and therefore not many people can make use of potential healthy Nam Leuk reservoir fisheries.

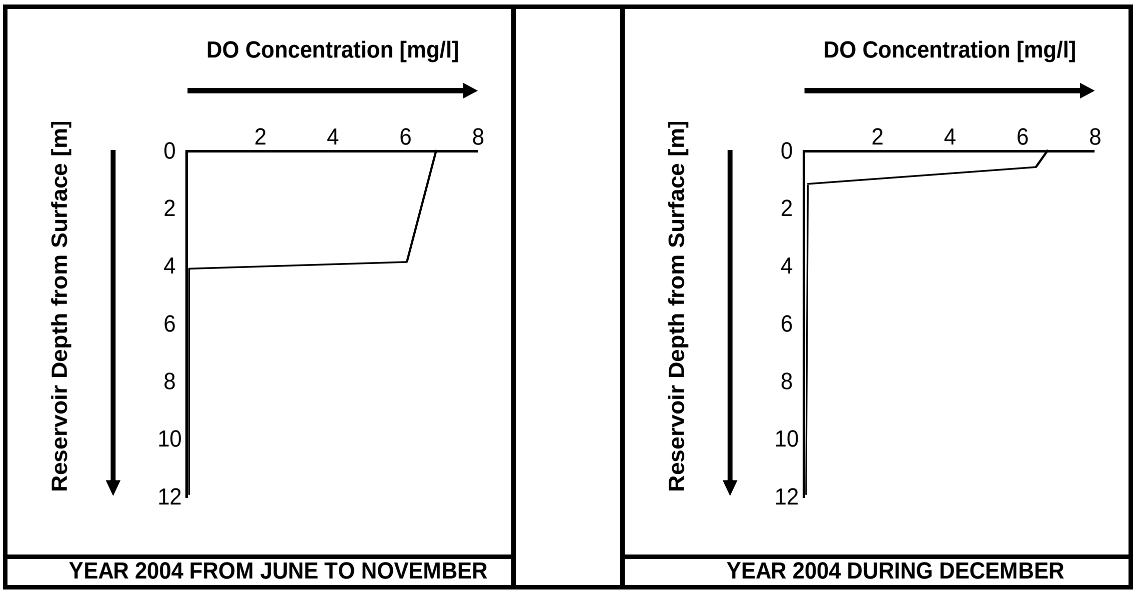
3 Nam Mang 3

The Nam Mang 3 Reservoir (located close to Nam Leuk Reservoir in Nam Ngum River Basin) is also a trans-basin diversion project. Nam Mang 3 was impounded in 2002. Biomass has been removed from the impoundment area. The period between the date that the reservoir reached Full Supply Level and the start of operation of the powerhouse was 6 months. The operators made use of the opportunity to flush reservoir water to downstream locations before and during filling.

The first year after impoundment, the anaerobic reservoir water layer was measured at a depth of 4 meters from the surface down to the bottom of the reservoir. However, data obtained from the water quality monitoring program at Nam Mang 3, clearly show the depth of the aerobic reservoir layer decreasing to only 1 meter in the month of December 2004, 2 year after impoundment. See figure 2.3.1 and 2.3.2

[11] Hydreco, NT2 Hydropower Project in Lao PDR, The Dissolved Oxygen Consumption Kinetics in the Water Turbined by the Nam Leuk Power Plant.

Figures 2.3. 1 and 2.3.2 **DO Concentrations in Nam Mang 3 Reservoir During 2004, First Year After Impoundment[12].**



Such phenomenon can be explained with the annual drop of air temperatures during December each year. As a result of drop of air temperatures, reservoirs in Lao PDR and northern Thailand de-stratify. In Nam Mang 3, the volume of the reservoir water bottom layer (with low water quality) is much more than the volume of the reservoir surface layer (with high water quality). Consequently, the water quality becomes worse in December each year when air temperature drop (the process of stratification and de-stratification of reservoirs in Lao PDR is discussed in section 2.6 of this report).

Due to a water layer of not more than 4 meters deep with high DO concentrations, while the deeper water layer was anoxic, no much space was left within the reservoir with favorable conditions for aquatic life. The surface water layer of 4 meters with favorable conditions for aquatic life even decreased to approximately 1 meter only during the month of December in 2004. The same event occurred in December, 2005. During the hot season, the reservoir surface layer had a depth of 4 meters, but in December, 2005, the reservoir water surface layer with high DO concentrations and highly favorable for aquatic life reduced to a depth of only 1 meter.

In Nam Ngum River Basin, in deep reservoirs at higher elevations, such as NN 3 reservoir, there is always a risk that surface water layers high in DO concentrations will decrease in depth during the month of December. In the month of December when the cold season starts in Lao PDR, air temperatures (especially at higher elevations) can significantly drop causing a mix of the reservoir water surface layer and the reservoir water bottom layer. When the reservoir bottom layer has high Biological Oxygen Demand (BOD) or when the anaerobic reservoir bottom water layer is simply deep and contains a much higher volume of water than the reservoir surface water layer then during the mixing of the two layers each year in December, the surface water layer with high DO concentrations shrinks.

A potential highly profitable human utilization of aquatic resources in Nam Mang 3 reservoir has been delayed for a period of three to five years due to poor reservoir water quality conditions during the first few years after impoundment.

[12] National University of Laos and Garry Thorncraft, 2006, Final Report Nam Mang 3, Aquatic Ecology and Water Quality Monitoring Programme, Prepared for Electricité du Lao.

Annex H

SATELLITE INTERPRETATION AT SURROUNDINGS OF NN3’S RESERVOIR AREA.

Report on Quickbird Satellite Interpretation to Identify the Presence of Human Activity and/or Settlement in the Nam Ngum 3 Hydropower Project's Middle Reservoir Area.

Introduction

In November, 2007 NORPLAN, on behalf of GMS and the Nam Ngum 3 Hydropower Project in Lao PDR commissioned the acquisition of satellite imagery of the middle reservoir area of the future Nam Ngum 3 impoundment. Images were acquired from Digital Globe's Quickbird 2 satellite captured on the14th December, 2008 at 04:07:25 UTC (11:07 am local time).

The imagery has a resolution of approximately 60 cm, which is ample to identify human settlement structures and agricultural activity (however it is still difficult to confirm the presence of boats or animals). Originally Norplan had ordered an area of 443 km², however after several attempts the satellite was only able to capture a scene 290 km², due to persistent cloud cover. The remaining portion was to the far west of the middle reservoir area, over the escarpment and into the Vang Vieng Valley. The area captured is a rectangle bound by the coordinates

Northwest Corner Latitude = 19.31115037 North;

Northwest Corner Longitude = 102.72359374 East;

Southeast Corner Latitude = 19.16439000 North;

Southeast Corner Longitude = 102.87343000 East;

It was also decided not to rely on archived imagery as these scenes were captured years earlier and would not represent the current situation in the area.

The scenes acquired were analysed for any sign of human activity that would represent a presence of possibly not yet identified communities that may be impacted by the Nam Ngum 3 Project and the creation of the Nam Ngum 3 reservoir. The primary indicators would be evidence of:

- Agricultural production systems (paddy fields, up land rice, maize, poppy fields, livestock grazing, and vegetable gardens);
- Settlement or structures (houses, barns, field houses, and cave dwellings);
- Roads, tracks, or paths;
- Boats on the river or riverbanks;
- Logs, log storage.

Interpretation Results

The area analysed is displayed in Figure 1, which shows an overview of the area. The main identified evidence of human activity is indicated on this map. There are many areas in scene that could be disturbed forest or could indicate evidence of fallow areas of previous shifting cultivation. This study is focusing, however, on areas with a very strong likelihood of present human activity.

Figure 1 is a guide map and indicates the 6 main Zones of interest. Figure 1 is a reference guide to the more detailed figures 2 to 8 that show identified human activities in more detail at the 6 zones.

Zone 1

Figure 2 shows the different features identified in Zone 1. This is an area to the west of the Nam Ngum valley which rises up into the escarpment that separates the Nam Ngum and the Vang Vieng valleys. The area under scrutiny is approximately 25 km² and lies on the eastern slopes of the escarpment (See Figure 2, Scene A), at the headwaters of a tributary to Nam

Ngum. This zone lies on the upper-left edge of the captured scene at a distance of about 6 kilometres from Nam Ngum. Here there is strong evidence for agricultural activities.

Three clear agricultural areas are identified of approximately 80 Ha, 22 Ha, and 23 Ha (see Figure 2, Scenes A and B). These fields obviously extend to the west outside of the captured scene and so probably are larger than this.

There is also a good deal more land on these slopes which could be agricultural, but where it is difficult to determine if cleared areas are agricultural or clearings caused by natural geology or erosion, they have not been counted.

At strategic points within each field small lighter box shapes with a discernable shadow can be seen. These are almost certainly field houses. What is strange is the lack of any obvious foot paths or tracks.

Approximately 7 field houses can be identified four of which can be seen in Figure 2, Scenes A-1, A-2, B-1 and B-2, with a further 12 possible structures believed to having been built.

Two possible cave entrances have been identified (see Figure 2, Scenes C and D). These are thought to be cave entrances because there is an obvious cliff face, with trees overhanging creating a distinct shadow and a cleared or 'trampled' area in front. The caves may be used as a (temporary) residence.

In the case of frame 'D' a path can be seen leading to the east and towards the river. There is no evidence of a settlement or a village, and unless the people that attend the obvious agricultural activities do live in the caves as identified above, then their settlement likely lies out of view to the west of the captured scene.

These areas with evidence of human activities are located between 5 and 7 kilometres from the main Nam Ngum River and hence are unlikely to be flooded as a result of NN 3 reservoir. The structures and agricultural fields are located adjacent to the Nam Xo (a tributary to Nam Ngum), which at this location is above the Full Supply Level of NN 3 reservoir.

Zone 2

As shown in Figure 3, Zone 2 is an area where an obvious human settlement has been established. It is a clear ridge line settlement centred around 102° 46' 59" E, 19° 16' 9" N and lies approximately 1.2 km from the Nam Ngum River. It is composed of 5 sections, each section containing between 2 and 8 homes and several other additional structures (see Figure 3 Scenes A-1 and A-2). In total not less than 25 residential homes and 19 additional structures (barns, rice banks, sties etc) have been identified.

The settlement lies on a ridge with no indication of presence of logs in the immediate vicinity of the settlement. There is a burnt area to the south of the settlement that can be seen on the lower edge of Figure 3 Scene A-2. There are distinct tracks leading around the village and between housing clusters. Tracks also lead to the east and toward Nam Ngum River. There are further tracks leading to the north and south and toward two areas of cleared land.

The evidence for agriculture is weak, with two relatively cleared areas to the northwest and southeast of the settlement where agriculture may be practiced (see Figure 4 Scenes A and B). There is a burnt area to the south of the settlement that can be seen on the lower edge of Figure 3 Scene A-2.

Figure 5 shows possible boats along Nam Ngum River farther away from the settlement, though this is not easily confirmed. Boats generally have the same size and shape as logs and considering that logging takes place in the surrounding area along Nam Ngum outside the captured area; the possible boats in the images in Figure 5 may be just logs. The items which appear to be boats or logs are between 5 and 7 metres long (the size of fishing canoes in the area).

Scene A shows also what appears to be a structure and could be a temporary fisherman's shelter. All items in Figure 5 lie within 1.2 and 3 kilometres of the settlement but adjacent to Nam Ngum River.

There is a bare patch of earth in one of the clusters which could be a sports area or a landing zone for a helicopter.

It is not sure whether this obvious settlement is a permanent rural community, an army encampment, or possibly a camp of a timber extraction company. As the evidence of agricultural activities is weak and the amount of logs is low, most likely the settlement is an army camp.

Zone 3

This Zone is shown in Figure 6 and is made up of 3 agricultural (and possibly settlement) areas around the mouth of the Nam Xo tributary on the right bank of the Nam Ngum. The three areas are centred on approximately 102° 47' 41" E and 19° 13' 5" N and the whole area is approximately 4 km^2.

The first area centred around 102° 46' 55" E and 19° 13' 29" N and lying adjacent to the Nam Xo tributary can be seen in Figure 6 Scene A. It is made up of 4 agricultural fields of 0.3, 0.7, 2.0 and 0.6 hectares. Field houses can be observed within these four agricultural areas. There is no obvious sign of residential housing.

The second area (Figure 6 Scene B) centred around 102° 48' 2" E and 19° 13' 26" N is made up of three upland agricultural fields (possibly rice or poppy). The fields have areas of 0.8, 0.2, and 0.1 hectares. There is no obvious sign of housing.

The third and largest area (Figure 6 Scene C) is adjacent to the Nam Xo tributary at the confluence with the Nam Ngum centred around 102° 47' 54" E and 19° 12' 29" N. It is made up of two large agricultural fields, one on each bank. They have a surface area of 1.9 and 3.2 hectares. Field houses can clearly be seen in Figure 6 Scene C.

A further area of potential agricultural activity can be seen in Figure 6 Scene D. This area is on the slope down to the river and there is a distinct impression of some kind of crops being grown there.

Zone 4

Zone 4 is part of the village area of Ban Xam Thong. Ban Xam Thong is identified in the Social Impact Assessment as NN 3 project affected village. Ban Xam Thong is located along the public road from Long Cheng to Xieng Khouang Province, just north of Long Cheng and NN 3 dam site.

In Figure 7 Scene A an obvious agriculture field with a field house is shown. It is located near to the confluence of the Nam Xeng Tributary at 102° 47' 49" E and 19° 11' 6" N. From the evidence of residual rice stacking areas, it is believed that this field was cultivated during the previous rainy season. It is approximately 0.36 Ha. There are tracks coming through the area and leading to the river in the north.

Scene B shows an area of grazing land, where cattle are identified. There are several animal or human paths.

Scene C shows an agricultural field and a field house.

Scene D shows the public road from Long Cheng to Xieng Khouang Province, where twice weekly a public bus passes. The public road is unsealed.

Zone 5

Zone 5 is made up of two areas of agricultural activity (Figure 8, Scenes A and B). Scene A shows the agricultural area close to the Nam Xo River with a field house.

Scene B shows an area of possible plantation agriculture (due to the uniform rows of planting). It is near to the Nam Kumang tributary and lies at 102° 49' 10" E and 19° 10' 40" N.

Zone 6

Zone 6 is also shown in Figure 8 and details can be seen in Scenes C and D. It shows potential human activity, but not confirmed.

Scene C shows an area of burnt (or cleared) land in the lower left-hand corner of the satellite image. This could be the result of natural fires or agricultural clearances. There are further areas of interest to the east of this burnt area. It is not at all sure whether or not these represent human activity. Bare patches of earth and surrounding land cleared of vegetation could mean an area of previous agriculture or a settlement in the years gone by.

Conclusion

The satellite images provide evidence of human activities in 6 different zones of the captured area.

Only in two of these 6 zones could it be identified where the people that execute these activities actually live.

- Zone 2. In this area obvious human settlement, but only weak evidence of agricultural production.

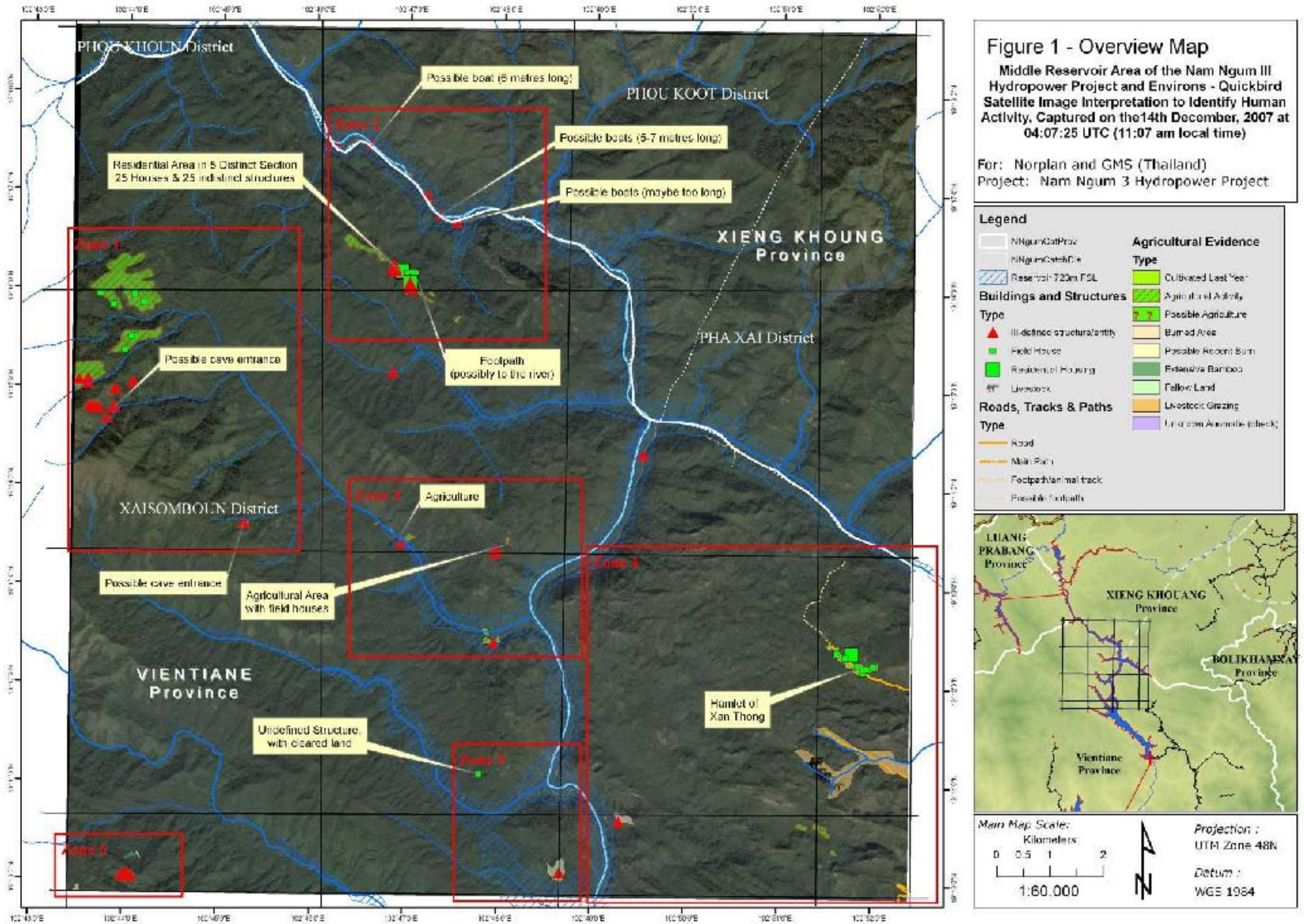
- Zone 4. The area belongs to the village area of Xam Thong.

In the 4 remaining zones, Zone 1, 3, 5, and 6, human activities have been identified, but no human settlement could be clearly identified.

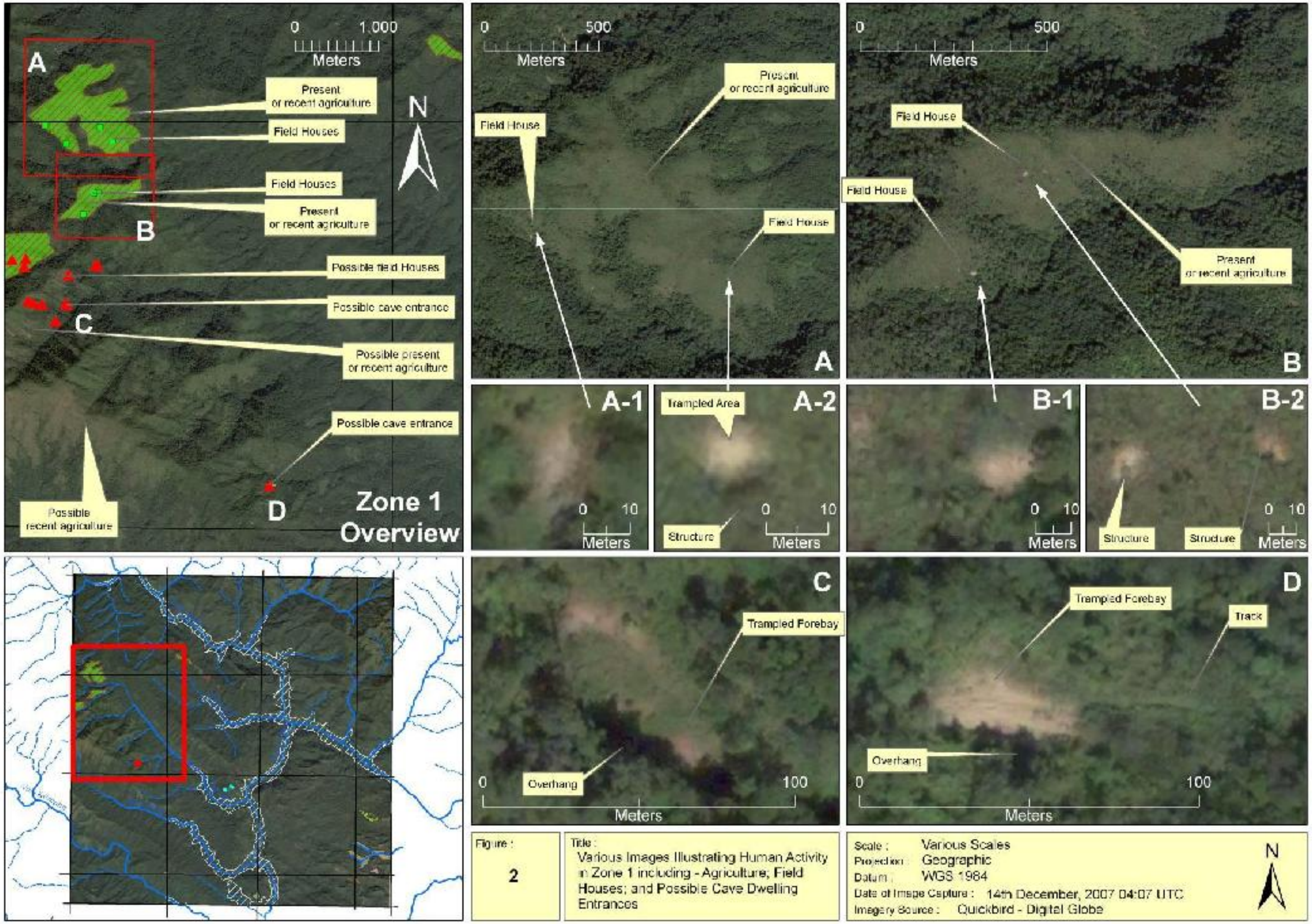
- Zone 1. In this zone there is evidence of caves and regular access to these caves. There is a possibility that human beings use these two caves as a residence or settlement place. There is also a strong possibility that human beings use these caves as a temporary seasonal settlement as large agricultural areas are identified in this zone. These same human beings may have their permanent housing in a village located more to the west in Vang Vieng Valley that is located outside the captured area.
  Besides the trampled area in front of the caves one clear footpath leading toward a stream could be observed.

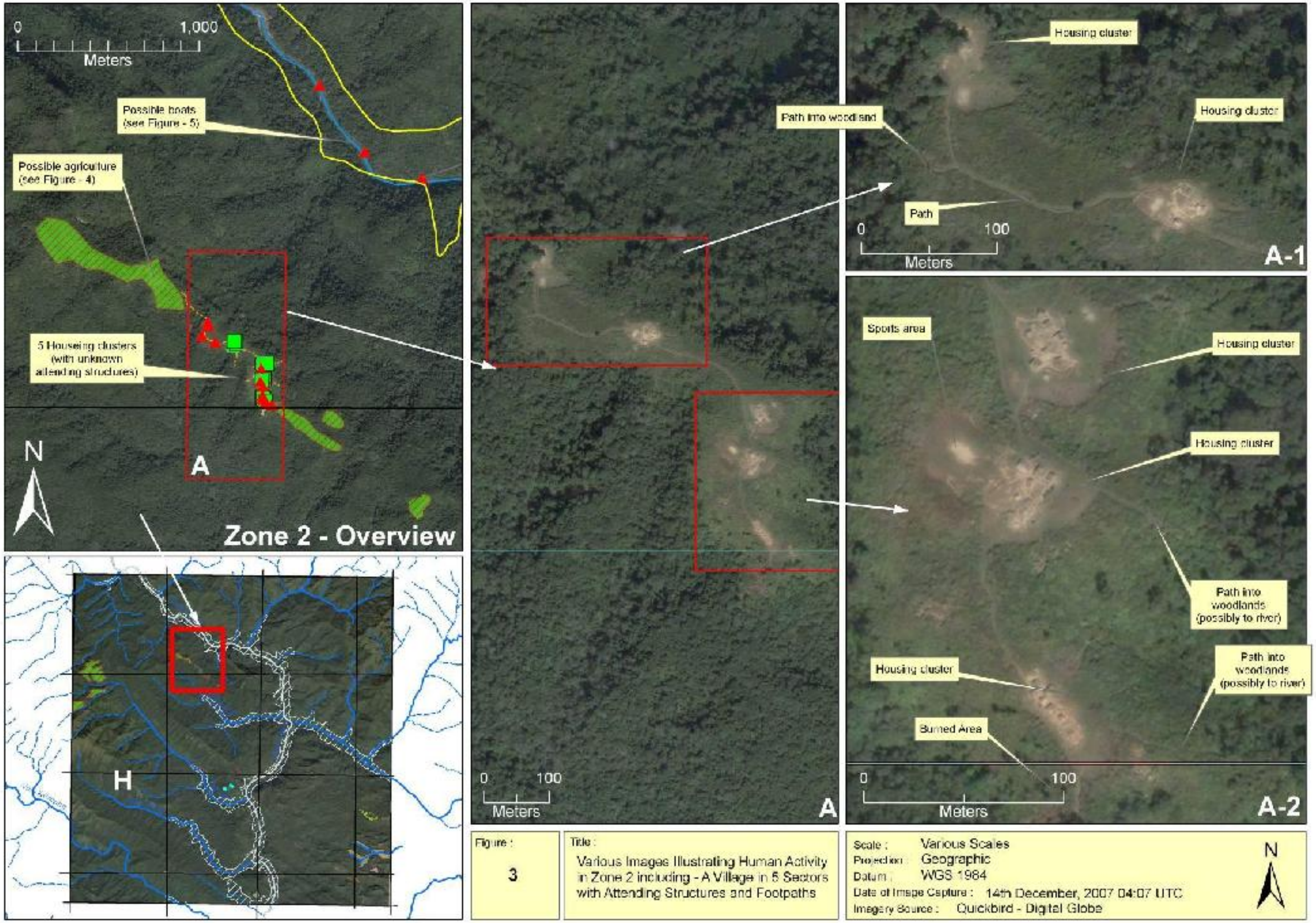
- Zone 3, 5 and 6. In these three zones in the middle NN 3 reservoir area, agricultural activities have been confirmed, however, they lack unequivocal evidence of human settlement.

Summarizing, there appear no people living permanently in proximity to the Nam Ngum who depend on the natural resources to be affected by the NN3 Reservoir. Consultations should be undertaken to identify the type of livelihood carried by the people living in the area, even on a seasonal basis.

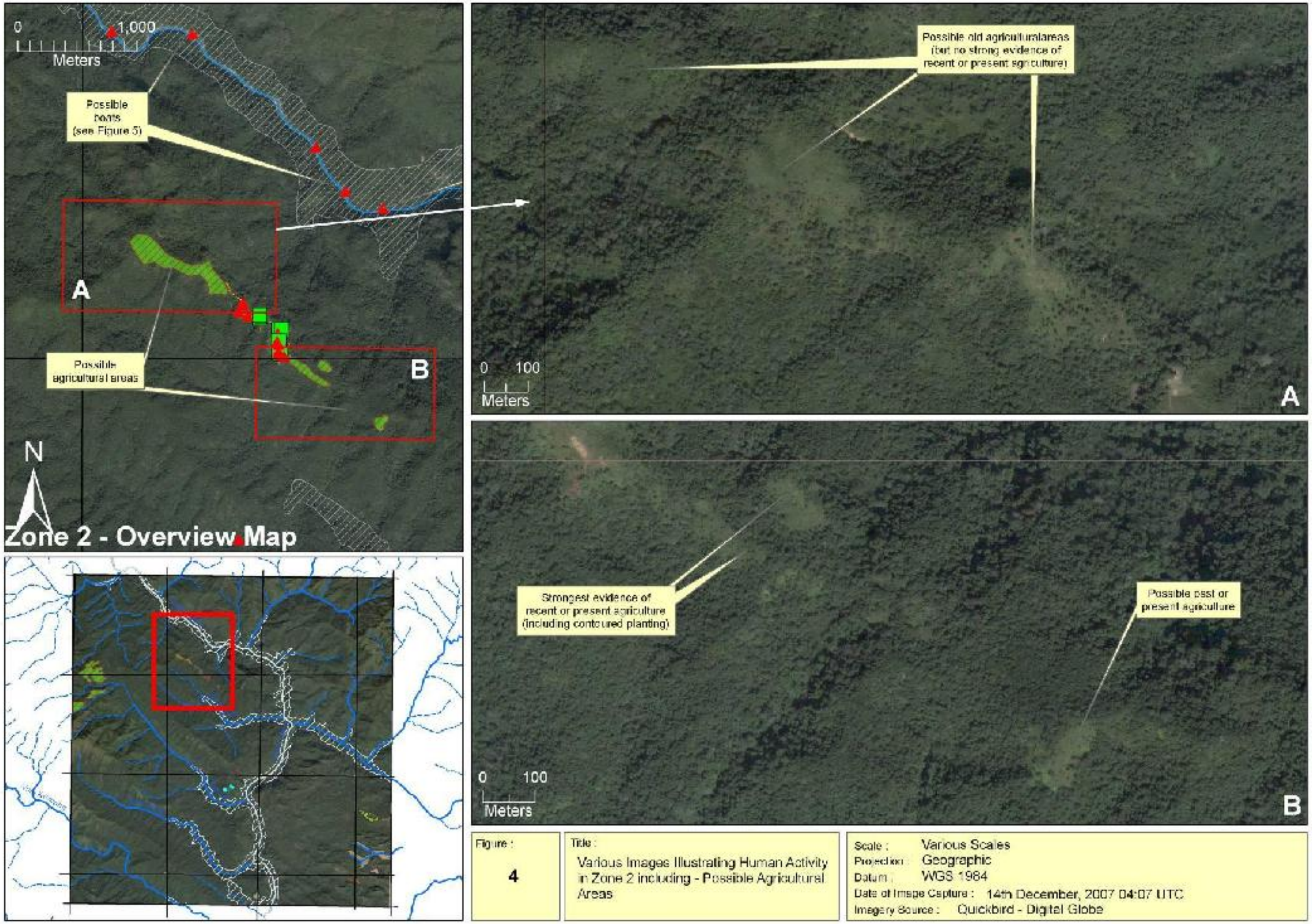


PHOU KHOUN District
Possible boat (6 metres long)
PHOU KOOT District
Zone 2
Possible boats (5-7 metres long)
Residential Area in 5 Distinct Section
25 Houses & 25 indistinct structures
Possible boats (maybe too long)
XIENG KHOUNG
Province
Zone 1
PHA XAI District
Possible cave entrance
Footpath
(possibly to the river)
Zone 3
Agriculture
XAISOMBOUN District
Zone 4
Possible cave entrance
Agricultural Area
with field houses
VIENTIANE
Province
Hamlet of
Xan Thong
Undefined Structure,
with cleared land
Zone 5
Zone 6
Figure 1 - Overview Map
Middle Reservoir Area of the Nam Ngum III Hydropower Project and Environs - Quickbird Satellite Image Interpretation to Identify Human Activity. Captured on the14th December, 2007 at 04:07:25 UTC (11:07 am local time)
For: Norplan and GMS (Thailand)
Project: Nam Ngum 3 Hydropower Project
Legend
Agricultural Evidence
Type
Buildings and Structures
Type
Roads, Tracks & Paths
Type
LUANG PRABANG Province
XIENG KHOUANG Province
BOLIKHAMXAY Province
Vientiane Province
Main Map Scale:
Kilometers
0 0.5 1 2
1:60,000
Projection :
UTM Zone 48N
Datum :
WGS 1984


0 1,000 Meters
A
Present or recent agriculture
Field Houses
N
Field Houses
Present or recent agriculture
B
Possible field Houses
Possible cave entrance
C
Possible present or recent agriculture
Possible cave entrance
Possible recent agriculture
D
Zone 1 Overview
0 500 Meters
Present or recent agriculture
Field House
Field House
A
0 500 Meters
Field House
Field House
Present or recent agriculture
B
A-1
0 10 Meters
Trampled Area
A-2
Structure
0 10 Meters
B-1
0 10 Meters
B-2
Structure
Structure
0 10 Meters
C
Trampled Forebay
Overhang
0 100 Meters
D
Trampled Forebay
Track
Overhang
0 100 Meters
Figure :
2
Title :
Various Images Illustrating Human Activity in Zone 1 including - Agriculture; Field Houses; and Possible Cave Dwelling Entrances
Scale : Various Scales
Projection : Geographic
Datum : WGS 1984
Date of Image Capture : 14th December, 2007 04:07 UTC
Imagery Source : Quickbird - Digital Globe
N

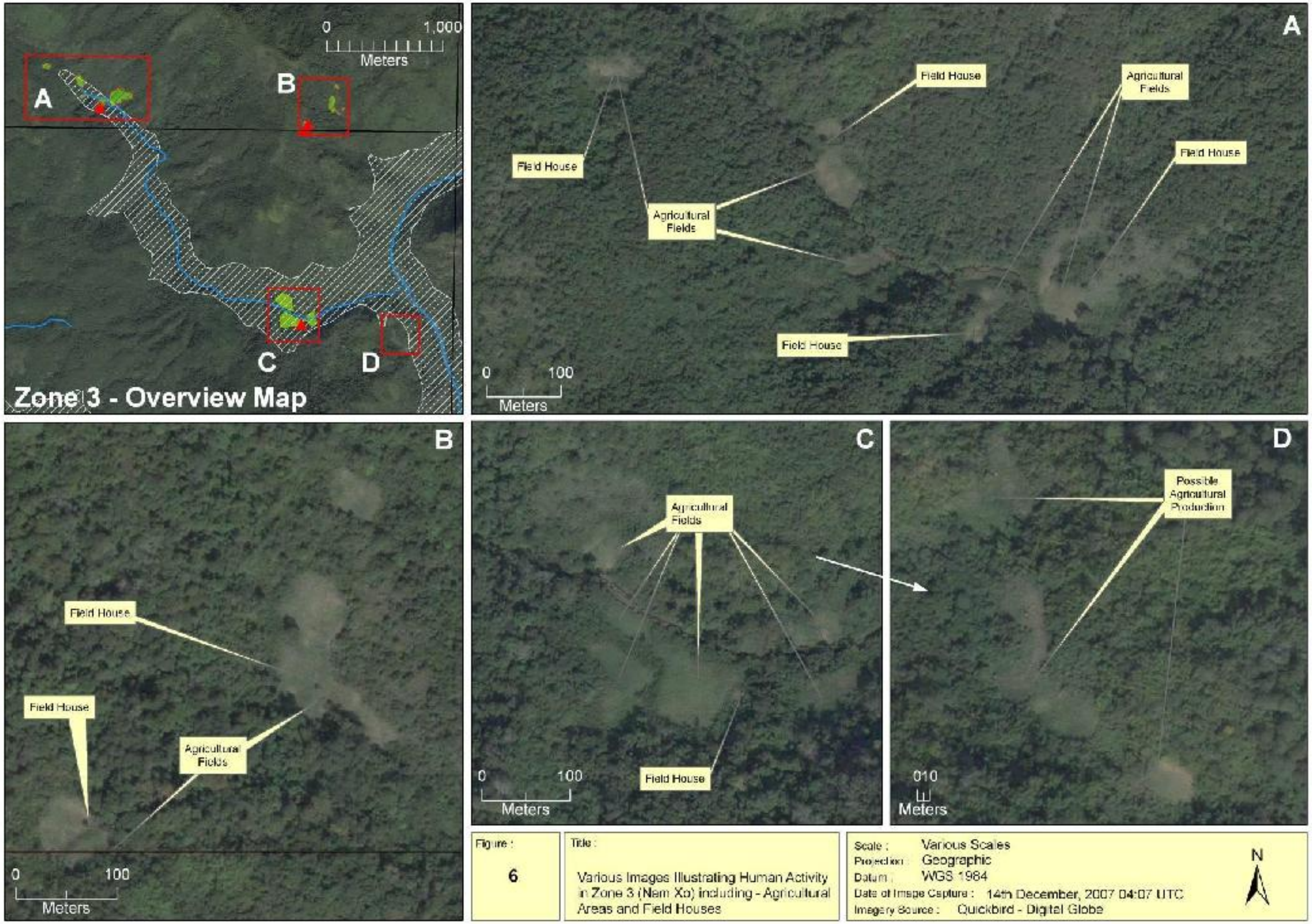


0
1,000
Meters
Possible boats
(see Figure - 5)
Possible agriculture
(see Figure - 4)
5 Houseing clusters
(with unknown
attending structures)
A
N
Zone 2 - Overview
H
Path into woodland
Housing cluster
Housing cluster
Path
0
100
Meters
A-1
Sports area
Housing cluster
Housing cluster
Path into
woodlands
(possibly to river)
Path into
woodlands
(possibly to river)
Housing cluster
Burned Area
0
100
Meters
A-2
0
100
Meters
A
Figure :
3
Title :
Various Images Illustrating Human Activity
in Zone 2 including - A Village in 5 Sectors
with Attending Structures and Footpaths
Scale : Various Scales
Projection : Geographic
Datum : WGS 1984
Date of Image Capture : 14th December, 2007 04:07 UTC
Imagery Source : Quickbird - Digital Globe
N



0
1,000
Meters
Possible boats (see Figure 5)
A
Possible agricultural areas
B
N
Zone 2 - Overview Map
Possible old agriculturalareas (but no strong evidence of recent or present agriculture)
0 100
Meters
A
Strongest evidence of recent or present agriculture (including contoured planting)
Possible past or present agriculture
0 100
Meters
B
Figure :
4
Title :
Various Images Illustrating Human Activity in Zone 2 including - Possible Agricultural Areas
Scale : Various Scales
Projection : Geographic
Datum : WGS 1984
Date of Image Capture : 14th December, 2007 04:07 UTC
Imagery Source : Quickbird - Digital Globe


0
1,000
Meters
A
B
C
D
Possible evidence of river usage
Small settlement on the ridge above the river
N
H
Structure - Possibly Fishing Hut
Boat or Tree Log
Boat or Tree Log
Boat or Tree Log
Boat or Tree Log
Boats or Tree Logs
0 10
Meters
Figure :
5
Title :
Various Images Illustrating Human Activity in Zone 2 including - Possible Boats or Tree Logs (indicating logging)
Scale : Various Scales
Projection : Geographic
Datum : WGS 1984
Date of Image Capture : 14th December, 2007 04:07 UTC
Imagery Source : Quickbird - Digital Globe


Zone 3 - Overview Map
0
1,000
Meters
A
B
C
D
Field House
Agricultural Fields
Field House
Agricultural Fields
Field House
Field House
0
100
Meters
Field House
Field House
Agricultural Fields
0
100
Meters
Agricultural Fields
Field House
0
100
Meters
Possible Agricultural Production
010
Meters
Figure :
6
Title :
Various Images Illustrating Human Activity in Zone 3 (Nam Xo) including - Agricultural Areas and Field Houses
Scale : Various Scales
Projection : Geographic
Datum : WGS 1984
Date of Image Capture : 14th December, 2007 04:07 UTC
Imagery Source : Quickbird - Digital Globe
N

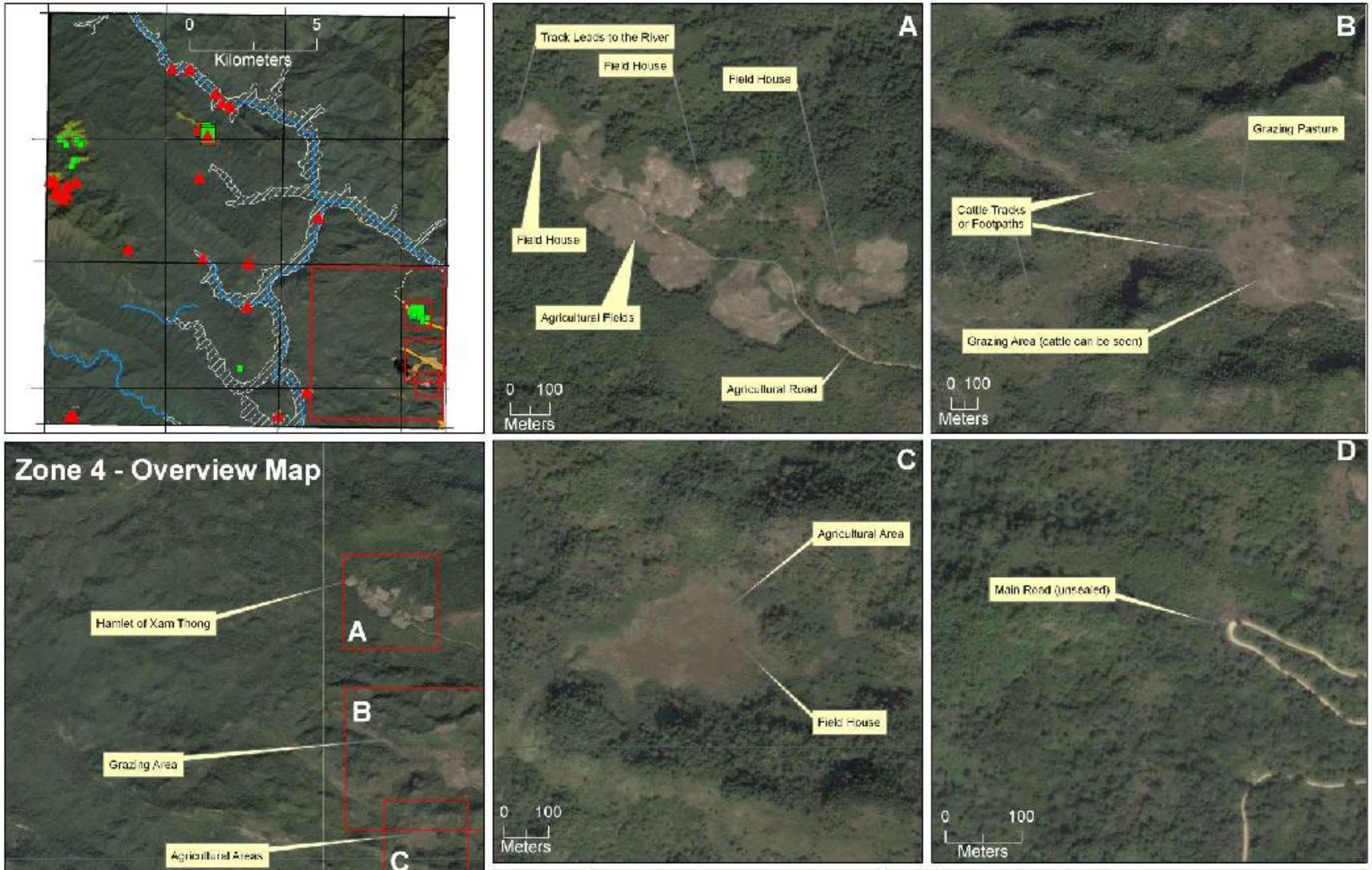
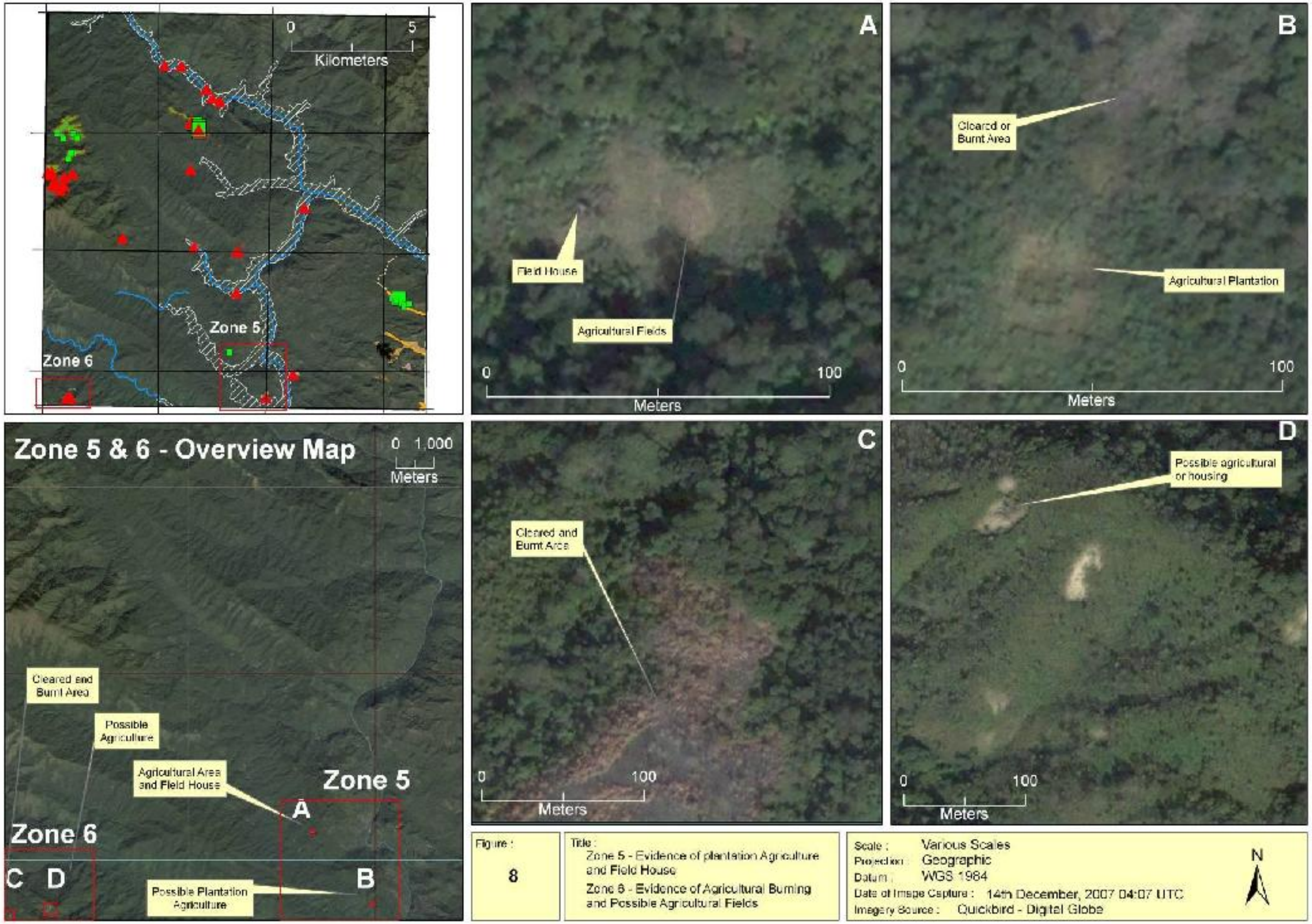


Figure : 7

Title : Zone 4 - Hamlet of Xam Thong with Agricultural Fields, Houses, Field Houses and Main Road (unsealed)

Scale : Various Scales
Projection : Geographic
Datum : WGS 1984
Date of Image Capture : 14th December, 2007 04:07 UTC
Imagery Source : Quickbird - Digital Globe


0 5
Kilometers
Zone 5
Zone 6
A
Field House
Agricultural Fields
0 100
Meters
B
Cleared or Burnt Area
Agricultural Plantation
0 100
Meters
Zone 5 & 6 - Overview Map
0 1,000
Meters
Cleared and Burnt Area
Possible Agriculture
Agricultural Area and Field House
Zone 5
A
Zone 6
C D
Possible Plantation Agriculture
B
C
Cleared and Burnt Area
0 100
Meters
D
Possible agricultural or housing
0 100
Meters
Figure :
8
Title :
Zone 5 - Evidence of plantation Agriculture and Field House
Zone 6 - Evidence of Agricultural Burning and Possible Agricultural Fields
Scale : Various Scales
Projection : Geographic
Datum : WGS 1984
Date of Image Capture : 14th December, 2007 04:07 UTC
Imagery Source : Quickbird - Digital Globe
N

Annex I

IFC ENVIRONMENTAL, HEALTH AND SAFETY GENERAL GUIDELINES

Environmental, Health, and Safety General Guidelines

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)[1]. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These **General EHS Guidelines** are designed to be used together with the relevant **Industry Sector EHS Guidelines** which provide guidance to users on EHS issues in specific industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment[2] in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

The **General EHS Guidelines** are organized as follows:

[1] Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

[2] For IFC, such assessment is carried out consistent with Performance Standard 1, and for the World Bank, with Operational Policy 4.01.

General Approach to the Management of EHS Issues at the Facility or Project Level

Effective management of environmental, health, and safety (EHS) issues entails the inclusion of EHS considerations into corporate- and facility-level business processes in an organized, hierarchical approach that includes the following steps:

- Identifying EHS project hazards[3] and associated risks[4] as early as possible in the facility development or project cycle, including the incorporation of EHS considerations into the site selection process, product design process, engineering planning process for capital requests, engineering work orders, facility modification authorizations, or layout and process change plans.
- Involving EHS professionals, who have the experience, competence, and training necessary to assess and manage EHS impacts and risks, and carry out specialized environmental management functions including the preparation of project or activity-specific plans and procedures that incorporate the technical recommendations presented in this document that are relevant to the project.
- Understanding the likelihood and magnitude of EHS risks, based on:
    - The nature of the project activities, such as whether the project will generate significant quantities of emissions or effluents, or involve hazardous materials or processes;
    - The potential consequences to workers, communities, or the environment if hazards are not adequately managed, which may depend on the proximity of project activities to people or to the environmental resources on which they depend.
- Prioritizing risk management strategies with the objective of achieving an overall reduction of risk to human health and the environment, focusing on the prevention of irreversible and / or significant impacts.
- Favoring strategies that eliminate the cause of the hazard at its source, for example, by selecting less hazardous materials or processes that avoid the need for EHS controls.
- When impact avoidance is not feasible, incorporating engineering and management controls to reduce or minimize the possibility and magnitude of undesired consequences, for example, with the application of pollution controls to reduce the levels of emitted contaminants to workers or environments.
- Preparing workers and nearby communities to respond to accidents, including providing technical and financial resources to effectively and safely control such events, and restoring workplace and community environments to a safe and healthy condition.
- Improving EHS performance through a combination of ongoing monitoring of facility performance and effective accountability.

3 Defined as "threats to humans and what they value" (Kates, et al., 1985).

4 Defined as "quantitative measures of hazard consequences, usually expressed as conditional probabilities of experiencing harm" (Kates, et. al., 1985)

1.0 Environmental

1.1 Air Emissions and Ambient Air Quality

Applicability and Approach

This guideline applies to facilities or projects that generate emissions to air at any stage of the project life-cycle. It complements the industry-specific emissions guidance presented in the Industry Sector Environmental, Health, and Safety (EHS) Guidelines by providing information about common techniques for emissions management that may be applied to a range of industry sectors. This guideline provides an approach to the management of significant sources of emissions, including specific guidance for assessment and monitoring of impacts. It is also intended to provide additional information on approaches to emissions management in projects located in areas of poor air quality, where it may be necessary to establish project-specific emissions standards.

Emissions of air pollutants can occur from a wide variety of activities during the construction, operation, and decommissioning phases of a project. These activities can be categorized based on the spatial characteristic of the source including point sources, fugitive sources, and mobile sources and, further, by process, such as combustion, materials storage, or other industry sector-specific processes.

Where possible, facilities and projects should avoid, minimize, and control adverse impacts to human health, safety, and the environment from emissions to air. Where this is not possible, the generation and release of emissions of any type should be managed through a combination of:

- Energy use efficiency
- Process modification
- Selection of fuels or other materials, the processing of which may result in less polluting emissions
- Application of emissions control techniques

The selected prevention and control techniques may include one or more methods of treatment depending on:

- Regulatory requirements
- Significance of the source
- Location of the emitting facility relative to other sources
- Location of sensitive receptors
- Existing ambient air quality, and potential for degradation of the airshed from a proposed project
- Technical feasibility and cost effectiveness of the available options for prevention, control, and release of emissions

Ambient Air Quality

General Approach

Projects with significant[5,6] sources of air emissions, and potential for significant impacts to ambient air quality, should prevent or minimize impacts by ensuring that:

- Emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards[9] by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines[10] (see Table 1.1.1), or other internationally recognized sources[11];
- Emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards. As a general rule, this Guideline suggests 25 percent of the applicable air quality standards to allow additional, future sustainable development in the same airshed.[12]

At facility level, impacts should be estimated through qualitative or quantitative assessments by the use of baseline air quality assessments and atmospheric dispersion models to assess potential ground level concentrations. Local atmospheric, climatic, and air quality data should be applied when modeling dispersion, protection against atmospheric downwash, wakes, or eddy effects of the source, nearby[13] structures, and terrain features. The dispersion model applied should be internationally recognized, or comparable. Examples of acceptable emission estimation and dispersion modeling approaches for point and fugitive sources are

Table 1.1.1: WHO Ambient Air Quality Guidelines[7],[8]

	Averaging Period	Guideline value in $\mu g/m^3$
Sulfur dioxide (SO_2)	24-hour 10 minute	125 (Interim target-1) 50 (Interim target-2) 20 (guideline) 500 (guideline)
Nitrogen dioxide (NO_2)	1-year 1-hour	40 (guideline) 200 (guideline)
Particulate Matter PM_{10}	1-year 24-hour	70 (Interim target-1) 50 (Interim target-2) 30 (Interim target-3) 20 (guideline) 150 (Interim target-1) 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)
Particulate Matter $PM_{2.5}$	1-year 24-hour	35 (Interim target-1) 25 (Interim target-2) 15 (Interim target-3) 10 (guideline) 75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)
Ozone	8-hour daily maximum	160 (Interim target-1) 100 (guideline)

5 Significant sources of point and fugitive emissions are considered to be general sources which, for example, can contribute a net emissions increase of one or more of the following pollutants within a given airshed: PM10: 50 tons per year (tpy); NOx: 500 tpy; SO2: 500 tpy; or as established through national legislation; and combustion sources with an equivalent heat input of 50 MWth or greater. The significance of emissions of inorganic and organic pollutants should be established on a project-specific basis taking into account toxic and other properties of the pollutant.

6 United States Environmental Protection Agency, Prevention of Significant Deterioration of Air Quality, 40 CFR Ch. 1 Part 52.21. Other references for establishing significant emissions include the European Commission. 2000. "Guidance Document for EPER implementation." http://ec.europa.eu/environment/ippc/eper/index.htm ; and Australian Government. 2004. "National Pollutant Inventory Guide." http://www.npi.gov.au/handbooks/pubs/npiguide.pdf

7 World Health Organization (WHO). Air Quality Guidelines Global Update, 2005. PM 24-hour value is the 99th percentile.

8 Interim targets are provided in recognition of the need for a staged approach to achieving the recommended guidelines.

9 Ambient air quality standards are ambient air quality levels established and published through national legislative and regulatory processes, and ambient quality guidelines refer to ambient quality levels primarily developed through clinical, toxicological, and epidemiological evidence (such as those published by the World Health Organization).

10 Available at World Health Organization (WHO). http://www.who.int/en

11 For example the United States National Ambient Air Quality Standards (NAAQS) (http://www.epa.gov/air/criteria.html) and the relevant European Council Directives (Council Directive 1999/30/EC of 22 April 1999 / Council Directive 2002/3/EC of February 12 2002).

12 US EPA Prevention of Significant Deterioration Increments Limits applicable to non-degraded airsheds.

included in Annex 1.1.1. These approaches include screening models for single source evaluations (SCREEN3 or AIRSCREEN), as well as more complex and refined models (AERMOD OR ADMS). Model selection is dependent on the complexity and geo-morphology of the project site (e.g. mountainous terrain, urban or rural area).

Projects Located in Degraded Airsheds or Ecologically Sensitive Areas

Facilities or projects located within poor quality airsheds[14], and within or next to areas established as ecologically sensitive (e.g. national parks), should ensure that any increase in pollution levels is as small as feasible, and amounts to a fraction of the applicable short-term and annual average air quality guidelines or standards as established in the project-specific environmental assessment. Suitable mitigation measures may also include the relocation of significant sources of emissions outside the airshed in question, use of cleaner fuels or technologies, application of comprehensive pollution control measures, offset activities at installations controlled by the project sponsor or other facilities within the same airshed, and buy-down of emissions within the same airshed.

Specific provisions for minimizing emissions and their impacts in poor air quality or ecologically sensitive airsheds should be established on a project-by-project or industry-specific basis. Offset provisions outside the immediate control of the project sponsor or buy-downs should be monitored and enforced by the local agency responsible for granting and monitoring emission permits. Such provisions should be in place prior to final commissioning of the facility / project.

Point Sources

Point sources are discrete, stationary, identifiable sources of emissions that release pollutants to the atmosphere. They are typically located in manufacturing or production plants. Within a given point source, there may be several individual 'emission points' that comprise the point source.[15]

Point sources are characterized by the release of air pollutants typically associated with the combustion of fossil fuels, such as nitrogen oxides (NO_X), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM), as well as other air pollutants including certain volatile organic compounds (VOCs) and metals that may also be associated with a wide range of industrial activities.

Emissions from point sources should be avoided and controlled according to good international industry practice (GIIP) applicable to the relevant industry sector, depending on ambient conditions, through the combined application of process modifications and emissions controls, examples of which are provided in Annex 1.1.2. Additional recommendations regarding stack height and emissions from small combustion facilities are provided below.

Stack Height

The stack height for all point sources of emissions, whether 'significant' or not, should be designed according to GIIP (see Annex 1.1.3) to avoid excessive ground level concentrations due to downwash, wakes, and eddy effects, and to ensure reasonable diffusion to minimize impacts. For projects where there are multiple sources of emissions, stack heights should be established with due consideration to emissions from all other project sources, both point and fugitive. Non-significant sources of emissions,

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13 "Nearby" generally considers an area within a radius of up to 20 times the stack height.

14 An airshed should be considered as having poor air quality if nationally legislated air quality standards or WHO Air Quality Guidelines are exceeded significantly.

15 Emission points refer to a specific stack, vent, or other discrete point of pollution release. This term should not be confused with point source, which is a regulatory distinction from area and mobile sources. The characterization of point sources into multiple emissions points is useful for allowing more detailed reporting of emissions information.

including small combustion sources,[16] should also use GIIP in stack design.

Small Combustion Facilities Emissions Guidelines

Small combustion processes are systems designed to deliver electrical or mechanical power, steam, heat, or any combination of these, regardless of the fuel type, with a total, rated heat input capacity of between three Megawatt thermal (MWth) and 50 MWth.

The emissions guidelines in Table 1.1.2 are applicable to small combustion process installations operating more than 500 hours per year, and those with an annual capacity utilization of more than 30 percent. Plants firing a mixture of fuels should compare emissions performance with these guidelines based on the sum of the relative contribution of each applied fuel[17]. Lower emission values may apply if the proposed facility is located in an ecologically sensitive airshed, or airshed with poor air quality, in order to address potential cumulative impacts from the installation of more than one small combustion plant as part of a distributed generation project.

[16] Small combustion sources are those with a total rated heat input capacity of 50MWth or less.

[17] The contribution of a fuel is the percentage of heat input (LHV) provided by this fuel multiplied by its limit value.

Table 1.1.2 - Small Combustion Facilities Emissions Guidelines (3MWth – 50MWth) – (in mg/Nm^3 or as indicated)

Combustion Technology / Fuel	Particulate Matter (PM)	Sulfur Dioxide (SO_2)	Nitrogen Oxides (NOx)	Dry Gas, Excess O_2 Content (%)
Engine				
Gas	N/A	N/A	200 (Spark Ignition) 400 (Dual Fuel) 1,600 (Compression Ignition)	15
Liquid	50 or up to 100 if justified by project specific considerations (e.g. Economic feasibility of using lower ash content fuel, or adding secondary treatment to meet 50, and available environmental capacity of the site)	1.5 percent Sulfur or up to 3.0 percent Sulfur if justified by project specific considerations (e.g. Economic feasibility of using lower S content fuel, or adding secondary treatment to meet levels of using 1.5 percent Sulfur, and available environmental capacity of the site)	If bore size diameter [mm] < 400: 1460 (or up to 1,600 if justified to maintain high energy efficiency.) If bore size diameter [mm] > or = 400: 1,850	15
Turbine				
Natural Gas =3MWth to < 15MWth	N/A	N/A	42 ppm (Electric generation) 100 ppm (Mechanical drive)	15
Natural Gas =15MWth to < 50MWth	N/A	N/A	25 ppm	15
Fuels other than Natural Gas =3MWth to < 15MWth	N/A	0.5 percent Sulfur or lower percent Sulfur (e.g. 0.2 percent Sulfur) if commercially available without significant excess fuel cost	96 ppm (Electric generation) 150 ppm (Mechanical drive)	15
Fuels other than Natural Gas =15MWth to < 50MWth	N/A	0.5% S or lower % S (0.2%S) if commercially available without significant excess fuel cost	74 ppm	15
Boiler				
Gas	N/A	N/A	320	3
Liquid	50 or up to 150 if justified by environmental assessment	2000	460	3
Solid	50 or up to 150 if justified by environmental assessment	2000	650	6

Notes: -N/A/ - no emissions guideline; Higher performance levels than these in the Table should be applicable to facilities located in urban / industrial areas with degraded airsheds or close to ecologically sensitive areas where more stringent emissions controls may be needed.; MWth is heat input on HHV basis; Solid fuels include biomass; Nm^3 is at one atmosphere pressure, 0°C.; MWth category is to apply to the entire facility consisting of multiple units that are reasonably considered to be emitted from a common stack except for NOx and PM limits for turbines and boilers. Guidelines values apply to facilities operating more than 500 hours per year with an annual capacity utilization factor of more than 30 percent.

Fugitive Sources

Fugitive source air emissions refer to emissions that are distributed spatially over a wide area and not confined to a specific discharge point. They originate in operations where exhausts are not captured and passed through a stack. Fugitive emissions have the potential for much greater ground-level impacts per unit than stationary source emissions, since they are discharged and dispersed close to the ground. The two main types of fugitive emissions are Volatile Organic Compounds (VOCs) and particulate matter (PM). Other contaminants (NO_x, SO_2 and CO) are mainly associated with combustion processes, as described above. Projects with potentially significant fugitive sources of emissions should establish the need for ambient quality assessment and monitoring practices.

Open burning of solid wastes, whether hazardous or non-hazardous, is not considered good practice and should be avoided, as the generation of polluting emissions from this type of source cannot be controlled effectively.

Volatile Organic Compounds (VOCs)

The most common sources of fugitive VOC emissions are associated with industrial activities that produce, store, and use VOC-containing liquids or gases where the material is under pressure, exposed to a lower vapor pressure, or displaced from an enclosed space. Typical sources include equipment leaks, open vats and mixing tanks, storage tanks, unit operations in wastewater treatment systems, and accidental releases. Equipment leaks include valves, fittings, and elbows which are subject to leaks under pressure. The recommended prevention and control techniques for VOC emissions associated with equipment leaks include:

- Equipment modifications, examples of which are presented in Annex 1.1.4;
- Implementing a leak detection and repair (LDAR) program that controls fugitive emissions by regularly monitoring to detect leaks, and implementing repairs within a predefined time period.[18]

For VOC emissions associated with handling of chemicals in open vats and mixing processes, the recommended prevention and control techniques include:

- Substitution of less volatile substances, such as aqueous solvents;
- Collection of vapors through air extractors and subsequent treatment of gas stream by removing VOCs with control devices such as condensers or activated carbon absorption;
- Collection of vapors through air extractors and subsequent treatment with destructive control devices such as:
  - Catalytic Incinerators: Used to reduce VOCs from process exhaust gases exiting paint spray booths, ovens, and other process operations
  - Thermal Incinerators: Used to control VOC levels in a gas stream by passing the stream through a combustion chamber where the VOCs are burned in air at temperatures between 700º C to 1,300º C
  - Enclosed Oxidizing Flares: Used to convert VOCs into CO_2 and H_2O by way of direct combustion
- Use of floating roofs on storage tanks to reduce the opportunity for volatilization by eliminating the headspace present in conventional storage tanks.

Particulate Matter (PM)

The most common pollutant involved in fugitive emissions is dust or particulate matter (PM). This is released during certain operations, such as transport and open storage of solid materials, and from exposed soil surfaces, including unpaved roads.

[18] For more information, see Leak Detection and Repair Program (LDAR), at: http://www.ldar.net

Recommended prevention and control of these emissions sources include:

- Use of dust control methods, such as covers, water suppression, or increased moisture content for open materials storage piles, or controls, including air extraction and treatment through a baghouse or cyclone for material handling sources, such as conveyors and bins;
- Use of water suppression for control of loose materials on paved or unpaved road surfaces. Oil and oil by-products is not a recommended method to control road dust. Examples of additional control options for unpaved roads include those summarized in Annex 1.1.5.

Ozone Depleting Substances (ODS)

Several chemicals are classified as ozone depleting substances (ODSs) and are scheduled for phase-out under the Montreal Protocol on Substances that Deplete the Ozone Layer.[19] No new systems or processes should be installed using CFCs, halons, 1,1,1-trichloroethane, carbon tetrachloride, methyl bromide or HBFCs. HCFCs should only be considered as interim / bridging alternatives as determined by the host country commitments and regulations.[20]

Mobile Sources – Land-based

Similar to other combustion processes, emissions from vehicles include CO, NO_x, SO_2, PM and VOCs. Emissions from on-road and off-road vehicles should comply with national or regional programs. In the absence of these, the following approach should be considered:

- Regardless of the size or type of vehicle, fleet owners / operators should implement the manufacturer recommended engine maintenance programs;
- Drivers should be instructed on the benefits of driving practices that reduce both the risk of accidents and fuel consumption, including measured acceleration and driving within safe speed limits;
- Operators with fleets of 120 or more units of heavy duty vehicles (buses and trucks), or 540 or more light duty vehicles[21] (cars and light trucks) within an airshed should consider additional ways to reduce potential impacts including:
  - Replacing older vehicles with newer, more fuel efficient alternatives
  - Converting high-use vehicles to cleaner fuels, where feasible
  - Installing and maintaining emissions control devices, such as catalytic converters
  - Implementing a regular vehicle maintenance and repair program

Greenhouse Gases (GHGs)

Sectors that may have potentially significant emissions of greenhouse gases (GHGs)[22] include energy, transport, heavy industry (e.g. cement production, iron / steel manufacturing, aluminum smelting, petrochemical industries, petroleum refining, fertilizer manufacturing), agriculture, forestry and waste management. GHGs may be generated from direct emissions

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[19] Examples include: chlorofluorocarbons (CFCs); halons; 1,1,1-trichloroethane (methyl chloroform); carbon tetrachloride; hydrochlorofluorocarbons (HCFCs); hydrobromofluorocarbons (HBFCs); and methyl bromide. They are currently used in a variety of applications including: domestic, commercial, and process refrigeration (CFCs and HCFCs); domestic, commercial, and motor vehicle air conditioning (CFCs and HCFCs); for manufacturing foam products (CFCs); for solvent cleaning applications (CFCs, HCFCs, methyl chloroform, and carbon tetrachloride); as aerosol propellants (CFCs); in fire protection systems (halons and HBFCs); and as crop fumigants (methyl bromide).

[20] Additional information is available through the Montreal Protocol Secretariat web site available at: http://ozone.unep.org/

[21] The selected fleet size thresholds are assumed to represent potentially significant sources of emissions based on individual vehicles traveling 100,000 km / yr using average emission factors.

[22] The six greenhouse gases that form part of the Kyoto Protocol to the United Nations Framework Convention on Climate Change include carbon dioxide ($C0_2$); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); and sulfur hexafluoride (SF_6).

from facilities within the physical project boundary and indirect emissions associated with the off-site production of power used by the project.

Recommendations for reduction and control of greenhouse gases include:

- Carbon financing;[23]
- Enhancement of energy efficiency (see section on 'Energy Conservation');
- Protection and enhancement of sinks and reservoirs of greenhouse gases;
- Promotion of sustainable forms of agriculture and forestry;
- Promotion, development and increased use of renewable forms of energy;
- Carbon capture and storage technologies;[24]
- Limitation and / or reduction of methane emissions through recovery and use in waste management, as well as in the production, transport and distribution of energy (coal, oil, and gas).

Monitoring

Emissions and air quality monitoring programs provide information that can be used to assess the effectiveness of emissions management strategies. A systematic planning process is recommended to ensure that the data collected are adequate for their intended purposes (and to avoid collecting unnecessary data). This process, sometimes referred to as a data quality objectives process, defines the purpose of collecting the data, the decisions to be made based on the data and the consequences of making an incorrect decision, the time and geographic boundaries, and the quality of data needed to make a correct decision.[25] The air quality monitoring program should consider the following elements:

- *Monitoring parameters*: The monitoring parameters selected should reflect the pollutants of concern associated with project processes. For combustion processes, indicator parameters typically include the quality of inputs, such as the sulfur content of fuel.
- *Baseline calculations*: Before a project is developed, baseline air quality monitoring at and in the vicinity of the site should be undertaken to assess background levels of key pollutants, in order to differentiate between existing ambient conditions and project-related impacts.
- *Monitoring type and frequency*: Data on emissions and ambient air quality generated through the monitoring program should be representative of the emissions discharged by the project over time. Examples of time-dependent variations in the manufacturing process include batch process manufacturing and seasonal process variations. Emissions from highly variable processes may need to be sampled more frequently or through composite methods. Emissions monitoring frequency and duration may also range from continuous for some combustion process operating parameters or inputs (e.g. the quality of fuel) to less frequent, monthly, quarterly or yearly stack tests.
- *Monitoring locations*: Ambient air quality monitoring may consists of off-site or fence line monitoring either by the project sponsor, the competent government agency, or by collaboration between both. The location of ambient air

[23] Carbon financing as a carbon emissions reduction strategy may include the host government-endorsed Clean Development Mechanism or Joint Implementation of the United Nations Framework Convention on Climate Change.

[24] Carbon dioxide capture and storage (CCS) is a process consisting of the separation of CO_2 from industrial and energy-related sources; transport to a storage location; and long-term isolation from the atmosphere, for example in geological formations, in the ocean, or in mineral carbonates (reaction of CO_2 with metal oxides in silicate minerals to produce stable carbonates). It is the object of intensive research worldwide (Intergovernmental Panel on Climate Change (IPCC), Special Report, Carbon Dioxide Capture and Storage (2006).

[25] See, for example, United States Environmental Protection Agency, Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4, EPA/240/B-06/001 February 2006.

quality monitoring stations should be established based on the results of scientific methods and mathematical models to estimate potential impact to the receiving airshed from an emissions source taking into consideration such aspects as the location of potentially affected communities and prevailing wind directions.

- *Sampling and analysis methods*: Monitoring programs should apply national or international methods for sample collection and analysis, such as those published by the International Organization for Standardization,[26] the European Committee for Standardization,[27] or the U.S. Environmental Protection Agency.[28] Sampling should be conducted by, or under, the supervision of trained individuals. Analysis should be conducted by entities permitted or certified for this purpose. Sampling and analysis Quality Assurance / Quality Control (QA/QC) plans should be applied and documented to ensure that data quality is adequate for the intended data use (e.g., method detection limits are below levels of concern). Monitoring reports should include QA/QC documentation.

Monitoring of Small Combustion Plants Emissions

- Additional recommended monitoring approaches for **boilers**:

  Boilers with capacities between =3 MWth and < 20 MWth:

  - Annual Stack Emission Testing: SO_2, NO_x and PM. For gaseous fuel-fired boilers, only NO_x. SO_2 can be calculated based on fuel quality certification if no SO_2 control equipment is used.
  - If Annual Stack Emission Testing demonstrates results consistently and significantly better than the required levels, frequency of Annual Stack Emission Testing can be reduced from annual to every two or three years.
  - Emission Monitoring: None

  Boilers with capacities between =20 MWth and < 50 MWth

  - Annual Stack Emission Testing: SO_2, NO_x and PM. For gaseous fuel-fired boilers, only NO_x. SO_2 can be calculated based on fuel quality certification (if no SO_2 control equipment is used)
  - Emission Monitoring: SO_2. Plants with SO_2 control equipment: Continuous. NO_x: Continuous monitoring of either NO_x emissions or indicative NO_x emissions using combustion parameters. PM: Continuous monitoring of either PM emissions, opacity, or indicative PM emissions using combustion parameters / visual monitoring.

- Additional recommended monitoring approaches for **turbines**:
  - Annual Stack Emission Testing: NO_x and SO_2 (NO_x only for gaseous fuel-fired turbines).
  - If Annual Stack Emission Testing results show constantly (3 consecutive years) and significantly (e.g. less than 75 percent) better than the required levels, frequency of Annual Stack Emission Testing can be reduced from annual to every two or three years.
  - Emission Monitoring: NO_x: Continuous monitoring of either NO_x emissions or indicative NO_x emissions using combustion parameters.SO_2: Continuous monitoring if SO_2 control equipment is used.

- Additional recommended monitoring approaches for **engines**:
  - Annual Stack Emission Testing: NO_x ,SO_2 and PM (NO_x only for gaseous fuel-fired diesel engines).

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26 An on-line catalogue of ISO standards relating to the environment, health protection, and safety is available at: http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?ICS1=13&ICS2=&ICS3=&scopelist=

27 An on-line catalogue of European Standards is available at: http://www.cen.eu/catweb/cwen.htm .

28 The National Environmental Methods Index provides a searchable clearinghouse of U.S. methods and procedures for both regulatory and non-regulatory monitoring purposes for water, sediment, air and tissues, and is available at http://www.nemi.gov/.

- If Annual Stack Emission Testing results show constantly (3 consecutive years) and significantly (e.g. less than 75 percent) better than the required levels, frequency of Annual Stack Emission Testing can be reduced from annual to every two or three years.
- Emission Monitoring: NO_x: Continuous monitoring of either NO_x emissions or indicative NO_x emissions using combustion parameters. SO_2: Continuous monitoring if SO_2 control equipment is used. PM: Continuous monitoring of either PM emissions or indicative PM emissions using operating parameters.

Annex 1.1.1 – Air Emissions Estimation and Dispersion Modeling Methods

The following is a partial list of documents to aid in the estimation of air emissions from various processes and air dispersion models:

Australian Emission Estimation Technique Manuals
http://www.npi.gov.au/handbooks/

Atmospheric Emission Inventory Guidebook, UN / ECE / EMEP and the European Environment Agency
http://www.aeat.co.uk/netcen/airqual/TFEI/unece.htm

Emission factors and emission estimation methods, US EPA Office of Air Quality Planning & Standards
http://www.epa.gov/ttn/chief

Guidelines on Air Quality Models (Revised), US Environmental Protection Agency (EPA), 2005
http://www.epa.gov/scram001/guidance/guide/appw_05.pdf

Frequently Asked Questions, Air Quality Modeling and Assessment Unit (AQMAU), UK Environment Agency
http://www.environment-agency.gov.uk/subjects/airquality/236092/?version=1&lang=_e

OECD Database on Use and Release of Industrial Chemicals
http://www.olis.oecd.org/ehs/urchem.nsf/

Annex 1.1.2 – Illustrative Point Source Air Emissions Prevention and Control Technologies

Principal Sources and Issues	General Prevention / Process Modification Approach	Control Options	Reduction Efficiency (%)	Gas Condition	Comments
Particulate Matter (PM)					
Main sources are the combustion of fossil fuels and numerous manufacturing processes that collect PM through air extraction and ventilation systems. Volcanoes, ocean spray, forest fires and blowing dust (most prevalent in dry and semiarid climates) contribute to background levels.	Fuel switching (e.g. selection of lower sulfur fuels) or reducing the amount of fine particulates added to a process.	Fabric Filters	99 - 99.7%	Dry gas, temp <400F	Applicability depends on flue gas properties including temperature, chemical properties, abrasion and load. Typical air to cloth ratio range of 2.0 to 3.5 cfm/ft^2 Achievable outlet concentrations of 23 mg/Nm^3
		Electrostatic Precipitator (ESP)	97 – 99%	Varies depending of particle type	Precondition gas to remove large particles. Efficiency dependent on resistivity of particle. Achievable outlet concentration of 23 mg/Nm^3
		Cyclone	74 – 95%	None	Most efficient for large particles. Achievable outlet concentrations of 30 - 40 mg/Nm^3
		Wet Scrubber	93 – 95%	None	Wet sludge may be a disposal problem depending on local infrastructure. Achievable outlet concentrations of 30 - 40 mg/Nm3
Sulfur Dioxide (SO_2)					
Mainly produced by the combustion of fuels such as oil and coal and as a by-product from some chemical production or wastewater treatment processes.	Control system selection is heavily dependent on the inlet concentration. For SO2 concentrations in excess of 10%, the stream is passed through an acid plant not only to lower the SO2 emissions but also to generate high grade sulfur for sale. Levels below 10% are not rich enough for this process and should therefore utilize absorption or 'scrubbing,' where SO2 molecules are captured into a liquid phase or adsorption, where SO2 molecules are captured on the surface of a solid adsorbent.	Fuel Switching	>90%		Alternate fuels may include low sulfur coal, light diesel or natural gas with consequent reduction in particulate emissions related to sulfur in the fuel. Fuel cleaning or beneficiation of fuels prior to combustion is another viable option but may have economic consequences.
		Sorbent Injection	30% - 70%		Calcium or lime is injected into the flue gas and the SO_2 is adsorbed onto the sorbent
		Dry Flue Gas Desulfurization	70%-90%		Can be regenerable or throwaway.
		Wet Flue Gas Desulfurization	>90%		Produces gypsum as a by-product

<table>
<tr><th colspan="6">Annex 1.1.2: Illustrative Point Source Air Emissions Prevention and Control Technologies (continued)</th></tr>
<tr><th colspan="2">Oxides of Nitrogen (NOx)</th><th colspan="3">Percent Reduction by Fuel Type</th><th>Comments</th></tr>
<tr><td rowspan="9">Associated with combustion of fuel. May occur in several forms of nitrogen oxide; namely nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O), which is also a greenhouse gas. The term NOx serves as a composite between NO and NO_2 and emissions are usually reported as NOx. Here the NO is multiplied by the ratio of molecular weights of NO_2 to NO and added to the NO_2 emissions.

Means of reducing NOx emissions are based on the modification of operating conditions such as minimizing the resident time at peak temperatures, reducing the peak temperatures by increasing heat transfer rates or minimizing the availability of oxygen.</td><td>Combustion modification (Illustrative of boilers)</td><td>Coal</td><td>Oil</td><td>Gas</td><td rowspan="6">These modifications are capable of reducing NOx emissions by 50 to 95%. The method of combustion control used depends on the type of boiler and the method of firing fuel.</td></tr>
<tr><td>Low-excess-air firing</td><td>10–30</td><td>10–30</td><td>10–30</td></tr>
<tr><td>Staged Combustion</td><td>20–50</td><td>20–50</td><td>20–50</td></tr>
<tr><td>Flue Gas Recirculation</td><td>N/A</td><td>20–50</td><td>20–50</td></tr>
<tr><td>Water/Steam Injection</td><td>N/A</td><td>10–50</td><td>N/A.</td></tr>
<tr><td>Low-NOx Burners</td><td>30–40</td><td>30–40</td><td>30–40</td></tr>
<tr><td>Flue Gas Treatment</td><td>Coal</td><td>Oil</td><td>Gas</td><td rowspan="3">Flue gas treatment is more effective in reducing NOx emissions than are combustion controls. Techniques can be classified as SCR, SNCR, and adsorption. SCR involves the injection of ammonia as a reducing agent to convert NOx to nitrogen in the presence of a catalyst in a converter upstream of the air heater. Generally, some ammonia slips through and is part of the emissions. SNCR also involves the injection of ammonia or urea based products without the presence of a catalyst.</td></tr>
<tr><td>Selective Catalytic Reduction (SCR)</td><td>60–90</td><td>60–90</td><td>60–90</td></tr>
<tr><td>Selective Non-Catalytic Reduction (SNCR)</td><td>N/A</td><td>30–70</td><td>30–70</td></tr>
<tr><td colspan="6">Note: Compiled by IFC based on inputs from technical experts.</td></tr>
</table>

Annex 1.1.3 - Good International Industry Practice (GIIP) Stack Height

(Based on United States 40 CFR, part 51.100 (ii)).

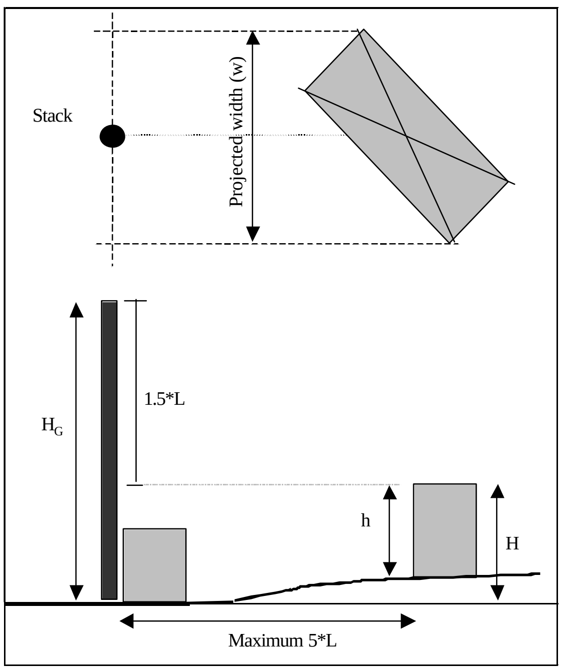
$H_G = H + 1.5L$; where

H_G = GEP stack height measured from the ground level elevation at the base of the stack

H = Height of nearby structure(s) above the base of the stack.

L = Lesser dimension, height (h) or width (w), of nearby structures

"Nearby structures" = Structures within/touching a radius of 5L but less than 800 m.



Annex 1.1.4 - Examples of VOC Emissions Controls

Equipment Type	Modification	Approximate Control Efficiency (%)
Pumps	Seal-less design	100[29]
	Closed-vent system	90[30]
	Dual mechanical seal with barrier fluid maintained at a higher pressure than the pumped fluid	100
Compressors	Closed-vent system	90
	Dual mechanical seal with barrier fluid maintained at a higher pressure than the compressed gas	100
Pressure Relief Devices	Closed-vent system	Variable[31]
	Rupture disk assembly	100
Valves	Seal-less design	100
Connectors	Weld together	100
Open-ended Lines	Blind, cap, plug, or second valve	100
Sampling Connections	Closed-loop sampling	100
Note: Examples of technologies are provided for illustrative purposes. The availability and applicability of any particular technology will vary depending on manufacturer specifications.		

29 Seal-less equipment can be a large source of emissions in the event of equipment failure.
30 Actual efficiency of a closed-vent system depends on percentage of vapors collected and efficiency of control device to which the vapors are routed.
31 Control efficiency of closed vent-systems installed on a pressure relief device may be lower than other closed-vent systems.

Annex 1.1.5 - Fugitive PM Emissions Controls

Control Type	Control Efficiency
Chemical Stabilization	0% - 98%
Hygroscopic salts Bitumens/adhesives	60% - 96%
Surfactants	0% - 68%
Wet Suppression – Watering	12% - 98%
Speed Reduction	0% - 80%
Traffic Reduction	Not quantified
Paving (Asphalt / Concrete)	85% - 99%
Covering with Gravel, Slag, or "Road Carpet"	30% - 50%
Vacuum Sweeping	0% - 58%
Water Flushing/Broom Sweeping	0% - 96%

1.2 Energy Conservation

Applicability and Approach

This guideline applies to facilities or projects that consume energy in process heating and cooling; process and auxiliary systems, such as motors, pumps, and fans; compressed air systems and heating, ventilation and air conditioning systems (HVAC); and lighting systems. It complements the industry-specific emissions guidance presented in the Industry Sector Environmental, Health, and Safety (EHS) Guidelines by providing information about common techniques for energy conservation that may be applied to a range of industry sectors.

Energy management at the facility level should be viewed in the context of overall consumption patterns, including those associated with production processes and supporting utilities, as well as overall impacts associated with emissions from power sources. The following section provides guidance on energy management with a focus on common utility systems often representing technical and financially feasible opportunities for improvement in energy conservation. However, operations should also evaluate energy conservation opportunities arising from manufacturing process modifications.

Energy Management Programs

Energy management programs should include the following elements:

- Identification, and regular measurement and reporting of principal energy flows within a facility at unit process level
- Preparation of mass and energy balance;
- Definition and regular review of energy performance targets, which are adjusted to account for changes in major influencing factors on energy use
- Regular comparison and monitoring of energy flows with performance targets to identify where action should be taken to reduce energy use
- Regular review of targets, which may include comparison with benchmark data, to confirm that targets are set at appropriate levels

Energy Efficiency

For any energy-using system, a systematic analysis of energy efficiency improvements and cost reduction opportunities should include a hierarchical examination of opportunities to**:**

- Demand/Load Side Management by reducing loads on the energy system
- Supply Side Management by:
    - Reduce losses in energy distribution
    - Improve energy conversion efficiency
    - Exploit energy purchasing opportunities
    - Use lower-carbon fuels

Common opportunities in each of these areas are summarized below.[32]

Process Heating

Process heating is vital to many manufacturing processes, including heating for fluids, calcining, drying, heat treating, metal heating, melting, melting agglomeration, curing, and forming[33].

In process heating systems, a system heat and mass balance will show how much of the system's energy input provides true process heating, and quantify fuel used to satisfy energy losses caused by excessive parasitic loads, distribution, or conversion losses. Examination of savings opportunities should be directed by the results of the heat and mass balance, though the following techniques are often valuable and cost-effective.

Heating Load Reduction

- Ensure adequate insulation to reduce heat losses through furnace/oven etc. structure
- Recover heat from hot process or exhaust streams to reduce system loads
- In intermittently-heated systems, consider use of low thermal mass insulation to reduce energy required to heat the system structure to operating temperature
- Control process temperature and other parameters accurately to avoid, for example, overheating or overdrying
- Examine opportunities to use low weight and/or low thermal mass product carriers, such as heated shapers, kiln cars etc.
- Review opportunities to schedule work flow to limit the need for process reheating between stages
- Operate furnaces/ovens at slight positive pressure, and maintain air seals to reduce air in-leakage into the heated system, thereby reducing the energy required to heat unnecessary air to system operating temperature
- Reduce radiant heat losses by sealing structural openings and keep viewing ports closed when not in use
- Where possible, use the system for long runs close to or at operating capacity
- Consider use of high emissivity coatings of high temperature insulation, and consequent reduction in process temperature
- Near net weight and shape heat designs
- Robust Quality assurance on input material
- Robust Scheduled maintenance programs

Heat Distribution Systems

Heat distribution in process heating applications typically takes place through steam, hot water, or thermal fluid systems. Losses can be reduced through the following actions:

- Promptly repair distribution system leaks
- Avoid steam leaks despite a perceived need to get steam through the turbine. Electricity purchase is usually cheaper overall, especially when the cost to treat turbine-quality boiler feed water is included. If the heat-power ratio of the distribution process is less than that of power systems, opportunities should be considered to increase the ratio; for example, by using low-pressure steam to drive absorption cooling systems rather than using electrically-driven vapor-compression systems.
- Regularly verify correct operation of steam traps in steam systems, and ensure that traps are not bypassed. Since

32 Additional guidance on energy efficiency is available from sources such as Natural Resources Canada (NRCAN http://oee.nrcan.gc.ca/commercial/financial-assistance/new-buildings/mnecb.cfm?attr=20); the European Union (EUROPA. http://europa.eu.int/scadplus/leg/en/s15004.htm), and United States Department of Energy (US DOE, http://www.eere.energy.gov/consumer/industry/process.html).

33 US DOE. http://www.eere.energy.gov/consumer/industry/process.html

steam traps typically last approximately 5 years, 20% should be replaced or repaired annually

- Insulate distribution system vessels, such as hot wells and de-aerators, in steam systems and thermal fluid or hot water storage tanks
- Insulate all steam, condensate, hot water and thermal fluid distribution pipework, down to and including 1" (25 mm) diameter pipe, in addition to insulating all hot valves and flanges
- In steam systems, return condensate to the boiler house for re-use, since condensate is expensive boiler-quality water and valuable beyond its heat content alone
- Use flash steam recovery systems to reduce losses due to evaporation of high-pressure condensate
- Consider steam expansion through a back-pressure turbine rather than reducing valve stations
- Eliminate distribution system losses by adopting point-of-use heating systems

Energy Conversion System Efficiency Improvements

The following efficiency opportunities should be examined for process furnaces or ovens, and utility systems, such as boilers and fluid heaters:

- Regularly monitor CO, oxygen or CO2 content of flue gases to verify that combustion systems are using the minimum practical excess air volumes
- Consider combustion automation using oxygen-trim controls
- Minimize the number of boilers or heaters used to meet loads. It is typically more efficient to run one boiler at 90% of capacity than two at 45%. Minimize the number of boilers kept at hot–standby
- Use flue dampers to eliminate ventilation losses from hot boilers held at standby
- Maintain clean heat transfer surfaces; in steam boilers, flue gases should be no more than 20 K above steam temperature)
- In steam boiler systems, use economizers to recover heat from flue gases to pre-heat boiler feed water or combustion air
- Consider reverse osmosis or electrodialysis feed water treatment to minimize the requirement for boiler blowdown
- Adopt automatic (continuous) boiler blowdown
- Recover heat from blowdown systems through flash steam recovery or feed-water preheat
- Do not supply excessive quantities of steam to the de-aerator
- With fired heaters, consider opportunities to recover heat to combustion air through the use of recuperative or regenerative burner systems
- For systems operating for extended periods (> 6000 hours/year), cogeneration of electrical power, heat and /or cooling can be cost effective
- Oxy Fuel burners
- Oxygen enrichment/injection
- Use of turbolators in boilers
- Sizing design and use of multiple boilers for different load configurations
- Fuel quality control/fuel blending

Process Cooling

The general methodology outlined above should be applied to process cooling systems. Commonly used and cost-effective measures to improve process cooling efficiency are described below.

Load Reduction

- Ensure adequate insulation to reduce heat gains through cooling system structure and to below-ambient temperature refrigerant pipes and vessels
- Control process temperature accurately to avoid overcooling
- Operate cooling tunnels at slight positive pressure and maintain air seals to reduce air in-leakage into the cooled system, thus reducing the energy required to cool this unnecessary air to system operating temperature
- Examine opportunities to pre-cool using heat recovery to a process stream requiring heating, or by using a higher temperature cooling utility
- In cold and chill stores, minimize heat gains to the cooled space by use of air curtains, entrance vestibules, or rapidly opening/closing doors. Where conveyors carry products into chilled areas, minimize the area of transfer openings, for example, by using strip curtains
- Quantify and minimize "incidental" cooling loads, for example, those due to evaporator fans, other machinery, defrost systems and lighting in cooled spaces, circulation fans in cooling tunnels, or secondary refrigerant pumps (e.g. chilled water, brines, glycols)
- Do not use refrigeration for auxiliary cooling duties, such as compressor cylinder head or oil cooling
- While not a thermal load, ensure there is no gas bypass of the expansion valve since this imposes compressor load while providing little effective cooling
- In the case of air conditioning applications, energy efficiency techniques include:
    - Placing air intakes and air-conditioning units in cool, shaded locations
    - Improving building insulation including seals, vents, windows, and doors
    - Planting trees as thermal shields around buildings
    - Installing timers and/or thermostats and/or enthalpy-based control systems
    - Installing ventilation heat recovery systems[34]

Energy Conversion

The efficiency of refrigeration service provision is normally discussed in terms of Coefficient of Performance ("COP"), which is the ratio of cooling duty divided by input power. COP is maximized by effective refrigeration system design and increased refrigerant compression efficiency, as well as minimization of the temperature difference through which the system works and of auxiliary loads (i.e. those in addition to compressor power demand) used to operate the refrigeration system.

System Design

- If process temperatures are above ambient for all, or part, of the year, use of ambient cooling systems, such as provided by cooling towers or dry air coolers, may be appropriate, perhaps supplemented by refrigeration in summer conditions.
- Most refrigeration systems are electric-motor driven vapor compression systems using positive displacement or centrifugal compressors. The remainder of this guideline relates primarily to vapor-compression systems. However, when a cheap or free heat source is available (e.g. waste heat from an engine-driven generator—low-pressure steam

[34] More information on HVAC energy efficiency can be found at the British Columbia Building Corporation (Woolliams, 2002. http://www.greenbuildingsbc.com/new_buildings/pdf_files/greenbuild_strategies_guide.pdf), NRCAN's EnerGuide (http://oee.nrcan.gc.ca/equipment/english/index.cfm?PrintView=N&Text=N) and NRCAN's Energy Star Programs (http://oee.nrcan.gc.ca/energystar/english/consumers/heating.cfm?text=N&printview=N#AC), and the US Energy Star Program (http://www.energystar.gov/index.cfm?c=guidelines.download_guidelines).

that has passed through a back-pressure turbine), absorption refrigeration may be appropriate.

- Exploit high cooling temperature range: precooling by ambient and/or 'high temperature' refrigeration before final cooling can reduce refrigeration capital and running costs. High cooling temperature range also provides an opportunity for countercurrent (cascade) cooling, which reduces refrigerant flow needs.
- Keep 'hot' and 'cold' fluids separate, for example, do not mix water leaving the chiller with water returning from cooling circuits.
- In low-temperature systems where high temperature differences are inevitable, consider two-stage or compound compression, or economized screw compressors, rather than single-stage compression.

Minimizing Temperature Differences

A vapor-compression refrigeration system raises the temperature of the refrigerant from somewhat below the lowest process temperature (the evaporating temperature) to provide process cooling, to a higher temperature (the condensing temperature), somewhat above ambient, to facilitate heat rejection to the air or cooling water systems. Increasing evaporating temperature typically increases compressor cooling capacity without greatly affecting power consumption. Reducing condensing temperature increases evaporator cooling capacity and substantially reduces compressor power consumption.

Elevating Evaporating Temperature

- Select a large evaporator to permit relatively low temperature differences between process and evaporating temperatures. Ensure that energy use of auxiliaries (e.g. evaporator fans) does not outweigh compression savings. In air-cooling applications, a design temperature difference of 6-10 K between leaving air temperature and evaporating temperature is indicative of an appropriately sized evaporator. When cooling liquids, 2K between leaving liquid and evaporating temperatures can be achieved, though a 4K difference is generally indicative of a generously-sized evaporator.
- Keep the evaporator clean. When cooling air, ensure correct defrost operation. In liquid cooling, monitor refrigerant/process temperature differences and compare with design expectations to be alert to heat exchanger contamination by scale or oil.
- Ensure oil is regularly removed from the evaporator, and that oil additions and removals balance.
- Avoid the use of back-pressure valves.
- Adjust expansion valves to minimize suction superheat consistent with avoidance of liquid carry-over to compressors.
- Ensure that an appropriate refrigerant charge volume is present.

Reducing Condensing Temperature

- Consider whether to use air-cooled or evaporation-based cooling (e.g. evaporative or water cooled condensers and cooling towers). Air-cooled evaporators usually have higher condensing temperatures, hence higher compressor energy use, and auxiliary power consumption, especially in low humidity climates. If a wet system is used, ensure adequate treatment to prevent growth of *legionella* bacteria.
- Whichever basic system is chosen, select a relatively large condenser to minimize differences between condensing and the heat sink temperatures. Condensing temperatures with air cooled or evaporative condensers should not be more than 10K above design ambient condition, and a 4K approach in a liquid-cooled condenser is possible.

- Avoid accumulation of non-condensable gases in the condenser system. Consider the installation of refrigerated non-condensable purgers, particularly for systems operating below atmospheric pressure.
- Keep condensers clean and free from scale. Monitor refrigerant/ambient temperature differences and compare with design expectations to be alert to heat exchanger contamination.
- Avoid liquid backup, which restricts heat transfer area in condensers. This can be caused by installation errors such as concentric reducers in horizontal liquid refrigerant pipes, or "up and over" liquid lines leading from condensers.
- In multiple condenser applications, refrigerant liquid lines should be connected via drop-leg traps to the main liquid refrigerant line to ensure that hot gases flow to all condensers.
- Avoid head pressure control to the extent possible. Head pressure control maintains condensing temperature at, or near, design levels. It therefore prevents reduction in compressor power consumption, which accompanies reduced condensing temperature, by restricting condenser capacity (usually by switching off the condenser, or cooling tower fans, or restricting cooling water flow) under conditions of less severe than design load or ambient temperature conditions. Head pressure is often kept higher than necessary to facilitate hot gas defrost or adequate liquid refrigerant circulation. Use of electronic rather than thermostatic expansion valves, and liquid refrigerant pumps can permit effective refrigerant circulation at much reduced condensing temperatures.
- Site condensers and cooling towers with adequate spacing so as to prevent recirculation of hot air into the tower.

Refrigerant Compression Efficiency

- Some refrigerant compressors and chillers are more efficient than others offered for the same duty. Before purchase, identify the operating conditions under which the compressor or chiller is likely to operate for substantial parts of its annual cycle. Check operating efficiency under these conditions, and ask for estimates of annual running cost. Note that refrigeration and HVAC systems rarely run for extended periods at design conditions, which are deliberately extreme. Operational efficiency under the most commonly occurring off-design conditions is likely to be most important.
- Compressors lose efficiency when unloaded. Avoid operation of multiple compressors at part-load conditions. Note that package chillers can gain coefficient of performance (COP) when slightly unloaded, as loss of compressor efficiency can be outweighed by the benefits of reduced condensing and elevated evaporating temperature. However, it is unlikely to be energy efficient to operate a single compressor-chiller at less than 50% of capacity.
- Consider turndown efficiency when specifying chillers. Variable speed control or multiple compressor chillers can be highly efficient at part loads.
- Use of thermal storage systems (e.g., ice storage) can avoid the need for close load-tracking and, hence, can avoid part-loaded compressor operation.

Refrigeration System Auxiliaries

Many refrigeration system auxiliaries (e.g. evaporator fans and chilled water pumps) contribute to refrigeration system load, so reductions in their energy use have a double benefit. General energy saving techniques for pumps and fans, listed in the next section of these guidelines, should be applied to refrigeration auxiliaries.

Additionally, auxiliary use can be reduced by avoidance of part-load operation and in plant selection (e.g. axial fan evaporative condensers generally use less energy than equivalent centrifugal fan towers).

Under extreme off-design conditions, reduction in duty of cooling system fans and pumps can be worthwhile, usually when the lowest possible condensing pressure has been achieved.

Compressed Air Systems

Compressed air is the most commonly found utility service in industry, yet in many compressed air systems, the energy contained in compressed air delivered to the user is often 10% or less of energy used in air compression. Savings are often possible through the following techniques:

Load reduction

- Examine each true user of compressed air to identify the air volume needed and the pressure at which this should be delivered.
- Do not mix high volume low pressure and low volume high pressure loads. Decentralize low volume high-pressure applications or provide dedicated low-pressure utilities, for example, by using fans rather than compressed air.
- Review air use reduction opportunities, for example:
    - Use air amplifier nozzles rather than simple open-pipe compressed air jets
    - Consider whether compressed air is needed at all
    - Where air jets are required intermittently (e.g. to propel product), consider operating the jet via a process-related solenoid valve, which opens only when air is required
    - Use manual or automatically operated valves to isolate air supply to individual machines or zones that are not in continuous use
    - Implement systems for systematic identification and repair of leaks
    - All condensate drain points should be trapped. Do not leave drain valves continuously 'cracked open'
    - Train workers never to direct compressed air against their bodies or clothing to dust or cool themselves down.

Distribution

- Monitor pressure losses in filters and replace as appropriate
- Use adequately sized distribution pipework designed to minimize pressure losses

1.3 Wastewater and Ambient Water Quality

Applicability and Approach

This guideline applies to projects that have either direct or indirect discharge of process wastewater, wastewater from utility operations or stormwater to the environment. These guidelines are also applicable to industrial discharges to sanitary sewers that discharge to the environment without any treatment. Process wastewater may include contaminated wastewater from utility operations, stormwater, and sanitary sewage. It provides information on common techniques for wastewater management, water conservation, and reuse that can be applied to a wide range of industry sectors. This guideline is meant to be complemented by the industry-specific effluent guidelines presented in the Industry Sector Environmental, Health, and Safety (EHS) Guidelines. Projects with the potential to generate process wastewater, sanitary (domestic) sewage, or stormwater should incorporate the necessary precautions to avoid, minimize, and control adverse impacts to human health, safety, or the environment.

In the context of their overall ESHS management system, facilities should:

- Understand the quality, quantity, frequency and sources of liquid effluents in its installations. This includes knowledge about the locations, routes and integrity of internal drainage systems and discharge points
- Plan and implement the segregation of liquid effluents principally along industrial, utility, sanitary, and stormwater categories, in order to limit the volume of water requiring specialized treatment. Characteristics of individual streams may also be used for source segregation.
- Identify opportunities to prevent or reduce wastewater pollution through such measures as recycle/reuse within their facility, input substitution, or process modification (e.g. change of technology or operating conditions/modes).
- Assess compliance of their wastewater discharges with the applicable: (i) discharge standard (if the wastewater is discharged to a surface water or sewer), and (ii) water quality standard for a specific reuse (e.g. if the wastewater is reused for irrigation).

Additionally, the generation and discharge of wastewater of any type should be managed through a combination of:

- Water use efficiency to reduce the amount of wastewater generation
- Process modification, including waste minimization, and reducing the use of hazardous materials to reduce the load of pollutants requiring treatment
- If needed, application of wastewater treatment techniques to further reduce the load of contaminants prior to discharge, taking into consideration potential impacts of cross-media transfer of contaminants during treatment (e.g., from water to air or land)

When wastewater treatment is required prior to discharge, the level of treatment should be based on:

- Whether wastewater is being discharged to a sanitary sewer system, or to surface waters
- National and local standards as reflected in permit requirements and sewer system capacity to convey and treat wastewater if discharge is to sanitary sewer
- Assimilative capacity of the receiving water for the load of contaminant being discharged wastewater if discharge is to surface water
- Intended use of the receiving water body (e.g. as a source of drinking water, recreation, irrigation, navigation, or other)
- Presence of sensitive receptors (e.g., endangered species) or habitats
- Good International Industry Practice (GIIP) for the relevant industry sector

General Liquid Effluent Quality

Discharge to Surface Water

Discharges of process wastewater, sanitary wastewater, wastewater from utility operations or stormwater to surface water should not result in contaminant concentrations in excess of local ambient water quality criteria or, in the absence of local criteria, other sources of ambient water quality.[35] Receiving water use[36] and assimilative capacity[37], taking other sources of discharges to the receiving water into consideration, should also influence the acceptable pollution loadings and effluent discharge quality. Additional considerations that should be included in the setting of project-specific performance levels for wastewater effluents include:

- Process wastewater treatment standards consistent with applicable Industry Sector EHS Guidelines. Projects for which there are no industry-specific guidelines should reference the effluent quality guidelines of an industry sector with suitably analogous processes and effluents;
- Compliance with national or local standards for sanitary wastewater discharges or, in their absence, the indicative guideline values applicable to sanitary wastewater discharges shown in Table 1.3.1 below;
- Temperature of wastewater prior to discharge does not result in an increase greater than 3°C of ambient temperature at the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use and assimilative capacity among other considerations.

Discharge to Sanitary Sewer Systems

Discharges of industrial wastewater, sanitary wastewater, wastewater from utility operations or stormwater into public or private wastewater treatment systems should:

- Meet the pretreatment and monitoring requirements of the sewer treatment system into which it discharges.
- Not interfere, directly or indirectly, with the operation and maintenance of the collection and treatment systems, or pose a risk to worker health and safety, or adversely impact

[35] An example is the US EPA National Recommended Water Quality Criteria http://www.epa.gov/waterscience/criteria/wqcriteria.html

[36] Examples of receiving water uses as may be designated by local authorities include: drinking water (with some level of treatment), recreation, aquaculture, irrigation, general aquatic life, ornamental, and navigation. Examples of health-based guideline values for receiving waters include World Health Organization (WHO) guidelines for recreational use (http://www.who.int/water_sanitation_health/dwq/guidelines/en/index.html)

[37] The assimilative capacity of the receiving water body depends on numerous factors including, but not limited to, the total volume of water, flow rate, flushing rate of the water body and the loading of pollutants from other effluent sources in the area or region. A seasonally representative baseline assessment of ambient water quality may be required for use with established scientific methods and mathematical models to estimate potential impact to the receiving water from an effluent source.

characteristics of residuals from wastewater treatment operations.

- Be discharged into municipal or centralized wastewater treatment systems that have adequate capacity to meet local regulatory requirements for treatment of wastewater generated from the project. Pretreatment of wastewater to meet regulatory requirements before discharge from the project site is required if the municipal or centralized wastewater treatment system receiving wastewater from the project does not have adequate capacity to maintain regulatory compliance.

Land Application of Treated Effluent

The quality of treated process wastewater, wastewater from utility operations or stormwater discharged on land, including wetlands, should be established based on local regulatory requirements. . Where land is used as part of the treatment system and the ultimate receptor is surface water, water quality guidelines for surface water discharges specific to the industry sector process should apply.[38] Potential impact on soil, groundwater, and surface water, in the context of protection, conservation and long term sustainability of water and land resources should be assessed when land is used as part of any wastewater treatment system.

Septic Systems

Septic systems are commonly used for treatment and disposal of domestic sanitary sewage in areas with no sewerage collection networks, Septic systems should only be used for treatment of sanitary sewage, and unsuitable for industrial wastewater treatment. When septic systems are the selected form of wastewater disposal and treatment, they should be:

- Properly designed and installed in accordance with local regulations and guidance to prevent any hazard to public health or contamination of land, surface or groundwater.
- Well maintained to allow effective operation.
- Installed in areas with sufficient soil percolation for the design wastewater loading rate.
- Installed in areas of stable soils that are nearly level, well drained, and permeable, with enough separation between the drain field and the groundwater table or other receiving waters.

Wastewater Management

Wastewater management includes water conservation, wastewater treatment, stormwater management, and wastewater and water quality monitoring.

Industrial Wastewater

Industrial wastewater generated from industrial operations includes process wastewater, wastewater from utility operations,, runoff from process and materials staging areas, and miscellaneous activities including wastewater from laboratories, equipment maintenance shops, etc.. The pollutants in an industrial wastewater may include acids or bases (exhibited as low or high pH), soluble organic chemicals causing depletion of dissolved oxygen, suspended solids, nutrients (phosphorus, nitrogen), heavy metals (e.g. cadmium, chromium, copper, lead, mercury, nickel, zinc), cyanide, toxic organic chemicals, oily materials, and volatile materials. , as well as from thermal characteristics of the discharge (e.g., elevated temperature). Transfer of pollutants to another phase, such as air, soil, or the sub-surface, should be minimized through process and engineering controls.

Process Wastewater – – Examples of treatment approaches typically used in the treatment of industrial wastewater are summarized in Annex 1.3.1. While the choice of treatment

[38] Additional guidance on water quality considerations for land application is available in the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume 2: Wastewater Use in Agriculture http://www.who.int/water_sanitation_health/wastewater/gsuweg2/en/index.html

technology is driven by wastewater characteristics, the actual performance of this technology depends largely on the adequacy of its design, equipment selection, as well as operation and maintenance of its installed facilities. Adequate resources are required for proper operation and maintenance of a treatment facility, and performance is strongly dependent on the technical ability and training of its operational staff. One or more treatment technologies may be used to achieve the desired discharge quality and to maintain consistent compliance with regulatory requirements. The design and operation of the selected wastewater treatment technologies should avoid uncontrolled air emissions of volatile chemicals from wastewaters. Residuals from industrial wastewater treatment operations should be disposed in compliance with local regulatory requirements, in the absence of which disposal has to be consistent with protection of public health and safety, and conservation and long term sustainability of water and land resources.

Wastewater from Utilities Operations - Utility operations such as cooling towers and demineralization systems may result in high rates of water consumption, as well as the potential release of high temperature water containing high dissolved solids, residues of biocides, residues of other cooling system anti-fouling agents, etc. Recommended water management strategies for utility operations include:

- Adoption of water conservation opportunities for facility cooling systems as provided in the Water Conservation section below;
- Use of heat recovery methods (also energy efficiency improvements) or other cooling methods to reduce the temperature of heated water prior to discharge to ensure the discharge water temperature does not result in an increase greater than 3°C of ambient temperature at the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use, potential receptors and assimilative capacity among other considerations;
- Minimizing use of antifouling and corrosion inhibiting chemicals by ensuring appropriate depth of water intake and use of screens. Least hazardous alternatives should be used with regards to toxicity, biodegradability, bioavailability, and bioaccumulation potential. Dose applied should accord with local regulatory requirements and manufacturer recommendations;
- Testing for residual biocides and other pollutants of concern should be conducted to determine the need for dose adjustments or treatment of cooling water prior to discharge.

Stormwater Management - Stormwater includes any surface runoff and flows resulting from precipitation, drainage or other sources. Typically stormwater runoff contains suspended sediments, metals, petroleum hydrocarbons, Polycyclic Aromatic Hydrocarbons (PAHs), coliform, etc. Rapid runoff, even of uncontaminated stormwater, also degrades the quality of the receiving water by eroding stream beds and banks. In order to reduce the need for stormwater treatment, the following principles should be applied:

- Stormwater should be separated from process and sanitary wastewater streams in order to reduce the volume of wastewater to be treated prior to discharge
- Surface runoff from process areas or potential sources of contamination should be prevented
- Where this approach is not practical, runoff from process and storage areas should be segregated from potentially less contaminated runoff
- Runoff from areas without potential sources of contamination should be minimized (e.g. by minimizing the area of impermeable surfaces) and the peak discharge rate should

be reduced (e.g. by using vegetated swales and retention ponds);

- Where stormwater treatment is deemed necessary to protect the quality of receiving water bodies, priority should be given to managing and treating the first flush of stormwater runoff where the majority of potential contaminants tend to be present;
- When water quality criteria allow, stormwater should be managed as a resource, either for groundwater recharge or for meeting water needs at the facility;
- Oil water separators and grease traps should be installed and maintained as appropriate at refueling facilities, workshops, parking areas, fuel storage and containment areas.
- Sludge from stormwater catchments or collection and treatment systems may contain elevated levels of pollutants and should be disposed in compliance with local regulatory requirements, in the absence of which disposal has to be consistent with protection of public health and safety, and conservation and long term sustainability of water and land resources.

Sanitary Wastewater

Sanitary wastewater from industrial facilities may include effluents from domestic sewage, food service, and laundry facilities serving site employees. Miscellaneous wastewater from laboratories, medical infirmaries, water softening etc. may also be discharged to the sanitary wastewater treatment system. Recommended sanitary wastewater management strategies include:

- Segregation of wastewater streams to ensure compatibility with selected treatment option (e.g. septic system which can only accept domestic sewage);
- Segregation and pretreatment of oil and grease containing effluents (e.g. use of a grease trap) prior to discharge into sewer systems;
- If sewage from the industrial facility is to be discharged to surface water, treatment to meet national or local standards for sanitary wastewater discharges or, in their absence, the indicative guideline values applicable to sanitary wastewater discharges shown in Table 1.3.1;
- If sewage from the industrial facility is to be discharged to either a septic system, or where land is used as part of the treatment system, treatment to meet applicable national or local standards for sanitary wastewater discharges is required.
- Sludge from sanitary wastewater treatment systems should be disposed in compliance with local regulatory requirements, in the absence of which disposal has to be consistent with protection of public health and safety, and conservation and long term sustainability of water and land resources.

Table 1.3.1 Indicative Values for Treated Sanitary Sewage Discharges[a]

Pollutants	Units	Guideline Value
pH	pH	6 – 9
BOD	mg/l	30
COD	mg/l	125
Total nitrogen	mg/l	10
Total phosphorus	mg/l	2
Oil and grease	mg/l	10
Total suspended solids	mg/l	50
Total coliform bacteria	MPN[b] / 100 ml	400[a]

Notes:
[a] Not applicable to centralized, municipal, wastewater treatment systems which are included in EHS Guidelines for Water and Sanitation.
[b] MPN = Most Probable Number

Emissions from Wastewater Treatment Operations

Air emissions from wastewater treatment operations may include hydrogen sulfide, methane, ozone (in the case of ozone disinfection), volatile organic compounds (e.g., chloroform generated from chlorination activities and other volatile organic compounds (VOCs) from industrial wastewater), gaseous or volatile chemicals used for disinfection processes (e.g., chlorine and ammonia), and bioaerosols. Odors from treatment facilities can also be a nuisance to workers and the surrounding community. Recommendations for the management of emissions are presented in the Air Emissions and Ambient Air Quality section of this document and in the EHS Guidelines for Water and Sanitation.

Residuals from Wastewater Treatment Operations

Sludge from a waste treatment plant needs to be evaluated on a case-by-case basis to establish whether it constitutes a hazardous or a non-hazardous waste and managed accordingly as described in the Waste Management section of this document.

Occupational Health and Safety Issues in Wastewater Treatment Operations

Wastewater treatment facility operators may be exposed to physical, chemical, and biological hazards depending on the design of the facilities and the types of wastewater effluents managed. Examples of these hazards include the potential for trips and falls into tanks, confined space entries for maintenance operations, and inhalation of VOCs, bioaerosols, and methane, contact with pathogens and vectors, and use of potentially hazardous chemicals, including chlorine, sodium and calcium hypochlorite, and ammonia. Detailed recommendations for the management of occupational health and safety issues are presented in the relevant section of this document. Additional guidance specifically applicable to wastewater treatment systems is provided in the EHS Guidelines for Water and Sanitation.

Monitoring

A wastewater and water quality monitoring program with adequate resources and management oversight should be developed and implemented to meet the objective(s) of the monitoring program. The wastewater and water quality monitoring program should consider the following elements:

- *Monitoring parameters*: The parameters selected for monitoring should be indicative of the pollutants of concern from the process, and should include parameters that are regulated under compliance requirements;

- *Monitoring type and frequency*: Wastewater monitoring should take into consideration the discharge characteristics from the process over time. Monitoring of discharges from processes with batch manufacturing or seasonal process variations should take into consideration of time-dependent variations in discharges and, therefore, is more complex than monitoring of continuous discharges. Effluents from highly variable processes may need to be sampled more frequently or through composite methods. Grab samples or, if automated equipment permits, composite samples may offer more insight on average concentrations of pollutants over a 24-hour period. Composite samplers may not be appropriate where analytes of concern are short-lived (e.g., quickly degraded or volatile).

- *Monitoring locations*: The monitoring location should be selected with the objective of providing representative monitoring data. Effluent sampling stations may be located at the final discharge, as well as at strategic upstream points prior to merging of different discharges. Process discharges should not be diluted prior or after treatment with the objective of meeting the discharge or ambient water quality standards.

- *Data quality*: Monitoring programs should apply internationally approved methods for sample collection, preservation and analysis. Sampling should be conducted by or under the supervision of trained individuals. Analysis should be conducted by entities permitted or certified for this purpose. Sampling and Analysis Quality Assurance/Quality Control (QA/QC) plans should be prepared and, implemented. QA/QC documentation should be included in monitoring reports.

Annex 1.3.1 - Examples of Industrial Wastewater Treatment Approaches

Pollutant/Parameter	Control Options / Principle	Common End of Pipe Control Technology
pH	Chemical, Equalization	Acid/Base addition, Flow equalization
Oil and Grease / TPH	Phase separation	Dissolved Air Floatation, oil water separator, grease trap
TSS - Settleable	Settling, Size Exclusion	Sedimentation basin, clarifier, centrifuge, screens
TSS - Non-Settleable	Floatation, Filtration - traditional and tangential	Dissolved air floatation, Multimedia filter, sand filter, fabric filter, ultrafiltration, microfiltration
Hi - BOD (> 2 Kg/m^3)	Biological - Anaerobic	Suspended growth, attached growth, hybrid
Lo - BOD (< 2 Kg/m^3)	Biological - Aerobic, Facultative	Suspended growth, attached growth, hybrid
COD - Non-Biodegradable	Oxidation, Adsorption, Size Exclusion	Chemical oxidation, Thermal oxidation, Activated Carbon, Membranes
Metals - Particulate and Soluble	Coagulation, flocculation, precipitation, size exclusion	Flash mix with settling, filtration - traditional and tangential
Inorganics / Non-metals	Coagulation, flocculation, precipitation, size exclusion, Oxidation, Adsorption	Flash mix with settling, filtration - traditional and tangential, Chemical oxidation, Thermal oxidation, Activated Carbon, Reverse Osmosis, Evaporation
Organics - VOCs and SVOCs	Biological - Aerobic, Anaerobic, Facultative; Adsorption, Oxidation	Biological : Suspended growth, attached growth, hybrid; Chemical oxidation, Thermal oxidation, Activated Carbon
Emissions – Odors and VOCs	Capture – Active or Passive; Biological; Adsorption, Oxidation	Biological : Attached growth; Chemical oxidation, Thermal oxidation, Activated Carbon
Nutrients	Biological Nutrient Removal, Chemical, Physical, Adsorption	Aerobic/Anoxic biological treatment, chemical hydrolysis and air stripping, chlorination, ion exchange
Color	Biological - Aerobic, Anaerobic, Facultative; Adsorption, Oxidation	Biological Aerobic, Chemical oxidation, Activated Carbon
Temperature	Evaporative Cooling	Surface Aerators, Flow Equalization
TDS	Concentration, Size Exclusion	Evaporation, crystallization, Reverse Osmosis
Active Ingredients/Emerging Contaminants	Adsorption, Oxidation, Size Exclusion, Concentration	Chemical oxidation, Thermal oxidation, Activated Carbon, Ion Exchange, Reverse Osmosis, Evaporation, Crystallization
Radionuclides	Adsorption,Size Exclusion, Concentration	Ion Exchange, Reverse Osmosis, Evaporation, Crystallization
Pathogens	Disinfection, Sterilization	Chlorine, Ozone, Peroxide, UV, Thermal
Toxicity	Adsorption, Oxidation, Size Exclusion, Concentration	Chemical oxidation, Thermal oxidation, Activated Carbon, Evaporation, crystallization, Reverse Osmosis

1.4 Water Conservation

Applicability and Approach

Water conservation programs should be implemented commensurate with the magnitude and cost of water use. These programs should promote the continuous reduction in water consumption and achieve savings in the water pumping, treatment and disposal costs. Water conservation measures may include water monitoring/management techniques; process and cooling/heating water recycling, reuse, and other techniques; and sanitary water conservation techniques.

General recommendations include:

- Storm/Rainwater harvesting and use
- Zero discharge design/Use of treated waste water to be included in project design processes
- Use of localized recirculation systems in plant/facility/shops (as opposed to centralized recirculation system), with provision only for makeup water
- Use of dry process technologies e.g. dry quenching
- Process water system pressure management
- Project design to have measures for adequate water collection, spill control and leakage control system

Water Monitoring and Management

The essential elements of a water management program involve:

- Identification, regular measurement, and recording of principal flows within a facility;
- Definition and regular review of performance targets, which are adjusted to account for changes in major factors affecting water use (e.g. industrial production rate);
- Regular comparison of water flows with performance targets to identify where action should be taken to reduce water use.

Water measurement (metering) should emphasize areas of greatest water use. Based on review of metering data, 'unaccounted' use–indicating major leaks at industrial facilities–could be identified.

Process Water Reuse and Recycling

Opportunities for water savings in industrial processes are highly industry-specific. However, the following techniques have all been used successfully, and should be considered in conjunction with the development of the metering system described above.

- *Washing Machines:* Many washing machines use large quantities of hot water. Use can increase as nozzles become enlarged due to repeated cleaning and /or wear. Monitor machine water use, compare with specification, and replace nozzles when water and heat use reaches levels warranting such work.

- *Water reuse:* Common water reuse applications include countercurrent rinsing, for example in multi-stage washing and rinsing processes, or reusing waste water from one process for another with less exacting water requirements. For example, using bleaching rinse water for textile washing, or bottle-washer rinse water for bottle crate washing, or even washing the floor. More sophisticated reuse projects requiring treatment of water before reuse are also sometimes practical.

- *Water jets/sprays:* If processes use water jets or sprays (e.g. to keep conveyors clean or to cool product) review the accuracy of the spray pattern to prevent unnecessary water loss.
- *Flow control optimization:* Industrial processes sometimes require the use of tanks, which are refilled to control losses. It is often possible to reduce the rate of water supply to such tanks, and sometimes to reduce tank levels to reduce spillage. If the process uses water cooling sprays, it may be possible to reduce flow while maintaining cooling performance. Testing can determine the optimum balance.
    - o If hoses are used in cleaning, use flow controls to restrict wasteful water flow
    - o Consider the use of high pressure, low volume cleaning systems rather than using large volumes of water sprayed from hosepipes
    - o Using flow timers and limit switches to control water use
    - o Using 'clean-up' practices rather than hosing down

Building Facility Operations

Consumption of building and sanitary water is typically less than that used in industrial processes. However, savings can readily be identified, as outlined below:

- Compare daily water use per employee to existing benchmarks taking into consideration the primary use at the facility, whether sanitary or including other activities such as showering or catering
- Regularly maintain plumbing, and identify and repair leaks
- Shut off water to unused areas
- Install self-closing taps, automatic shut-off valves, spray nozzles, pressure reducing valves, and water conserving fixtures (e.g. low flow shower heads, faucets, toilets, urinals; and spring loaded or sensored faucets)
- Operate dishwashers and laundries on full loads, and only when needed
- Install water-saving equipment in lavatories, such as low-flow toilets

Cooling Systems

Water conservation opportunities in cooling systems include:

- Use of closed circuit cooling systems with cooling towers rather than once-through cooling systems
- Limiting condenser or cooling tower blowdown to the minimum required to prevent unacceptable accumulation of dissolved solids
- Use of air cooling rather than evaporative cooling, although this may increase electricity use in the cooling system
- Use of treated waste water for cooling towers
- Reusing/recycling cooling tower blowdown

Heating Systems

Heating systems based on the circulation of low or medium pressure hot water (which do not consume water) should be closed. If they do consume water, regular maintenance should be conducted to check for leaks. However, large quantities of water may be used by steam systems, and this can be reduced by the following measures:

- Repair of steam and condensate leaks, and repair of all failed steam traps
- Return of condensate to the boilerhouse, and use of heat exchangers (with condensate return) rather than direct steam injection where process permits
- Flash steam recovery
- Minimizing boiler blowdown consistent with maintaining acceptably low dissolved solids in boiler water. Use of reverse osmosis boiler feed water treatment substantially reduces the need for boiler blowdown
- Minimizing deaerator heating

1.5 Hazardous Materials Management

Applicability and Approach

These guidelines apply to projects that use, store, or handle any quantity of hazardous materials (Hazmats), defined as materials that represent a risk to human health, property, or the environment due to their physical or chemical characteristics. Hazmats can be classified according to the hazard as explosives; compressed gases, including toxic or flammable gases; flammable liquids; flammable solids; oxidizing substances; toxic materials; radioactive material; and corrosive substances. Guidance on the transport of hazardous materials is covered in Section 3 of this document.

When a hazardous material is no longer usable for its original purpose and is intended for disposal, but still has hazardous properties, it is considered a *hazardous waste* (see Section 1.4).

This guidance is intended to be applied in conjunction with traditional occupational health and safety and emergency preparedness programs which are included in Section 2.0 on Occupational Health and Safety Management, and Section 3.7 on Emergency Preparedness and Response. Guidance on the Transport of Hazardous Materials is provided in Section 3.5.

This section is divided into two main subsections:

General Hazardous Materials Management: Guidance applicable to all projects or facilities that handle or store any quantity of hazardous materials.

Management of Major Hazards: Additional guidance for projects or facilities that store or handle hazardous materials at, or above, threshold quantities[39], and thus require special treatment to prevent accidents such as fire, explosions, leaks or spills, and to prepare and respond to emergencies.

The overall objective of hazardous materials management is to avoid or, when avoidance is not feasible, minimize uncontrolled releases of hazardous materials or accidents (including explosion and fire) during their production, handling, storage and use. This objective can be achieved by:

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39 For examples, threshold quantities should be those established for emergency planning purposes such as provided in the US Environmental Protection Agency. *Protection of Environment* (Title Threshold quantities are provided in the US Environmental Protection Agency. *Protection of Environment* (Title 40 CFR Parts 68, 112, and 355).

- Establishing hazardous materials management priorities based on hazard analysis of risky operations identified through Social and Environmental Assessment;
- Where practicable, avoiding or minimizing the use of hazardous materials. For example, non-hazardous materials have been found to substitute asbestos in building materials, PCBs in electrical equipment, persistent organic pollutants (POPs) in pesticides formulations, and ozone depleting substances in refrigeration systems;
- Preventing uncontrolled releases of hazardous materials to the environment or uncontrolled reactions that might result in fire or explosion;
- Using engineering controls (containment, automatic alarms, and shut-off systems) commensurate with the nature of hazard;
- Implementing management controls (procedures, inspections, communications, training, and drills) to address residual risks that have not been prevented or controlled through engineering measures.

General Hazardous Materials Management

Projects which manufacture, handle, use, or store hazardous materials should establish management programs that are commensurate with the potential risks present. The main objectives of projects involving hazardous materials should be the protection of the workforce and the prevention and control of releases and accidents. These objectives should be addressed by integrating prevention and control measures, management actions, and procedures into day-to-day business activities. Potentially applicable elements of a management program include the following:

Hazard Assessment

The level of risk should be established through an on-going assessment process based on:

- The types and amounts of hazardous materials present in the project. This information should be recorded and should include a summary table with the following information:
    - o Name and description (e.g. composition of a mixture) of the Hazmat
    - o Classification (e.g. code, class or division) of the Hazmat
    - o Internationally accepted regulatory reporting threshold quantity or national equivalent[40] of the Hazmat
    - o Quantity of Hazmat used per month
    - o Characteristic(s) that make(s) the Hazmat hazardous (e.g. flammability, toxicity)
- Analysis of potential spill and release scenarios using available industry statistics on spills and accidents where available
- Analysis of the potential for uncontrolled reactions such as fire and explosions
- Analysis of potential consequences based on the physical-geographical characteristics of the project site, including aspects such as its distance to settlements, water resources, and other environmentally sensitive areas

Hazard assessment should be performed by specialized professionals using internationally-accepted methodologies such as Hazardous Operations Analysis (HAZOP), Failure Mode and Effects Analysis (FMEA), and Hazard Identification (HAZID).

Management Actions

The management actions to be included in a Hazardous Materials Management Plan should be commensurate with the level of

[40] Threshold quantities are provided in the US Environmental Protection Agency. *Protection of Environment* (Title 40 CFR Parts 68, 112, and 355).

potential risks associated with the production, handling, storage, and use of hazardous materials.

Release Prevention and Control Planning

Where there is risk of a spill of uncontrolled hazardous materials, facilities should prepare a spill control, prevention, and countermeasure plan as a specific component of their Emergency Preparedness and Response Plan (described in more detail in Section 3.7). The plan should be tailored to the hazards associated with the project, and include:

- Training of operators on release prevention, including drills specific to hazardous materials as part of emergency preparedness response training
- Implementation of inspection programs to maintain the mechanical integrity and operability of pressure vessels, tanks, piping systems, relief and vent valve systems, containment infrastructure, emergency shutdown systems, controls and pumps, and associated process equipment
- Preparation of written Standard Operating Procedures (SOPs) for filling USTs, ASTs or other containers or equipment as well as for transfer operations by personnel trained in the safe transfer and filling of the hazardous material, and in spill prevention and response
- SOPs for the management of secondary containment structures, specifically the removal of any accumulated fluid, such as rainfall, to ensure that the intent of the system is not accidentally or willfully defeated
- Identification of locations of hazardous materials and associated activities on an emergency plan site map
- Documentation of availability of specific personal protective equipment and training needed to respond to an emergency
- Documentation of availability of spill response equipment sufficient to handle at least initial stages of a spill and a list of external resources for equipment and personnel, if necessary, to supplement internal resources
- Description of response activities in the event of a spill, release, or other chemical emergency including:
    - Internal and external notification procedures
    - Specific responsibilities of individuals or groups
    - Decision process for assessing severity of the release, and determining appropriate actions
    - Facility evacuation routes
    - Post-event activities such as clean-up and disposal, incident investigation, employee re-entry, and restoration of spill response equipment.

Occupational Health and Safety

The Hazardous Materials Management Plan should address applicable, essential elements of occupational health and safety management as described in Section 2.0 on Occupational Health and Safety, including:

- Job safety analysis to identify specific potential occupational hazards and industrial hygiene surveys, as appropriate, to monitor and verify chemical exposure levels, and compare with applicable occupational exposure standards[41]
- Hazard communication and training programs to prepare workers to recognize and respond to workplace chemical hazards. Programs should include aspects of hazard identification, safe operating and materials handling procedures, safe work practices, basic emergency procedures, and special hazards unique to their jobs.

[41] Including: Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®), American Conference of Governmental Industrial Hygienists (ACGIH), http://www.acgih.org/TLV/; U.S. National Institute for Occupational Health and Safety (NIOSH), http://www.cdc.gov/niosh/npg/; Permissible Exposure Limits (PELs), U.S. Occupational Safety and Health Administration (OSHA), http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992; Indicative Occupational Exposure Limit Values, European Union, http://europe.osha.eu.int/good_practice/risks/ds/oel/; and other similar sources.

Training should incorporate information from Material Safety Data Sheets[42] (MSDSs) for hazardous materials being handled. MSDSs should be readily accessible to employees in their local language.

- Definition and implementation of permitted maintenance activities, such as hot work or confined space entries
- Provision of suitable personal protection equipment (PPE) (footwear, masks, protective clothing and goggles in appropriate areas), emergency eyewash and shower stations, ventilation systems, and sanitary facilities
- Monitoring and record-keeping activities, including audit procedures designed to verify and record the effectiveness of prevention and control of exposure to occupational hazards, and maintaining accident and incident investigation reports on file for a period of at least five years

Process Knowledge and Documentation

The Hazardous Materials Management Plan should be incorporated into, and consistent with, the other elements of the facility ES/OHS MS and include:

- Written process safety parameters (i.e., hazards of the chemical substances, safety equipment specifications, safe operation ranges for temperature, pressure, and other applicable parameters, evaluation of the consequences of deviations, etc.)
- Written operating procedures
- Compliance audit procedures

Preventive Measures

Hazardous Materials Transfer

Uncontrolled releases of hazardous materials may result from small cumulative events, or from more significant equipment failure associated with events such as manual or mechanical transfer between storage systems or process equipment. Recommended practices to prevent hazardous material releases from processes include:

- Use of dedicated fittings, pipes, and hoses specific to materials in tanks (e.g., all acids use one type of connection, all caustics use another), and maintaining procedures to prevent addition of hazardous materials to incorrect tanks
- Use of transfer equipment that is compatible and suitable for the characteristics of the materials transferred and designed to ensure safe transfer
- Regular inspection, maintenance and repair of fittings, pipes and hoses
- Provision of secondary containment, drip trays or other overflow and drip containment measures, for hazardous materials containers at connection points or other possible overflow points.

Overfill Protection

Overfills of vessels and tanks should be prevented as they are among the most common causes of spills resulting in soil and water contamination, and among the easiest to prevent. Recommended overfill protection measures include:

- Prepare written procedures for transfer operations that includes a checklist of measures to follow during filling operations and the use of filling operators trained in these procedures
- Installation of gauges on tanks to measure volume inside
- Use of dripless hose connections for vehicle tank and fixed connections with storage tanks

[42] MSDSs are produced by the manufacturer, but might not be prepared for chemical intermediates that are not distributed in commerce. In these cases, employers still need to provide workers with equivalent information.

- Provision of automatic fill shutoff valves on storage tanks to prevent overfilling
- Use of a catch basin around the fill pipe to collect spills
- Use of piping connections with automatic overfill protection (float valve)
- Pumping less volume than available capacity into the tank or vessel by ordering less material than its available capacity
- Provision of overfill or over pressure vents that allow controlled release to a capture point

Reaction, Fire, and Explosion Prevention

Reactive, flammable, and explosive materials should also be managed to avoid uncontrolled reactions or conditions resulting in fire or explosion. Recommended prevention practices include:

- Storage of incompatible materials (acids, bases, flammables, oxidizers, reactive chemicals) in separate areas, and with containment facilities separating material storage areas
- Provision of material-specific storage for extremely hazardous or reactive materials
- Use of flame arresting devices on vents from flammable storage containers
- Provision of grounding and lightning protection for tank farms, transfer stations, and other equipment that handles flammable materials
- Selection of materials of construction compatible with products stored for all parts of storage and delivery systems, and avoiding reuse of tanks for different products without checking material compatibility
- Storage of hazardous materials in an area of the facility separated from the main production works. Where proximity is unavoidable, physical separation should be provided using structures designed to prevent fire, explosion, spill, and other emergency situations from affecting facility operations
- Prohibition of all sources of ignition from areas near flammable storage tanks

Control Measures

Secondary Containment (Liquids)

A critical aspect for controlling accidental releases of liquid hazardous materials during storage and transfer is the provision of secondary containment. It is not necessary for secondary containment methods to meet long term material compatibility as with primary storage and piping, but their design and construction should hold released materials effectively until they can be detected and safely recovered. Appropriate secondary containment structures consist of berms, dikes, or walls capable of containing the larger of 110 percent of the largest tank or 25% percent of the combined tank volumes in areas with above-ground tanks with a total storage volume equal or greater than 1,000 liters and will be made of impervious, chemically resistant material. Secondary containment design should also consider means to prevent contact between incompatible materials in the event of a release.

Other secondary containment measures that should be applied depending on site-specific conditions include:

- Transfer of hazardous materials from vehicle tanks to storage in areas with surfaces sufficiently impervious to avoid loss to the environment and sloped to a collection or a containment structure not connected to municipal wastewater/stormwater collection system
- Where it is not practical to provide permanent, dedicated containment structures for transfer operations, one or more alternative forms of spill containment should be provided, such as portable drain covers (which can be deployed for the duration of the operations), automatic shut-off valves on storm water basins, or shut off valves in drainage or sewer facilities, combined with oil-water separators

- Storage of drummed hazardous materials with a total volume equal or greater than 1,000 liters in areas with impervious surfaces that are sloped or bermed to contain a minimum of 25 percent of the total storage volume
- Provision of secondary containment for components (tanks, pipes) of the hazardous material storage system, to the extent feasible
- Conducting periodic (e.g. daily or weekly) reconciliation of tank contents, and inspection of visible portions of tanks and piping for leaks;
- Use of double-walled, composite, or specially coated storage and piping systems particularly in the use of underground storage tanks (USTs) and underground piping. If double-walled systems are used, they should provide a means of detecting leaks between the two walls.

Storage Tank and Piping Leak Detection

Leak detection may be used in conjunction with secondary containment, particularly in high-risk locations[43]. Leak detection is especially important in situations where secondary containment is not feasible or practicable, such as in long pipe runs. Acceptable leak detection methods include:

- Use of automatic pressure loss detectors on pressurized or long distance piping
- Use of approved or certified integrity testing methods on piping or tank systems, at regular intervals
- Considering the use of SCADA[44] if financially feasible

43 High-risk locations are places where the release of product from the storage system could result in the contamination of drinking water source or those located in water resource protection areas as designated by local authorities.

44 Supervisory Control and Data Acquisition

Underground Storage Tanks (USTs)[45]

Although there are many environmental and safety advantages of underground storage of hazardous materials, including reduced risk of fire or explosion, and lower vapor losses into the atmosphere, leaks of hazardous materials can go undetected for long periods of time with potential for soil and groundwater contamination. Examples of techniques to manage these risks include:

- Avoiding use of USTs for storage of highly soluble organic materials
- Assessing local soil corrosion potential, and installing and maintaining cathodic protection (or equivalent rust protection) for steel tanks
- For new installations, installing impermeable liners or structures (e.g., concrete vaults) under and around tanks and lines that direct any leaked product to monitoring ports at the lowest point of the liner or structure
- Monitoring the surface above any tank for indications of soil movement
- Reconciling tank contents by measuring the volume in store with the expected volume, given the stored quantity at last stocking, and deliveries to and withdrawals from the store
- Testing integrity by volumetric, vacuum, acoustic, tracers, or other means on all tanks at regular intervals
- Considering the monitoring groundwater of quality down gradient of locations where multiple USTs are in use
- Evaluating the risk of existing UST in newly acquired facilities to determine if upgrades are required for USTs that will be continued to be used, including replacement with new systems or permanent closure of abandoned USTs. Ensuring that new USTs are sited away from wells,

45 Additional details on the management of USTs is provided in the EHS Guidelines for Retail Petroleum Stations.

reservoirs and other source water protection areas and floodplains, and maintained so as to prevent corrosion.

Management of Major Hazards

In addition to the application of the above-referenced guidance on prevention and control of releases of hazardous materials, projects involving production, handling, and storage of hazardous materials *at or above threshold limits*[46] should prepare a Hazardous Materials Risk Management Plan, in the context of its overall ES/OHS MS, containing all of the elements presented below.[47] The objective of this guidance is the prevention and control of catastrophic releases of toxic, reactive, flammable, or explosive chemicals that may result in toxic, fire, or explosion hazards.[48]

Management Actions

- *Management of Change:* These procedures should address:
    - The technical basis for changes in processes and operations
    - The impact of changes on health and safety
    - Modification to operating procedures
    - Authorization requirements
    - Employees affected
    - Training needs
- *Compliance Audit:* A compliance audit is a way to evaluate compliance with the prevention program requirements for each process. A compliance audit covering each element of the prevention measures (see below) should be conducted at least every three years and should include:
    - Preparation of a report of the findings
    - Determination and documentation of the appropriate response to each finding
    - Documentation that any deficiency has been corrected
- *Incident Investigation:* Incidents can provide valuable information about site hazards and the steps needed to prevent accidental releases. An incident investigation mechanism should include procedures for:
    - Initiation of the investigation promptly
    - Summarizing the investigation in a report
    - Addressing the report findings and recommendations
    - A review of the report with staff and contractors
- *Employee Participation:* A written plan of action should describe an active employee participation program for the prevention of accidents.
- *Contractors:* There should be a mechanism for contractor control which should include a requirement for them to develop hazard materials management procedures that meet the requirements of the hazardous materials management plan. Their procedures should be consistent with those of the contracting company and the contractor workforce should undergo the same training. Additionally, procedures should require that contractors are:
    - Provided with safety performance procedures and safety and hazard information
    - Observe safety practices
    - Act responsibly
    - Have access to appropriate training for their employees
    - Ensure that their employees know process hazards and applicable emergency actions

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[46] Threshold quantities should be those established for emergency planning purposes such as provided in the US Environmental Protection Agency. *Protection of Environment* (Title 40 CFR Parts 300-399 and 700 to 789).

[47] For further information and guidance, please refer to International Finance Corporation (IFC) Hazardous Materials Risk Management Manual. Washington, D.C. December 2000.

[48] The approach to the management of major hazards is largely based on an approach to Process Safety Management developed by the American Institute of Chemical Engineers.

- Prepare and submit training records for their employees to the contracting company
- Inform their employees about the hazards presented by their work
- Assess trends of repeated similar incidents
- Develop and implement procedures to manage repeated similar incidents

- *Training*: Project employees should be provided training on Hazmat management. The training program should include:
  - A list of employees to be trained
  - Specific training objectives
  - Mechanisms to achieve the objectives (i.e., hands-on workshops, videos, etc.)
  - The means to determine whether the training program is effective
  - Training procedures for new hires and refresher courses for existing employees

Preventive Measures

The purpose of preventive measures is to ensure that safety-related aspects of the process and equipment are considered, limits to be placed on the operations are well known, and accepted standards and codes are adopted, where they apply.

- *Process Safety Information:* Procedures should be prepared for each hazardous materials and include:
  - Compilation of Material Safety Data Sheets (MSDS)
  - Identification of maximum intended inventories and safe upper/lower parameters
  - Documentation of equipment specifications and of codes and standards used to design, build and operate the process

- *Operating Procedures:* SOPs should be prepared for each step of all processes or operations within the project (e.g. initial startup, normal operations, temporary operations, emergency shutdown, emergency operations, normal shutdown, and start-up following a normal or emergency shutdown or major change). These SOPs should include special considerations for Mazmats used in the process or operations (e.g. temperature control to prevent emissions of a volatile hazardous chemical; diversion of gaseous discharges of hazardous pollutants from the process to a temporary storage tank in case of emergency).

Other procedures to be developed include impacts of deviations, steps to avoid deviations, prevention of chemical exposure, exposure control measures, and equipment inspections.

Mechanical Integrity of process equipment, piping and instrumentation: Inspection and maintenance procedures should be developed and documented to ensure mechanical integrity of equipment, piping, and instrumentation and prevent uncontrolled releases of hazardous materials from the project. These procedures should be included as part of the project SOPs. The specific process components of major interest include pressure vessels and storage tanks, piping systems, relief and vent systems and devices, emergency shutdown systems, controls, and pumps. Recommended aspects of the inspection and maintenance program include:

- Developing inspection and maintenance procedures
- Establishing a quality assurance plan for equipment, maintenance materials, and spare parts
- Conducting employee training on the inspection and maintenance procedures
- Conducting equipment, piping, and instrumentation inspections and maintenance
- Identifying and correcting identified deficiencies

- Evaluating the inspection and maintenance results and, if necessary, updating the inspection and maintenance procedures
- Reporting the results to management.

- *Hot Work Permit:* Hot work operations – such as brazing, torch-cutting, grinding, soldering, and welding – are associated with potential health, safety, and property hazards resulting from the fumes, gases, sparks, and hot metal and radiant energy produced during hot work. Hot work permit is required for any operation involving open flames or producing heat and/or sparks. The section of SOPs on hot work should include the responsibility for hot work permitting, personal protection equipment (PPE), hot work procedures, personnel training, and recordkeeping.
- *Pre-Start Review:* Procedures should be prepared to carry out pre-start reviews when a modification is significant enough to require a change in safety information under the management of change procedure. The procedures should:
  - Confirm that the new or modified construction and/or equipment meet design specifications
  - Ensure that procedures for safety, operation, maintenance, and emergency are adequate
  - Include a process hazard assessment, and resolve or implement recommendations for new process
  - Ensure that training for all affected employees is being conducted

Emergency Preparedness and Response

When handling hazardous materials, procedures and practices should be developed allowing for quick and efficient responses to accidents that could result in human injury or damage to the environment. An Emergency Preparedness and Response Plan, incorporated into and consistent with, the facility's overall ES/OHS MS, should be prepared to cover the following:[49]

- *Planning Coordination:* Procedures should be prepared for:
  - Informing the public and emergency response agencies
  - Documenting first aid and emergency medical treatment
  - Taking emergency response actions
  - Reviewing and updating the emergency response plan to reflect changes, and ensuring that employees are informed of such changes
- *Emergency Equipment:* Procedures should be prepared for using, inspecting, testing, and maintaining the emergency response equipment.
- *Training:* Employees and contractors should be trained on emergency response procedures.

Community Involvement and Awareness

When hazardous materials are in use above threshold quantities, the management plan should include a system for community awareness, notification and involvement that should be commensurate with the potential risks identified for the project during the hazard assessment studies. This should include mechanisms for sharing the results of hazard and risk assessment studies in a timely, understandable and culturally sensitive manner with potentially affected communities that provides a means for public feedback. Community involvement activities should include:

- Availability of general information to the potentially affected community on the nature and extent of project operations, and the prevention and control measures in place to ensure no effects to human health

[49] For a comprehensive treatment of the development of emergency response plans in conjunction with communities refer to the Awareness and Preparedness for Emergencies at Local Level (APELL) Guidelines available at: http://www.uneptie.org/pc/apell/publications/handbooks.html

- The potential for off-site effects to human health or the environment following an accident at planned or existing hazardous installations
- Specific and timely information on appropriate behavior and safety measures to be adopted in the event of an accident including practice drills in locations with higher risks
- Access to information necessary to understand the nature of the possible effect of an accident and an opportunity to contribute effectively, as appropriate, to decisions concerning hazardous installations and the development of community emergency preparedness plans.

1.6 Waste Management

Applicability and Approach

These guidelines apply to projects that generate, store, or handle any quantity of waste across a range of industry sectors. It is not intended to apply to projects or facilities where the primary business is the collection, transportation, treatment, or disposal of wastes. Specific guidance for these types of facilities is presented in the Environmental Health and Safety (EHS) Guidelines for Waste Management Facilities.

A *waste* is any solid, liquid, or contained gaseous material that is being discarded by disposal, recycling, burning or incineration. It can be byproduct of a manufacturing process or an obsolete commercial product that can no longer be used for intended purpose and requires disposal.

Solid (non-hazardous) wastes generally include any garbage, refuse. Examples of such waste include domestic trash and garbage; inert construction / demolition materials; refuse, such as metal scrap and empty containers (except those previously used to contain hazardous materials which should, in principle, be managed as a hazardous waste); and residual waste from industrial operations, such as boiler slag, clinker, and fly ash.

Hazardous waste shares the properties of a hazardous material (e.g. ignitability, corrosivity, reactivity, or toxicity), or other physical, chemical, or biological characteristics that may pose a potential risk to human health or the environment if improperly managed. Wastes may also be defined as "hazardous" by local regulations or international conventions, based on the origin of the waste and its inclusion on hazardous waste lists, or based on its characteristics.

Sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial operations needs to be evaluated on a case-by-case basis to establish whether it constitutes a hazardous or a non-hazardous waste.

Facilities that generate and store wastes should practice the following:

- Establishing waste management priorities at the outset of activities based on an understanding of potential Environmental, Health, and Safety (EHS) risks and impacts and considering waste generation and its consequences
- Establishing a waste management hierarchy that considers prevention, reduction, reuse, recovery, recycling, removal and finally disposal of wastes.
- Avoiding or minimizing the generation waste materials, as far as practicable
- Where waste generation cannot be avoided but has been minimized, recovering and reusing waste

- Where waste can not be recovered or reused, treating, destroying, and disposing of it in an environmentally sound manner

General Waste Management

The following guidance applies to the management of non-hazardous and hazardous waste. Additional guidance specifically applicable to hazardous wastes is presented below. Waste management should be addressed through a Waste management system that addresses issues linked to waste minimization, generation, transport, disposal, and monitoring.

Waste Management Planning

Facilities that generate waste should characterize their waste according to composition, source, types of wastes produced, generation rates, or according to local regulatory requirements. Effective planning and implementation of waste management strategies should include:

- Review of new waste sources during planning, siting, and design activities, including during equipment modifications and process alterations, to identify expected waste generation, pollution prevention opportunities, and necessary treatment, storage, and disposal infrastructure
- Collection of data and information about the process and waste streams in existing facilities, including characterization of waste streams by type, quantities, and potential use/disposition
- Establishment of priorities based on a risk analysis that takes into account the potential EHS risks during the waste cycle and the availability of infrastructure to manage the waste in an environmentally sound manner
- Definition of opportunities for source reduction, as well as reuse and recycling
- Definition of procedures and operational controls for on-site storage
- Definition of options / procedures / operational controls for treatment and final disposal

Waste Prevention

Processes should be designed and operated to prevent, or minimize, the quantities of wastes generated and hazards associated with the wastes generated in accordance with the following strategy:

- Substituting raw materials or inputs with less hazardous or toxic materials, or with those where processing generates lower waste volumes
- Applying manufacturing process that convert materials efficiently, providing higher product output yields, including modification of design of the production process, operating conditions, and process controls[50]
- Instituting good housekeeping and operating practices, including inventory control to reduce the amount of waste resulting from materials that are out-of-date, off-specification, contaminated, damaged, or excess to plant needs
- Instituting procurement measures that recognize opportunities to return usable materials such as containers and which prevents the over ordering of materials
- Minimizing hazardous waste generation by implementing stringent waste segregation to prevent the commingling of non-hazardous and hazardous waste to be managed

[50] Examples of waste prevention strategies include the concept of Lean Manufacturing found at http://www.epa.gov/epaoswer/hazwaste/minimize/lean.htm

Recycling and Reuse

In addition to the implementation of waste prevention strategies, the total amount of waste may be significantly reduced through the implementation of recycling plans, which should consider the following elements:

- Evaluation of waste production processes and identification of potentially recyclable materials
- Identification and recycling of products that can be reintroduced into the manufacturing process or industry activity at the site
- Investigation of external markets for recycling by other industrial processing operations located in the neighborhood or region of the facility (e.g., waste exchange)
- Establishing recycling objectives and formal tracking of waste generation and recycling rates
- Providing training and incentives to employees in order to meet objectives

Treatment and Disposal

If waste materials are still generated after the implementation of feasible waste prevention, reduction, reuse, recovery and recycling measures, waste materials should be treated and disposed of and all measures should be taken to avoid potential impacts to human health and the environment. Selected management approaches should be consistent with the characteristics of the waste and local regulations, and may include one or more of the following:

- On-site or off-site biological, chemical, or physical treatment of the waste material to render it non-hazardous prior to final disposal
- Treatment or disposal at permitted facilities specially designed to receive the waste. Examples include: composting operations for organic non-hazardous wastes; properly designed, permitted and operated landfills or incinerators designed for the respective type of waste; or other methods known to be effective in the safe, final disposal of waste materials such as bioremediation.

Hazardous Waste Management

Hazardous wastes should always be segregated from non-hazardous wastes. If generation of hazardous waste can not be prevented through the implementation of the above general waste management practices, its management should focus on the prevention of harm to health, safety, and the environment, according to the following additional principles:

- Understanding potential impacts and risks associated with the management of any generated hazardous waste during its complete life cycle
- Ensuring that contractors handling, treating, and disposing of hazardous waste are reputable and legitimate enterprises, licensed by the relevant regulatory agencies and following good international industry practice for the waste being handled
- Ensuring compliance with applicable local and international regulations[51]

Waste Storage

Hazardous waste should be stored so as to prevent or control accidental releases to air, soil, and water resources in area location where:

[51] International requirements may include host-country commitments under the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their disposal (http://www.basel.int/) and Rotterdam Convention on the prior Inform Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (http://www.pic.int/)

- Waste is stored in a manner that prevents the commingling or contact between incompatible wastes, and allows for inspection between containers to monitor leaks or spills. Examples include sufficient space between incompatibles or physical separation such as walls or containment curbs
- Store in closed containers away from direct sunlight, wind and rain
- Secondary containment systems should be constructed with materials appropriate for the wastes being contained and adequate to prevent loss to the environment
- Secondary containment is included wherever liquid wastes are stored in volumes greater than 220 liters. The available volume of secondary containment should be at least 110 percent of the largest storage container, or 25 percent of the total storage capacity (whichever is greater), in that specific location
- Provide adequate ventilation where volatile wastes are stored.

Hazardous waste storage activities should also be subject to special management actions, conducted by employees who have received specific training in handling and storage of hazardous wastes:

- Provision of readily available information on chemical compatibility to employees, including labeling each container to identify its contents
- Limiting access to hazardous waste storage areas to employees who have received proper training
- Clearly identifying (label) and demarcating the area, including documentation of its location on a facility map or site plan
- Conducting periodic inspections of waste storage areas and documenting the findings
- Preparing and implementing spill response and emergency plans to address their accidental release (additional information on Emergency Plans in provided in Section 3 of this document)
- Avoiding underground storage tanks and underground piping of hazardous waste

Transportation

On-site and Off-site transportation of waste should be conducted so as to prevent or minimize spills, releases, and exposures to employees and the public. All waste containers designated for off-site shipment should be secured and labeled with the contents and associated hazards, be properly loaded on the transport vehicles before leaving the site, and be accompanied by a shipping paper (i.e., manifest) that describes the load and its associated hazards, consistent with the guidance provided in Section 3.4 on the Transport of Hazardous Materials.

Treatment and Disposal

In addition to the recommendations for treatment and disposal applicable to general wastes, the following issues specific to hazardous wastes should be considered:

Commercial or Government Waste Contractors

In the absence of qualified commercial or government-owned waste vendors (taking into consideration proximity and transportation requirements), facilities generating waste should consider using:

- Have the technical capability to manage the waste in a manner that reduces immediate and future impact to the environment
- Have all required permits, certifications, and approvals, of applicable government authorities

- Have been secured through the use of formal procurement agreements

In the absence of qualified commercial or government-owned waste disposal operators (taking into consideration proximity and transportation requirements), project sponsors should consider using:

- Installing on-site waste treatment or recycling processes
- As a final option, constructing facilities that will provide for the environmental sound long-term storage of wastes on-site (as described elsewhere in the General EHS Guidelines) or at an alternative appropriate location up until external commercial options become available

Small Quantities of Hazardous Waste

Hazardous waste materials are frequently generated in small quantities by many projects through a variety of activities such as equipment and building maintenance activities. Examples of these types of wastes include: spent solvents and oily rags, empty paint cans, chemical containers; used lubricating oil; used batteries (such as nickel-cadmium or lead acid); and lighting equipment, such as lamps or lamp ballasts. These wastes should be managed following the guidance provided in the above sections.

Monitoring

Monitoring activities associated with the management of hazardous and non-hazardous waste should include:

- Regular visual inspection of all waste storage collection and storage areas for evidence of accidental releases and to verify that wastes are properly labeled and stored. When significant quantities of hazardous wastes are generated and stored on site, monitoring activities should include:
    - Inspection of vessels for leaks, drips or other indications of loss
    - Identification of cracks, corrosion, or damage to tanks, protective equipment, or floors
    - Verification of locks, emergency valves, and other safety devices for easy operation (lubricating if required and employing the practice of keeping locks and safety equipment in standby position when the area is not occupied)
    - Checking the operability of emergency systems
    - Documenting results of testing for integrity, emissions, or monitoring stations (air, soil vapor, or groundwater)
    - Documenting any changes to the storage facility, and any significant changes in the quantity of materials in storage
- Regular audits of waste segregation and collection practices
- Tracking of waste generation trends by type and amount of waste generated, preferably by facility departments
- Characterizing waste at the beginning of generation of a new waste stream, and periodically documenting the characteristics and proper management of the waste, especially hazardous wastes
- Keeping manifests or other records that document the amount of waste generated and its destination
- Periodic auditing of third party treatment, and disposal services including re-use and recycling facilities when significant quantities of hazardous wastes are managed by third parties. Whenever possible, audits should include site visits to the treatment storage and disposal location

- Regular monitoring of groundwater quality in cases of Hazardous Waste on site storage and/or pretreatment and disposal
- Monitoring records for hazardous waste collected, stored, or shipped should include:
  - Name and identification number of the material(s) composing the hazardous waste
  - Physical state (i.e., solid, liquid, gaseous or a combination of one, or more, of these)
  - Quantity (e.g., kilograms or liters, number of containers)
  - Waste shipment tracking documentation to include, quantity and type, date dispatched, date transported and date received, record of the originator, the receiver and the transporter
  - Method and date of storing, repacking, treating, or disposing at the facility, cross-referenced to specific manifest document numbers applicable to the hazardous waste
  - Location of each hazardous waste within the facility, and the quantity at each location

1.7 Noise

Applicability

This section addresses impacts of noise beyond the property boundary of the facilities. Worker exposure to noise is covered in Section 2.0 on Occupational Health and Safety.

Prevention and Control

Noise prevention and mitigation measures should be applied where predicted or measured noise impacts from a project facility or operations exceed the applicable noise level guideline at the most sensitive point of reception.[52] The preferred method for controlling noise from stationary sources is to implement noise control measures at source.[53] Methods for prevention and control of sources of noise emissions depend on the source and proximity of receptors. Noise reduction options that should be considered include:

- Selecting equipment with lower sound power levels
- Installing silencers for fans
- Installing suitable mufflers on engine exhausts and compressor components
- Installing acoustic enclosures for equipment casing radiating noise
- Improving the acoustic performance of constructed buildings, apply sound insulation
- Installing acoustic barriers without gaps and with a continuous minimum surface density of 10 kg/m^2 in order to minimize the transmission of sound through the barrier. Barriers should be located as close to the source or to the receptor location to be effective
- Installing vibration isolation for mechanical equipment
- Limiting the hours of operation for specific pieces of equipment or operations, especially mobile sources operating through community areas
- Re-locating noise sources to less sensitive areas to take advantage of distance and shielding
- Siting permanent facilities away from community areas if possible
- Taking advantage of the natural topography as a noise buffer during facility design
- Reducing project traffic routing through community areas wherever possible
- Planning flight routes, timing and altitude for aircraft (airplane and helicopter) flying over community areas
- Developing a mechanism to record and respond to complaints

Noise Level Guidelines

Noise impacts should not exceed the levels presented in Table 1.7.1, or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site.

[52] A point of reception or receptor may be defined as any point on the premises occupied by persons where extraneous noise and/or vibration are received. Examples of receptor locations may include: permanent or seasonal residences; hotels / motels; schools and daycares; hospitals and nursing homes; places of worship; and parks and campgrounds.

[53] At the design stage of a project, equipment manufacturers should provide design or construction specifications in the form of *"Insertion Loss Performance"* for silencers and mufflers, and *"Transmission Loss Performance"* for acoustic enclosures and upgraded building construction.

Table 1.7.1- Noise Level Guidelines[54]		
	One Hour L_{Aeq} (dBA)	
Receptor	Daytime 07:00 - 22:00	Nighttime 22:00 - 07:00
Residential; institutional; educational[55]	55	45
Industrial; commercial	70	70

Highly intrusive noises, such as noise from aircraft flyovers and passing trains, should not be included when establishing background noise levels.

Monitoring

Noise monitoring[56] may be carried out for the purposes of establishing the existing ambient noise levels in the area of the proposed or existing facility, or for verifying operational phase noise levels.

Noise monitoring programs should be designed and conducted by trained specialists. Typical monitoring periods should be sufficient for statistical analysis and may last 48 hours with the use of noise monitors that should be capable of logging data continuously over this time period, or hourly, or more frequently, as appropriate (or else cover differing time periods within several days, including weekday and weekend workdays). The type of acoustic indices recorded depends on the type of noise being monitored, as established by a noise expert. Monitors should be located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface (e.g., wall). In general, the noise level limit is represented by the background or ambient noise levels that would be present in the absence of the facility or noise source(s) under investigation.

[54] Guidelines values are for noise levels measured out of doors. Source: Guidelines for Community Noise, World Health Organization (WHO), 1999.
[55] For acceptable indoor noise levels for residential, institutional, and educational settings refer to WHO (1999).

[56] Noise monitoring should be carried out using a Type 1 or 2 sound level meter meeting all appropriate IEC standards.

1.8 Contaminated Land

Applicability and Approach

This section provides a summary of management approaches for land contamination due to anthropogenic releases of hazardous materials, wastes, or oil, including naturally occurring substances. Releases of these materials may be the result of historic or current site activities, including, but not limited to, accidents during their handling and storage, or due to their poor management or disposal.

Land is considered contaminated when it contains hazardous materials or oil concentrations above background or naturally occurring levels.

Contaminated lands may involve surficial soils or subsurface soils that, through leaching and transport, may affect groundwater, surface water, and adjacent sites. Where subsurface contaminant sources include volatile substances, soil vapor may also become a transport and exposure medium, and create potential for contaminant infiltration of indoor air spaces of buildings.

Contaminated land is a concern because of:

- The potential risks to human health and ecology (e.g. risk of cancer or other human health effects, loss of ecology);
- The liability that it may pose to the polluter/business owners (e.g., cost of remediation, damage of business reputation and/or business-community relations) or affected parties (e.g. workers at the site, nearby property owners).

Contamination of land should be avoided by preventing or controlling the release of hazardous materials, hazardous wastes, or oil to the environment. When contamination of land is suspected or confirmed during any project phase, the cause of the uncontrolled release should be identified and corrected to avoid further releases and associated adverse impacts.

Contaminated lands should be managed to avoid the risk to human health and ecological receptors. The preferred strategy for land decontamination is to reduce the level of contamination at the site while preventing the human exposure to contamination.

To determine whether risk management actions are warranted, the following assessment approach should be applied to establish whether the three risk factors of 'Contaminants', 'Receptors', and 'Exposure Pathways' co-exist, or are likely to co-exist, at the project site under current or possible future land use:

- *Contaminant(s)*: Presence of hazardous materials, waste, or oil in any environmental media at potentially hazardous concentrations
- *Receptor(s)*: Actual or likely contact of humans, wildlife, plants, and other living organisms with the contaminants of concern
- *Exposure pathway(s)*: A combination of the route of migration of the contaminant from its point of release (e.g., leaching into potable groundwater) and exposure routes

(e.g., ingestion, transdermal absorption), which would allow receptor(s) to come into actual contact with contaminants

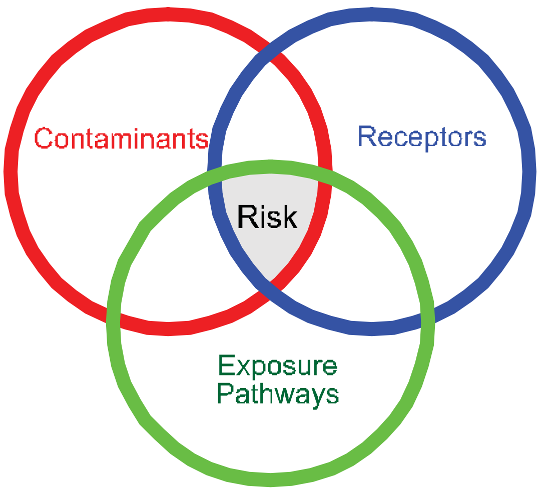

FIGURE 1.8.1: Inter-Relationship of Contaminant Risk Factors

When the three risk factors are considered to be present (in spite of limited data) under current or foreseeable future conditions, the following steps should be followed (as described in the remaining parts of this section):

1) Risk screening;
2) Interim risk management;
3) Detailed quantitative risk assessment; and
4) Permanent risk reduction measures.

Risk Screening

This step is also known as "problem formulation" for environmental risk assessment. Where there is potential evidence of contamination at a site, the following steps are recommended:

- Identification of the location of suspected highest level of contamination through a combination of visual and historical operational information;
- Sampling and testing of the contaminated media (soils or water) according to established technical methods applicable to suspected type of contaminant[57,58];
- Evaluation of the analytical results against the local and national contaminated sites regulations. In the absence of such regulations or environmental standards, other sources of risk-based standards or guidelines should be consulted to obtain comprehensive criteria for screening soil concentrations of pollutants.[59]
- Verification of the potential human and/or ecological receptors and exposure pathways relevant to the site in question

The outcome of risk-screening may reveal that there is no overlap between the three risk-factors as the contaminant levels identified are below those considered to pose a risk to human health or the environment. Alternatively, interim or permanent

57 BC MOE. http://www.env.gov.bc.ca/epd/epdpa/contam_sites/guidance

58 Massachusetts Department of Environment. http://www.mass.gov/dep/cleanup

59 These may include the USEPA Region 3 Risk-Based Concentrations (RBCs). http://www.epa.gov/reg3hwmd/risk/human/index.htm. These RBCs are considered acceptable for specific land use and contaminant exposure scenarios as they have been developed by governments using risk assessment techniques for use as general targets in the site remediation. Separate PRGs have been developed or adopted for soil, sediment or groundwater, and often a distinction is made between land uses (as noted earlier) because of the need for more stringent guidelines for residential and agricultural versus commercial/industrial landuse. The RBC Tables contains Reference Doses (RfDs) and Cancer Slope Factors (CSFs) for about 400 chemicals. These toxicity factors have been combined with "standard" exposure scenarios to calculate RBCs--chemical concentrations corresponding to fixed levels of risk (i.e., a Hazard Quotient (HQ) of 1, or lifetime cancer risk of 1E-6, whichever occurs at a lower concentration) in water, air, fish tissue, and soil for individual chemical substances. The primary use of RBCs is for chemical screening during baseline risk assessment (see EPA Regional Guidance EPA/903/R-93-001, "Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening"). Additional useful soil quality guidelines can also be obtained from Lijzen et al. 2001.

risk reduction measures may need to be taken with, or without, more detailed risk assessment activities, as described below.

Interim Risk Management

Interim risk management actions should be implemented at any phase of the project life cycle if the presence of land contamination poses an "imminent hazard", i.e., representing an immediate risk to human health and the environment if contamination were allowed to continue, even a short period of time. Examples of situations considered to involve imminent hazards include, but are not restricted to:

- Presence of an explosive atmosphere caused by contaminated land
- Accessible and excessive contamination for which short-term exposure and potency of contaminants could result in acute toxicity, irreversible long term effects, sensitization, or accumulation of persistent biocumulative and toxic substances
- Concentrations of pollutants at concentrations above the Risk Based Concentrations (RBCs[60]) or drinking water standards in potable water at the point of abstraction

Appropriate risk reduction should be implemented as soon as practicable to remove the condition posing the imminent hazard.

Detailed Risk Assessment

As an alternative to complying with numerical standards or preliminary remediation goals, and depending on local regulatory requirements, a detailed site-specific, environmental risk assessment may be used to develop strategies that yield acceptable health risks, while achieving low level contamination on-site. An assessment of contaminant risks needs to be considered in the context of current and future land use, and development scenarios (e.g., residential, commercial, industrial, and urban parkland or wilderness use).

A detailed quantitative risk assessment builds on risk screening (problem formulation). It involves first, a detailed site investigation to identify the scope of contamination.[61] Site investigation programs should apply quality assurance/quality control (QA/QC) measures to ensure that data quality is adequate for the intended data use (e.g., method detection limits are below levels of concern). The site investigation in turn should be used to develop a *conceptual site model* of how and where contaminants exist, how they are transported, and where routes of exposure occur to organisms and humans. The risk factors and conceptual site model provide a framework for assessing contaminant risks.

Human or ecological risk assessments facilitate risk management decisions at contaminated sites. Specific risk assessment objectives include:

- Identifying relevant human and ecological receptors (e.g., children, adults, fish, wildlife)
- Determining if contaminants are present at levels that pose potential human health and/or ecological concerns (e.g., levels above applicable regulatory criteria based on health or environmental risk considerations)
- Determining how human or ecological receptors are exposed to the contaminants (e.g., ingestions of soil, dermal contact, inhalation of dust)

[60] For example, USEPA Region 3 Risk-Based Concentrations (RBCs). http://www.epa.gov/reg3hwmd/risk/human/index.htm.

[61] Examples include processes defined by the American Society of Testing and Materials (ASTM) Phase II ESA Process; the British Columbia Ministry of Environment Canada (BC MOE) http://www.env.gov.bc.ca/epd/epdpa/contam_sites/guidance); and the Massachusetts Department of Environment http://www.mass.gov/dep/cleanup.

- Identifying the types of adverse effects that might result from exposure to the contaminants (e.g., effect on target organ, cancer, impaired growth or reproduction) in the absence of regulatory standards
- Quantifying the magnitude of health risks to human and ecological receptors based on a quantitative analysis of contaminant exposure and toxicity (e.g. calculate lifetime cancer risk or ratios of estimated exposure rates compared to safe exposure rates)
- Determining how current and proposed future land use influence the predicted risks (e.g. change of land use from industrial to residential with more sensitive receptors such as children)
- Quantifying the potential environmental and/or human health risks from off-site contaminant migration (e.g., consider if leaching and groundwater transport, or surface water transport results in exposure at adjacent lands/receptors)
- Determining if the risk is likely to remain stable, increase, or decrease with time in the absence of any remediation (e.g., consider if the contaminant is reasonably degradable and likely to remain in place, or be transported to other media)[62]

Addressing these objectives provides a basis to develop and implement risk reduction measures (e.g., clean-up, on-site controls) at the site. If such a need exists, the following additional objectives become relevant:

- Determining where, and in what conceptual manner, risk reduction measures should be implemented
- Identifying the preferred technologies (including engineering controls) needed to implement the conceptual risk reduction measures
- Developing a monitoring plan to ascertain whether risk reduction measures are effective
- Considering the need and appropriateness for institutional controls (e.g. deed restriction, land use restrictions) as part of a comprehensive approach

Permanent Risk Reduction Measures

The *risk factors* and *conceptual site model* within the contaminant risk approach described also provide a basis to manage and mitigate environmental contaminant health risks. The underlying principle is to reduce, eliminate, or control any or all of the three risk factors illustrated in Figure 1.8.1. A short list of examples of risk mitigation strategies is provided below, although actual strategies should be developed based on site-specific conditions, and the practicality of prevailing factors and site constraints. Regardless of the management options selected, the action plan should include, whenever possible, *contaminant source reduction* (i.e., net improvement of the site) as part of the overall strategy towards managing health risks at contaminated sites, as this alone provides for improved environmental quality.

Figure 1.8.2 presents a schematic of the inter-relationship of risk factors and example strategies to mitigate contaminant health risk by modifying the conditions of one or more risk factors to ultimately reduce contaminant exposure to the receptor. The selected approach should take into consideration the technical and financial feasibility (e.g. operability of a selected technology given the local availability of technical expertise and equipment and its associated costs).

Example risk mitigation strategies for contaminant source and exposure concentrations include:

[62] An example of a simplified quantitative risk assessment method is the ASTM E1739-95(2002) Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites and the ASTM E2081-00(2004)e1 Standard Guide for Risk-Based Corrective Action (at chemical release sites).

- Soil, sediment, and sludge:
  - In situ biological treatment (aerobic or anaerobic)
  - In situ physical/chemical treatment (e.g., soil vapor extraction with off-gas treatment, chemical oxidation)
  - In situ thermal treatment (e.g., steam injection, 6-phase heating)
  - Ex situ biological treatment (e.g., excavation and composting)
  - Ex situ physical/chemical treatment (e.g., excavation and stabilization)
  - Ex situ thermal treatment (e.g., excavation and thermal desorption or incineration)
  - Containment (e.g. landfill)
  - Natural attenuation
  - Other treatment processes
- Groundwater, surface water, and leachate:
  - In situ biological treatment (aerobic and/or aerobic)
  - In situ physical/chemical treatment (e.g., air sparging, zero-valent iron permeable reactive barrier)
  - Ex situ biological, physical, and or chemical treatment (i.e., groundwater extraction and treatment)
  - Containment (e.g., slurry wall or sheet pile barrier)
  - Natural attenuation
  - Other treatment processes
- Soil vapor intrusion:
  - Soil vapor extraction to reduce VOC contaminant source in soil
  - Installation of a sub-slab depressurization system to prevent migration of soil vapor into the building
  - Creating a positive pressure condition in buildings
  - Installation (during building construction) of an impermeable barrier below the building and/or an alternative flow pathway for soil vapor beneath building foundations (e.g., porous media and ventilation to shunt vapors away from building)

Example risk mitigation strategies for receptors include:

- Limiting or preventing access to contaminant by receptors (actions targeted at the receptor may include signage with instructions, fencing, or site security)
- Imposing health advisory or prohibiting certain practices leading to exposure such as fishing, crab trapping, shellfish collection
- Educating receptors (people) to modify behavior in order to reduce exposure (e.g., improved work practices, and use of protective clothing and equipment)

Example risk mitigation strategies for exposure pathways include:

- Providing an alternative water supply to replace, for example, a contaminated groundwater supply well
- Capping contaminated soil with at least 1m of clean soil to prevent human contact, as well as plant root or small mammal penetration into contaminated soils
- Paving over contaminated soil as an interim measure to negate the pathway of direct contact or dust generation and inhalation
- Using an interception trench and pump, and treat technologies to prevent contaminated groundwater from discharging into fish streams

The above-reference containment measures should also be considered for immediate implementation in situations where source reduction measures are expected to take time.

Occupational Health and Safety Considerations

Investigation and remediation of contaminated lands requires that workers be mindful of the occupational exposures that could arise from working in close contact with contaminated soil or other environmental media (e.g., groundwater, wastewater, sediments, and soil vapor). Occupational health and safety precautions should be exercised to minimize exposure, as described in Section 2 on Occupational Health and Safety. In addition, workers on contaminated sites should receive special health and safety training specific to contaminated site investigation and remediation activities.[63]

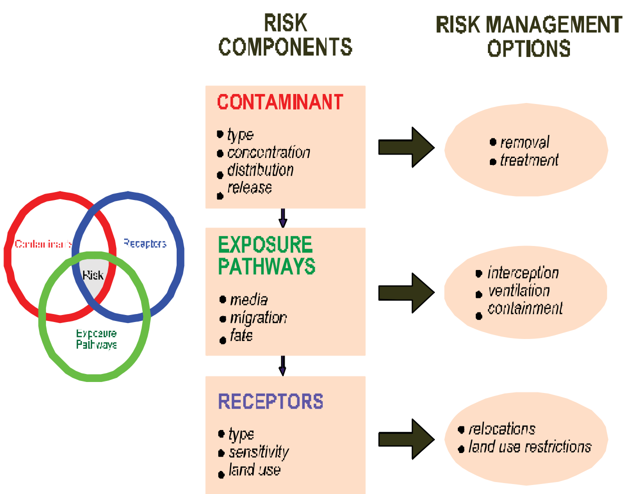

FIGURE 1.8.2: Inter-Relationship of Risk Factors and Management Options

63 For example, US Occupational Safety and Health Agency (OSHA) regulations found at 40 CFR 1910.120. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9765

2.0 Occupational Health and Safety

Applicability and Approach

Employers and supervisors are obliged to implement all reasonable precautions to protect the health and safety of workers. This section provides guidance and examples of reasonable precautions to implement in managing principal risks to occupational health and safety. Although the focus is placed on the operational phase of projects, much of the guidance also applies to construction and decommissioning activities. Companies should hire contractors that have the technical capability to manage the occupational health and safety issues of their employees, extending the application of the hazard management activities through formal procurement agreements.

Preventive and protective measures should be introduced according to the following order of priority:

- *Eliminating the hazard* by removing the activity from the work process. Examples include substitution with less hazardous chemicals, using different manufacturing processes, etc;
- *Controlling the hazard* at its source through use of engineering controls. Examples include local exhaust ventilation, isolation rooms, machine guarding, acoustic insulating, etc;
- *Minimizing the hazard* through design of safe work systems and administrative or institutional control measures. Examples include job rotation, training safe work procedures, lock-out and tag-out, workplace monitoring, limiting exposure or work duration, etc.
- *Providing appropriate personal protective equipment (PPE)* in conjunction with training, use, and maintenance of the PPE.

The application of prevention and control measures to occupational hazards should be based on comprehensive job safety or job hazard analyses. The results of these analyses should be prioritized as part of an action plan based on the likelihood and severity of the consequence of exposure to the identified hazards. An example of a qualitative risk ranking or analysis matrix to help identify priorities is described in Table 2.1.1.

Table 2.1.1. Risk Ranking Table to Classify Worker Scenarios Based on Likelihood and Consequence

	Consequences				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catas-trophic 5
A. Almost certain	L	M	E	E	E
B. Likely	L	M	H	E	E
C. Moderate	L	M	H	E	E
D. Unlikely	L	L	M	H	E
E. Rare	L	L	M	H	H

Legend

E: extreme risk; immediate action required

H: high risk; senior management attention needed

M: moderate risk; management responsibility should be specified

L: low risk; manage by routine procedures

2.1 General Facility Design and Operation

Integrity of Workplace Structures

Permanent and recurrent places of work should be designed and equipped to protect OHS:

- Surfaces, structures and installations should be easy to clean and maintain, and not allow for accumulation of hazardous compounds.
- Buildings should be structurally safe, provide appropriate protection against the climate, and have acceptable light and noise conditions.
- Fire resistant, noise-absorbing materials should, to the extent feasible, be used for cladding on ceilings and walls.
- Floors should be level, even, and non-skid.
- Heavy oscillating, rotating or alternating equipment should be located in dedicated buildings or structurally isolated sections.

Severe Weather and Facility Shutdown

- Work place structures should be designed and constructed to withstand the expected elements for the region and have an area designated for safe refuge, if appropriate.
- Standard Operating Procedures (SOPs) should be developed for project or process shut-down, including an evacuation plan. Drills to practice the procedure and plan should also be undertaken annually.

Workspace and Exit

- The space provided for each worker, and in total, should be adequate for safe execution of all activities, including transport and interim storage of materials and products.
- Passages to emergency exits should be unobstructed at all times. Exits should be clearly marked to be visible in total darkness. The number and capacity of emergency exits should be sufficient for safe and orderly evacuation of the greatest number of people present at any time, and there should be a minimum two exits from any work area.

- Facilities also should be designed and built taking into account the needs of disabled persons.

Fire Precautions

The workplace should be designed to prevent the start of fires through the implementation of fire codes applicable to industrial settings. Other essential measures include:

- Equipping facilities with fire detectors, alarm systems, and fire-fighting equipment. The equipment should be maintained in good working order and be readily accessible. It should be adequate for the dimensions and use of the premises, equipment installed, physical and chemical properties of substances present, and the maximum number of people present.
- Provision of manual firefighting equipment that is easily accessible and simple to use
- Fire and emergency alarm systems that are both audible and visible

The IFC Life and Fire Safety Guideline should apply to buildings accessible to the public (See Section 3.3).

Lavatories and Showers

- Adequate lavatory facilities (toilets and washing areas) should be provided for the number of people expected to work in the facility and allowances made for segregated facilities, or for indicating whether the toilet facility is "In Use" or "Vacant". Toilet facilities should also be provided with adequate supplies of hot and cold running water, soap, and hand drying devices.
- Where workers may be exposed to substances poisonous by ingestion and skin contamination may occur, facilities for showering and changing into and out of street and work clothes should be provided.

Potable Water Supply

- Adequate supplies of potable drinking water should be provided from a fountain with an upward jet or with a sanitary means of collecting the water for the purposes of drinking
- Water supplied to areas of food preparation or for the purpose of personal hygiene (washing or bathing) should meet drinking water quality standards

Clean Eating Area

- Where there is potential for exposure to substances poisonous by ingestion, suitable arrangements are to be made for provision of clean eating areas where workers are not exposed to the hazardous or noxious substances

Lighting

- Workplaces should, to the degree feasible, receive natural light and be supplemented with sufficient artificial illumination to promote workers' safety and health, and enable safe equipment operation. Supplemental 'task lighting' may be required where specific visual acuity requirements should be met.
- Emergency lighting of adequate intensity should be installed and automatically activated upon failure of the principal artificial light source to ensure safe shut-down, evacuation, etc.

Safe Access

- Passageways for pedestrians and vehicles within and outside buildings should be segregated and provide for easy, safe, and appropriate access
- Equipment and installations requiring servicing, inspection, and/or cleaning should have unobstructed, unrestricted, and ready access
- Hand, knee and foot railings should be installed on stairs, fixed ladders, platforms, permanent and interim floor openings, loading bays, ramps, etc.

- Openings should be sealed by gates or removable chains
- Covers should, if feasible, be installed to protect against falling items
- Measures to prevent unauthorized access to dangerous areas should be in place

First Aid

- The employer should ensure that qualified first-aid can be provided at all times. Appropriately equipped first-aid stations should be easily accessible throughout the place of work
- Eye-wash stations and/or emergency showers should be provided close to all workstations where immediate flushing with water is the recommended first-aid response
- Where the scale of work or the type of activity being carried out so requires, dedicated and appropriately equipped first-aid room(s) should be provided. First aid stations and rooms should be equipped with gloves, gowns, and masks for protection against direct contact with blood and other body fluids
- Remote sites should have written emergency procedures in place for dealing with cases of trauma or serious illness up to the point at which patient care can be transferred to an appropriate medical facility.

Air Supply

- Sufficient fresh air should be supplied for indoor and confined work spaces. Factors to be considered in ventilation design include physical activity, substances in use, and process-related emissions. Air distribution systems should be designed so as not to expose workers to draughts
- Mechanical ventilation systems should be maintained in good working order. Point-source exhaust systems required for maintaining a safe ambient environment should have local indicators of correct functioning.
- Re-circulation of contaminated air is not acceptable. Air inlet filters should be kept clean and free of dust and microorganisms. Heating, ventilation and air conditioning (HVAC) and industrial evaporative cooling systems should be equipped, maintained and operated so as to prevent growth and spreading of disease agents (e.g. *Legionnella pneumophilia*) or breeding of vectors (e.g. mosquitoes and flies) of public health concern.

Work Environment Temperature

- The temperature in work, rest room and other welfare facilities should, during service hours, be maintained at a level appropriate for the purpose of the facility.

2.2 Communication and Training

OHS Training

- Provisions should be made to provide OHS orientation training to all new employees to ensure they are apprised of the basic site rules of work at / on the site and of personal protection and preventing injury to fellow employees.
- Training should consist of basic hazard awareness, site-specific hazards, safe work practices, and emergency procedures for fire, evacuation, and natural disaster, as appropriate. Any site-specific hazard or color coding in use should be thoroughly reviewed as part of orientation training.

Visitor Orientation

- If visitors to the site can gain access to areas where hazardous conditions or substances may be present, a visitor orientation and control program should be established to ensure visitors do not enter hazard areas unescorted.

New Task Employee and Contractor Training

- The employer should ensure that workers and contractors, prior to commencement of new assignments, have received adequate training and information enabling them to

understand work hazards and to protect their health from hazardous ambient factors that may be present.
The training should adequately cover:

- Knowledge of materials, equipment, and tools
- Known hazards in the operations and how they are controlled
- Potential risks to health
- Precautions to prevent exposure
- Hygiene requirements
- Wearing and use of protective equipment and clothing
- Appropriate response to operation extremes, incidents and accidents

Basic OHS Training

- A basic occupational training program and specialty courses should be provided, as needed, to ensure that workers are oriented to the specific hazards of individual work assignments. Training should generally be provided to management, supervisors, workers, and occasional visitors to areas of risks and hazards.
- Workers with rescue and first-aid duties should receive dedicated training so as not to inadvertently aggravate exposures and health hazards to themselves or their co-workers. Training would include the risks of becoming infected with blood–borne pathogens through contact with bodily fluids and tissue.
- Through appropriate contract specifications and monitoring, the employer should ensure that service providers, as well as contracted and subcontracted labor, are trained adequately before assignments begin.

Area Signage

- Hazardous areas (electrical rooms, compressor rooms, etc), installations, materials, safety measures, and emergency exits, etc. should be marked appropriately.
- Signage should be in accordance with international standards and be well known to, and easily understood by workers, visitors and the general public as appropriate.

Labeling of Equipment

- All vessels that may contain substances that are hazardous as a result of chemical or toxicological properties, or temperature or pressure, should be labeled as to the contents and hazard, or appropriately color coded.
- Similarly, piping systems that contain hazardous substances should be labeled with the direction of flow and contents of the pipe, or color coded whenever the pipe passing through a wall or floor is interrupted by a valve or junction device.

Communicate Hazard Codes

- Copies of the hazard coding system should be posted outside the facility at emergency entrance doors and fire emergency connection systems where they are likely to come to the attention of emergency services personnel.
- Information regarding the types of hazardous materials stored, handled or used at the facility, including typical maximum inventories and storage locations, should be shared proactively with emergency services and security personnel to expedite emergency response when needed.
- Representatives of local emergency and security services should be invited to participate in periodic (annual) orientation tours and site inspections to ensure familiarity with potential hazards present.

2.3 Physical Hazards

Physical hazards represent potential for accident or injury or illness due to repetitive exposure to mechanical action or work activity. Single exposure to physical hazards may result in a wide range of injuries, from minor and medical aid only, to disabling, catastrophic, and/or fatal. Multiple exposures over prolonged periods can result in disabling injuries of comparable significance and consequence.

Rotating and Moving Equipment

Injury or death can occur from being trapped, entangled, or struck by machinery parts due to unexpected starting of equipment or unobvious movement during operations. Recommended protective measures include:

- Designing machines to eliminate trap hazards and ensuring that extremities are kept out of harm's way under normal operating conditions. Examples of proper design considerations include two-hand operated machines to prevent amputations or the availability of emergency stops dedicated to the machine and placed in strategic locations. Where a machine or equipment has an exposed moving part or exposed pinch point that may endanger the safety of any worker, the machine or equipment should be equipped with, and protected by, a guard or other device that prevents access to the moving part or pinch point. Guards should be designed and installed in conformance with appropriate machine safety standards.[64]
- Turning off, disconnecting, isolating, and de-energizing (Locked Out and Tagged Out) machinery with exposed or guarded moving parts, or in which energy can be stored (e.g. compressed air, electrical components) during servicing or maintenance, in conformance with a standard such as CSA Z460 Lockout or equivalent ISO or ANSI standard
- Designing and installing equipment, where feasible, to enable routine service, such as lubrication, without removal of the guarding devices or mechanisms

Noise

Noise limits for different working environments are provided in Table 2.3.1.

- No employee should be exposed to a noise level greater than 85 dB(A) for a duration of more than 8 hours per day without hearing protection. In addition, no unprotected ear should be exposed to a peak sound pressure level (instantaneous) of more than 140 dB(C).
- The use of hearing protection should be enforced actively when the equivalent sound level over 8 hours reaches 85 dB(A), the peak sound levels reach 140 dB(C), or the average maximum sound level reaches 110dB(A). Hearing protective devices provided should be capable of reducing sound levels at the ear to at least 85 dB(A).
- Although hearing protection is preferred for any period of noise exposure in excess of 85 dB(A), an equivalent level of protection can be obtained, but less easily managed, by limiting the duration of noise exposure. For every 3 dB(A) increase in sound levels, the 'allowed' exposure period or duration should be reduced by 50 percent.[65]
- Prior to the issuance of hearing protective devices as the final control mechanism, use of acoustic insulating materials, isolation of the noise source, and other engineering controls should be investigated and implemented, where feasible
- Periodic medical hearing checks should be performed on workers exposed to high noise levels

Vibration

Exposure to hand-arm vibration from equipment such as hand and power tools, or whole-body vibrations from surfaces on which the worker stands or sits, should be controlled through choice of equipment, installation of vibration dampening pads or devices, and limiting the duration of exposure. Limits for vibration and

[64] For example: CSA Z432.04 Safe Guarding of Machinery, CSA Z434 Robot Safety, ISO 11161 Safety of Machinery – Integrated Manufacturing Systems or ISO 14121 Safety of Machinery – Principals of Risk Management or equivalent ANSI standard.

[65] The American Conference of Governmental Industrial Hygienists (ACGIH), 2006

action values, (i.e. the level of exposure at which remediation should be initiated) are provided by the ACGIH[66]. Exposure levels should be checked on the basis of daily exposure time and data provided by equipment manufacturers.

Electrical

Exposed or faulty electrical devices, such as circuit breakers,

Table 2.3.1. Noise Limits for Various Working Environments

Location /activity	Equivalent level $LA_{eq},8h$	Maximum $LA_{max},fast$
Heavy Industry (no demand for oral communication)	85 dB(A)	110 dB(A)
Light industry (decreasing demand for oral communication)	50-65 dB(A)	110 dB(A)
Open offices, control rooms, service counters or similar	45-50 dB(A)	-
Individual offices (no disturbing noise)	40-45 dB(A)	-
Classrooms, lecture halls	35-40 dB(A)	-
Hospitals	30-35 dB(A)	40 dB(A)

panels, cables, cords and hand tools, can pose a serious risk to workers. Overhead wires can be struck by metal devices, such as poles or ladders, and by vehicles with metal booms. Vehicles or grounded metal objects brought into close proximity with overhead wires can result in arcing between the wires and the object, without actual contact. Recommended actions include:

- Marking all energized electrical devices and lines with warning signs
- Locking out (de-charging and leaving open with a controlled locking device) and tagging-out (warning sign placed on the lock) devices during service or maintenance
- Checking all electrical cords, cables, and hand power tools for frayed or exposed cords and following manufacturer recommendations for maximum permitted operating voltage of the portable hand tools
- Double insulating / grounding all electrical equipment used in environments that are, or may become, wet; using equipment with ground fault interrupter (GFI) protected circuits
- Protecting power cords and extension cords against damage from traffic by shielding or suspending above traffic areas
- Appropriate labeling of service rooms housing high voltage equipment ('electrical hazard') and where entry is controlled or prohibited (see also Section 3 on Planning, Siting, and Design);
- Establishing "No Approach" zones around or under high voltage power lines in conformance with Table 2.3.2
- Rubber tired construction or other vehicles that come into direct contact with, or arcing between, high voltage wires may need to be taken out of service for periods of 48 hours and have the tires replaced to prevent catastrophic tire and wheel assembly failure, potentially causing serious injury or death;
- Conducting detailed identification and marking of all buried electrical wiring prior to any excavation work

[66] ACGIH, 2005

Table 2.3.2. No Approach Zones for High Voltage Power Lines	
Nominal phase-to-phase voltage rating	Minimum distance
750 or more volts, but no more than 150,000 volts	3 meters
More than 150,000 volts, but no more than 250,000 volts	4.5 meters
More than 250,000 volts	6 meters

Eye Hazards

Solid particles from a wide variety of industrial operations, and / or a liquid chemical spray may strike a worker in the eye causing an eye injury or permanent blindness. Recommended measures include:

- Use of machine guards or splash shields and/or face and eye protection devices, such as safety glasses with side shields, goggles, and/or a full face shield. Specific Safe Operating Procedures (SOPs) may be required for use of sanding and grinding tools and/or when working around liquid chemicals. Frequent checks of these types of equipment prior to use to ensure mechanical integrity is also good practice. Machine and equipment guarding should conform to standards published by organizations such as CSA, ANSI and ISO (see also Section 2.3 on Rotating and Moving Equipment and 2.7 on Personal Protective Equipment).
- Moving areas where the discharge of solid fragments, liquid, or gaseous emissions can reasonably be predicted (e.g. discharge of sparks from a metal cutting station, pressure relief valve discharge) away from places expected to be occupied or transited by workers or visitors. Where machine or work fragments could present a hazard to transient workers or passers-by, extra area guarding or proximity restricting systems should be implemented, or PPE required for transients and visitors.
- Provisions should be made for persons who have to wear prescription glasses either through the use overglasses or prescription hardened glasses.

Welding / Hot Work

Welding creates an extremely bright and intense light that may seriously injur a worker's eyesight. In extreme cases, blindness may result. Additionally, welding may produce noxious fumes to which prolonged exposure can cause serious chronic diseases. Recommended measures include:

- Provision of proper eye protection such as welder goggles and/or a full-face eye shield for all personnel involved in, or assisting, welding operations. Additional methods may include the use of welding barrier screens around the specific work station (a solid piece of light metal, canvas, or plywood designed to block welding light from others). Devices to extract and remove noxious fumes at the source may also be required.
- Special hot work and fire prevention precautions and Standard Operating Procedures (SOPs) should be implemented if welding or hot cutting is undertaken outside established welding work stations, including 'Hot Work Permits, stand-by fire extinguishers, stand-by fire watch, and maintaining the fire watch for up to one hour after welding or hot cutting has terminated. Special procedures are required for hotwork on tanks or vessels that have contained flammable materials.

Industrial Vehicle Driving and Site Traffic

Poorly trained or inexperienced industrial vehicle drivers have increased risk of accident with other vehicles, pedestrians, and equipment. Industrial vehicles and delivery vehicles, as well as private vehicles on-site, also represent potential collision scenarios. Industrial vehicle driving and site traffic safety practices include:

- Training and licensing industrial vehicle operators in the safe operation of specialized vehicles such as forklifts, including safe loading/unloading, load limits
- Ensuring drivers undergo medical surveillance
- Ensuring moving equipment with restricted rear visibility is outfitted with audible back-up alarms
- Establishing rights-of-way, site speed limits, vehicle inspection requirements, operating rules and procedures (e.g. prohibiting operation of forklifts with forks in down position), and control of traffic patterns or direction
- Restricting the circulation of delivery and private vehicles to defined routes and areas, giving preference to 'one-way' circulation, where appropriate

Working Environment Temperature

Exposure to hot or cold working conditions in indoor or outdoor environments can result temperature stress-related injury or death. Use of personal protective equipment (PPE) to protect against other occupational hazards can accentuate and aggravate heat-related illnesses. Extreme temperatures in permanent work environments should be avoided through implementation of engineering controls and ventilation. Where this is not possible, such as during short-term outdoor work, temperature-related stress management procedures should be implemented which include:

- Monitoring weather forecasts for outdoor work to provide advance warning of extreme weather and scheduling work accordingly
- Adjustment of work and rest periods according to temperature stress management procedures provided by ACGIH[67], depending on the temperature and workloads
- Providing temporary shelters to protect against the elements during working activities or for use as rest areas
- Use of protective clothing
- Providing easy access to adequate hydration such as drinking water or electrolyte drinks, and avoiding consumption of alcoholic beverages

Ergonomics, Repetitive Motion, Manual Handling

Injuries due to ergonomic factors, such as repetitive motion, over-exertion, and manual handling, take prolonged and repeated exposures to develop, and typically require periods of weeks to months for recovery. These OHS problems should be minimized or eliminated to maintain a productive workplace. Controls may include:

- Facility and workstation design with 5th to 95th percentile operational and maintenance workers in mind
- Use of mechanical assists to eliminate or reduce exertions required to lift materials, hold tools and work objects, and requiring multi-person lifts if weights exceed thresholds
- Selecting and designing tools that reduce force requirements and holding times, and improve postures
- Providing user adjustable work stations
- Incorporating rest and stretch breaks into work processes, and conducting job rotation
- Implementing quality control and maintenance programs that reduce unnecessary forces and exertions
- Taking into consideration additional special conditions such as left handed persons

Working at Heights

Fall prevention and protection measures should be implemented whenever a worker is exposed to the hazard of falling more than two meters; into operating machinery; into water or other liquid; into hazardous substances; or through an opening in a work surface. Fall prevention / protection measures may also be warranted on a case-specific basis when there are risks of falling from lesser heights. Fall prevention may include:

67 ACGIH, 2005

- Installation of guardrails with mid-rails and toe boards at the edge of any fall hazard area
- Proper use of ladders and scaffolds by trained employees
- Use of fall prevention devices, including safety belt and lanyard travel limiting devices to prevent access to fall hazard area, or fall protection devices such as full body harnesses used in conjunction with shock absorbing lanyards or self-retracting inertial fall arrest devices attached to fixed anchor point or horizontal life-lines
- Appropriate training in use, serviceability, and integrity of the necessary PPE
- Inclusion of rescue and/or recovery plans, and equipment to respond to workers after an arrested fall

Illumination

Work area light intensity should be adequate for the general purpose of the location and type of activity, and should be supplemented with dedicated work station illumination, as needed. The minimum limits for illumination intensity for a range of locations/activities appear in Table 2.3.3.

Table 2.3.3. Minimum Limits For Workplace Illumination Intensity	
Location / Activity	**Light Intensity**
Emergency light	10 lux
Outdoor non working areas	20 lux
Simple orientation and temporary visits (machine storage, garage, warehouse)	50 lux
Workspace with occasional visual tasks only (corridors, stairways, lobby, elevator, auditorium, etc.)	100 lux
Medium precision work (simple assembly, rough machine works, welding, packing, etc.)	200 lux
Precision work (reading, moderately difficult assembly, sorting, checking, medium bench and machine works, etc.), offices.	500 lux
High precision work (difficult assembly, sewing, color inspection, fine sorting etc.)	1,000 – 3,000 lux

Controls should include:

- Use of energy efficient light sources with minimum heat emission
- Undertaking measures to eliminate glare / reflections and flickering of lights
- Taking precautions to minimize and control optical radiation including direct sunlight. Exposure to high intensity UV and IR radiation and high intensity visible light should also be controlled
- Controlling laser hazards in accordance with equipment specifications, certifications, and recognized safety standards. The lowest feasible class Laser should be applied to minimize risks.

2.4 Chemical Hazards

Chemical hazards represent potential for illness or injury due to single acute exposure or chronic repetitive exposure to toxic, corrosive, sensitizing or oxidative substances. They also represent a risk of uncontrolled reaction, including the risk of fire and explosion, if incompatible chemicals are inadvertently mixed. Chemical hazards can most effectively be prevented through a hierarchical approach that includes:

- Replacement of the hazardous substance with a less hazardous substitute
- Implementation of engineering and administrative control measures to avoid or minimize the release of hazardous substances into the work environment keeping the level of exposure below internationally established or recognized limits
- Keeping the number of employees exposed, or likely to become exposed, to a minimum

- Communicating chemical hazards to workers through labeling and marking according to national and internationally recognized requirements and standards, including the International Chemical Safety Cards (ICSC), Materials Safety Data Sheets (MSDS), or equivalent. Any means of written communication should be in an easily understood language and be readily available to exposed workers and first-aid personnel
- Training workers in the use of the available information (such as MSDSs), safe work practices, and appropriate use of PPE

Air Quality

Poor air quality due to the release of contaminants into the work place can result in possible respiratory irritation, discomfort, or illness to workers. Employers should take appropriate measures to maintain air quality in the work area. These include:

- Maintaining levels of contaminant dusts, vapors and gases in the work environment at concentrations below those recommended by the ACGIH[68] as TWA-TLV's (threshold limit value)—concentrations to which most workers can be exposed repeatedly (8 hours/day, 40 hrs/week, week-after-week), without sustaining adverse health effects.
- Developing and implementing work practices to minimize release of contaminants into the work environment including:
  - Direct piping of liquid and gaseous materials
  - Minimized handling of dry powdered materials;
  - Enclosed operations
  - Local exhaust ventilation at emission / release points
  - Vacuum transfer of dry material rather than mechanical or pneumatic conveyance
  - Indoor secure storage, and sealed containers rather than loose storage
- Where ambient air contains several materials that have similar effects on the same body organs (additive effects), taking into account combined exposures using calculations recommended by the ACGIH[69]
- Where work shifts extend beyond eight (8) hours, calculating adjusted workplace exposure criteria recommended by the ACGIH[70]

Fire and Explosions

Fires and or explosions resulting from ignition of flammable materials or gases can lead to loss of property as well as possible injury or fatalities to project workers. Prevention and control strategies include:

- Storing flammables away from ignition sources and oxidizing materials. Further, flammables storage area should be:
  - Remote from entry and exit points into buildings
  - Away from facility ventilation intakes or vents
  - Have natural or passive floor and ceiling level ventilation and explosion venting
  - Use spark-proof fixtures
  - Be equipped with fire extinguishing devices and self-closing doors, and constructed of materials made to withstand flame impingement for a moderate period of time
- Providing bonding and grounding of, and between, containers and additional mechanical floor level ventilation if materials are being, or could be, dispensed in the storage area
- Where the flammable material is mainly comprised of dust, providing electrical grounding, spark detection, and, if needed, quenching systems

[68] ACGIH, 2005

[69] ACGIH, 2005.

[70] ACGIH, 2005.

- Defining and labeling fire hazards areas to warn of special rules (e.g. prohibition in use of smoking materials, cellular phones, or other potential spark generating equipment)
- Providing specific worker training in handling of flammable materials, and in fire prevention or suppression

Corrosive, oxidizing, and reactive chemicals

Corrosive, oxidizing, and reactive chemicals present similar hazards and require similar control measures as flammable materials. However, the added hazard of these chemicals is that inadvertent mixing or intermixing may cause serious adverse reactions. This can lead to the release of flammable or toxic materials and gases, and may lead directly to fires and explosions. These types of substances have the additional hazard of causing significant personal injury upon direct contact, regardless of any intermixing issues. The following controls should be observed in the work environment when handling such chemicals:

- Corrosive, oxidizing and reactive chemicals should be segregated from flammable materials and from other chemicals of incompatible class (acids vs. bases, oxidizers vs. reducers, water sensitive vs. water based, etc.), stored in ventilated areas and in containers with appropriate secondary containment to minimize intermixing during spills
- Workers who are required to handle corrosive, oxidizing, or reactive chemicals should be provided with specialized training and provided with, and wear, appropriate PPE (gloves, apron, splash suits, face shield or goggles, etc).
- Where corrosive, oxidizing, or reactive chemicals are used, handled, or stored, qualified first-aid should be ensured at all times. Appropriately equipped first-aid stations should be easily accessible throughout the place of work, and eye-wash stations and/or emergency showers should be provided close to all workstations where the recommended first-aid response is immediate flushing with water

Asbestos Containing Materials (ACM)

The use of asbestos containing materials (ACM) should be avoided in new buildings or as a new material in remodeling or renovation activities. Existing facilities with ACM should develop an asbestos management plan which clearly identifies the locations where the ACM is present, its condition (e.g. whether it is in friable form with the potential to release fibers), procedures for monitoring its condition, procedures to access the locations where ACM is present to avoid damage, and training of staff who can potentially come into contact with the material to avoid damage and prevent exposure. The plan should be made available to all persons involved in operations and maintenance activities. Repair or removal and disposal of existing ACM in buildings should only be performed by specially trained personnel[71] following host country requirements, or in their absence, internationally recognized procedures.[72]

2.5 Biological Hazards

Biological agents represent potential for illness or injury due to single acute exposure or chronic repetitive exposure. Biological hazards can be prevented most effectively by implementing the following measures:

- If the nature of the activity permits, use of any harmful biological agents should be avoided and replaced with an agent that, under normal conditions of use, is not dangerous or less dangerous to workers. If use of harmful agents can not be avoided, precautions should be taken to keep the risk of exposure as low as possible and maintained below internationally established and recognized exposure limits.

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[71] Training of specialized personnel and the maintenance and removal methods applied should be equivalent to those required under applicable regulations in the United States and Europe (examples of North American training standards are available at: http://www.osha.gov/SLTC/asbestos/training.html)

[72] Examples include the American Society for Testing and Materials (ASTM) E 1368 - Standard Practice for Visual Inspection of Asbestos Abatement Projects; E 2356 - Standard Practice for Comprehensive Building Asbestos Surveys; and E 2394 - Standard Practice for Maintenance, Renovation and Repair of Installed Asbestos Cement Products.

- Work processes, engineering, and administrative controls should be designed, maintained, and operated to avoid or minimize release of biological agents into the working environment. The number of employees exposed or likely to become exposed should be kept at a minimum.
- The employer should review and assess known and suspected presence of biological agents at the place of work and implement appropriate safety measures, monitoring, training, and training verification programs.
- Measures to eliminate and control hazards from known and suspected biological agents at the place of work should be designed, implemented and maintained in close co-operation with the local health authorities and according to recognized international standards.

Biological agents should be classified into four groups[73]:

- *Group 1:* Biological agents unlikely to cause human disease, and consequently only require controls similar to those required for hazardous or reactive chemical substances;
- *Group 2:* Biological agents that can cause human disease and are thereby likely to require additional controls, but are unlikely to spread to the community;
- *Group 3*: Biological agents that can cause severe human disease, present a serious hazard to workers, and may present a risk of spreading to the community, for which there usually is effective prophylaxis or treatment available and are thereby likely to require extensive additional controls;
- *Group 4:* Biological agents that can cause severe human disease, are a serious hazard to workers, and present a high risk of spreading to the community, for which there is usually no effective prophylaxis or treatment available and are thereby likely to require very extensive additional controls.

The employer should at all times encourage and enforce the highest level of hygiene and personal protection, especially for activities employing biological agents of Groups 3 and 4 above. Work involving agents in Groups 3 and 4 should be restricted only to those persons who have received specific verifiable training in working with and controlling such materials.

Areas used for the handling of Groups 3 and 4 biological agents should be designed to enable their full segregation and isolation in emergency circumstances, include independent ventilation systems, and be subject to SOPs requiring routine disinfection and sterilization of the work surfaces.

HVAC systems serving areas handling Groups 3 and 4 biological agents should be equipped with High Efficiency Particulate Air (HEPA) filtration systems. Equipment should readily enable their disinfection and sterilization, and maintained and operated so as to prevent growth and spreading of disease agents, amplification of the biological agents, or breeding of vectors e.g. mosquitoes and flies of public health concern.

[73] World Health Organization (WHO) Classification of Infective Microorganisms by Risk Group (2004).

2.6 Radiological Hazards

Radiation exposure can lead to potential discomfort, injury or serious illness to workers. Prevention and control strategies include:

- Places of work involving occupational and/or natural exposure to ionizing radiation should be established and operated in accordance with recognized international safety standards and guidelines.[74] The acceptable effective dose limits appear Table 2.6.1.
- Exposure to non-ionizing radiation (including static magnetic fields; sub-radio frequency magnetic fields; static electric fields; radio frequency and microwave radiation; light and near-infrared radiation; and ultraviolet radiation) should be controlled to internationally recommended limits[75].

Table 2.6.1. Acceptable Effective Dose Limits for Workplace Radiological Hazards

Exposure	Workers (min.19 years of age)	Apprentices and students (16-18 years of age)
Five consecutive year average – effective dose	20 mSv/year	
Single year exposure – effective dose	50 mSv/year	6 mSv/year
Equivalent dose to the lens of the eye	150 mSv/year	50 mSv/year
Equivalent dose to the extremities (hands, feet) or the skin	500 mSv/year	150 mSv/year

- In the case of both ionizing and non-ionizing radiation, the preferred method for controlling exposure is shielding and limiting the radiation source. Personal protective equipment is supplemental only or for emergency use. Personal protective equipment for near-infrared, visible and ultraviolet range radiation can include appropriate sun block creams, with or without appropriate screening clothing.

2.7 Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) provides additional protection to workers exposed to workplace hazards in conjunction with other facility controls and safety systems.

PPE is considered to be a last resort that is above and beyond the other facility controls and provides the worker with an extra level of personal protection. Table 2.7.1 presents general examples of occupational hazards and types of PPE available for different purposes. Recommended measures for use of PPE in the workplace include:

- Active use of PPE if alternative technologies, work plans or procedures cannot eliminate, or sufficiently reduce, a hazard or exposure
- Identification and provision of appropriate PPE that offers adequate protection to the worker, co-workers, and occasional visitors, without incurring unnecessary inconvenience to the individual
- Proper maintenance of PPE, including cleaning when dirty and replacement when damaged or worn out. Proper use of PPE should be part of the recurrent training programs for employees

[74] International Basic Safety Standard for protection against Ionizing Radiation and for the Safety of Radiation Sources and its three interrelated Safety Guides.

IAEA. http://www-ns.iaea.org/standards/documents/default.asp?sub=160

[75] For example ACGIH (2005) and International Commission for Non-Ionizing Radiation (ICNIRP).

- Selection of PPE should be based on the hazard and risk ranking described earlier in this section, and selected according to criteria on performance and testing established by recognized organizations[76].

Table 2.7.1. Summary of Recommended Personal Protective Equipment According to Hazard

Objective	Workplace Hazards	Suggested PPE
Eye and face protection	Flying particles, molten metal, liquid chemicals, gases or vapors, light radiation.	Safety Glasses with side-shields, protective shades, etc.
Head protection	Falling objects, inadequate height clearance, and overhead power cords.	Plastic Helmets with top and side impact protection.
Hearing protection	Noise, ultra-sound.	Hearing protectors (ear plugs or ear muffs).
Foot protection	Falling or rolling objects, pointed objects. Corrosive or hot liquids.	Safety shoes and boots for protection against moving & falling objects, liquids and chemicals.
Hand protection	Hazardous materials, cuts or lacerations, vibrations, extreme temperatures.	Gloves made of rubber or synthetic materials (Neoprene), leather, steel, insulating materials, etc.
Respiratory protection	Dust, fogs, fumes, mists, gases, smokes, vapors.	Facemasks with appropriate filters for dust removal and air purification (chemicals, mists, vapors and gases). Single or multi-gas personal monitors, if available.
	Oxygen deficiency	Portable or supplied air (fixed lines). On-site rescue equipment.
Body/leg protection	Extreme temperatures, hazardous materials, biological agents, cutting and laceration.	Insulating clothing, body suits, aprons etc. of appropriate materials.

2.8 Special Hazard Environments

Special hazard environments are work situations where all of the previously described hazards may exist under unique or especially hazardous circumstances. Accordingly, extra precautions or rigor in application of precautions is required.

Confined Space

A confined space is defined as a wholly or partially enclosed space not designed or intended for human occupancy and in which a hazardous atmosphere could develop as a result of the contents, location or construction of the confined space or due to work done in or around the confined space. A "permit-required" confined space is one that also contains physical or atmospheric hazards that could trap or engulf the person.[77]

Confined spaces can occur in enclosed or open structures or locations. Serious injury or fatality can result from inadequate preparation to enter a confined space or in attempting a rescue from a confined space. Recommended management approaches include:

- Engineering measures should be implemented to eliminate, to the degree feasible, the existence and adverse character of confined spaces.
- Permit-required confined spaces should be provided with permanent safety measures for venting, monitoring, and rescue operations, to the extent possible. The area adjoining an access to a confined space should provide ample room for emergency and rescue operations.

[76] Examples include the American National Standards Institute (ANSI), http://www.ansi.org/; National Institute for Occupational Safety and Health[76] (NIOSH), http://www.cdc.gov/niosh/homepage.html; Canadian Standards Association[76] (CSA), http://www.csa.ca/Default.asp?language=english; Mine Safety and Health Administration[76] (MSHA), http://www.msha.gov.

[77] US OSHA CFR 1910.146

- Access hatches should accommodate 90% of the worker population with adjustments for tools and protective clothing. The most current ISO and EN standards should be consulted for design specifications;
- Prior to entry into a permit-required confined space:
  - Process or feed lines into the space should be disconnected or drained, and blanked and locked-out.
  - Mechanical equipment in the space should be disconnected, de-energized, locked-out, and braced, as appropriate.
  - The atmosphere within the confined space should be tested to assure the oxygen content is between 19.5 percent and 23 percent, and that the presence of any flammable gas or vapor does not exceed 25 percent of its respective Lower Explosive Limit (LEL).
  - If the atmospheric conditions are not met, the confined space should be ventilated until the target safe atmosphere is achieved, or entry is only to be undertaken with appropriate and additional PPE.
- Safety precautions should include Self Contained Breathing Apparatus (SCBA), life lines, and safety watch workers stationed outside the confined space, with rescue and first aid equipment readily available.
- Before workers are required to enter a permit-required confined space, adequate and appropriate training in confined space hazard control, atmospheric testing, use of the necessary PPE, as well as the serviceability and integrity of the PPE should be verified. Further, adequate and appropriate rescue and / or recovery plans and equipment should be in place before the worker enters the confined space.

Lone and Isolated Workers

A lone and isolated worker is a worker out of verbal and line of sight communication with a supervisor, other workers, or other persons capable of providing aid and assistance, for continuous periods exceeding one hour. The worker is therefore at increased risk should an accident or injury occur.

- Where workers may be required to perform work under lone or isolated circumstances, Standard Operating Procedures (SOPs) should be developed and implemented to ensure all PPE and safety measures are in place before the worker starts work. SOPs should establish, at a minimum, verbal contact with the worker at least once every hour, and ensure the worker has a capability for summoning emergency aid.
- If the worker is potentially exposed to highly toxic or corrosive chemicals, emergency eye-wash and shower facilities should be equipped with audible and visible alarms to summon aid whenever the eye-wash or shower is activated by the worker and without intervention by the worker.

2.9 Monitoring

Occupational health and safety monitoring programs should verify the effectiveness of prevention and control strategies. The selected indicators should be representative of the most significant occupational, health, and safety hazards, and the implementation of prevention and control strategies. The occupational health and safety monitoring program should include:

- *Safety inspection, testing and calibration:* This should include regular inspection and testing of all safety features and hazard control measures focusing on engineering and personal protective features, work procedures, places of work, installations, equipment, and tools used. The inspection should verify that issued PPE continues to provide adequate protection and is being worn as required. All instruments installed or used for monitoring and recording of working environment parameters should be regularly tested and calibrated, and the respective records maintained.
- *Surveillance of the working environment:* Employers should document compliance using an appropriate combination of

portable and stationary sampling and monitoring instruments. Monitoring and analyses should be conducted according to internationally recognized methods and standards. Monitoring methodology, locations, frequencies, and parameters should be established individually for each project following a review of the hazards. Generally, monitoring should be performed during commissioning of facilities or equipment and at the end of the defect and liability period, and otherwise repeated according to the monitoring plan.

- *Surveillance of workers health:* When extraordinary protective measures are required (for example, against biological agents Groups 3 and 4, and/or hazardous compounds), workers should be provided appropriate and relevant health surveillance prior to first exposure, and at regular intervals thereafter. The surveillance should, if deemed necessary, be continued after termination of the employment.
- *Training:* Training activities for employees and visitors should be adequately monitored and documented (curriculum, duration, and participants). Emergency exercises, including fire drills, should be documented adequately. Service providers and contractors should be contractually required to submit to the employer adequate training documentation before start of their assignment.

Accidents and Diseases monitoring

- The employer should establish procedures and systems for reporting and recording:
  - o Occupational accidents and diseases
  - o Dangerous occurrences and incidents

  These systems should enable workers to report immediately to their immediate supervisor any situation they believe presents a serious danger to life or health.
- The systems and the employer should further enable and encourage workers to report to management all:
  - o Occupational injuries and near misses
  - o Suspected cases of occupational disease
  - o Dangerous occurrences and incidents
- All reported occupational accidents, occupational diseases, dangerous occurrences, and incidents together with near misses should be investigated with the assistance of a person knowledgeable/competent in occupational safety. The investigation should:
  - o Establish what happened
  - o Determine the cause of what happened
  - o Identify measures necessary to prevent a recurrence
- Occupational accidents and diseases should, at a minimum, be classified according to Table 2.10.1. Distinction is made between fatal and non-fatal injuries. The two main categories are divided into three sub-categories according to time of death or duration of the incapacity to work. The total work hours during the specified reporting period should be reported to the appropriate regulatory agency.

Table 2.9.1. Occupational Accident Reporting

a. Fatalities (number)	**b. Non-fatal injuries** (number) [78]	**c. Total time lost** non-fatal injuries (days)
a.1 Immediate	**b.1** Less than one day	
a.2 Within a month	**b.2** Up to 3 days	**c.1** Category b.2
a.3 Within a year	**b.3** More than 3 days	**c.2** Category b.3

[78] The day on which an incident occurs is not included in b.2 and b.3.

3.0 Community Health and Safety

This section complements the guidance provided in the preceding environmental and occupational health and safety sections, specifically addressing some aspects of project activities taking place outside of the traditional project boundaries, but nonetheless related to the project operations, as may be applicable on a project basis. These issues may arise at any stage of a project life cycle and can have an impact beyond the life of the project.

3.1 Water Quality and Availability

Groundwater and surface water represent essential sources of drinking and irrigation water in developing countries, particularly in rural areas where piped water supply may be limited or unavailable and where available resources are collected by the consumer with little or no treatment. Project activities involving wastewater discharges, water extraction, diversion or impoundment should prevent adverse impacts to the quality and availability of groundwater and surface water resources.

Water Quality

Drinking water sources, whether public or private, should at all times be protected so that they meet or exceed applicable national acceptability standards or in their absence the current edition of WHO Guidelines for Drinking-Water Quality. Air emissions, wastewater effluents, oil and hazardous materials, and wastes should be managed according to the guidance provided in the respective sections of the General EHS Guidelines with the objective of protecting soil and water resources.

Where the project includes the delivery of water to the community or to users of facility infrastructure (such as hotel hosts and hospital patients), where water may be used for drinking, cooking, washing, and bathing, water quality should comply with national acceptability standards or in their absence the current edition of with WHO Drinking Water Guidelines. Water quality for more sensitive well-being-related demands such as water used in health care facilities or food production may require more stringent, industry-specific guidelines or standards, as applicable. Any dependency factors associated with the deliver of water to the local community should be planned for and managed to ensure the sustainability of the water supply by involving the community in its management to minimize the dependency in the long-term.

Water Availability

The potential effect of groundwater or surface water abstraction for project activities should be properly assessed through a combination of field testing and modeling techniques, accounting for seasonal variability and projected changes in demand in the project area.

Project activities should not compromise the availability of water for personal hygiene needs and should take account of potential future increases in demand. The overall target should be the availability of 100 liters per person per day although lower levels may be used to meet basic health requirements.[79] Water volume requirements for well-being-related demands such as water use in health care facilities may need to be higher.

3.2 Structural Safety of Project Infrastructure

Hazards posed to the public while accessing project facilities may include:

- Physical trauma associated with failure of building structures
- Burns and smoke inhalation from fires
- Injuries suffered as a consequence of falls or contact with heavy equipment
- Respiratory distress from dust, fumes, or noxious odors
- Exposure to hazardous materials

Reduction of potential hazards is best accomplished during the design phase when the structural design, layout and site modifications can be adapted more easily. The following issues should be considered and incorporated as appropriate into the planning, siting, and design phases of a project:

- Inclusion of buffer strips or other methods of physical separation around project sites to protect the public from major hazards associated with hazardous materials incidents or process failure, as well as nuisance issues related to noise, odors, or other emissions
- Incorporation of siting and safety engineering criteria to prevent failures due to natural risks posed by earthquakes, tsunamis, wind, flooding, landslides and fire. To this end, all project structures should be designed in accordance with engineering and design criteria mandated by site-specific risks, including but not limited to seismic activity, slope stability, wind loading, and other dynamic loads
- Application of locally regulated or internationally recognized building codes[80] to ensure structures are designed and constructed in accordance with sound architectural and engineering practice, including aspects of fire prevention and response
- Engineers and architects responsible for designing and constructing facilities, building, plants and other structures should certify the applicability and appropriateness of the structural criteria employed.

International codes, such as those compiled by the International Code Council (ICC)[81], are intended to regulate the design, construction, and maintenance of a built environment and contain detailed guidance on all aspects of building safety, encompassing methodology, best practices, and documenting compliance. Depending on the nature of a project, guidance provided in the ICC or comparable codes should be followed, as appropriate, with respect to:

- Existing structures
- Soils and foundations
- Site grading
- Structural design
- Specific requirements based on intended use and occupancy
- Accessibility and means of egress
- Types of construction
- Roof design and construction
- Fire-resistant construction
- Flood-resistant construction

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79 World Health Organization (WHO) defines 100 liters/capita/day as the amount required to meet all consumption and hygiene needs. Additional information on lower service levels and potential impacts on health are described in "Domestic Water Quantity, Service Level and Health" 2003. http://www.who.int/water_sanitation_health/diseases/wsh0302/en/index.html

80 ILO-OSH, 2001. http://www.ilo.org/public/english/protection/safework/cops/english/download/e000013.pdf

81 ICC, 2006.

- Construction materials
- Interior environment
- Mechanical, plumbing and electrical systems
- Elevators and conveying systems
- Fire safety systems
- Safeguards during construction
- Encroachments into public right-of-way

Although major design changes may not be feasible during the operation phase of a project, hazard analysis can be undertaken to identify opportunities to reduce the consequences of a failure or accident. Illustrative management actions, applicable to hazardous materials storage and use, include:

- Reducing inventories of hazardous materials through inventory management and process changes to greatly reduce or eliminate the potential off-site consequences of a release
- Modifying process or storage conditions to reduce the potential consequences of an accidental off-site release
- Improving shut-down and secondary containment to reduce the amount of material escaping from containment and to reduce the release duration
- Reducing the probability that releases will occur through improved site operations and control, and through improvements in maintenance and inspection
- Reducing off-site impacts of releases through measures intended to contain explosions and fires, alert the public, provide for evacuation of surrounding areas, establish safety zones around a site, and ensure the provision of emergency medical services to the public

3.3 Life and Fire Safety (L&FS)

Applicability and Approach

All new buildings accessible to the public should be designed, constructed, and operated in full compliance with local building codes, local fire department regulations, local legal/insurance requirements, and in accordance with an internationally accepted life and fire safety (L&FS) standard. The Life Safety Code[82], which provides extensive documentation on life and fire safety provisions, is one example of an internationally accepted standard and may be used to document compliance with the Life and Fire Safety objectives outlined in these guidelines. With regard to these objectives:

- Project sponsors' architects and professional consulting engineers should demonstrate that affected buildings meet these life and fire safety objectives.
- Life and fire safety systems and equipment should be designed and installed using appropriate prescriptive standards and/or performance based design, and sound engineering practices.
- Life and fire safety design criteria for all existing buildings should incorporate all local building codes and fire department regulations.

These guidelines apply to buildings that are accessible to the public. Examples of such buildings include:

- Health and education facilities
- Hotels, convention centers, and leisure facilities
- Retail and commercial facilities
- Airports, other public transport terminals, transfer facilities

Specific Requirements for New Buildings

The nature and extent of life and fire safety systems required will depend on the building type, structure, construction, occupancy, and exposures. Sponsors should prepare a Life and Fire Safety Master Plan identifying major fire risks, applicable codes, standards and regulations, and mitigation measures. The Master

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[82] US NFPA. http://www.nfpa.org/catalog/product.asp?category%5Fname=&pid=10106&target%5Fpid=10106&src%5Fpid=&link%5Ftype=search

Plan should be prepared by a suitably qualified professional, and adequately cover, but not be limited to, the issues addressed briefly in the following points. The suitably qualified professional selected to prepare the Master Plan is responsible for a detailed treatment of the following illustrative, and all other required, issues.

Fire Prevention

Fire prevention addresses the identification of fire risks and ignition sources, and measures needed to limit fast fire and smoke development. These issues include:

- Fuel load and control of combustibles
- Ignition sources
- Interior finish flame spread characteristics
- Interior finish smoke production characteristics
- Human acts, and housekeeping and maintenance

Means of Egress

Means of Egress includes all design measures that facilitate a safe evacuation by residents and/or occupants in case of fire or other emergency, such as:

- Clear, unimpeded escape routes
- Accessibility to the impaired/handicapped
- Marking and signing
- Emergency lighting

Detection and Alarm Systems

These systems encompass all measures, including communication and public address systems needed to detect a fire and alert:

- Building staff
- Emergency response teams
- Occupants
- Civil defense

Compartmentation

Compartmentation involves all measures to prevent or slow the spread of fire and smoke, including:

- Separations
- Fire walls
- Floors
- Doors
- Dampers
- Smoke control systems

Fire Suppression and Control

Fire suppression and control includes all automatic and manual fire protection installations, such as:

- Automatic sprinkler systems
- Manual portable extinguishers
- Fire hose reels

Emergency Response Plan

An Emergency Response Plan is a set of scenario–based procedures to assist staff and emergency response teams during real life emergency and training exercises. This chapter of the Fire and Life Safety Master Plan should include an assessment of local fire prevention and suppression capabilities.

Operation and Maintenance

Operation and Maintenance involves preparing schedules for mandatory regular maintenance and testing of life and fire safety features to ensure that mechanical, electrical, and civil structures and systems are at all times in conformance with life and fire safety design criteria and required operational readiness.

L&FS Master Plan Review and Approval

- A suitably qualified professional prepares and submits a Life and Fire Safety (L&FS) Master Plan, including preliminary drawings and specifications, and certifies that the design meets the requirements of these L&FS guidelines. The findings and recommendations of the review are then used to establish the conditions of a Corrective Action Plan and a time frame for implementing the changes.

- The suitably qualified professional conducts a review as part of the project completion test at the time of life and fire safety systems testing and commissioning, and certifies that construction of these systems has been carried out in accordance with the accepted design. The findings and recommendations of the review are used as the basis for establishing project completion or to establish the conditions of a Pre-Completion Corrective Action Plan and a time frame for implementing the changes.

Specific Requirements for Existing Buildings

- All life and fire safety guideline requirements for new buildings apply to existing buildings programmed for renovation. A suitably qualified professional conducts a complete life and fire safety review of existing buildings slated for renovation. The findings and recommendations of the review are used as the basis to establish the scope of work of a Corrective Action Plan and a time frame for implementing the changes.
- If it becomes apparent that life and fire safety conditions are deficient in an existing building that is not part of the project or that has not been programmed for renovation, a life and fire safety review of the building may be conducted by a suitably qualified professional. The findings and recommendations of the review are used as the basis to establish the scope of work of a Corrective Action Plan and a time frame for implementing the changes.

Other Hazards

- Facilities, buildings, plants, and structures should be situated to minimize potential risks from forces of nature (e.g. earthquakes, tsunamis, floods, windstorms, and fires from surrounding areas).
- All such structures should be designed in accordance with the criteria mandated by situation-, climatic-, and geology-specific location risks (e.g. seismic activity, wind loading, and other dynamic loads).
- Structural engineers and architects responsible for facilities, buildings, plants and structures should certify the applicability and appropriateness of the design criteria employed.
- National or regional building regulations typically contain fire safety codes and standards[83] or these standards are found in separate Fire Codes.[84,85] Generally, such codes and regulations incorporate further compliance requirements with respect to methodology, practice, testing, and other codes and standards[86]. Such nationally referenced material constitutes the acceptable fire life safety code.

3.4 Traffic Safety

Traffic accidents have become one of the most significant causes of injuries and fatalities among members of the public worldwide. Traffic safety should be promoted by all project personnel during displacement to and from the workplace, and during operation of project equipment on private or public roads. Prevention and control of traffic related injuries and fatalities should include the adoption of safety measures that are protective of project workers and of road users, including those who are most vulnerable to road traffic accidents[87]. Road safety initiatives proportional to the scope and nature of project activities should include:

83 For example, Australia, Canada, South Africa, United Kingdom

84 Réglementation Incendie [des ERP]

85 USA NFPA, 2006.

86 Prepared by National Institutes and Authorities such as American Society for Testing and Materials (ASTM), British Standards (BS), German Institute of Standardization (DIN), and French Standards (NF)

87 Additional information on vulnerable users of public roads in developing countries is provided by Peden et al., 2004.

- Adoption of best transport safety practices across all aspects of project operations with the goal of preventing traffic accidents and minimizing injuries suffered by project personnel and the public. Measures should include:
  - Emphasizing safety aspects among drivers
  - Improving driving skills and requiring licensing of drivers
  - Adopting limits for trip duration and arranging driver rosters to avoid overtiredness
  - Avoiding dangerous routes and times of day to reduce the risk of accidents
  - Use of speed control devices (governors) on trucks, and remote monitoring of driver actions
- Regular maintenance of vehicles and use of manufacturer approved parts to minimize potentially serious accidents caused by equipment malfunction or premature failure.

Where the project may contribute to a significant increase in traffic along existing roads, or where road transport is a significant component of a project, recommended measures include:

- Minimizing pedestrian interaction with construction vehicles
- Collaboration with local communities and responsible authorities to improve signage, visibility and overall safety of roads, particularly along stretches located near schools or other locations where children may be present. Collaborating with local communities on education about traffic and pedestrian safety (e.g. school education campaigns)[88]
- Coordination with emergency responders to ensure that appropriate first aid is provided in the event of accidents
- Using locally sourced materials, whenever possible, to minimize transport distances. Locating associated facilities such as worker camps close to project sites and arranging worker bus transport to minimizing external traffic
- Employing safe traffic control measures, including road signs and flag persons to warn of dangerous conditions

3.5 Transport of Hazardous Materials

General Hazardous Materials Transport

- Projects should have procedures in place that ensure compliance with local laws and international requirements applicable to the transport of hazardous materials, including:
  - IATA requirements[89] for air transport
  - IMDG Code[90] sea transport
  - UN Model Regulations[91] of other international standards as well as local requirements for land transport
  - Host-country commitments under the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their disposal and Rotterdam Convention on the prior Inform Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, if applicable to the project activities
- The procedures for transportation of hazardous materials (Hazmats) should include:
  - Proper labeling of containers, including the identify and quantity of the contents, hazards, and shipper contact information
  - Providing a shipping document (e.g. shipping manifest) that describes the contents of the load and its associated hazards in addition to the labeling of the containers. The shipping document should establish a chain-of-custody using multiple signed copies to show that the waste was properly shipped, transported and received by the recycling or treatment/disposal facility

[88] Additional sources of information for implementation of road safety measures is available at WHO, 1989, Ross et al., 1991, Tsunokawa and Hoban, 1997, and OECD, 1999

[89] IATA, 2005. www.iata.org

[90] IMO. www.imo.org/safety

[91] United Nations. Transport of Dangerous Goods - Model Regulations. 14th Revised Edition. Geneva 2005. http://www.unece.org/trans/danger/publi/unrec/rev14/14files_e.html

- o Ensuring that the volume, nature, integrity and protection of packaging and containers used for transport are appropriate for the type and quantity of hazardous material and modes of transport involved
- o Ensuring adequate transport vehicle specifications
- o Training employees involved in the transportation of hazardous materials regarding proper shipping procedures and emergency procedures
- o Using labeling and placarding (external signs on transport vehicles), as required
- o Providing the necessary means for emergency response on call 24 hours/day

Major Transportation Hazards

Guidance related to major transportation hazards should be implemented in addition to measures presented in the preceding section for preventing or minimizing the consequences of catastrophic releases of hazardous materials, which may result in toxic, fire, explosion, or other hazards during transportation.

In addition to these aforementioned procedures, projects which transport hazardous materials *at or above the threshold quantities*[92] should prepare a Hazardous Materials Transportation Plan containing all of the elements presented below[93].

Hazard Assessment

The hazard assessment should identify the potential hazard involved in the transportation of hazardous materials by reviewing:

- The hazard characteristics of the substances identified during the screening stage
- The history of accidents, both by the company and its contractors, involving hazardous materials transportation
- The existing criteria for the safe transportation of hazardous materials, including environmental management systems used by the company and its contractors

This review should cover the management actions, preventive measures and emergency response procedures described below. The hazard assessment helps to determine what additional measures may be required to complete the plan.

Management Actions

- *Management of Change:* These procedures should address:
  - o The technical basis for changes in hazardous materials offered for transportation, routes and/or procedures
  - o The potential impact of changes on health and safety
  - o Modification required to operating procedures
  - o Authorization requirements
  - o Employees affected
  - o Training needs
- *Compliance Audit:* A compliance audit evaluates compliance with prevention requirements for each transportation route or for each hazardous material, as appropriate. A compliance audit covering each element of the prevention measures (see below) should be conducted at least every three years. The audit program should include:
  - o Preparation of a report of the findings
  - o Determination and documentation of the appropriate response to each finding
  - o Documentation that any deficiency has been corrected.
- *Incident Investigation:* Incidents can provide valuable information about transportation hazards and the steps needed to prevent accidental releases. The implementation of incident investigation procedures should ensure that:
  - o Investigations are initiated promptly
  - o Summaries of investigations are included in a report
  - o Report findings and recommendations are addressed

92 Threshold quantities for the transport of hazardous materials are found in the UN – Transport of Dangerous Goods – Model Regulations cited above.

93 For further information and guidance, please refer to International Finance Corporation (IFC) Hazardous Materials Transportation Manual. Washington, D.C. December 2000.

- Reports are reviewed with staff and contractors

- *Employee Participation:* There should be a written plan of action regarding the implementation of active employee participation in the prevention of accidents.

- *Contractors:* The plan should include procedures to ensure that:
  - The contractor is provided with safety performance procedures and safety and hazard information
  - Contractors observe safety practices
  - Verify that the contractor acts responsibly

  The plan should also include additional procedures to ensure the contractors will:
  - Ensure appropriate training for their employees
  - Ensure their employees know process hazards and applicable emergency actions
  - Prepare and submit training records
  - Inform employees about the hazards presented by their work

- *Training:* Good training programs on operating procedures will provide the employees with the necessary information to understand how to operate safely and why safe operations are needed. The training program should include:
  - The list of employees to be trained
  - Specific training objectives
  - Mechanisms to achieve objectives (i.e. hands-on workshops, videos, etc.)
  - Means to determine the effectiveness of the training program
  - Training procedures for new hires and refresher programs

Preventive Measures

The plan should include procedures to implement preventive measures specific to each hazardous material offered for transportation, including:

- Classification and segregation of hazardous materials in warehouses and transport units
- Packaging and packaging testing
- Marking and labeling of packages containing hazardous materials
- Handling and securing packages containing hazardous materials in transport units
- Marking and placarding of transport units
- Documentation (e.g. bills of lading)
- Application of special provisions, as appropriate

Emergency Preparedness and Response

It is important to develop procedures and practices for the handling of hazardous materials that allow for quick and efficient responses to accidents that may result in injury or environmental damage. The sponsor should prepare an Emergency Preparedness and Response Plan that should cover:

- *Planning Coordination:* This should include procedures for:
  - Informing the public and emergency response agencies
  - Documenting first aid and emergency medical treatment
  - Taking emergency response actions
  - Reviewing and updating the emergency response plan to reflect changes and ensuring that the employees are informed of such changes

- *Emergency Equipment:* The plan should include procedures for using, inspecting, testing, and maintaining emergency response equipment.

- *Training:* Employees should be trained in any relevant procedures

3.6 Disease Prevention

Communicable Diseases

Communicable diseases pose a significant public health threat worldwide. Health hazards typically associated with large development projects are those relating to poor sanitation and living conditions, sexual transmission and vector-borne infections. Communicable diseases of most concern during the construction phase due to labor mobility are sexually-transmitted diseases (STDs), such as HIV/AIDS. Recognizing that no single measure is likely to be effective in the long term, successful initiatives typically involve a combination of behavioral and environmental modifications.

Recommended interventions at the project level include[94]:

- Providing surveillance and active screening and treatment of workers
- Preventing illness among workers in local communities by:
    - Undertaking health awareness and education initiatives, for example, by implementing an information strategy to reinforce person-to-person counseling addressing systemic factors that can influence individual behavior as well as promoting individual protection, and protecting others from infection, by encouraging condom use
    - Training health workers in disease treatment
    - Conducting immunization programs for workers in local communities to improve health and guard against infection
    - Providing health services
- Providing treatment through standard case management in on-site or community health care facilities. Ensuring ready access to medical treatment, confidentiality and appropriate care, particularly with respect to migrant workers
- Promoting collaboration with local authorities to enhance access of workers families and the community to public health services and promote immunization

Vector-Borne Diseases

Reducing the impact of vector-borne disease on the long-term health of workers is best accomplished through implementation of diverse interventions aimed at eliminating the factors that lead to disease. Project sponsors, in close collaboration with community health authorities, can implement an integrated control strategy for mosquito and other arthropod-borne diseases that might involve:

- Prevention of larval and adult propagation through sanitary improvements and elimination of breeding habitats close to human settlements
- Elimination of unusable impounded water
- Increase in water velocity in natural and artificial channels
- Considering the application of residual insecticide to dormitory walls
- Implementation of integrated vector control programs
- Promoting use of repellents, clothing, netting, and other barriers to prevent insect bites
- Use of chemoprophylaxis drugs by non-immune workers and collaborating with public health officials to help eradicate disease reservoirs
- Monitoring and treatment of circulating and migrating populations to prevent disease reservoir spread
- Collaboration and exchange of in-kind services with other control programs in the project area to maximize beneficial effects
- Educating project personnel and area residents on risks, prevention, and available treatment
- Monitoring communities during high-risk seasons to detect and treat cases

[94] Additional sources of information on disease prevention include IFC, 2006; UNDP, 2000, 2003; Walley et al., 2000; Kindhauser, 2003; Heymann, 2004.

- Distributing appropriate education materials
- Following safety guidelines for the storage, transport, and distribution of pesticides to minimize the potential for misuse, spills, and accidental human exposure

3.7 Emergency Preparedness and Response

An emergency is an unplanned event when a project operation loses control, or could lose control, of a situation that may result in risks to human health, property, or the environment, either within the facility or in the local community. Emergencies do not normally include safe work practices for frequent upsets or events that are covered by occupational health and safety.

All projects should have an Emergency Preparedness and Response Plan that is commensurate with the risks of the facility and that includes the following basic elements:

- Administration (policy, purpose, distribution, definitions, etc)
- Organization of emergency areas (command centers, medical stations, etc)
- Roles and responsibilities
- Communication systems
- Emergency response procedures
- Emergency resources
- Training and updating
- Checklists (role and action list and equipment checklist)
- Business Continuity and Contingency

Additional information is provided for key components of the emergency plan, as follows below.

Communication Systems

Worker notification and communication

Alarm bells, visual alarms, or other forms of communication should be used to reliably alert workers to an emergency. Related measures include:

- Testing warning systems at least annually (fire alarms monthly), and more frequently if required by local regulations, equipment, or other considerations
- Installing a back-up system for communications on-site with off-site resources, such as fire departments, in the event that normal communication methods may be inoperable during an emergency

Community Notification

If a local community may be at risk from a potential emergency arising at the facility, the company should implement communication measures to alert the community, such as:

- Audible alarms, such as fire bells or sirens
- Fan out telephone call lists
- Vehicle mounted speakers
- Communicating details of the nature of the emergency
- Communicating protection options (evacuation, quarantine)
- Providing advise on selecting an appropriate protection option

Media and Agency Relations

Emergency information should be communicated to the media through:

- A trained, local spokesperson able to interact with relevant stakeholders, and offer guidance to the company for speaking to the media, government, and other agencies
- Written press releases with accurate information, appropriate level of detail for the emergency, and for which accuracy can be guaranteed

Emergency Resources

Finance and Emergency Funds

- A mechanism should be provided for funding emergency activities.

Fire Services

- The company should consider the level of local fire fighting capacity and whether equipment is available for use at the facility in the event of a major emergency or natural disaster. If insufficient capacity is available, fire fighting capacity should be acquired that may include pumps, water supplies, trucks, and training for personnel.

Medical Services

- The company should provide first aid attendants for the facility as well as medical equipment suitable for the personnel, type of operation, and the degree of treatment likely to be required prior to transportation to hospital.

Availability of Resources

Appropriate measures for managing the availability of resources in case of an emergency include:

- Maintaining a list of external equipment, personnel, facilities, funding, expert knowledge, and materials that may be required to respond to emergencies. The list should include personnel with specialized expertise for spill clean-up, flood control, engineering, water treatment, environmental science, etc., or any of the functions required to adequately respond to the identified emergency
- Providing personnel who can readily call up resources, as required
- Tracking and managing the costs associated with emergency resources
- Considering the quantity, response time, capability, limitations, and cost of these resources, for both site-specific emergencies, and community or regional emergencies
- Considering if external resources are unable to provide sufficient capacity during a regional emergency and whether additional resources may need to be maintained on-site

Mutual Aid

Mutual aid agreements decrease administrative confusion and provide a clear basis for response by mutual aid providers.

- Where appropriate, mutual aid agreements should be maintained with other organizations to allow for sharing of personnel and specialized equipment.

Contact List

- The company should develop a list of contact information for all internal and external resources and personnel. The list should include the name, description, location, and contact details (telephone, email) for each of the resources, and be maintained annually.

Training and Updating

The emergency preparedness facilities and emergency response plans require maintenance, review, and updating to account for changes in equipment, personnel, and facilities. Training programs and practice exercises provide for testing systems to ensure an adequate level of emergency preparedness. Programs should:

- Identify training needs based on the roles and responsibilities, capabilities and requirements of personnel in an emergency
- Develop a training plan to address needs, particularly for fire fighting, spill response, and evacuation

- Conduct annual training, at least, and perhaps more frequent training when the response includes specialized equipment, procedures, or hazards, or when otherwise mandated
- Provide training exercises to allow personnel the opportunity to test emergency preparedness, including:
    - Desk top exercises with only a few personnel, where the contact lists are tested and the facilities and communication assessed
    - Response exercises, typically involving drills that allow for testing of equipment and logistics
- Debrief upon completion of a training exercise to assess what worked well and what aspects require improvement
- Update the plan, as required, after each exercise. Elements of the plan subject to significant change (such as contact lists) should be replaced
- Record training activities and the outcomes of the training

Business Continuity and Contingency

Measures to address business continuity and contingency include:

- Identifying replacement supplies or facilities to allow business continuity following an emergency. For example, alternate sources of water, electricity, and fuel are commonly sought.
- Using redundant or duplicate supply systems as part of facility operations to increase the likelihood of business continuity.
- Maintaining back-ups of critical information in a secure location to expedite the return to normal operations following an emergency.

4.0 Construction and Decommissioning

Applicability and Approach

This section provides additional, specific guidance on prevention and control of community health and safety impacts that may occur during new project development, at the end of the project life-cycle, or due to expansion or modification of existing project facilities. Cross referencing is made to various other sections of the General EHS Guidelines.

4.1 Environment{ TC "4.1 Environment" \f C \l "2" }

Noise and Vibration

During construction and decommissioning activities, noise and vibration may be caused by the operation of pile drivers, earth moving and excavation equipment, concrete mixers, cranes and the transportation of equipment, materials and people. Some recommended noise reduction and control strategies to consider in areas close to community areas include:

- Planning activities in consultation with local communities so that activities with the greatest potential to generate noise are planned during periods of the day that will result in least disturbance
- Using noise control devices, such as temporary noise barriers and deflectors for impact and blasting activities, and exhaust muffling devices for combustion engines.
- Avoiding or minimizing project transportation through community areas

Soil Erosion

Soil erosion may be caused by exposure of soil surfaces to rain and wind during site clearing, earth moving, and excavation activities. The mobilization and transport of soil particles may, in turn, result in sedimentation of surface drainage networks, which may result in impacts to the quality of natural water systems and ultimately the biological systems that use these waters. Recommended soil erosion and water system management approaches include:

Sediment mobilization and transport

- Reducing or preventing erosion by:
  - o Scheduling to avoid heavy rainfall periods (i.e., during the dry season) to the extent practical
  - o Contouring and minimizing length and steepness of slopes
  - o Mulching to stabilize exposed areas
  - o Re-vegetating areas promptly
  - o Designing channels and ditches for post-construction flows
  - o Lining steep channel and slopes (e.g. use jute matting)
- Reducing or preventing off-site sediment transport through use of settlement ponds, silt fences, and water treatment, and modifying or suspending activities during extreme rainfall and high winds to the extent practical.

Clean runoff management

- Segregating or diverting clean water runoff to prevent it mixing with water containing a high solids content, to minimize the volume of water to be treated prior to release

Road design

- Limiting access road gradients to reduce runoff-induced erosion
- Providing adequate road drainage based on road width, surface material, compaction, and maintenance

Disturbance to water bodies

- Depending on the potential for adverse impacts, installing free-spanning structures (e.g., single span bridges) for road watercourse crossings
- Restricting the duration and timing of in-stream activities to lower low periods, and avoiding periods critical to biological cycles of valued flora and fauna (e.g., migration, spawning, etc.)
- For in-stream works, using isolation techniques such as berming or diversion during construction to limit the exposure of disturbed sediments to moving water
- Consider using trenchless technology for pipeline crossings (e.g., suspended crossings) or installation by directional drilling

Structural (slope) stability

- Providing effective short term measures for slope stabilization, sediment control and subsidence control until long term measures for the operational phase can be implemented
- Providing adequate drainage systems to minimize and control infiltration

Air Quality

Construction and decommissioning activities may generate emission of fugitive dust caused by a combination of on-site excavation and movement of earth materials, contact of construction machinery with bare soil, and exposure of bare soil and soil piles to wind. A secondary source of emissions may include exhaust from diesel engines of earth moving equipment, as well as from open burning of solid waste on-site. Techniques to consider for the reduction and control of air emissions from construction and decommissioning sites include:

- Minimizing dust from material handling sources, such as conveyors and bins, by using covers and/or control equipment (water suppression, bag house, or cyclone)
- Minimizing dust from open area sources, including storage piles, by using control measures such as installing enclosures and covers, and increasing the moisture content
- Dust suppression techniques should be implemented, such as applying water or non-toxic chemicals to minimize dust from vehicle movements
- Selectively removing potential hazardous air pollutants, such as asbestos, from existing infrastructure prior to demolition
- Managing emissions from mobile sources according to Section 1.1
- Avoiding open burning of solid (refer to solid waste management guidance in Section 1.6)

Solid Waste

Non-hazardous solid waste generated at construction and decommissioning sites includes excess fill materials from grading and excavation activities, scrap wood and metals, and small concrete spills. Other non-hazardous solid wastes include office, kitchen, and dormitory wastes when these types of operations are part of construction project activities. *Hazardous solid waste* includes contaminated soils, which could potentially be encountered on-site due to previous land use activities, or small amounts of machinery maintenance materials, such as oily rags, used oil filters, and used oil, as well as spill cleanup materials from oil and fuel spills. Techniques for preventing and controlling non-hazardous and hazardous construction site solid waste include those already discussed in Section 1.6.

Hazardous Materials

Construction and decommissioning activities may pose the potential for release of petroleum based products, such as lubricants, hydraulic fluids, or fuels during their storage, transfer, or use in equipment. These materials may also be encountered during decommissioning activities in building components or industrial process equipment. Techniques for prevention, minimization, and control of these impacts include:

- Providing adequate secondary containment for fuel storage tanks and for the temporary storage of other fluids such as lubricating oils and hydraulic fluids,
- Using impervious surfaces for refueling areas and other fluid transfer areas
- Training workers on the correct transfer and handling of fuels and chemicals and the response to spills
- Providing portable spill containment and cleanup equipment on site and training in the equipment deployment
- Assessing the contents of hazardous materials and petroleum-based products in building systems (e.g. PCB containing electrical equipment, asbestos-containing building materials) and process equipment and removing them prior to initiation of decommissioning activities, and managing their treatment and disposal according to Sections 1.5 and 1.6 on Hazardous Materials and Hazardous Waste Management, respectively
- Assessing the presence of hazardous substances in or on building materials (e.g., polychlorinated biphenyls, asbestos-containing flooring or insulation) and decontaminating or properly managing contaminated building materials

Wastewater Discharges

Construction and decommissioning activities may include the generation of sanitary wastewater discharges in varying quantities depending on the number of workers involved. Adequate portable or permanent sanitation facilities serving all workers should be provided at all construction sites. Sanitary wastewater in construction and other sites should be managed as described in Section 1.3.

Contaminated Land

Land contamination may be encountered in sites under construction or decommissioning due to known or unknown historical releases of hazardous materials or oil, or due to the presence of abandoned infrastructure formerly used to store or handle these materials, including underground storage tanks. Actions necessary to manage the risk from contaminated land will depend on factors such as the level and location of contamination, the type and risks of the contaminated media, and the intended land use. However, a basic management strategy should include:

- Managing contaminated media with the objective of protecting the safety and health of occupants of the site, the surrounding community, and the environment post construction or post decommissioning
- Understanding the historical use of the land with regard to the potential presence of hazardous materials or oil prior to initiation of construction or decommissioning activities
- Preparing plans and procedures to respond to the discovery of contaminated media to minimize or reduce the risk to health, safety, and the environment consistent with the approach for Contaminated Land in Section 1.6
- Preparation of a management plan to manage obsolete, abandoned, hazardous materials or oil consistent with the approach to hazardous waste management described in Section 1.6.

Successful implementation of any management strategy may require identification and cooperation with whoever is responsible and liable for the contamination.

4.2 Occupational Health and Safety{ TC "4.2 Occupational Health and Safety" \f C \l "2" }

Over-exertion

Over-exertion, and ergonomic injuries and illnesses, such as repetitive motion, over-exertion, and manual handling, are among the most common causes of injuries in construction and decommissioning sites. Recommendations for their prevention and control include:

- Training of workers in lifting and materials handling techniques in construction and decommissioning projects, including the placement of weight limits above which mechanical assists or two-person lifts are necessary
- Planning work site layout to minimize the need for manual transfer of heavy loads
- Selecting tools and designing work stations that reduce force requirements and holding times, and which promote improved postures, including, where applicable, user adjustable work stations
- Implementing administrative controls into work processes, such as job rotations and rest or stretch breaks

Slips and Falls

Slips and falls on the same elevation associated with poor housekeeping, such as excessive waste debris, loose construction materials, liquid spills, and uncontrolled use of electrical cords and ropes on the ground, are also among the most frequent cause of lost time accidents at construction and decommissioning sites. Recommended methods for the prevention of slips and falls from, or on, the same elevation include:

- Implementing good house-keeping practices, such as the sorting and placing loose construction materials or demolition debris in established areas away from foot paths
- Cleaning up excessive waste debris and liquid spills regularly
- Locating electrical cords and ropes in common areas and marked corridors
- Use of slip retardant footwear

Work in Heights

Falls from elevation associated with working with ladders, scaffolding, and partially built or demolished structures are among the most common cause of fatal or permanent disabling injury at construction or decommissioning sites. If fall hazards exist, a fall protection plan should be in place which includes one or more of the following aspects, depending on the nature of the fall hazard[95]:

- Training and use of temporary fall prevention devices, such as rails or other barriers able to support a weight of 200 pounds, when working at heights equal or greater than two meters or at any height if the risk includes falling into operating machinery, into water or other liquid, into hazardous substances, or through an opening in a work surface
- Training and use of personal fall arrest systems, such as full body harnesses and energy absorbing lanyards able to support 5000 pounds (also described in this section in Working at Heights above), as well as fall rescue procedures to deal with workers whose fall has been successfully arrested. The tie in point of the fall arresting system should also be able to support 5000 pounds
- Use of control zones and safety monitoring systems to warn workers of their proximity to fall hazard zones, as well as

95 Additional information on identification of fall hazards and design of protection systems can be found in the United States Occupational Health and Safety Administration's (US OSHA) web site: http://www.osha.gov/SLTC/fallprotection/index.html

securing, marking, and labeling covers for openings in floors, roofs, or walking surfaces

Struck By Objects

Construction and demolition activities may pose significant hazards related to the potential fall of materials or tools, as well as ejection of solid particles from abrasive or other types of power tools which can result in injury to the head, eyes, and extremities. Techniques for the prevention and control of these hazards include:

- Using a designated and restricted waste drop or discharge zones, and/or a chute for safe movement of wastes from upper to lower levels
- Conducting sawing, cutting, grinding, sanding, chipping or chiseling with proper guards and anchoring as applicable
- Maintaining clear traffic ways to avoid driving of heavy equipment over loose scrap
- Use of temporary fall protection measures in scaffolds and out edges of elevated work surfaces, such as hand rails and toe boards to prevent materials from being dislodged
- Evacuating work areas during blasting operations, and using blast mats or other means of deflection to minimize fly rock or ejection of demolition debris if work is conducted in proximity to people or structures
- Wearing appropriate PPE, such as safety glasses with side shields, face shields, hard hats, and safety shoes

Moving Machinery

Vehicle traffic and use of lifting equipment in the movement of machinery and materials on a construction site may pose temporary hazards, such as physical contact, spills, dust, emissions, and noise. Heavy equipment operators have limited fields of view close to their equipment and may not see pedestrians close to the vehicle. Center-articulated vehicles create a significant impact or crush hazard zone on the outboard side of a turn while moving. Techniques for the prevention and control of these impacts include:

- Planning and segregating the location of vehicle traffic, machine operation, and walking areas, and controlling vehicle traffic through the use of one-way traffic routes, establishment of speed limits, and on-site trained flag-people wearing high-visibility vests or outer clothing covering to direct traffic
- Ensuring the visibility of personnel through their use of high visibility vests when working in or walking through heavy equipment operating areas, and training of workers to verify eye contact with equipment operators before approaching the operating vehicle
- Ensuring moving equipment is outfitted with audible back-up alarms
- Using inspected and well-maintained lifting devices that are appropriate for the load, such as cranes, and securing loads when lifting them to higher job-site elevations.

Dust

- Dust suppression techniques should be implemented, such as applying water or non-toxic chemicals to minimize dust from vehicle movements
- PPE, such as dusk masks, should be used where dust levels are excessive

Confined Spaces and Excavations

Examples of confined spaces that may be present in construction or demolition sites include: silos, vats, hoppers, utility vaults, tanks, sewers, pipes, and access shafts. Ditches and trenches may also be considered a confined space when access or egress is limited. In addition to the guidance provided in Section 2.8 the occupational hazards associated with confined spaces and excavations in construction and decommissioning sites should be prevented according to the following recommendations:

- Controlling site-specific factors which may contribute to excavation slope instability including, for example, the use of excavation dewatering, side-walls support, and slope gradient adjustments that eliminate or minimize the risk of collapse, entrapment, or drowning
- Providing safe means of access and egress from excavations, such as graded slopes, graded access route, or stairs and ladders
- Avoiding the operation of combustion equipment for prolonged periods inside excavations areas where other workers are required to enter unless the area is actively ventilated

Other Site Hazards

Construction and decommissioning sites may pose a risk of exposure to dust, chemicals, hazardous or flammable materials, and wastes in a combination of liquid, solid, or gaseous forms, which should be prevented through the implementation of project-specific plans and other applicable management practices, including:

- Use of specially trained personnel to identify and remove waste materials from tanks, vessels, processing equipment or contaminated land as a first step in decommissioning activities to allow for safe excavation, construction, dismantling or demolition
- Use of specially trained personnel to identify and selectively remove potentially hazardous materials in building elements prior to dismantling or demolition including, for example, insulation or structural elements containing asbestos and Polychlorinated Biphenyls (PCBs), electrical components containing mercury[96]
- Use of waste-specific PPE based on the results of an occupational health and safety assessment, including respirators, clothing/protective suits, gloves and eye protection

4.3 Community Health and Safety{ TC "4.3 Community Health and Safety" \f C \l "2" }

General Site Hazards

Projects should implement risk management strategies to protect the community from physical, chemical, or other hazards associated with sites under construction and decommissioning. Risks may arise from inadvertent or intentional trespassing, including potential contact with hazardous materials, contaminated soils and other environmental media, buildings that are vacant or under construction, or excavations and structures which may pose falling and entrapment hazards. Risk management strategies may include:

- Restricting access to the site, through a combination of institutional and administrative controls, with a focus on high risk structures or areas depending on site-specific situations, including fencing, signage, and communication of risks to the local community
- Removing hazardous conditions on construction sites that cannot be controlled affectively with site access restrictions, such as covering openings to small confined spaces, ensuring means of escape for larger openings such as trenches or excavations, or locked storage of hazardous materials

Disease Prevention

Increased incidence of communicable and vector-borne diseases attributable to construction activities represents a potentially serious health threat to project personnel and residents of local communities. Recommendations for the prevention and control of communicable and vector-borne diseases also applicable to

[96] Additional information on the management and removal of asbestos containing building materials can be found in ASTM Standard E2356 and E1368

construction phase activities are provided in Section 3.6 (Disease Prevention).

Traffic Safety

Construction activities may result in a significant increase in movement of heavy vehicles for the transport of construction materials and equipment increasing the risk of traffic-related accidents and injuries to workers and local communities. The incidence of road accidents involving project vehicles during construction should be minimized through a combination of education and awareness-raising, and the adoption of procedures described in Section 3.4 (Traffic Safety).

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Annex J

IFC ENVIRONMENTAL, HEALTH AND SAFETY GENERAL GUIDELINES FOR ELECTRIC POWER TRANSMISSION AND DISTRIBUTION

Environmental, Health, and Safety Guidelines for Electric Power Transmission and Distribution

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)[1]. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them.

The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

Applicability

The EHS Guidelines for Electric Power Transmission and Distribution include information relevant to power transmission between a generation facility and a substation located within an electricity grid, in addition to power distribution from a substation to consumers located in residential, commercial, and industrial areas. Annex A provides a summary of industry sector activities. This document is organized according to the following sections:

Section 1.0 — Industry-Specific Impacts and Management
Section 2.0 — Performance Indicators and Monitoring
Section 3.0 — References and Additional Sources
Annex A — General Description of Industry Activities

[1] Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with electric power transmission and distribution that occur during the construction and operation phases of a facility, along with recommendations for their management. Additional recommendations for the management of environmental issues during the construction and decommissioning phases of power transmission and distribution systems are provided in the **General EHS Guidelines.** Examples of the impacts addressed in the General EHS Guidelines include:

- Construction site waste generation;
- Soil erosion and sediment control from materials sourcing areas and site preparation activities;
- Fugitive dust and other emissions (e.g. from vehicle traffic, land clearing activities, and materials stockpiles);
- Noise from heavy equipment and truck traffic;
- Potential for hazardous materials and oil spills associated with heavy equipment operation and fueling activities.

1.1 Environmental

Environmental issues during the construction phase of power transmission and distribution projects specific to this industry sector include the following:

- Terrestrial habitat alteration
- Aquatic habitat alteration
- Electric and magnetic fields
- Hazardous materials

Terrestrial Habitat Alteration

The construction and maintenance of transmission line rights-of-way, especially those aligned through forested areas, may result in alteration and disruption to terrestrial habitat, including impacts to avian species and an increased risk of forest fires.

Construction of Right-of-Way[2]

Right-of-way construction activities may transform habitats, depending on the characteristics of existing vegetation, topographic features, and installed height of the transmission lines. Examples of habitat alteration from these activities includes fragmentation of forested habitat; loss of wildlife habitat, including for nesting; establishment of non-native invasive plant species; and visual and auditory disturbance due to the presence of machinery, construction workers, transmission towers, and associated equipment.[3]

Recommended measures to prevent and control impacts to terrestrial habitats during construction of the right-of-way include:

- Site transmission and distribution rights-of-way, access roads, lines, towers, and substations to avoid critical habitat through use of existing utility and transport corridors for transmission and distribution, and existing roads and tracks for access roads, whenever possible;[4]
- Installation of transmission lines above existing vegetation to avoid land clearing;

[2] Also known as a "wayleave" or "easement" in some countries, but referred to as right-of-way for the purposes of these Guidelines.
[3] Alteration of terrestrial habitat for construction of transmission and distribution projects may also yield benefits for wildlife such as the creation of protective nesting, rearing, and foraging habitat for certain species; the establishment of travel and foraging corridors for ungulates and other large mammals; and nesting and perching opportunities for large bird species atop transmission towers and associated infrastructures. California Energy Commission (2005).
[4] Considering potential for electrical interference with telecommunication lines and railway lines due to mutual induction.

- Avoidance of construction activities during the breeding season and other sensitive seasons or times of day;
- Revegetation of disturbed areas with native plant species;
- Removal of invasive plant species during routine vegetation maintenance (see right-of-way maintenance section below);
- Management of construction site activities as described in relevant sections of the **General EHS Guidelines**.

Right-of-Way Maintenance

Regular maintenance of vegetation within the rights-of-way is necessary to avoid disruption to overhead power lines and towers. Unchecked growth of tall trees and accumulation of vegetation within rights-of-way may result in a number of impacts, including power outages through contact of branches and trees with transmission lines and towers; ignition of forest and brush fires; corrosion of steel equipment; blocking of equipment access; and interference with critical grounding equipment.

Regular maintenance of rights-of-way to control vegetation may involve the use of mechanical methods, such as mowing or pruning machinery that may disrupt wildlife and their habitats, in addition to manual hand clearing and herbicide use. Vegetation management should not eradicate all vegetation, but aim to maintain trees and plant growth that may negatively affect infrastructure at a level that is under an economically-damaging threshold. Excessive vegetation maintenance may remove unnecessary amounts of vegetation resulting in the continual replacement of successional species and an increased likelihood of the establishment of invasive species.

Recommended measures to prevent and control impacts from right-of-way vegetation maintenance include:

- Implementation of an integrated vegetation management approach (IVM). The selective removal of tall-growing tree species and the encouragement of low-growing grasses and shrubs is the common approach to vegetation management in transmission line rights-of-way. Alternative vegetation management techniques should be selected based on environmental and site considerations including potential impacts to non-target, endangered and threatened species;[5]
- Removal of invasive plant species, whenever possible, cultivating native plant species;
- Scheduling activities to avoid breeding and nesting seasons for any critically endangered or endangered wildlife species;
- Observing manufacturer machinery and equipment guidelines, procedures with regard to noise, and oil spill prevention and emergency response;
- Avoiding clearing in riparian areas;
- Avoiding use of machinery in the vicinity of watercourses.

An integrated approach to vegetation management may indicate that use of herbicides is the preferred approach to control fast-growing vegetation within transmission and distribution rights-of-way. In this case, the following guidance on herbicide application, storage, and handling should be considered.

If herbicides (in this sector, herbicides are the most common type of pesticide used) application is warranted, they should be managed to avoid their migration into off-site land or water

[5] Mowing with heavy-duty power equipment may be used to control growth of ground covers and prevent the establishment of trees and shrubs in the right-of-way. Herbicides, in combination with mowing, may control fast-growing weedy species that have a potential to mature to heights over those permitted within the right-of-way. Trimming and pruning may be utilized at the boundaries of rights-of-way to maintain corridor breadth and prevent the encroachment of tree branches. Hand removal or removal of vegetation, while labor intensive, may be used in the vicinity of structures, streams, fences, and other obstructions which make the use of machinery difficult or dangerous.

environments (see Pesticides under the Hazardous Materials section).

Forest Fires

If underlying growth is left unchecked, or slash from routine maintenance is left to accumulate within right-of-way boundaries, sufficient fuel can accumulate that may promote forest fires.

Recommended measures to prevent and control risk of forest fire include:

- Monitoring right-of-way vegetation according to fire risk;[6]
- Removing blowdown and other high-hazard fuel accumulations;
- Time thinning, slashing, and other maintenance activities to avoid forest fire seasons;
- Disposal of maintenance slash by truck or controlled burning[7] . Controlled burning should adhere to applicable burning regulations, fire suppression equipment requirements, and typically must be monitored by a fire watcher;
- Planting and managing fire resistant species (e.g. hardwoods) within, and adjacent to, rights-of-way;
- Establishing a network of fuel breaks of less flammable materials or cleared land to slow progress of fires and allow fire fighting access.

[6] As an example, the British Columbia Transmission Corporation (BCTC) maintains a Wildfire Risk Management System (WRMS) that classifies wildfire risk and provides a variety of corresponding mitigation measures. See (Blackwell et al., 2004).

[7] Controlled burning should only be performed after considering potential impacts to air quality and according to the local air quality management requirements.

Avian and Bat Collisions and Electrocutions

The combination of the height of transmission towers and distribution poles and the electricity carried by transmission and distribution lines can pose potentially fatal risk to birds and bats through collisions and electrocutions.[8] Avian collisions with power lines can occur in large numbers if located within daily flyways or migration corridors, or if groups are traveling at night or during low light conditions (e.g. dense fog).[9] In addition, bird and bat collisions with power lines may result in power outages and fires.

Recommended prevention and control measures to minimize avian and bat collisions and electrocutions include[10]:

- Aligning transmission corridors to avoid critical habitats (e.g. nesting grounds, heronries, rookeries, bat foraging corridors, and migration corridors);
- Maintaining 1.5 meter (60-inch)[11] spacing between energized components and grounded hardware or, where spacing is not feasible, covering energized parts and hardware;
- Retrofitting existing transmission or distribution systems by installing elevated perches, insulating jumper loops, placing obstructive perch deterrents (e.g. insulated ”V’s”), changing the location of conductors, and / or using raptor hoods;[12]

[8] Birds and bats may be electrocuted by power lines in one of three ways: i) Simultaneously touching an energized wire and a neutral wire; ii) Simultaneously touching two live wires; and iii) Simultaneously touching an energized wire and any other piece of equipment on a pole or tower that is bonded to the earth through a ground wire. Raptor Protection Video Group (2000)

[9] Larger species (e.g. hawks, falcons, owls, vultures, cranes, egrets, and ravens) are at particular risk of simultaneously touching two wires or components while flying due to their long wingspans. Anderson (1991)

[10] Further information is available from Avian Power Line Interaction Committee (2005) and the U.S. Fish and Wildlife Service (2005).

[11] Manville (2005)

[12] California Energy Commission (2005)

- Considering the installation of underground transmission and distribution lines in sensitive areas (e.g. critical natural habitats);
- Installing visibility enhancement objects such as marker balls, bird deterrents, or diverters.[13]

Aquatic Habitat Alteration

Power transmission and distribution lines, and associated access roads and facilities, may require construction of corridors crossing aquatic habitats that may disrupt watercourses and wetlands, and require the removal of riparian vegetation. In addition, sediment and erosion from construction activities and storm water runoff may increase turbidity of surface watercourses.

Recommended measures to prevent and control impacts to aquatic habitats include:

- Site power transmission towers and substations to avoid critical aquatic habitat (e.g. watercourses, wetlands, and riparian areas), as well as fish spawning habitat, and critical fish over-wintering habitat;
- Maintaining fish access when road crossings of watercourses are unavoidable by utilizing clearspan bridges, open-bottom culverts, or other approved methods;
- Minimizing clearing and disruption to riparian vegetation;
- Management of construction site activities as described in the relevant sections of the **General EHS Guidelines.**

Marine Habitat Alteration

Transmission across ocean stretches may require use of submarine transmission cables on the ocean floor. Submarine cables are also occasionally used to transmit high-voltage power across long stretches of water to islands and other locations that are inaccessible by conventional techniques. Cables are installed using a cable-laying vessel and a remotely operated, underwater vehicle. Issues associated with marine habitat alteration include disruption to intertidal vegetation (e.g. eelgrass), coral reefs, and marine life, including marine mammals, and sedimentation resulting in turbidity and reductions in water quality.

Recommended measures to prevent and control impacts to marine habitats include:

- Locating and siting cable routes, and shore access, to avoid critical marine habitats (e.g. breeding grounds and eelgrass) and coral reefs;
- Burying submarine cables when traversing sensitive intertidal habitat;
- Monitoring cable laying path for presence of marine mammals;
- Avoiding laying submarine cable during fish and marine mammals breeding periods, calving periods, and spawning seasons.

Electric and Magnetic Fields

Electric and magnetic fields (EMF) are invisible lines of force emitted by and surrounding any electrical device (e.g. power lines and electrical equipment). Electric fields are produced by voltage and increase in strength as the voltage increases. Electric field strength is measured in volts per meter (V/m). Magnetic fields result from the flow of electric current and increase in strength as the current increases. Magnetic fields are measured in units of gauss (G) or tesla (T), where 1T equals 10,000G. Electric fields are shielded by materials that conduct electricity, and other materials, such as trees and building

[13] Several studies have found that bird diverters that are installed to increase the visibility of power lines reduce collision rates considerably. Crowder and Rhodes (1999).

materials. Magnetic fields pass through most materials and are difficult to shield. Both electric and magnetic fields decrease rapidly with distance. Power frequency EMF typically has a frequency in the range of 50 – 60 Hertz (Hz), and is considered Extremely Low Frequency (ELF).[14]

Although there is public and scientific concern over the potential health effects associated with exposure to EMF (not only high-voltage power lines and substations, but also from everyday household uses of electricity), there is no empirical data demonstrating adverse health effects from exposure to typical EMF levels from power transmissions lines and equipment.[15] However, while the evidence of adverse health risks is weak, it is still sufficient to warrant limited concern.[16]

Recommendations applicable to the management of EMF exposures include:

- Evaluating potential exposure to the public against the reference levels developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).[17,18] Average and peak exposure levels should remain below the ICNIRP recommendation for General Public Exposure[19];
- Considering siting new facilities so as to avoid or minimize exposure to the public. Installation of transmission lines or other high voltage equipment above or adjacent to residential properties or other locations intended for highly frequent human occupancy, (e.g. schools or offices), should be avoided;
- If EMF levels are confirmed or expected to be above the recommended exposure limits, application of engineering techniques should be considered to reduce the EMF produced by power lines, substations, or transformers. Examples of these techniques include:
    - Shielding with specific metal alloys[20]
    - Burying transmission lines[21]
    - Increasing height of transmission towers
    - Modifications to size, spacing, and configuration of conductors

Hazardous Materials

Hazardous materials in this sector include insulating oils / gases (e.g. Polychlorinated Biphenyls [PCB] and sulfur hexafluoride [SF6], and fuels, in addition to chemicals or products for wood preservation for poles and associated wood construction material. The use of herbicides for right-of-way vegetation maintenance is discussed in the above section on 'Right-of–Way Maintenance'.

[14] National Institute of Environmental Health Sciences (2002)

[15] International Commission on Non-Ionizing Radiation Protection(ICNIRP) (2001); International Agency for Research on Cancer (2002); U.S. National Institute of Health (2002); Advisory Group to the Radiation Protection Board of the UK (2001), and U.S. National Institute of Environmental Health Sciences (1999)).

[16] U.S. National Institute of Environmental Health Sciences (2002)

[17] ICNIRP is a non-governmental organization formally recognized by the World Health Organization (WHO), which published the "Guidelines for Limiting Exposure to Time-varying Electric, Magnetic, and Electromagnetic Fields" following reviews of all the peer-reviewed scientific literature, including thermal and non-thermal effects. The standards are based on evaluations of biological effects that have been established to have health consequences. The main conclusion from the WHO reviews is that exposures below the limits recommended by the ICNIRP international guidelines do not appear to have any known consequence on health.

[18] An additional source of information is the Institute of Electrical and Electronics Engineers. See IEEE (2005).

[19] The ICNIRP exposure guidelines for General Public Exposure are listed in Section 2.1 of this Guideline.

[20] This is effective for reduction of electric field exposure, but not for reduction of magnetic field exposure.

[21] Ibid.

Insulating Oils and Fuels

Highly-refined, mineral insulating oils are used to cool transformers and provide electrical insulation between live components. They are typically found in the largest quantities at electrical substations and maintenance shops. Sulfur Hexafluoride (SF6) may also be used as a gas insulator for electrical switching equipment and in cables, tubular transmission lines, and transformers. SF6 may be used as an alternative to insulating oils. However, the use of SF6, a greenhouse gas with a significantly higher global warming potential (GWP) than CO_2, should be minimized. In cases the gas is used for applications involving high voltages (>350 KV), equipment with a low leakage- rate (<99 percent) should be used.

Liquid petroleum fuels for vehicles and other equipment may also be used and stored at transmission and distribution projects. Recommendations for prevention and control of hazards associated with spill prevention, emergency response, clean-up, and contaminated soil remediation are addressed in the **General EHS Guidelines.**

Polychlorinated Biphenyls (PCB) were widely used as a dielectric fluid to provide electrical insulation, although their use has been largely discontinued due to potential harmful effects on human health and the environment. Recommendations for the management of PCB include:

- Replacing existing transformers and other electrical equipment containing PCB, and ensuring appropriate storage, decontamination, and disposal of contaminated units;
- Prior to final disposal, retired transformers and equipment containing PCB should be stored on a concrete pad with curbs sufficient to contain the liquid contents of these containers should they be spilled or leaked. The storage area should also have a roof to prevent precipitation from collecting in the storage area. Disposal should involve facilities capable of safely transporting and disposing of hazardous waste containing PCB;[22]
- Surrounding soil exposed to PCB leakage from equipment should be assessed, and appropriate removal and / or remediation measures should be implemented, as addressed in the section on contaminated soil in the **General EHS Guidelines**.

Wood Preservatives

The majority of wooden utility poles are treated with pesticide preservatives to protect against insects, bacteria, and fungi, and to prevent rot. The preservatives most commonly used for power poles are oil-based pesticides such as creosote, pentachlorophenol (PCP), and chromated copper arsenate (CCA). Use of these preservatives is being limited in some countries due to their toxic effects on the environment. While in use, poles may leach preservatives into soils and groundwater, however, levels are highest directly beside poles and decrease to within normal levels at approximately 30 centimeters (cm) distance from the pole.[23] The most significant potential environmental impacts occur at specialized wood treatment facilities if not managed appropriately.

Poles should be pretreated at an appropriate facility to ensure chemical fixation and prevent leaching, and to impede the formation of surface residues at the right-of-way[24]. Further

[22] For a complete discussion on the identification and management of PCB in this industry sector, please see the UNEP publication "PCB Transformers and Capacitors: From Management to Reclassification and Disposal" (2002). Available at: http://www.chem.unep.ch/pops/pdf/PCBtranscap.pdf
[23] Zagury et al. (2003)
[24] Lebow and Tippie (2001)

information is available in the **EHS Guidelines for Sawmilling and Wood-based Products**.

Recommended measures to prevent and control the impacts of wood preservatives at the point of use include:

- Evaluating the cost and benefit of using alternative pole materials (e.g. steel, concrete, and fiberglass);
- Consider use of alternative preservatives(e.g. copper azote);
- Undertake appropriate disposal of used poles. Landfill facilities should be capable of handling wastes that may have chemical leaching properties. Disposal through incineration or through recycling should consider associated air emissions and secondary product residues of preservative chemicals.

Pesticides

Pesticide use should be established as part of an Integrated Pest Management (IPM) strategy and a documented Pest Management Plan (PMP). The following stages should be considered when designing and implementing an IPM strategy, giving preference to alternative pest management strategies, with the use of synthetic chemical pesticides as a last option.

Alternatives to Pesticide Application - The following alternatives to pesticides should be considered:

- Provide those responsible for deciding on pesticides application with training in pest identification, weed identification, and field scouting;
- Use mechanical weed control and / or thermal weeding;
- Support and use beneficial organisms, such as insects, birds, mites, and microbial agents, to perform biological control of pests;
- Protect natural enemies of pests by providing a favorable habitat, such as bushes for nesting sites and other original vegetation that can house pest predators;
- Use animals to graze areas and manage plant coverage;
- Use mechanical controls such as traps, barriers, light, and sound to kill, relocate, or repel pests.

Pesticide Application - If pesticide application is warranted, users should take the following precautions:

- Train personnel to apply pesticides and ensure that personnel have received applicable certifications or equivalent training where such certifications are not required; [25]
- Review the manufacturer's directions on maximum recommended dosage or treatment, as well as published reports on using the reduced rate of pesticide application without loss of effect, and apply the minimum effective dose;
- Apply pesticides based on criteria (e.g. field observations, weather data, time of treatment, and dosage) and maintain a pesticide logbook to record such information;
- Avoid the use of pesticides that fall under the World Health Organization Recommended Classification of Pesticides by Hazard Classes 1a and 1b;
- Avoid the use of pesticides that fall under the World Health Organization Recommended Classification of Pesticides by Hazard Class II if the project host country lacks restrictions on distribution and use of these chemicals, or if they are likely to be accessible to personnel without proper training,

[25] Examples of certification schemes are provided by the US EPA (2006), which classifies pesticides as either "unclassified" or "restricted" and requires workers that apply unclassified pesticides to be trained according to the Worker Protection Standard (40 CFR Part 170) for Agricultural Pesticides. It further requires restricted pesticides to be applied by or in the presence of a certified pesticide applicator.

equipment, and facilities to handle, store, apply, and dispose of these products properly;

- Avoid the use of pesticides listed in Annexes A and B of the Stockholm Convention, except under the conditions noted in the convention;[26]
- Use only pesticides that are manufactured under license and registered and approved by the appropriate authority and in accordance with the Food and Agriculture Organization's (FAO) International Code of Conduct on the Distribution and Use of Pesticides[27];
- Use only pesticides that are labeled in accordance with international standards and norms, such as the FAO Revised Guidelines for Good Labeling Practice for Pesticides[28];
- Select application technologies and practices designed to reduce unintentional drift or runoff only as indicated in an IPM program, and under controlled conditions;
- Maintain and calibrate pesticide application equipment in accordance with manufacturer's recommendations;
- Establish untreated buffer zones or strips along water sources, rivers, streams, ponds, lakes, and ditches to help protect water resources.

Pesticide Handling and Storage - Contamination of soils, groundwater, or surface water resources, due to accidental spills during transfer, mixing, and storage of pesticides should be prevented by following the hazardous materials storage and handling recommendations presented in the **General EHS Guidelines**. Additional recommendations include the following:

- Store pesticides in their original packaging, in a dedicated, dry, cool, frost-free, and well aerated location that can be locked and properly identified with signs, with access limited to authorized people[29]. No human or animal food may be stored in this location. The store room should also be designed with spill containment measures and sited in consideration of potential for contamination of soil and water resources;
- Mixing and transfer of pesticides should be undertaken by trained personnel in ventilated and well lit areas, using containers designed and dedicated for this purpose.
- Containers should not be used for any other purpose (e.g. drinking water). Contaminated containers should be handled as hazardous waste, and should be treated accordingly. Disposal of containers contaminated with pesticides should be done in a manner consistent with FAO guidelines and with manufacturer's directions;[30]
- Purchase and store no more pesticide than needed and rotate stock using a "first-in, first-out" principle so that pesticides do not become obsolete.[31] Additionally, the use of obsolete pesticides should be avoided under all circumstances;[32] A management plan that includes measures for the containment, storage and ultimate destruction of all obsolete stocks should be prepared in accordance to guidelines by FAO and consistent with country commitments under the Stockholm, Rotterdam and Basel Conventions.
- Collect rinse water from equipment cleaning for reuse (such as for the dilution of identical pesticides to concentrations used for application);

[26] The Stockholm Convention on Persistent Organic Pollutants (2001) controls the use of the following POPs-pesticides: Aldrin, Chlordane, DDT, Dieldrin, Endrin, Heptachlor, Hexachlorobenzene, Mirex, and Toxaphene.
[27] FAO (2002)
[28] FAO (2000)
[29] FAO (2002)
[30] See FAO Guidelines for the Disposal of Waste Pesticides and Pesticide Containers.
[31] See FAO (1996).
[32] See the FAO publication on pesticide storage and stock control manual. FAO Pesticide Disposal Series No. 3 (1996).

- Ensure that protective clothing worn during pesticide application is either cleaned or disposed of in an environmentally responsible manner
- Implement groundwater supply wellhead setbacks for pesticide application and storage
- Maintain records of pesticide use and effectiveness.

1.2 Occupational Health and Safety

Most occupational health and safety issues during the construction, operation, maintenance, and decommissioning of electric power distribution projects are common to those of large industrial facilities, and their prevention and control is discussed in the **General EHS Guidelines**. These impacts include, among others, exposure to physical hazards from use of heavy equipment and cranes; trip and fall hazards; exposure to dust and noise; falling objects; work in confined spaces; exposure to hazardous materials; and exposure to electrical hazards from the use of tools and machinery.

Occupational health and safety hazards specific to electric power transmission and distribution projects primarily include:

- Live power lines
- Working at height
- Electric and magnetic fields
- Exposure to chemicals

Live Power Lines

Workers may be exposed to occupational hazards from contact with live power lines during construction, maintenance, and operation activities. Prevention and control measures associated with live power lines include:

- Only allowing trained and certified workers to install, maintain, or repair electrical equipment;
- Deactivating and properly grounding live power distribution lines before work is performed on, or in close proximity, to the lines;
- Ensuring that live-wire work is conducted by trained workers with strict adherence to specific safety and insulation standards. Qualified or trained employees working on transmission or distribution systems should be able to achieve the following[33]:
    - o Distinguish live parts from other parts of the electrical system
    - o Determine the voltage of live parts
    - o Understand the minimum approach distances outlined for specific live line voltages
    - o Ensure proper use of special safety equipment and procedures when working near or on exposed energized parts of an electrical system
- Workers should not approach an exposed energized or conductive part even if properly trained unless:
    - o The worker is properly insulated from the energized part with gloves or other approved insulation; or,
    - o The energized part is properly insulated from the worker and any other conductive object; or,
    - o The worker is properly isolated and insulated from any other conductive object (live-line work).
- Where maintenance and operation is required within minimum setback distances, specific training, safety measures, personal safety devices, and other precautions should be defined in a health and safety plan. (Table 2 in Section 2.2 provides recommended minimum safety setbacks for workers);

[33] Further information is available from the Occupational Safety and Health Administration (OSHA). Available at: http://www.osha.gov/SLTC/powertransmission/standards.html

- Workers not directly associated with power transmission and distribution activities who are operating around power lines or power substations should adhere to local legislation, standards, and guidelines relating to minimum approach distances for excavations, tools, vehicles, pruning, and other activities;
- Minimum hot stick distances may only be reduced provided that the distance remaining is greater than the distance between the energized part and a grounded surface.

Working at height on poles and structures

Workers may be exposed to occupational hazards when working at elevation during construction, maintenance, and operation activities. Prevention and control measures for working at height include:

- Testing structures for integrity prior to undertaking work;
- Implementation of a fall protection program that includes training in climbing techniques and use of fall protection measures; inspection, maintenance, and replacement of fall protection equipment; and rescue of fall-arrested workers, among others;
- Establishment of criteria for use of 100 percent fall protection (typically when working over 2 meters above the working surface, but sometimes extended to 7 meters, depending on the activity). The fall protection system should be appropriate for the tower structure and necessary movements, including ascent, descent, and moving from point to point;
- Installation of fixtures on tower components to facilitate the use of fall protection systems;
- Provision of an adequate work-positioning device system for workers. Connectors on positioning systems should be compatible with the tower components to which they are attached;
- Hoisting equipment should be properly rated and maintained and hoist operators properly trained;
- Safety belts should be of not less than 16 millimeters (mm) (5/8 inch) two-in-one nylon or material of equivalent strength. Rope safety belts should be replaced before signs of aging or fraying of fibers become evident;
- When operating power tools at height, workers should use a second (backup) safety strap;
- Signs and other obstructions should be removed from poles or structures prior to undertaking work;
- An approved tool bag should be used for raising or lowering tools or materials to workers on structures.

Electric and magnetic fields

Electric and magnetic fields (EMF) are described in Section 1.1 above. Electric utility workers typically have a higher exposure to EMF than the general public due to working in proximity to electric power lines.[34,35] Occupational EMF exposure should be prevented or minimized through the preparation and implementation of an EMF safety program including the following components:

- Identification of potential exposure levels in the workplace, including surveys of exposure levels in new projects and the use of personal monitors during working activities;

[34] A 1994 study estimated the average exposure of electrical workers (including jobs in electric utilities and other industries) in Los Angeles, California to be 9.6 milligauss (mG), compared to 1.7 mG for workers in other fields (S. J. London et al., 1994).

[35] Although detailed studies of workplace exposure to EMF in the United States, Canada, France, England, and several Northern European countries have found no conclusive link or correlation between typical occupational EMF exposure and adverse health effects, some studies have identified a possible association between occupational exposure to EMF and cancer, such as brain cancer (U.S. National Institute of Environmental Health Sciences 2002) indicating there is evidence to warrant limited concern.

- Training of workers in the identification of occupational EMF levels and hazards;
- Establishment and identification of safety zones to differentiate between work areas with expected elevated EMF levels compared to those acceptable for public exposure, limiting access to properly trained workers;
- Implementation of action plans to address potential or confirmed exposure levels that exceed reference occupational exposure levels developed by international organizations such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the Institute of Electrical and Electronics Engineers (IEEE)[36]. Personal exposure monitoring equipment should be set to warn of exposure levels that are below occupational exposure reference levels (e.g. 50 percent). Action plans to address occupational exposure may include limiting exposure time through work rotation, increasing the distance between the source and the worker, when feasible, or the use of shielding materials.

Exposure to chemicals

Occupational exposures to chemicals in this sector primarily include handling of pesticides (herbicides) used for right–of-way maintenance, and exposure to PCB in transformers and other electrical components.

Pesticides

Occupational health and safety impacts associated with pesticides are similar to those for other hazardous substances, and their prevention and control are discussed in the **General EHS Guidelines**. Potential exposures to pesticides include dermal contact and inhalation during their storage, preparation and application. The effect of such impacts may be increased by climatic conditions such as wind, which may increase the chance of unintended drift, or high temperatures, which may deter the use of personal protective equipment (PPE). Recommendations specific to the use of pesticides include:

- Train personnel to apply pesticides and ensure that personnel have received the necessary certifications,[37] or equivalent training where such certifications are not required;
- Respect post-treatment intervals to avoid operator exposure during reentry to crops with residues of pesticides;
- Ensure hygiene practices are followed (in accordance to FAO and PMP) to avoid exposure of family members to pesticides residues.

PCBs

Maintenance shops and other facilities, and activities may involve potential contact with PCB or PCB-contaminated machinery. Recommendations for chemical exposure, including PCB, are addressed in the **General EHS Guidelines**.[38]

1.3 Community Health and Safety

Community health and safety impacts during the construction and decommissioning of transmission and distribution power lines are common to those of most large industrial facilities, and

[36] The ICNIRP exposure guidelines for Occupational Exposure are listed in Section 2.2 of this Guideline.

[37] The US EPA classifies pesticides as either "unclassified" or "restricted." All workers that apply unclassified pesticides must be trained according to the Worker Protection Standard (40 CFR Part 170 and 171) for Agricultural Pesticides. Restricted pesticides must be applied by or in the presence of a certified pesticide applicator. For more information, see http://www.epa.gov/pesticides/health/worker.htm

[38] Further information on the management of occupational exposure to PCB can be obtained at UNEP publication "PCB Transformers and Capacitors: From Management to Reclassification and Disposal" (2002) available at: http://www.chem.unep.ch/pops/pdf/PCBtranscap.pdf

are discussed in the **General EHS Guidelines**. These impacts include, among others, dust, noise, and vibration from construction vehicle transit, and communicable diseases associated with the influx of temporary construction labor. In addition to general health and safety standards outlined in the **General EHS Guidelines**, the operation of live power distribution lines and substations may generate the following industry-specific impacts:

- Electrocution
- Electromagnetic interference
- Visual amenity
- Noise and Ozone
- Aircraft Navigation Safety

Electrocution

Hazards most directly related to power transmission and distribution lines and facilities occur as a result of electrocution from direct contact with high-voltage electricity or from contact with tools, vehicles, ladders, or other devices that are in contact with high-voltage electricity. Recommended techniques to prevent these hazards include:

- Use of signs, barriers (e.g. locks on doors, use of gates, use of steel posts surrounding transmission towers, particularly in urban areas), and education / public outreach to prevent public contact with potentially dangerous equipment;
- Grounding conducting objects (e.g. fences or other metallic structures) installed near power lines, to prevent shock.

Electromagnetic Interference

The corona of overhead transmission line conductors and high-frequency currents of overhead transmission lines may result in the creation of radio noise. Typically, transmission line rights-of-way and conductor bundles are created to ensure radio reception at the outside limits remains normal. However, periods of rain, sleet or freezing rain sharply increases the streaming corona on conductors and may affect radio reception in residential areas near transmission lines.

Visual Amenity

Power transmission and distribution are necessary to transport energy from power facilities to residential communities, but may be visually intrusive and undesirable to local residents. To mitigate the visual impact of power distribution projects, the following mitigation measures should be implemented:

- Extensive public consultation during the planning of power line and power line right-of-way locations;
- Accurate assessment of changes in property values due to power line proximity;
- Siting power lines, and designing substations, with due consideration to landscape views and important environmental and community features;
- Location of high-voltage transmission and distribution lines in less populated areas, where possible;
- Burying transmission or distribution lines when power must be transported through dense residential or commercial areas.

Noise and Ozone

Noise in the form of buzzing or humming can often be heard around transformers or high voltage power lines producing corona. Ozone, a colorless gas with a pungent odor, may also be produced. Neither the noise nor ozone produced by power distribution lines or transformers carries any known health risks.[39]

The acoustic noise produced by transmission lines is greater with high voltage power lines (400-800 kilo volts [kV]) and even greater with ultra-high voltage lines (1000 kV and higher)[40]. Noise from transmission lines reaches its maximum during periods of precipitation, including rain, sleet, snow or hail, or as the result of fog. The sound of rain typically masks the increase in noise produced by the transmission lines, but during other forms of precipitation (e.g. snow and sleet) and fog, the noise from overhead power lines can be troubling to nearby residents.

Measures to mitigate this impact may be addressed during project planning stages to locate rights-of-way away from human receptors, to the extent possible. Use of noise barriers or noise canceling acoustic devices should be considered as necessary.

Aircraft Navigation Safety

Power transmission towers, if located near an airport or known flight paths, can impact aircraft safety directly through collision or indirectly through radar interference. Aircraft collision impacts may be mitigated by:

- Avoiding the siting of transmission lines and towers close to airports and outside of known flight path envelopes;
- Consultation with regulatory air traffic authorities prior to installation;
- Adherence to regional or national air traffic safety regulations;
- Use of buried lines when installation is required in flight sensitive areas.

[39] WHO (1998)
[40] Gerasimov (2003)

2.0 Performance Indicators and Monitoring

2.1 Environment

Emissions and Effluent Guidelines

The power transmission and distribution sector does not typically give rise to significant air emissions or effluents. Where dust or potentially contaminated water runoff exists, site operations should comply with principles and guidelines described in the **General EHS Guidelines** to meet ambient air and surface water guidelines. Table 1 lists exposure limits for general public exposure to electric and magnetic fields published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Table 1. ICNIRP exposure limits for general public exposure to electric and magnetic fields.

Frequency	Electric Field (V/m)	Magnetic Field (µT)
50 Hz	5000	100
60 Hz	4150	83

Source: ICNIRP (1998) : "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz).

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project. Monitoring frequency should be sufficient to provide representative data for the parameter being monitored.

Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®) published by American Conference of Governmental Industrial Hygienists (ACGIH),[41] the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),[42] Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),[43] Indicative Occupational Exposure Limit Values published by European Union member states,[44] or other similar sources.

Additional indicators specifically applicable to electric power transmission and distribution activities include the minimum safe working distances for trained employees listed in Table 2 and the ICNIRP exposure limits for occupational exposure to electric and magnetic fields listed in Table 3.

Table 2. Alternating Current - Minimum Working Distances for Trained Employees[a]

Voltage Range (phase to phase – Kilovolts)	Minimum Working and Clear Hot Stick Distance (meters)
2.1 to 15	0.6
15.1 to 35	0.71
35.1 to 46	0.76
46.1 to 72.5	0.91
72.6 to 121	1.01
138 to 145	1.06
161 to 169	1.11
230 to 242	1.5
345 to 362	2.13[b]
500 to 552	3.35[b]
700 to 765	4.5[b]

[a] OSHA

[b] NOTE: From 345-362 kv., 500-552 kv., and 700-765 kv., the minimum working distance and the minimum clear hot stick distance may be reduced provided that such distances are not less than the shortest distance between the energized part and a grounded surface.

Table 3. ICNIRP exposure limits for occupational exposure to electric and magnetic fields.

Frequency	Electric Field (V/m)	Magnetic Field (µT)
50 Hz	10,000	500
60 Hz	8300	415

Source: ICNIRP (1998) : "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with

[41] Available at: http://www.acgih.org/TLV/ and http://www.acgih.org/store/
[42] Available at: http://www.cdc.gov/niosh/npg/
[43] Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992
[44] Available at: http://europe.osha.eu.int/good_practice/risks/ds/oel/

published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)[45].

Occupational Health and Safety Monitoring

The working environment should be occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals[46] as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

[45] Available at: http://www.bls.gov/iif/ and http://www.hse.gov.uk/statistics/index.htm
[46] Accredited professionals may include Certified Industrial Hygienists, Registered Occupational Hygienists, or Certified Safety Professionals or their equivalent.

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Annex A: General Description of Industry Activities

Electric power transmission is the bulk transfer of electricity from one place to another. Typically, power transmission occurs between a power generation facility and a substation located in close proximity to consumers. Power distribution refers to the delivery of electricity from a substation to consumers located in residential, commercial, and industrial areas.

Due to the large amount of power involved, transmission-level voltages are generally considered those above 110 kilo volts (kV). Voltages between 110 kV and 33 kV are typically considered sub-transmission voltages, but are occasionally used for long transmission systems with light loads. Voltages of less than 33 kV are representative of distribution projects.

Electric power transmission and distribution systems are often located in conjunction with highway, road, and other rights-of-way to minimize both costs and disturbance to ecological, socio-economic and cultural resources. Other factors, including land value, view sheds, archaeological resources, geotechnical hazards, accessibility, parks and other important features also contribute to the locating of transmission and distribution line right-of-way alignments.

Project development and construction activities typically include access road construction or upgrade, site preparation and development, removal of select vegetation, if any, and the grading and excavation of soils for the installation of structural foundations and site utilities. These activities are typical of industrial development projects and depend upon a number of factors, including topography, hydrology, and desired site layout, among others. Activities generally associated with the development and construction of power transmission and distribution include land clearing for transmission line rights-of way, access road construction or upgrade, equipment staging areas, substation construction and / or upgrade, site preparation, and installation of transmission line components (e.g. transmission towers and substations, access and maintenance roads).

Operational activities may include maintenance of access to the transmission lines, towers and substations (e.g. low-impact trails or new / improved access roads) and vegetation management. Upgrades and maintenance for existing infrastructure are a consideration throughout the life cycle of the project.

Power transmission and distribution facilities are decommissioned when they are obsolete, damaged (e.g. by corrosion) or replaced due to increased power demand. Many power facilities are replaced with new or updated equipment at the same site or right-of-way. Decommissioning activities depend on the proposed subsequent use of the site, environmental sensitivities (e.g. natural grasslands) and the project specifics (e.g. aboveground or underground power lines). Activities may include demolition and removal of the installed infrastructure (e.g. transmission towers, substations, aboveground and underground utilities and road decommissioning) and reclamation of the project site, including ground stabilization and re-vegetation.

The following sections provide a description of the facilities and activities associated with the construction and operation of power transmission and distribution projects. Facilities and activities common to transmission and distribution projects, including right-of-way management and substations, are outlined below as well as facilities unique to transmission and distribution systems, including towers and utility poles. Typical components of a power transmission and distribution project are illustrated in Figure A-1.

Power Transmission Systems

The electric power transmission system is often referred to as a grid. Redundant paths and lines are provided so that power can be routed from any generation facility to any customer area through a variety of routes, based on the economics of the transmission path and the cost of power. The redundant paths and lines also allow power flow to be rerouted during planned maintenance and outages due to weather or accidents.

Power transmission occurs via a system of aboveground power lines and towers located between a power plant and a substation. When crossing a dense residential area is necessary, transmission and distribution systems can also be buried within underground conduits. Though the transmission efficiency is typically lower for underground lines and installation and maintenance are costly, locating the transmission system underground reduces impacts on land values, visual aesthetics, and vegetation loss. Submarine cables placed on the ocean floor by cable-laying boats are also occasionally used to transmit high-voltage power across long stretches of water to islands and other locations that are inaccessible by conventional techniques. Submarine cables are typically self-contained and fluid-filled to provide insulation over long distances.

Regional transmission grids consist of several large transmission systems connected by substations that are designed to transport electricity as efficiently as possible. Transmission networks can cover thousands of kilometers and encompass tens of thousands of towers. Energy is typically transmitted using a three-phase alternating current (AC) that is more efficient than a single phase. Energy is generally produced at low voltage (up to 30 kV) at a generating facility and then stepped up by a power station transformer to a higher voltage in order to reduce resistance and reduce the percentage of energy lost during transmission over a long distance. For long distance transmission, electricity is usually transmitted at voltages between 110 and 1200 kV. At extremely high voltages, such as those over 2000 kV, corona discharge[47] energy losses associated with charged conductors can offset benefits of reductions in energy losses from reduced resistance. Over long distances, energy can also be transmitted via High Voltage Direct Current (HVDC). In these instances, smaller losses in energy and lower construction costs offset the need to construct conversion stations at each end of the transmission line to convert the direct current to alternating current for use in distribution systems.

Transmission towers or pylons are utilized to suspend high-voltage overhead power lines. These systems usually transmit three-phase electric power (the common method for transmission of high-voltage lines of over 50 kV) and, therefore, are designed to carry three (or multiples of three) conductors. One or two ground conductors are often added at the top of each tower for lightning protection. Transmission towers can be constructed from steel, concrete, aluminum, wood and reinforced plastic. The wire conductors on high-voltage lines are generally constructed of aluminum, or aluminum reinforced with steel strands. Each transmission tower or support structure must be constructed to support the load imposed on it by the conductors. As a result, foundations for transmission towers can be large and costly, particularly in areas where ground conditions are poor such as in wetlands. Guy wires can be utilized to stabilize transmission towers and resist some of the force of the conductors.

There are three main types of transmission powers or pylons used in a transmission system. Suspension towers support straight stretches of a transmission line. Deviation towers are

[47] A corona discharge is an electrical discharge resulting from the ionization of the air around the conductor, generally generating power losses and ambient noise.

located at points where a transmission line changes direction. Terminal towers are located at the end of overhead transmission lines where they connect with substations or underground cables.

The most common type of transmission tower or pylon used for high-voltage power lines is a steel lattice structure. Tubular steel monopoles are also used to support high or medium voltage transmission lines, usually in urban areas. Transmission towers constructed of a steel framework can be used to support lines of all voltages, but they are most often used for voltages over 50 kV. Lattice towers can be assembled on the ground and erected by cable (which uses a large laydown area), erected by crane, or, in inaccessible areas, by helicopter. Transmission towers typically range from approximately 15 to 55 meters (m) in height.[48]

Wooden transmission towers consisting of single poles, H-frames, or shapes resembling A's or V's are also commonly used to support high-voltage transmission lines. Wooden transmission towers are limited by the height of available trees (approximately 30m), and generally carry voltages of between 23 kV and 230 kV, lower than those carried by steel lattice transmission towers[49]. Aluminum towers are often used in remote areas where they can be transported in and installed by helicopter. Towers of reinforced plastic are now available, but high costs currently restrict their use.

For underground transmission lines, the three wires used to transmit the three-phase power must be located in individual pipes or conduits. These pipes are covered in thermal concrete and surrounded in thermal backfill materials. Underground cable conduit systems typically require trenches of at least 1.5m in depth and width. Due to difficulties in dissipating heat, underground conduits are typically not used for high-voltage transmission lines over 350 kV.[50]

Power Distribution Systems

Prior to consumer use, high-voltage energy is stepped down to a lower voltage aboveground line for use in sub-transmission or distribution systems. Distribution lines typically vary from 2.5 to 25 kV. Finally, the energy is transformed to low voltage at the point of residential or commercial use. This voltage ranges between 100 and 600 volts (V) depending on country and customer requirements. Power distribution poles (or utility or telephone poles) are typically constructed of wood, but steel, concrete, aluminum and fiberglass are also used. Distribution poles are typically spaced no further than 60m apart and are at least 12m in height[51]. Wooden distribution poles are limited by the height of available trees (approximately 30m).

Electrical Substations

Electrical substations are stations along the electricity transmission and distribution system that transform voltage from low to high or high to low using transformers. Step-up transformers are used to increase voltage while decreasing current, while step-down transformers are used to decrease voltage while increasing current. Substations typically consist of one or more transformers, as well as switching, control, and protection equipment. Substations can be located in fenced enclosures, underground, or inside buildings.

There are two main types of electrical substations. Transmission substations contain high-voltage switches used to connect together high-voltage transmission lines or to allow specific

[48] United Kingdom Parliament (2001)
[49] Great River Energy (2006)
[50] American Transmission Company (2005)
[51] United States of America Department of Defense (2004)

systems to be isolated for maintenance. Distribution substations are used to transfer power from the transmission system to the distribution system. Typically at least two transmission or sub-transmission lines enter a distribution substation, where their voltage is reduced to a value suitable for local consumption. Distribution substations can also be used to isolate faults in either the transmission or distribution systems. Complicated distribution substations containing high-voltage switching, switching, and backup systems are often located within large urban centers.

Rights-of-Way Management

Both aboveground transmission and distribution projects require rights-of-way to protect the system from windfall, contact with trees and branches, and other potential hazards that may result in damage to the system, power failures, or forest fires. Rights-of-way are also utilized to access, service, and inspect transmission and distribution systems. Underground distribution lines also require rights-of-way where excavation is prohibited or strictly monitored, construction activity is limited, and access to lines can be achieved if necessary. Being larger systems transmitting higher voltages, transmission rights-of-way are typically much larger than those for distribution systems and, consequently, require more extensive management.

Right-of-ways widths[52] for transmission lines range from 15 to 100m depending on voltage and proximity to other rights-of-way (typical range is between 15 and 30m)[53]. For overhead distribution power lines up to 35 kV, 12 to 24m corridors (6 to 12m on each side) are recommended[54]. Access roads are often constructed in conjunction, or within, transmission line rights-of-way to provide access for maintenance and upkeep of the system.

To avoid disruption to overhead power lines and towers, regular maintenance of vegetation within the rights-of-way is required. Unchecked growth of tall trees and accumulation of vegetation within rights-of-way can result in a number of impacts including power outages through contact of branches and trees with transmission lines and towers; ignition of forest and brush fires; corrosion of steel equipment; blocking of equipment access; and interference with critical grounding equipment.

Regular maintenance and clearing of rights-of-way prevents natural forest succession and the establishment and growth of tall trees. Typically, tall trees of approximately 4.5m or more are not permitted within aboveground rights-of-way.[55] Underground rights-of-way have far fewer vegetation restrictions, though trees with deep tap roots that may interfere with duct banks are usually prohibited from being grown within the right-of-way. Vegetation maintenance of rights-of-way can be accomplished with the following measures.

Mowing with heavy-duty power equipment is used to control growth of ground covers and prevent the establishment of trees and shrubs in the right-of-way. Herbicides, in combination with mowing, control fast-growing weedy species that have a potential to mature to heights over those permitted within the right-of-way. Trimming and pruning is utilized at the boundaries of rights-of-way to maintain corridor breadth and prevent the encroachment of tree branches. Hand removal or removal of vegetation is costly and time-consuming but is often used in the vicinity of structures, streams, fences, and other obstructions making the use of machinery difficult or dangerous.

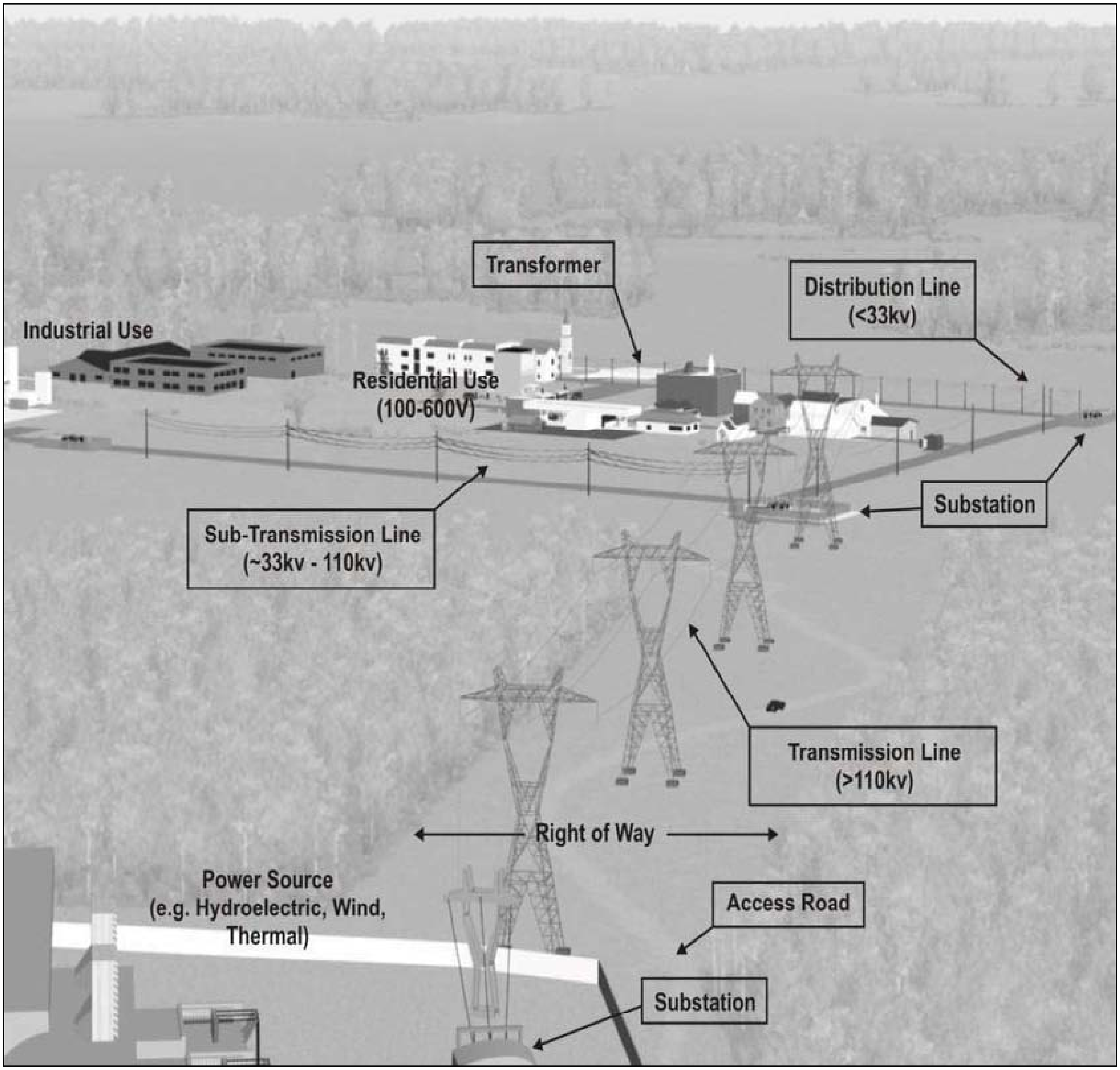
[52] For example, Duke Energy prescribes 21-meter minimum rights-of-way for voltages between 44 and 100 kV, 46-meter minimum rights-of-way for voltages of 230 kV, and 61-meter minimum rights-of-way for voltages of 525 kV (Duke Energy, 2006).

[53] Santee Cooper (2002)

[54] United States of America Department of National Defense (2004)

[55] Georgia Power (2006)

Figure A-1: Electric Power Transmission and Distribution

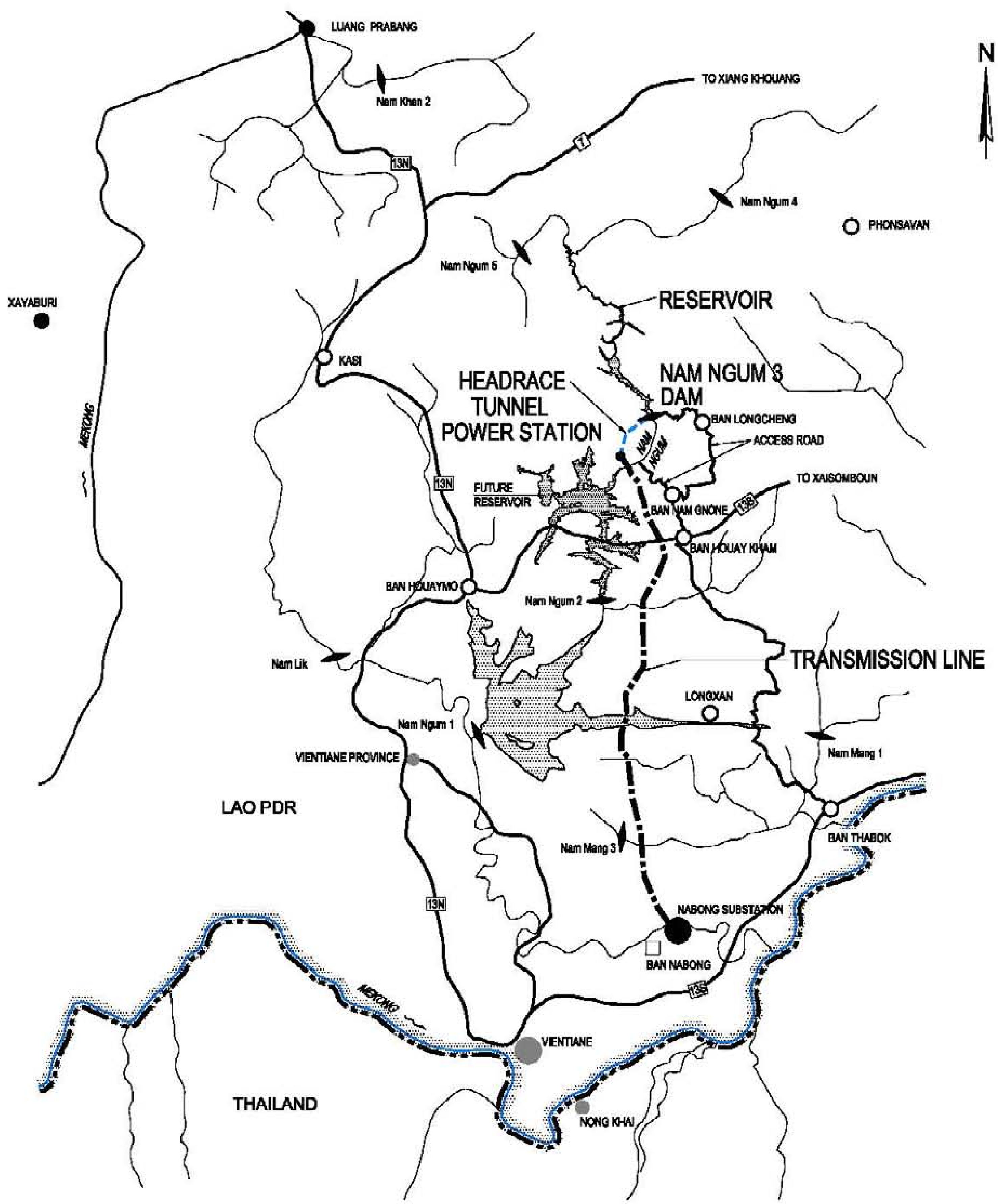


Annex K

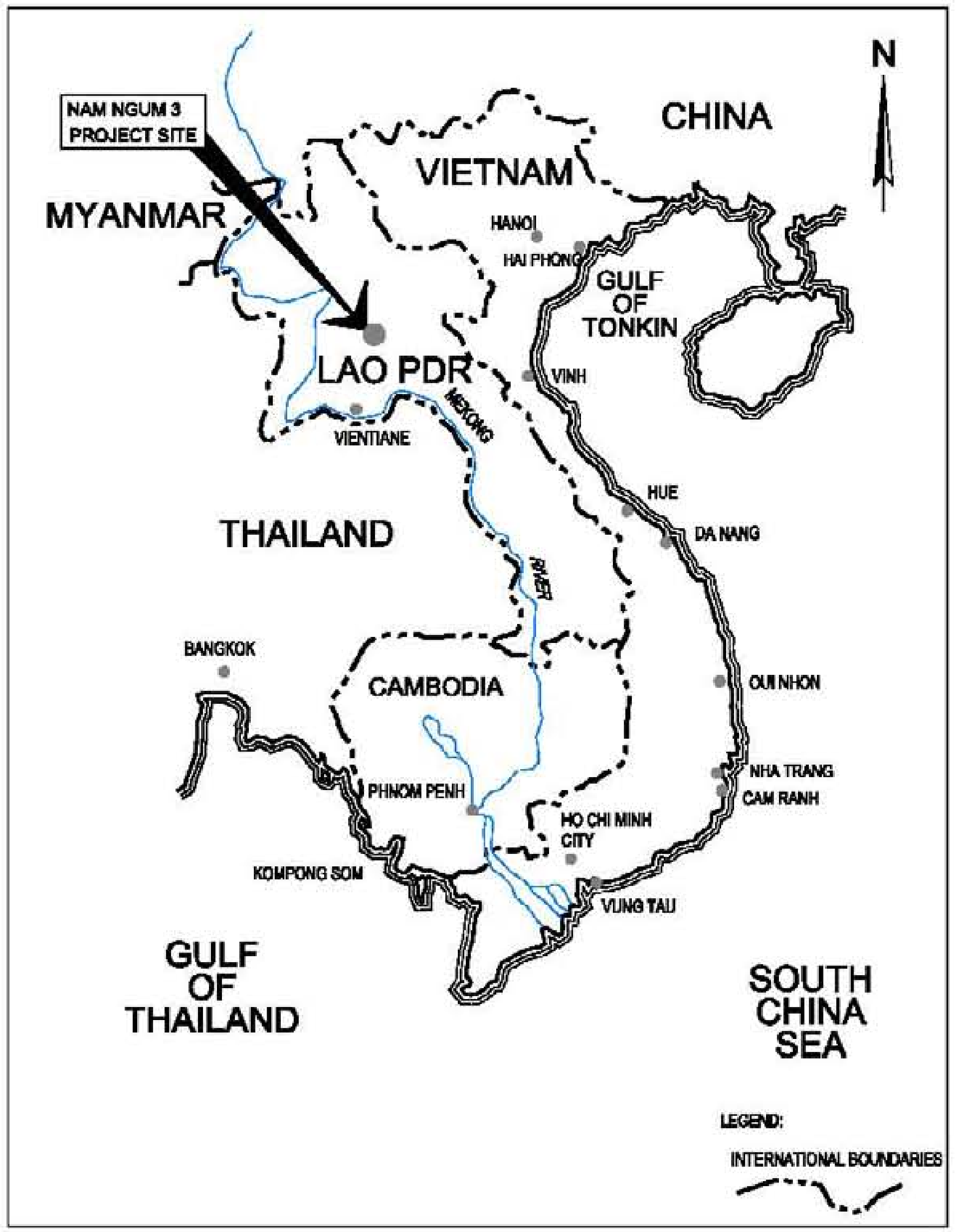
TECHNICAL DRAWINGS OF PROJECT INFRASTRUCTURE

This Annex presents a selection of the technical construction drawings, prepared for tendering purposes, of the key project features:

- Project location map;
- Overall project layout;
- Powerhouse and downstream areas;
- Dam area;
- Dam site layout plan;
- Diversion works;
- Concrete face rockfill dam, cross sections;
- Spillway structure;
- Spillway chute;
- Power intake and waterway, intake structure;
- Power intake and waterway, gate shaft;
- Surge shaft, pressure shaft and high pressure tunnel;
- Power complex, general layout;
- Power complex, powerhouse, general plan and profile;
- Tailrace tunnel;
- Tailrace tunnel, outlet structure.



LOCALITY MAP



LOCATION MAP

NTS

FOR TENDERING PURPOSES ONLY

Rev.No.	Description	CPE-NK Approval	NN3PC Approval	Date

NAM NGUM 3 POWER COMPANY LIMITED

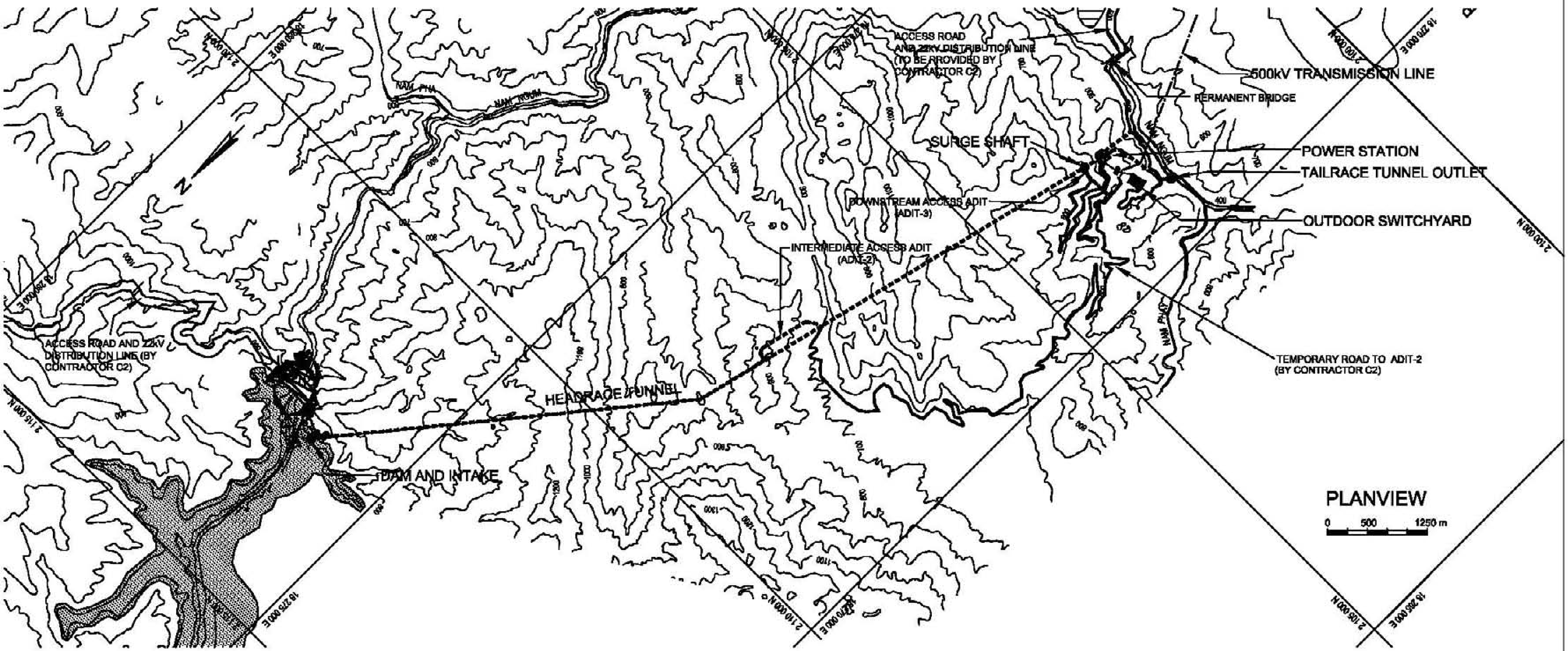
NAM NGUM 3 HYDROPOWER PROJECT

TENDER DESIGN

GENERAL DRAWINGS

PROJECT LOCATION MAP

NN3PC	COLENCO	NIPPON KOEI
Project Manager	Drafted / Dr. Check	Design / Des. Check
Managing Director	Pr. Manager	Pr. Director
ACAD File 2001.DWG	Drawing No. 1032/DWG/2001/0-E	



Rev./No. | Description | Approval | Approval | Date

NAM NGUM 3 POWER COMPANY LIMITED

NAM NGUM 3 HYDROPOWER PROJECT
TENDER DESIGN

GENERAL DRAWINGS
OVERALL PROJECT LAYOUT

NN3PC

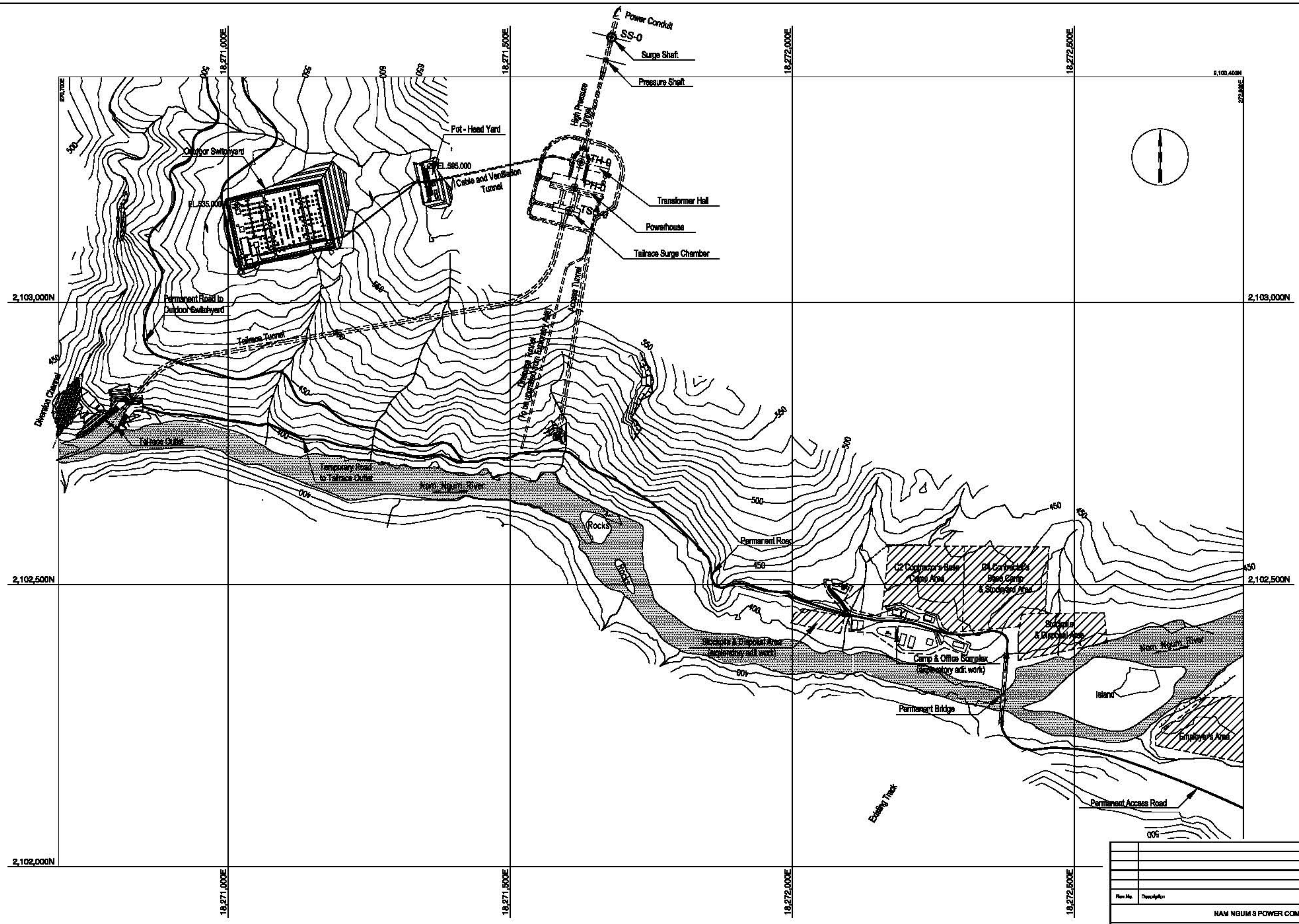
COLENCO

NIPPON KOEI

ACAD File 2003_0_C(cfrd).DWG

Drawing No. 1032/DWG/2003/0-C

FOR TENDERING PURPOSES ONLY



NOTES:

1) For coordinates see drawing 1032/ DWG/ 3201, 3451

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Rev.No.	Description	CPE-NK Approval	NN3PC Approval	Date

NAM NGUM 3 POWER COMPANY LIMITED

NAM NGUM 3 HYDROPOWER PROJECT

TENDER DESIGN

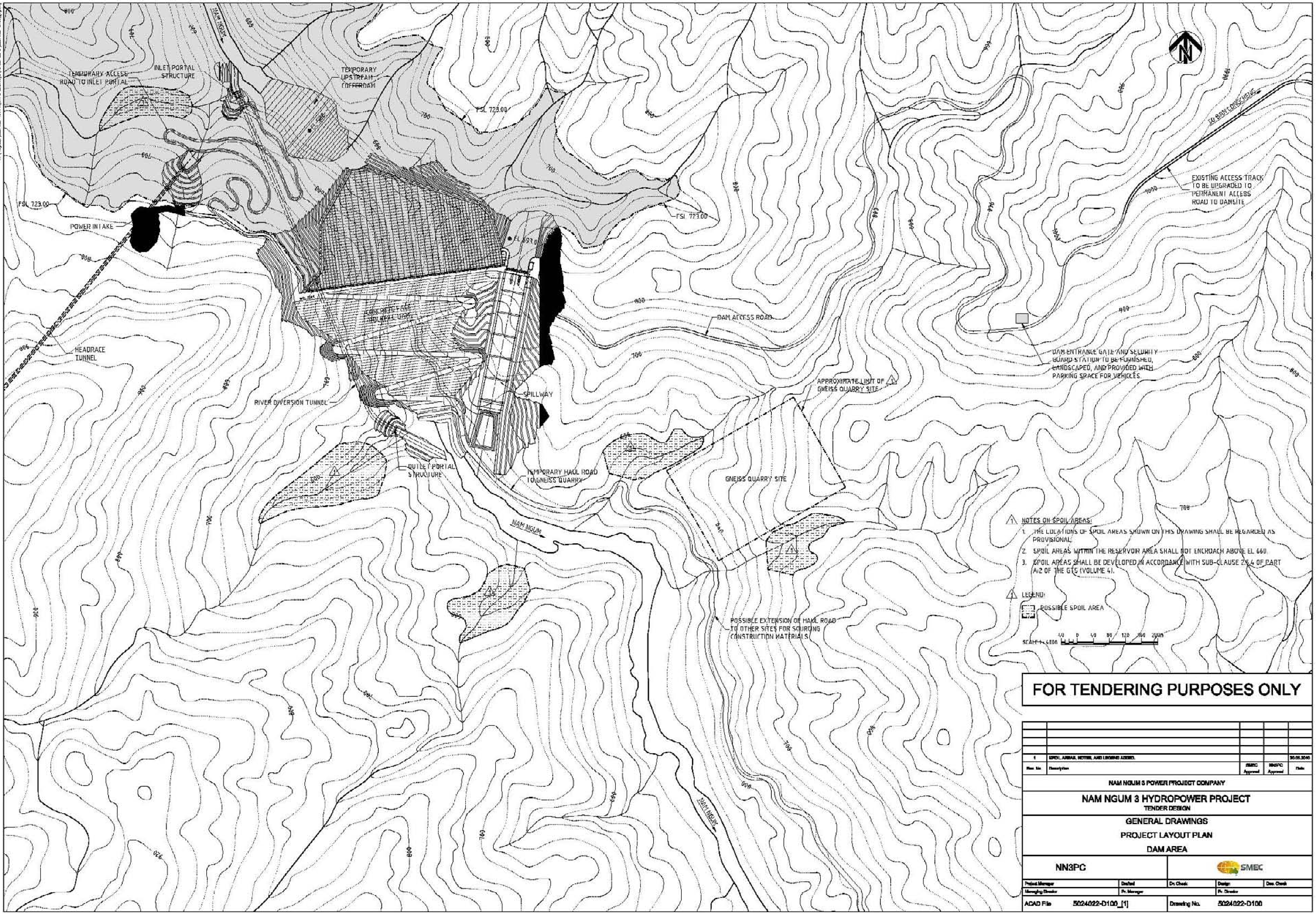
GENERAL DRAWINGS

PROJECT LAYOUT

POWERHOUSE AND DOWNSTREAM AREAS

NN3PC | COLENCO Colenco Power Engineering Ltd. | NIPPON KOEI

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	
ACAD File		Drawing No.	1032/DWG/2005/0	



FOR TENDERING PURPOSES ONLY

Rev. No.	Description	SMEC Approval	NN3PC Approval	Date
1	SPOIL AREAS, NOTES, AND LEGEND ADDED.			30.05.2016

NAM NGUM 3 POWER PROJECT COMPANY

NAM NGUM 3 HYDROPOWER PROJECT

TENDER DESIGN

GENERAL DRAWINGS

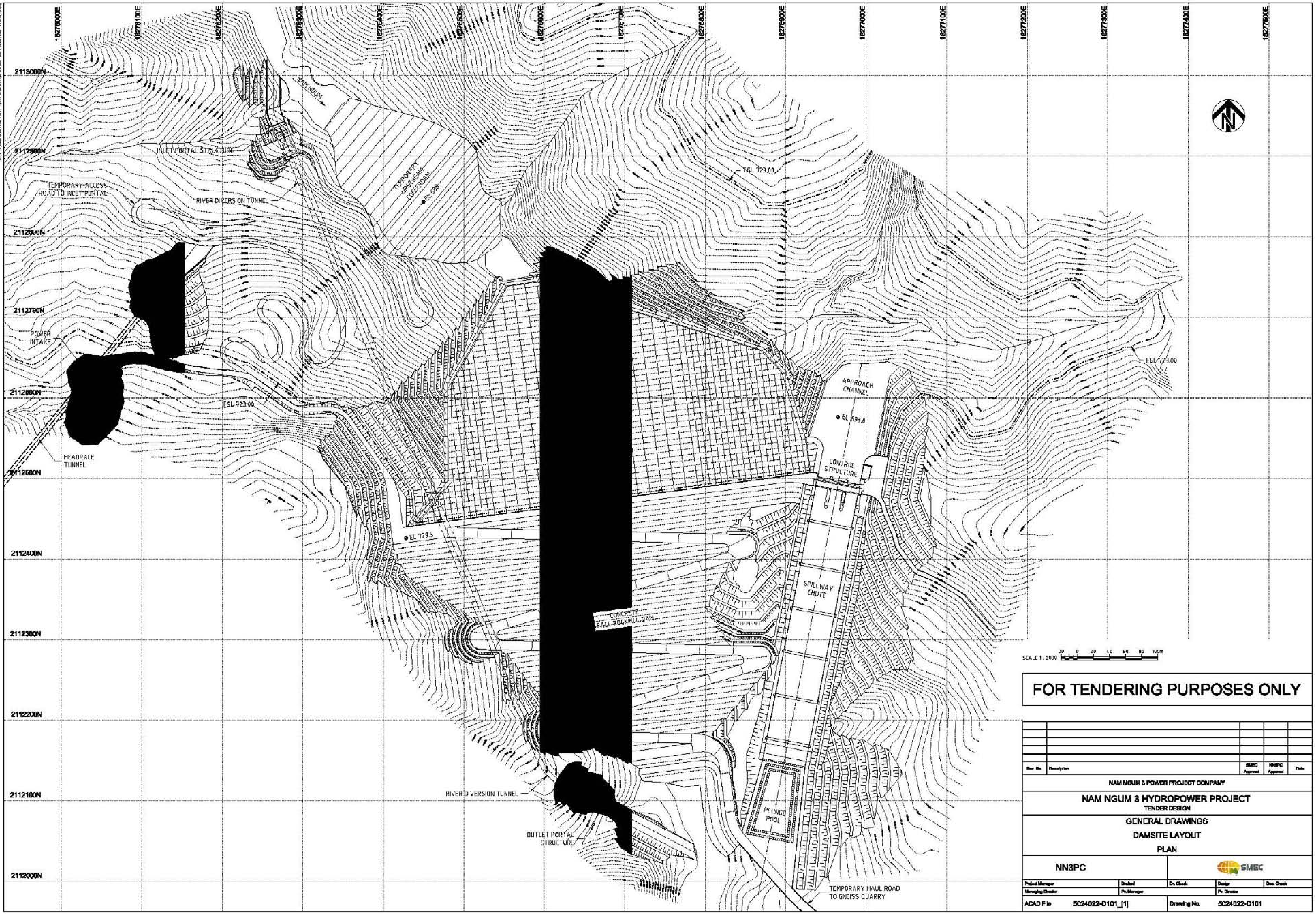
PROJECT LAYOUT PLAN

DAM AREA

NN3PC | SMEC

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	

ACAD File 5024022-D100_[1] | Drawing No. 5024022-D100



FOR TENDERING PURPOSES ONLY

Rev. No.	Description	SMEC Approval	NN3PC Approval	Date

NAM NGUM 3 POWER PROJECT COMPANY

NAM NGUM 3 HYDROPOWER PROJECT

TENDER DESIGN

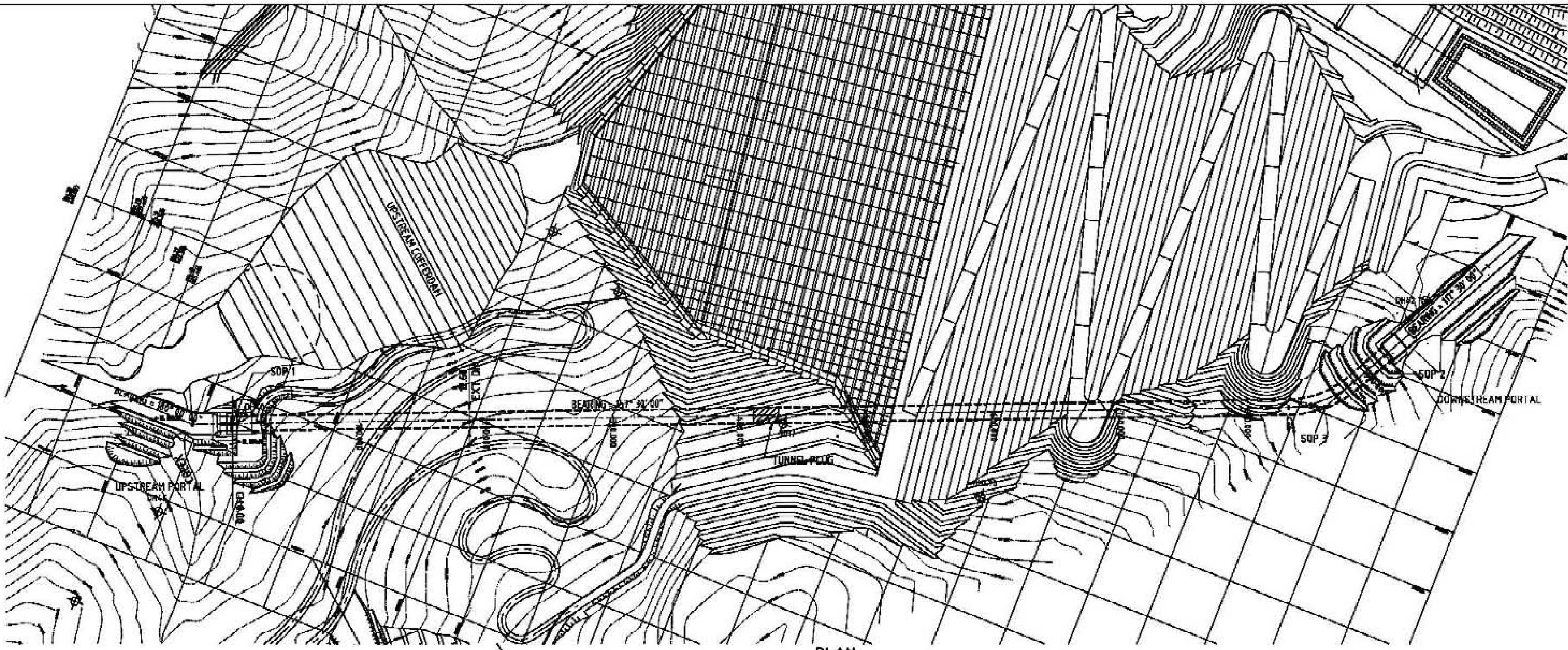
GENERAL DRAWINGS

DAMSITE LAYOUT

PLAN

NN3PC | SMEC

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	
ACAD File	5024022-D101_[1]	Drawing No.	5024022-D101	



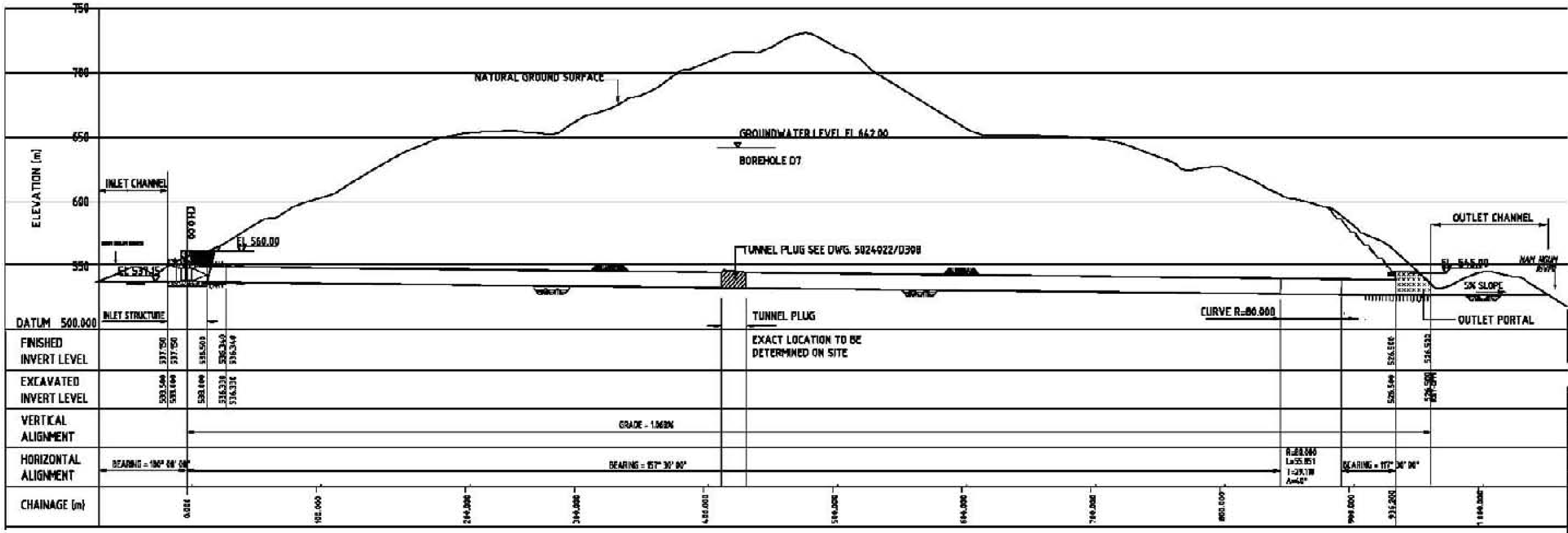
PLAN
SCALE 1:2000

NOTES

1. CO-ORDINATES REFER TO VIENTIANE DATUM.
2. ELEVATIONS REFER TO VIENTIANE DATUM (MEAN SEALEVEL) AT SOUTH CHINA SEA.
3. CONTOURS OF EXISTING GROUND SURFACE ARE BASED ON DRG No. 52423-D1008.
4. SETTING-OUT POINTS AT TUNNEL INLET AND OUTLET ARE APPROXIMATE ONLY AND MAY VARY DEPENDING ON SITE CONDITIONS.
5. FINAL EXCAVATION MAY VARY FROM ASSUMED EXCAVATION SURFACE.
6. LOCATION OF DRILLHOLES ARE APPROXIMATE ONLY.
7. FLOODING AND AERATION PIPES TO BE INSTALLED BETWEEN UPSTREAM DIVERSION PORTAL AND DAM CREST PRIOR TO DIVERSION CLOSURE.

NOTE:

1. ALL DIMENSIONS ARE IN METERS EXCEPT WHERE OTHERWISE NOTED.
2. ALL ELEVATIONS ARE IN METERS AND REFERRED TO EL. 0.00 M.A.S.L.
3. CT_ CONCRETE CLASSIFICATION
4. F_ FORMED SURFACE FINISHING
5. U_ UNFORMED SURFACE FINISHING



LONGITUDINAL SECTION
SCALE 1:2000

TUNNEL SETTING OUT POINTS			
SETTING OUT POINT No	NORTHING	EASTING	CHAINAGE
SOP 1	2 112 926.476	18 276 275.767	0.000
SOP 2	2 112 100.632	18 276 662.735	923.40
SOP 3	2 112 130.536	18 276 605.290	861.081
SOP 4	2 112 654.986	18 276 263.783	-30.00

SCALE 1: 2000

FOR TENDERING PURPOSES ONLY

Rev No	Description	SMEC Approval	NN3PC Approval	Date

NAM NGUM 3 POWER PROJECT COMPANY

NAM NGUM 3 HYDROPOWER PROJECT

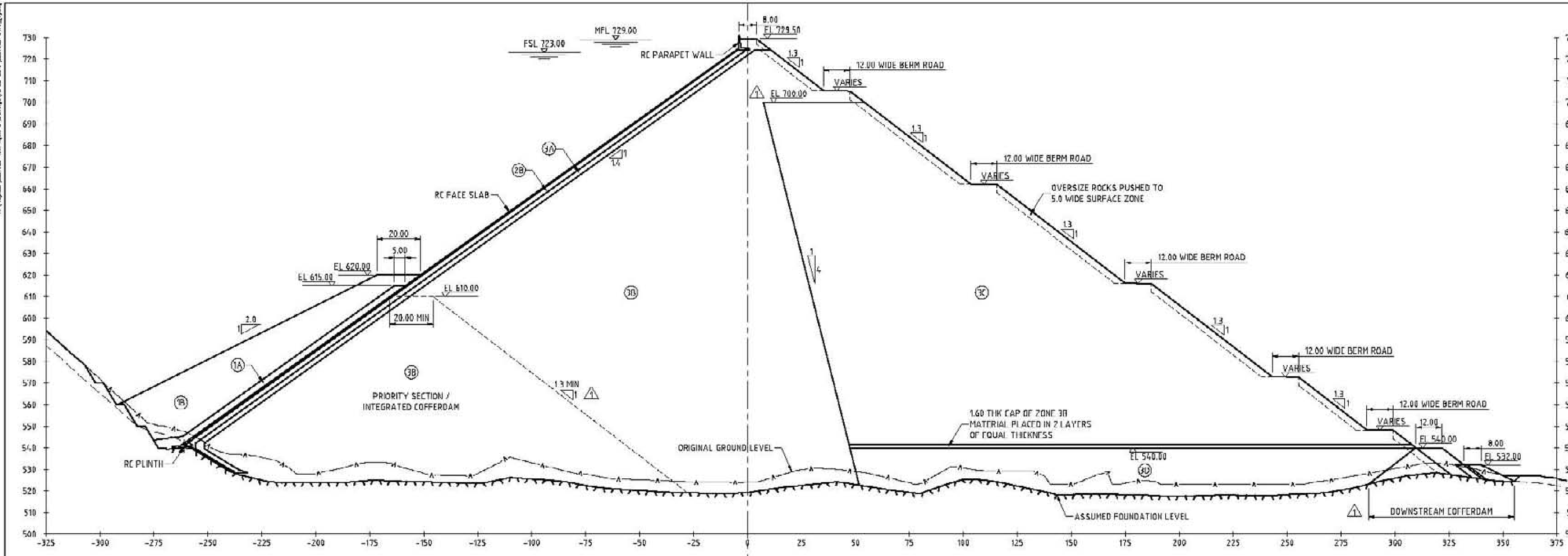
TENDER DESIGN

DIVERSION WORKS
GENERAL ARRANGEMENT
PLAN AND PROFILE

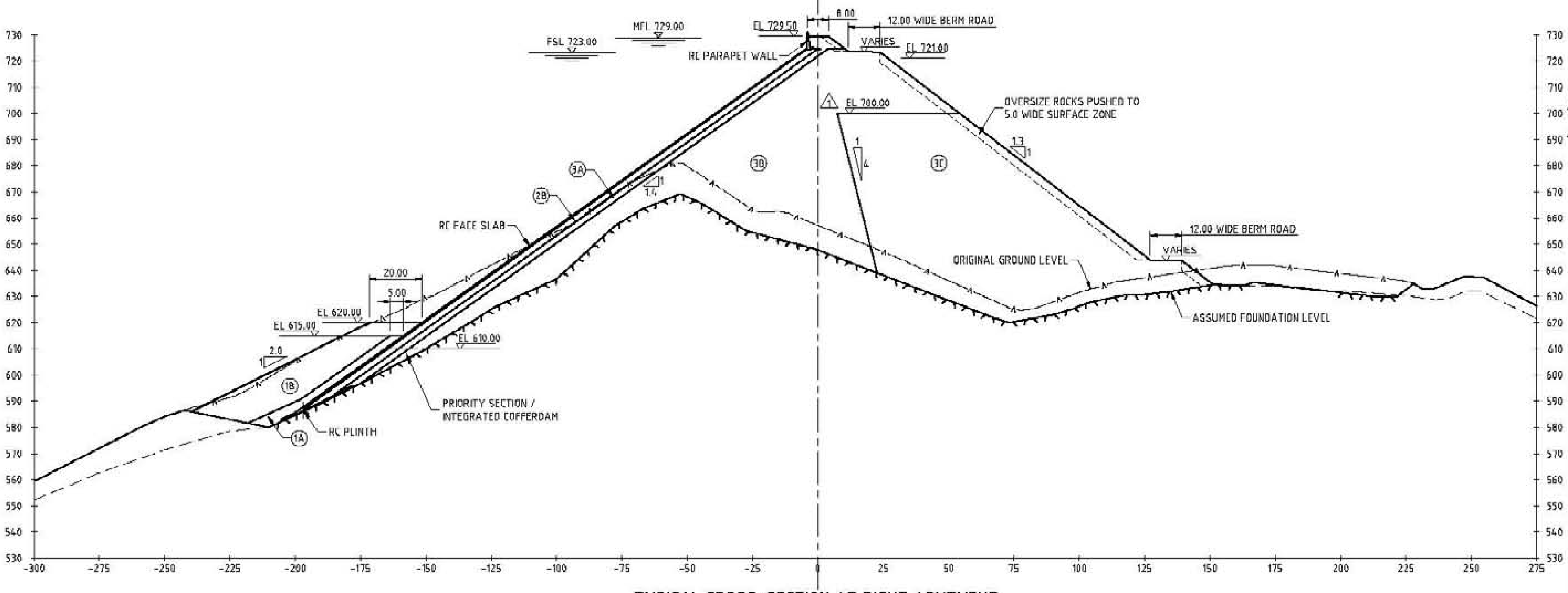
NN3PC

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	

ACAD File 5024022-D300_[]
Drawing No. 5024022-D300



TYPICAL CROSS-SECTION IN RIVERBED AREA
(BASED ON ACTUAL SECTION AT CH:300)
SCALE 1:1000 (A1)



TYPICAL CROSS-SECTION AT RIGHT ABUTMENT
(BASED ON ACTUAL SECTION AT CH:150)
SCALE 1:1000 (A1)

EMBANKMENT ZONES

- (1A) CRACK FILLER MATERIAL: SELECTED FINE-GRAINED COHESIONLESS SOIL
- (1B) ZONE 1A SUPPORT: RANDOM FILL
- (2A) PERIMETER ZONE FINE FILTER: SANDY GRAVEL (PROCESSED ROCK OR SAND) MAX. SIZE 19mm
- (2B) FACE SLAB BEDDING LAYER: SANDY GRAVEL (PROCESSED ROCK) MAX. SIZE 75mm
- (3A) TRANSITION ZONE: SOUND, WELL-GRADED, SMALL QUARRY-RUN ROCKFILL
- 1 (3B) "FIRST CLASS" ROCKFILL: FRESH TO SLIGHTLY WEATHERED, WELL-GRADED, QUARRY-RUN ROCKFILL
- 1 (3C) "SECOND CLASS" ROCKFILL: FRESH TO MODERATELY WEATHERED, WELL-GRADED, QUARRY-RUN ROCKFILL
- (3D) DRAINAGE ZONE: SOUND, WELL-GRADED, QUARRY-RUN ROCKFILL OF COARSE GRADATION

SCALE 1:1000 10 0 10 20 30 40 50m

FOR TENDERING PURPOSES ONLY

Rev. No.	Description	SMEC Approval	NN3PC Approval	Date
1	LIMIT OF ZONES 3B AND 3C LOWERED, DOWNSTREAM COFFERDAM ADDED, NOTES AMENDED.			[illegible]

NAM NGUM 3 POWER PROJECT COMPANY

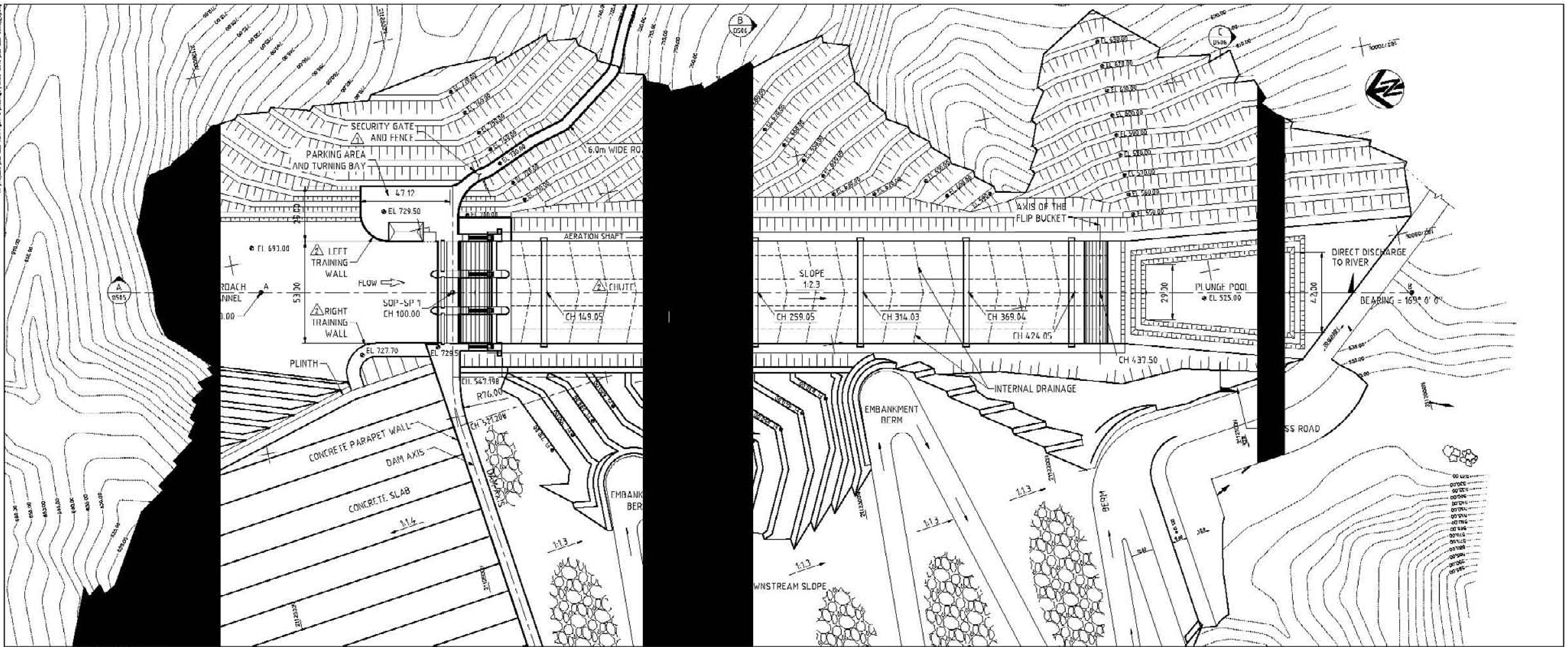
NAM NGUM 3 HYDROPOWER PROJECT
TENDER DESIGN

CONCRETE FACE ROCKFILL DAM
EMBANKMENT
TYPICAL CROSS-SECTIONS (SHEET 1 OF 2)

NN3PC — SMEC

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	

ACAD File: 6024022-D410_[1].dwg — Drawing No. 6024022-D410



PLAN

SCALE 1:1000

SCALE 1:1000 10 0 10 20 30 40 50m

NOTES:

1. ALL DIMENSIONS AND LEVELS ARE IN METRES UNLESS NOTED OTHERWISE.
2. CONTOURS, ELEVATIONS AND GRID REFERENCES ARE BASED ON GROUND SURVEY OF THE DAMSITE AREA.
3. LONGITUDINAL CHAINAGE DISTANCES ARE MEASURED HORIZONTALLY ALONG THE CENTRE LINE OF THE SPILLWAY.
4. THE EXCAVATION LINES/ SLOPES SHOWN IN PLAN AND SECTIONS ARE APPROXIMATE ONLY BASED ON LIMITED TOPOGRAPHIC AND GEOLOGICAL DATA AND ARE SUBJECT TO REVISION AS PER SITE CONDITIONS. ANY SUCH REVISIONS SHALL BE SUBJECT TO APPROVAL OF THE SUPERVISING ENGINEER.
5. WEAK AND ERODIBLE SEAMS, ZONES OR INTRUSIONS AT THE SURFACE OF THE FOUNDATION SHALL BE EXCAVATED AND BACKFILLED WITH CONCRETE.
6. SLOPE STABILITY MEASURES SUCH AS ROCK ANCHORS, SOIL NAILS & SHOTCRETE SHALL BE PROVIDED TIMELY AND PROGRESSIVELY AS REQUIRED & APPROVED BY THE ENGINEER.

LEGEND:

SOP SETTING OUT POINT

REFERENCE POINTS

LOCATION	NORTHING	EASTING
A	2112587.54	18276983.35
B	2111998.56	18276868.87
SOP-SP1	2112489.38	18276964.27

NOTE:

1. ALL DIMENSIONS ARE IN METERS EXCEPT WHERE OTHERWISE NOTED.
2. ALL ELEVATIONS ARE IN METERS AND REFERRED TO EL. 0.00 M.A.S.L.
3. CT CONCRETE CLASSIFICATION
4. F FORMED SURFACE FINISHING
5. U UNFORMED SURFACE FINISHING

FOR TENDERING PURPOSES ONLY

Rev. No.	Description	SMEC Approval	NN3PC Approval	Date
2	SPILLWAY COMPONENT LABELS AMENDED.			13.08.2013
1	SECURITY GATE AND FENCE RELOCATED.			07.08.2013

NAM NGUM 3 POWER PROJECT COMPANY

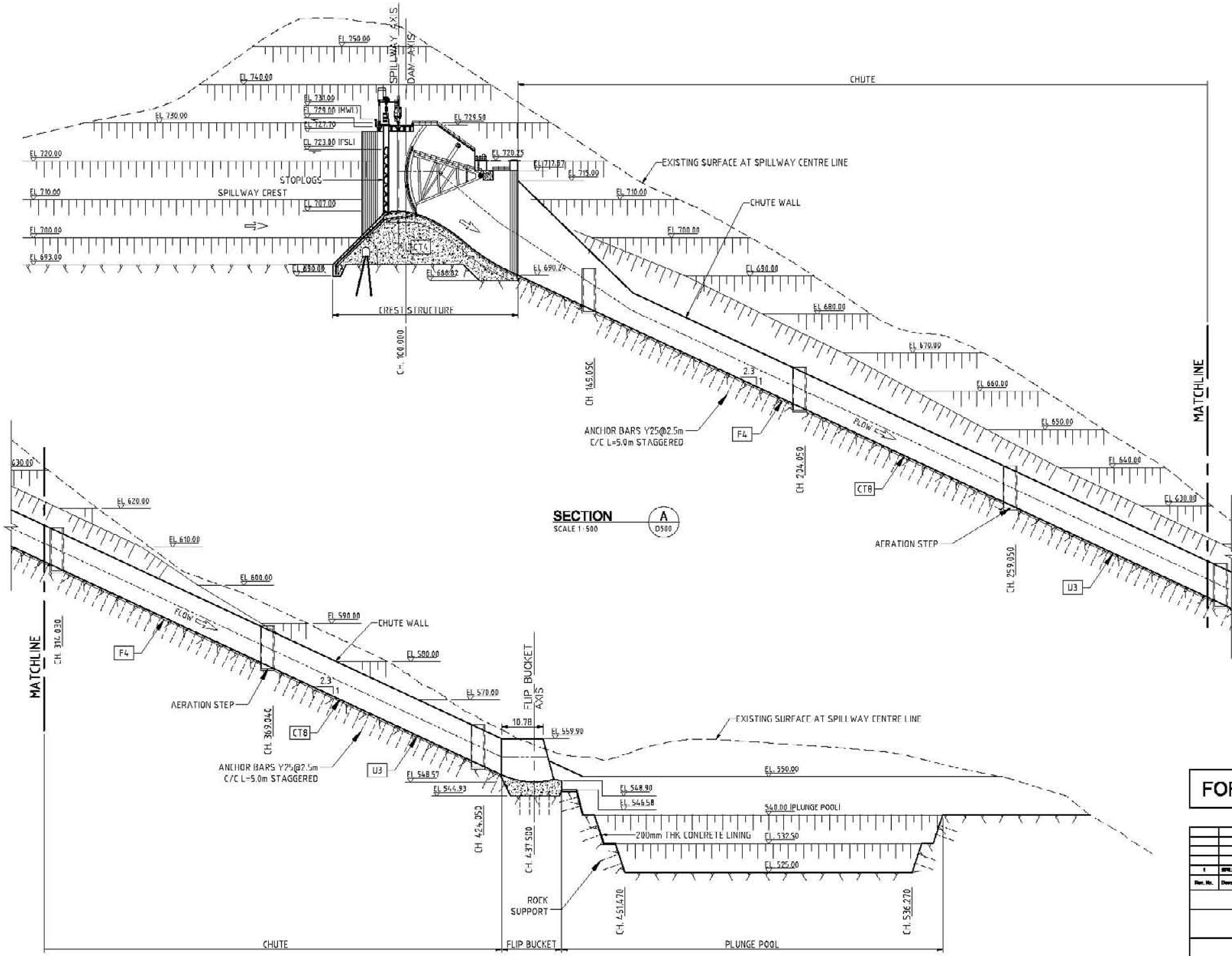
NAM NGUM 3 HYDROPOWER PROJECT
TENDER DESIGN

SPILLWAY STRUCTURE
GENERAL LAYOUT

NN3PC SMEC

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	

ACAD File 5024022-D500_[2].dwg Drawing No. 5024022-D500



SECTION A
SCALE 1:500
D500

SECTION A
SCALE 1:500
D500

SCALE 1:500 5 0 5 10 15 20 25m

FOR TENDERING PURPOSES ONLY

Rev. No.	Description	SMEC Approval	NN3PC Approval	Date
1	SPILLWAY COMPONENT LABELS AMENDED			15.09.2010

NAM NGUM 3 POWER PROJECT COMPANY

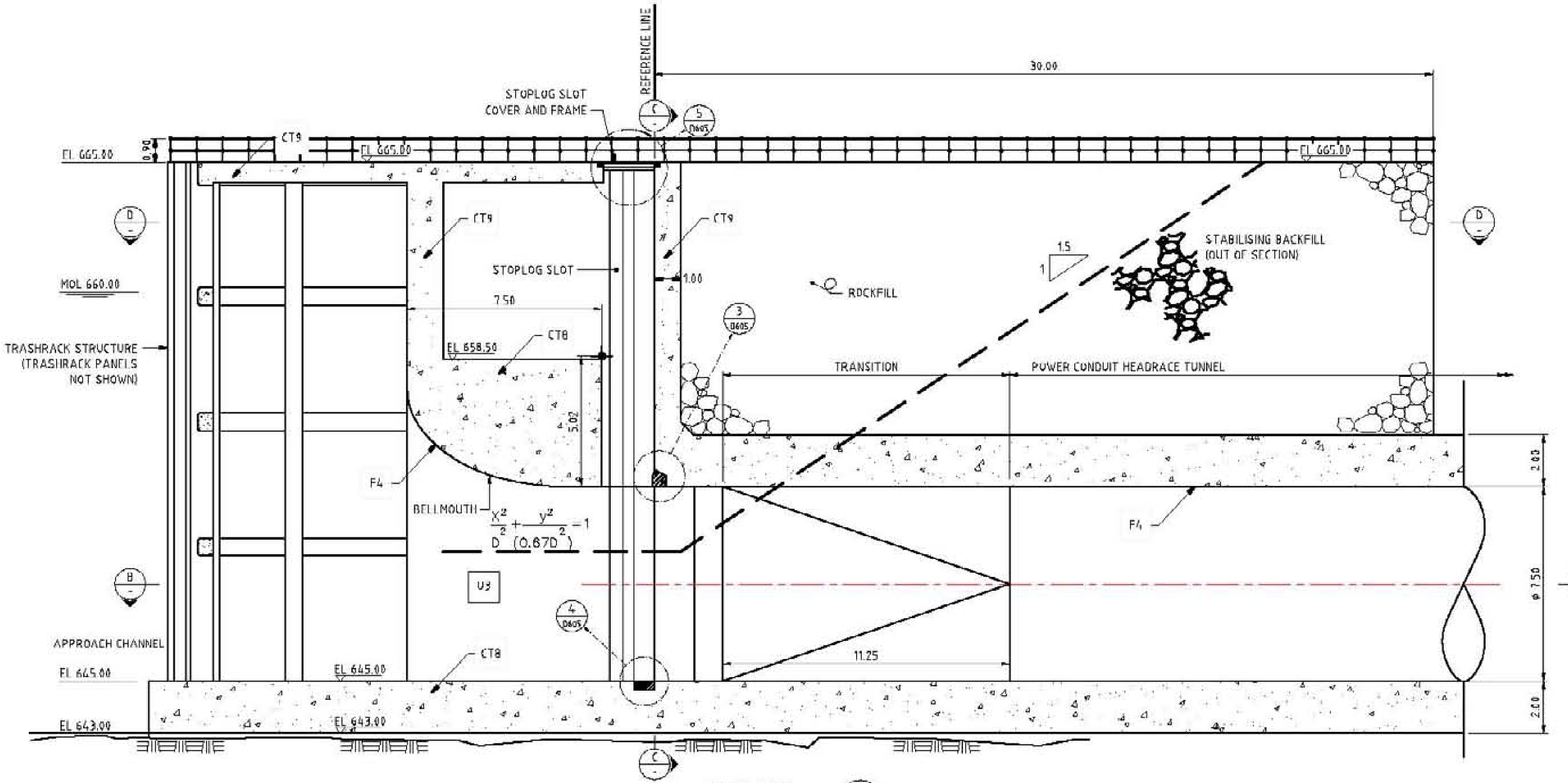
NAM NGUM 3 HYDROPOWER PROJECT
TENDER DESIGN

SPILLWAY STRUCTURE
SPILLWAY CHUTE
LONGITUDINAL SECTION

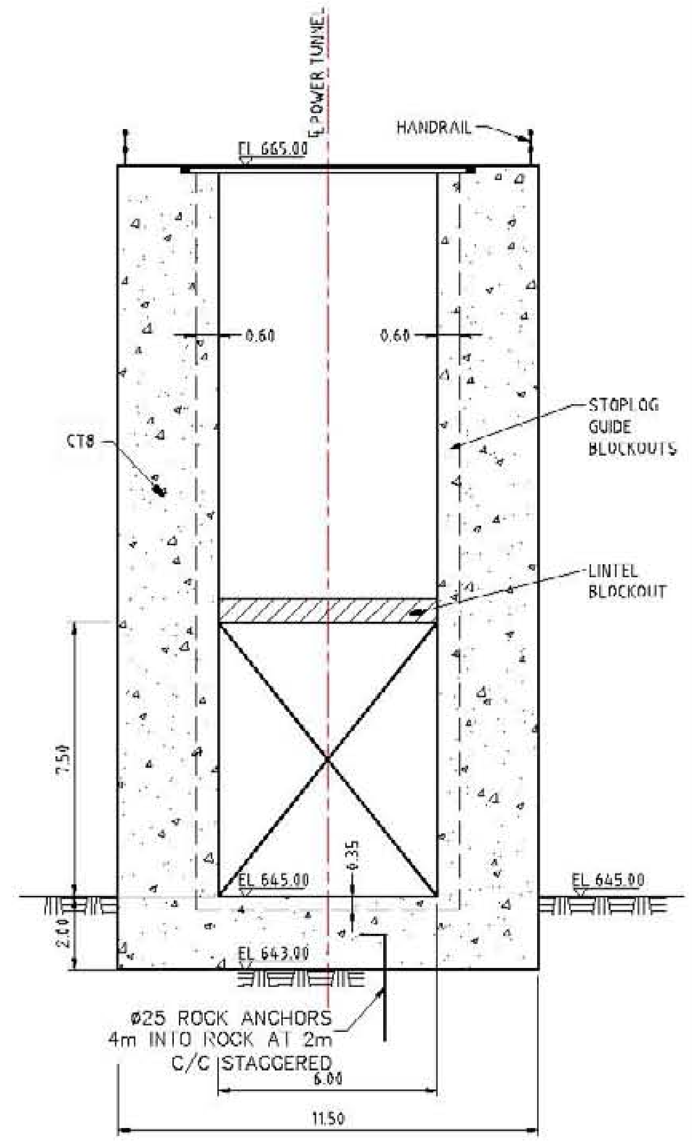
NN3PC | SMEC

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	

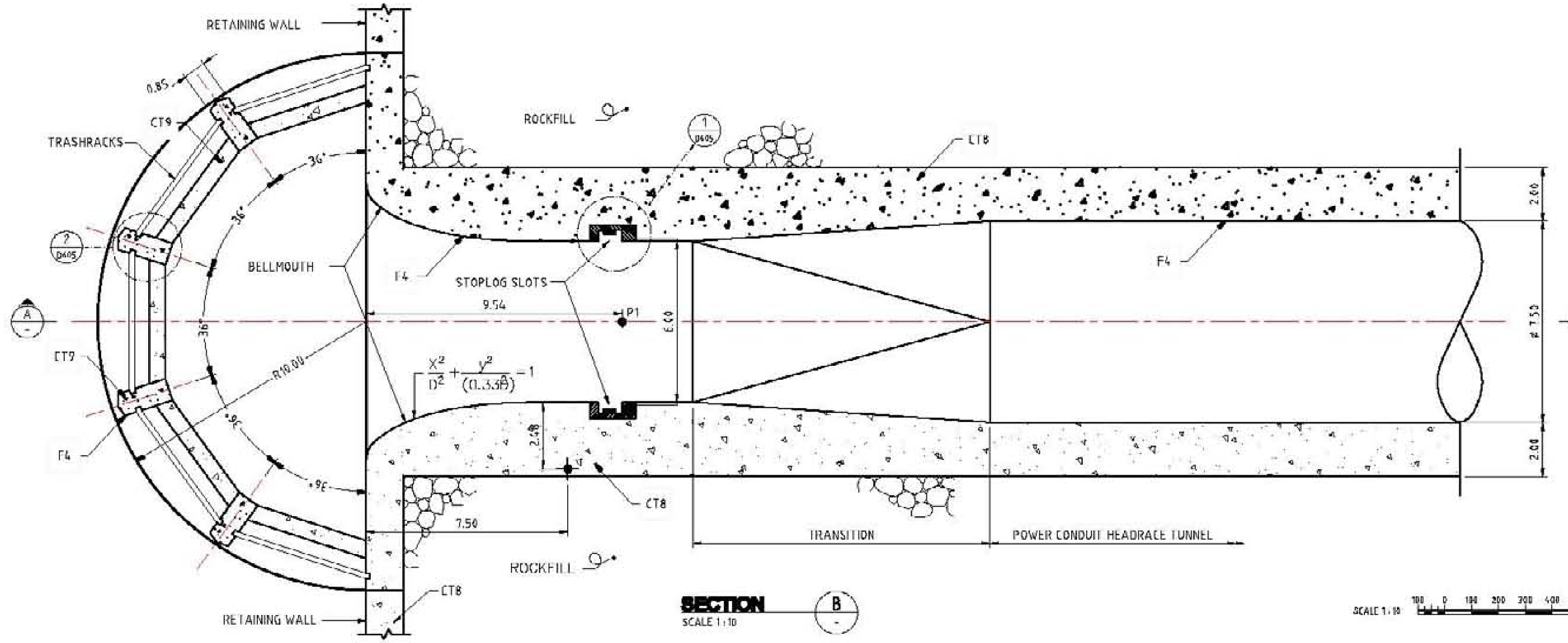
ACAD File 5024022-D505_[1].dwg | Drawing No. 5024022-D505



SECTION A
SCALE 1:10



SECTION C
SCALE 1:10



SECTION B
SCALE 1:10

SCALE 1:10 100 0 100 200 300 400 500mm

FOR TENDERING PURPOSES ONLY

Rev. No.	Description	SMEC Approval	NN3PC Approval	Date

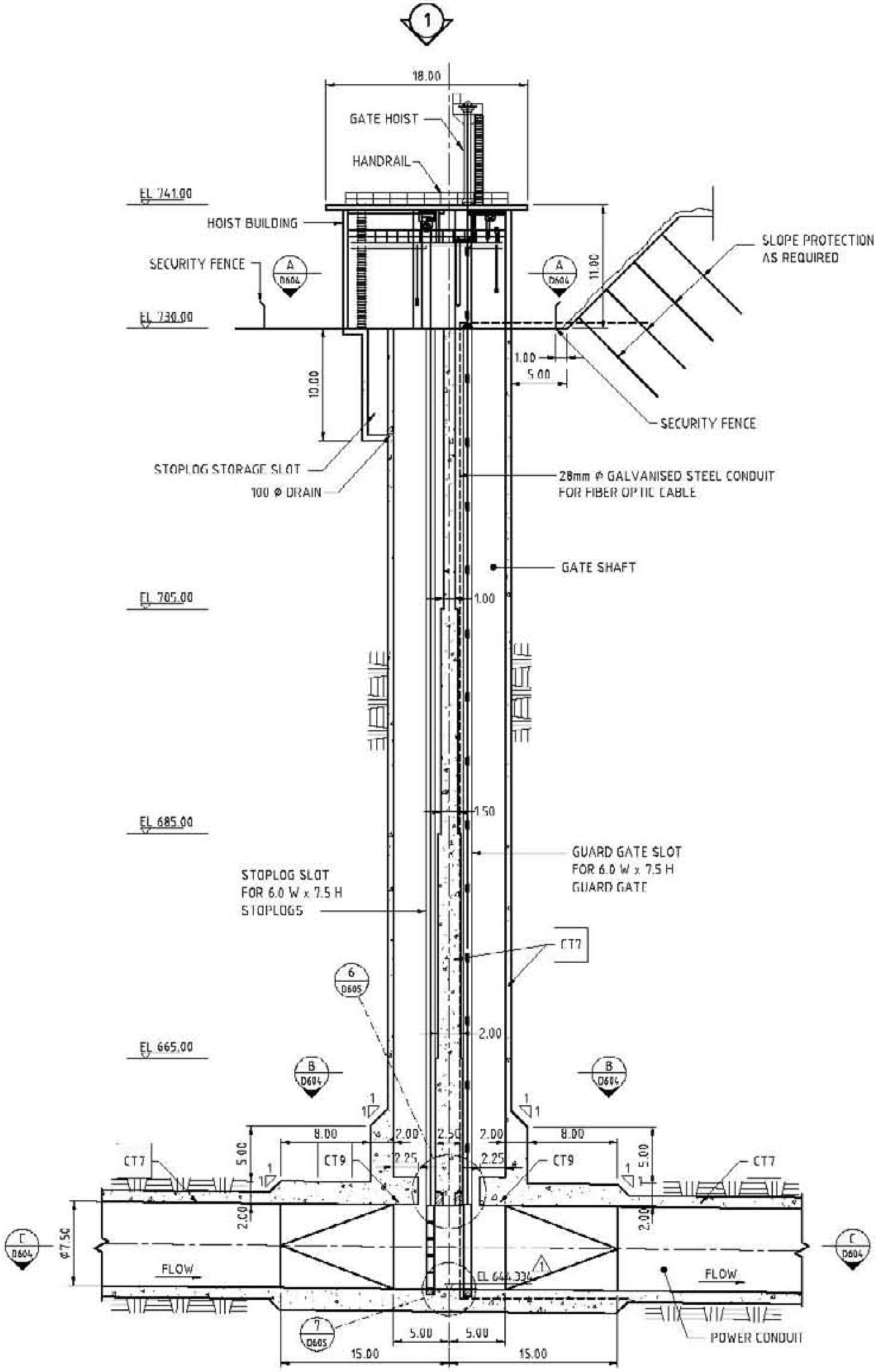
NAM NGUM 3 POWER PROJECT COMPANY

NAM NGUM 3 HYDROPOWER PROJECT
TENDER DESIGN

POWER INTAKE AND WATERWAY
INTAKE STRUCTURE
SECTIONS

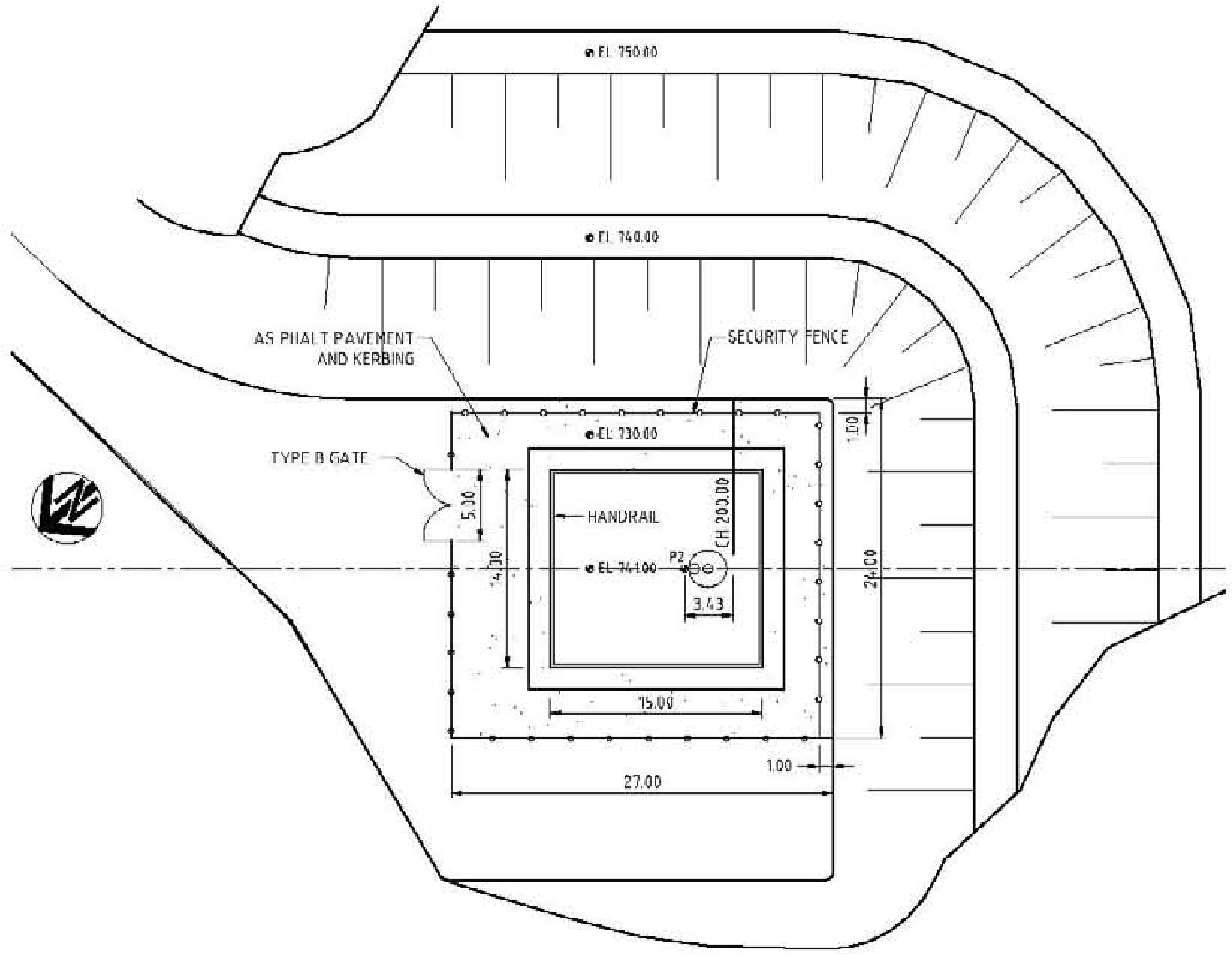
NN3PC — SMEC

Project Manager		Drafted	Dn Check	Design	Des. Check
Managing Director		Pr Manager		Pr Director	
ACAD File	5024022-D601_[]		Drawing No.	5024022-D601	



SECTION ELEVATION OF GATE SHAFT

SCALE 1:250



PLAN VIEW '1'

SCALE 1:250

SCALE 1:250 2500 0 2500 5000 7500 10000 12500mm

FOR TENDERING PURPOSES ONLY

1	INVERT ELEVATION AT GATE SHAFT CENTRELINE CORRECTED, SCALES CORRECTED.			02.07.2010
Rev. No.	Description	SMEC Approval	NN3PC Approval	Date

NAM NGUM 3 POWER PROJECT COMPANY

NAM NGUM 3 HYDROPOWER PROJECT

TENDER DESIGN

POWER INTAKE AND WATERWAY

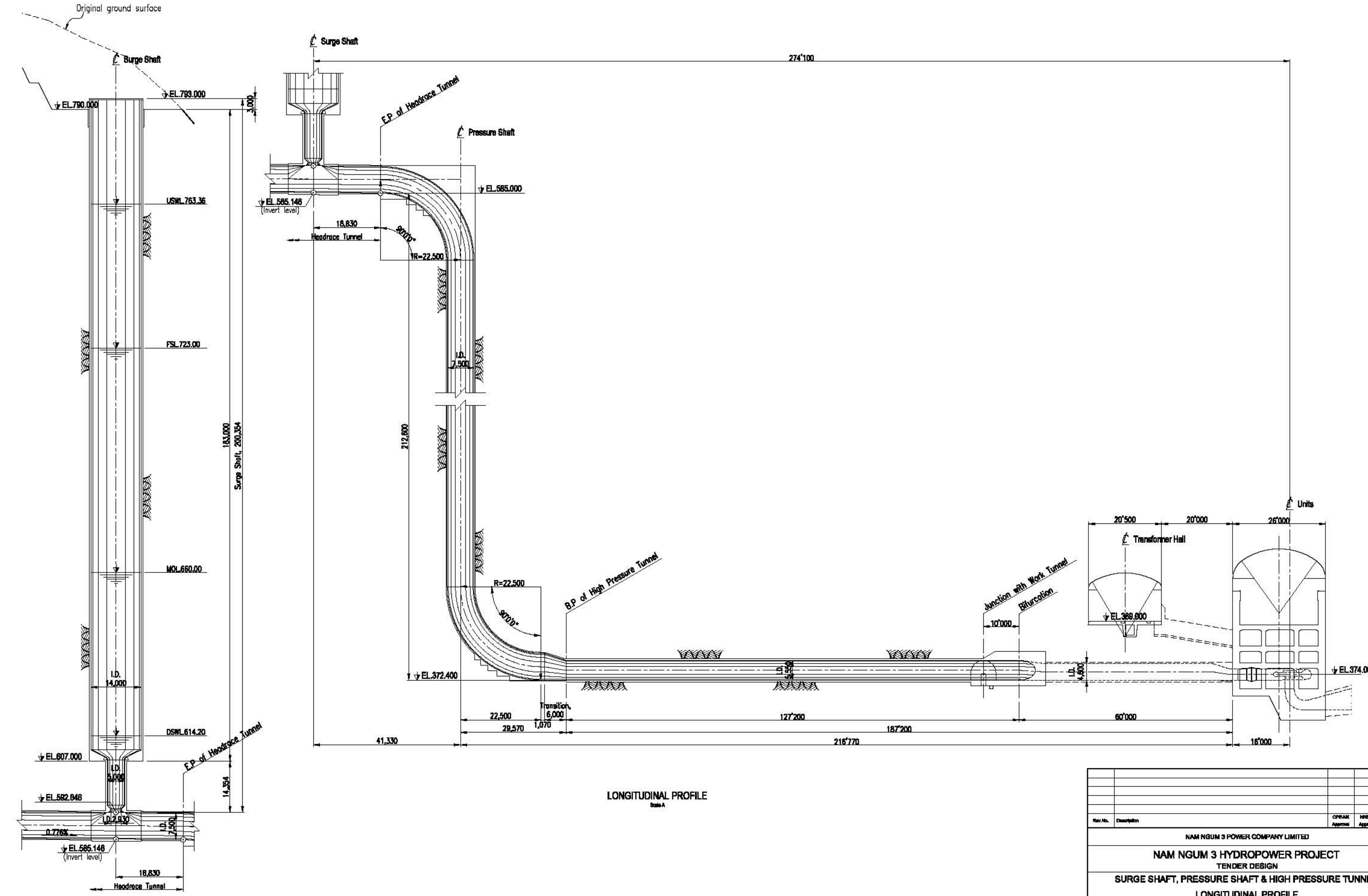
GATE SHAFT

PLAN AND SECTIONS

NN3PC

SMEC

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	
ACAD File	5024022-D603_[1]	Drawing No.	5024022-D603	



LONGITUDINAL PROFILE
Scale A

SCALE A 0 10.0 20.0 50.0 METRES

FOR TENDERING PURPOSES ONLY

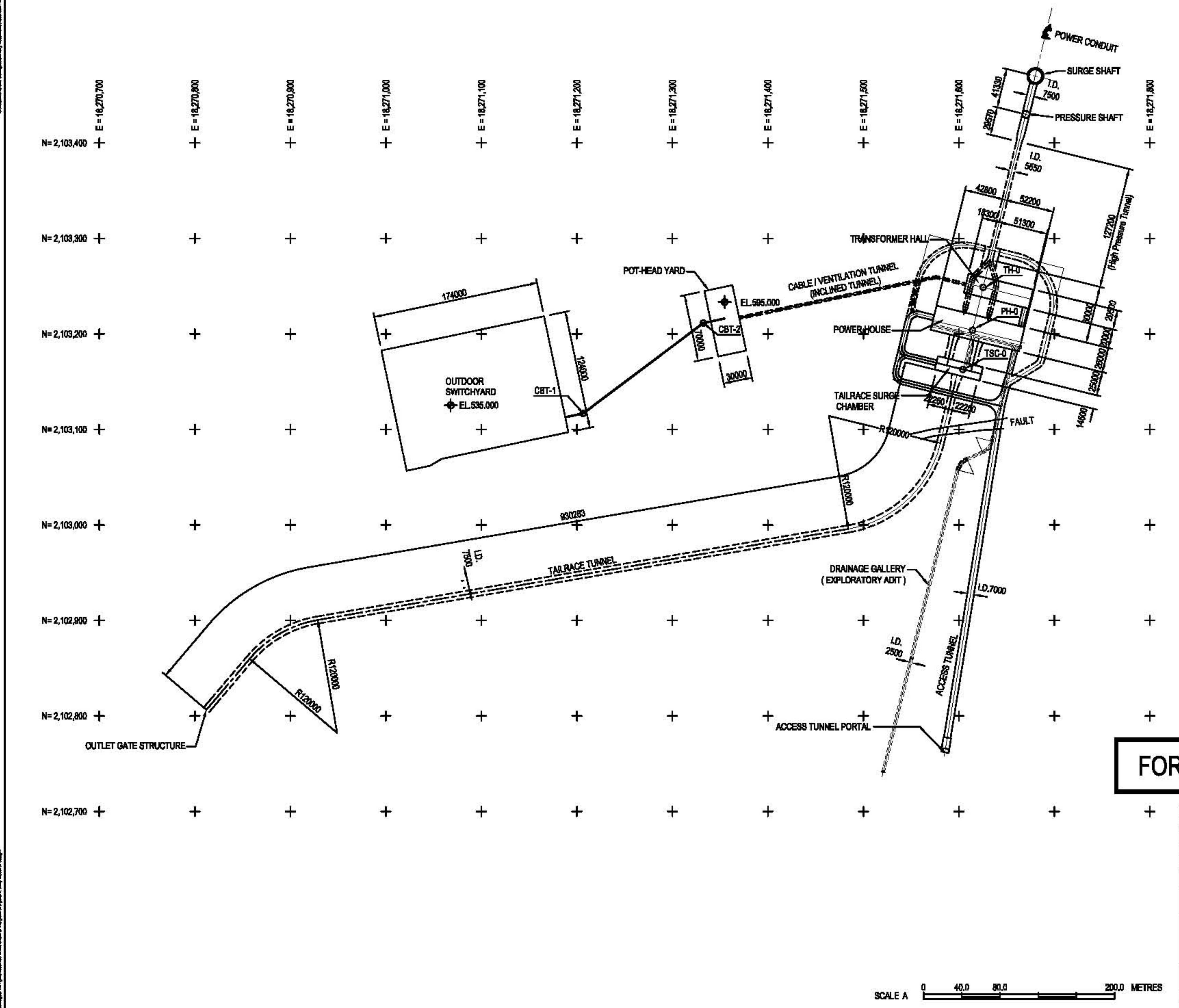
Rev.No.	Description	CPE-NK Approval	NN3PC Approval	Date

NAM NGUM 3 POWER COMPANY LIMITED

NAM NGUM 3 HYDROPOWER PROJECT
TENDER DESIGN

SURGE SHAFT, PRESSURE SHAFT & HIGH PRESSURE TUNNEL
LONGITUDINAL PROFILE

NN3PC	COLENCO Colenco Power Engineering Ltd.		NIPPON KOEI Challenging mind, Changing dynamics	
Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	
ACAD File 3152.DWG		Drawing No.	1032/DWG/3152/0	



COORDINATES

POINT	E	N
PH - 0	18,271,614.3227	2,103,203.8848
TH-0	18,271,625.4048	2,103,248.7875
TSC-0	18,271,604.1990	2,103,162.8656
CBT-1	18,271,206.4646	2,103,116.7067
CBT-2	18,271,332.3812	2,103,211.4012

FOR TENDERING PURPOSES ONLY

Rev.No.	Description	CPE-NK Approval	NDK Approval	Date
1	Revise coordinate of TSC-0			6/8/10

NAM NGUM 3 POWER COMPANY LIMITED

NAM NGUM 3 HYDROPOWER PROJECT

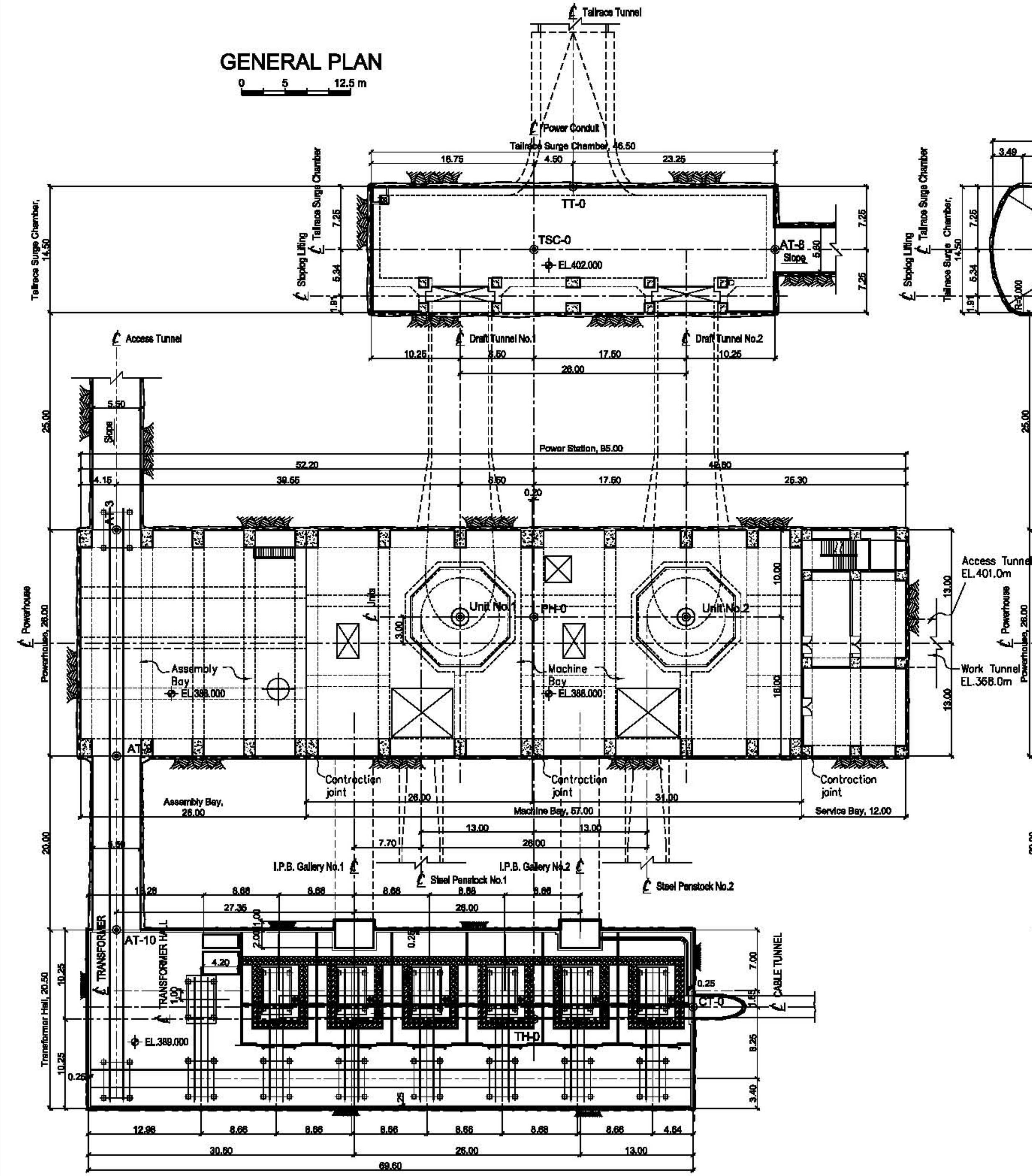
POWER COMPLEX
GENERAL LAYOUT

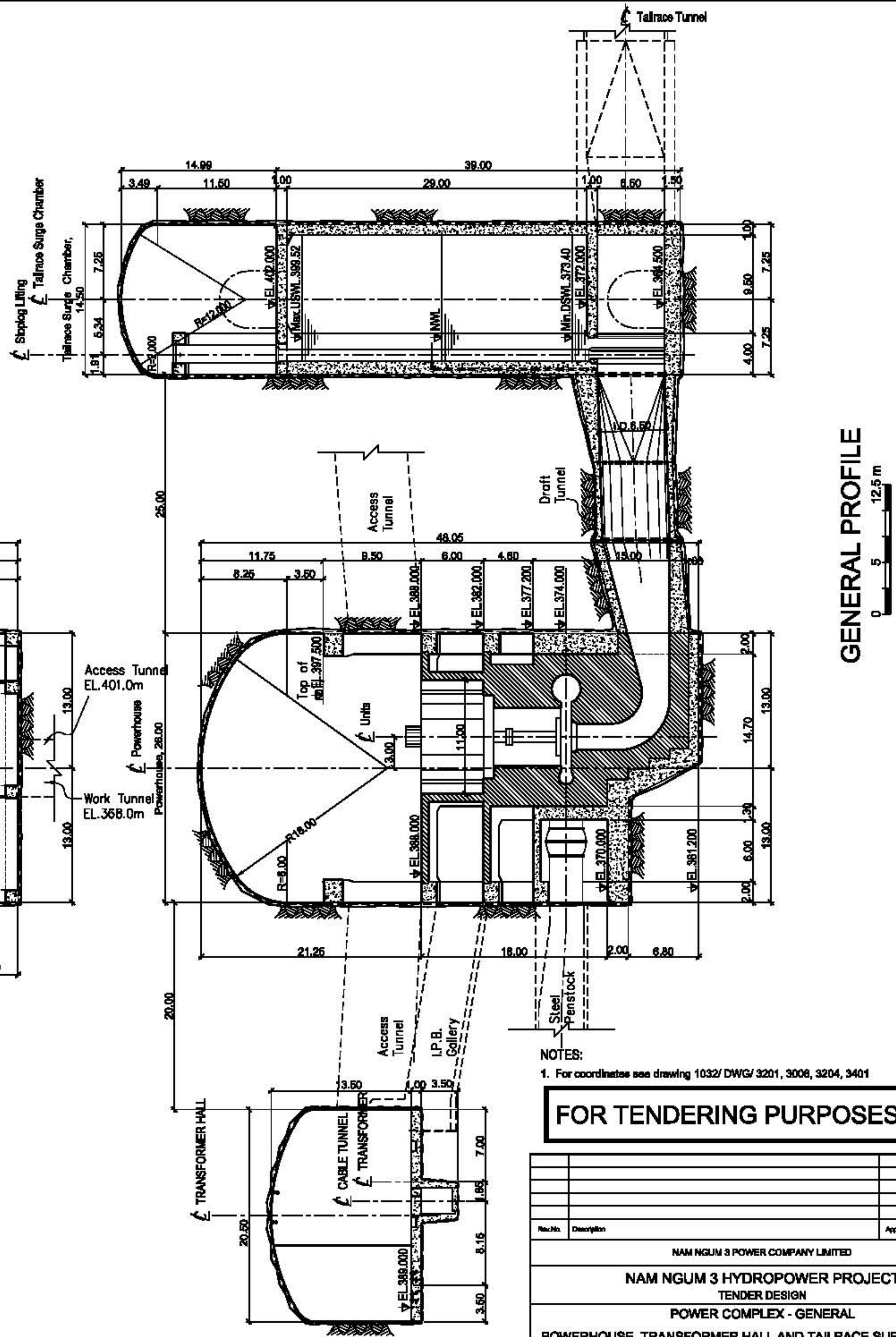
NN3 PPC

COLENCO
Colenco Power Engineering Ltd.

NIPPON KOEI
Challenging mind, Changing dynamics

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	
ACAD File		Drawing No.	1032/DWG/3201/1	





NOTES:

1. For coordinates see drawing 1032/ DWG/ 3201, 3006, 3204, 3401

FOR TENDERING PURPOSES ONLY

Rev.No.	Description	Approval	Approval	Date

NAM NGUM 3 POWER COMPANY LIMITED

NAM NGUM 3 HYDROPOWER PROJECT

TENDER DESIGN

POWER COMPLEX - GENERAL

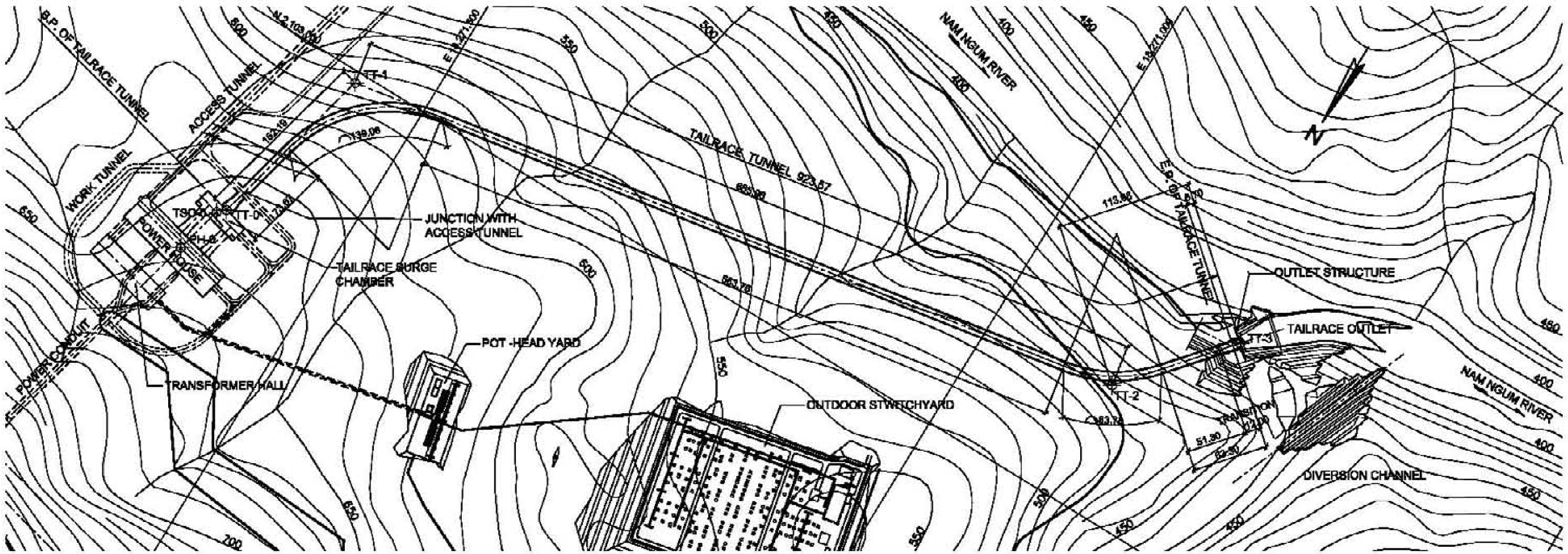
POWERHOUSE, TRANSFORMER HALL AND TAILRACE SURGE CHAMBER

GENERAL PLAN AND PROFILE

NN3PC | COLENCO Colenco Power Engineering Ltd. | NIPPON KOEI Challenging mind, Changing dynamics

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	
ACAD File		Drawing No.	1032/DWG/3202/0	

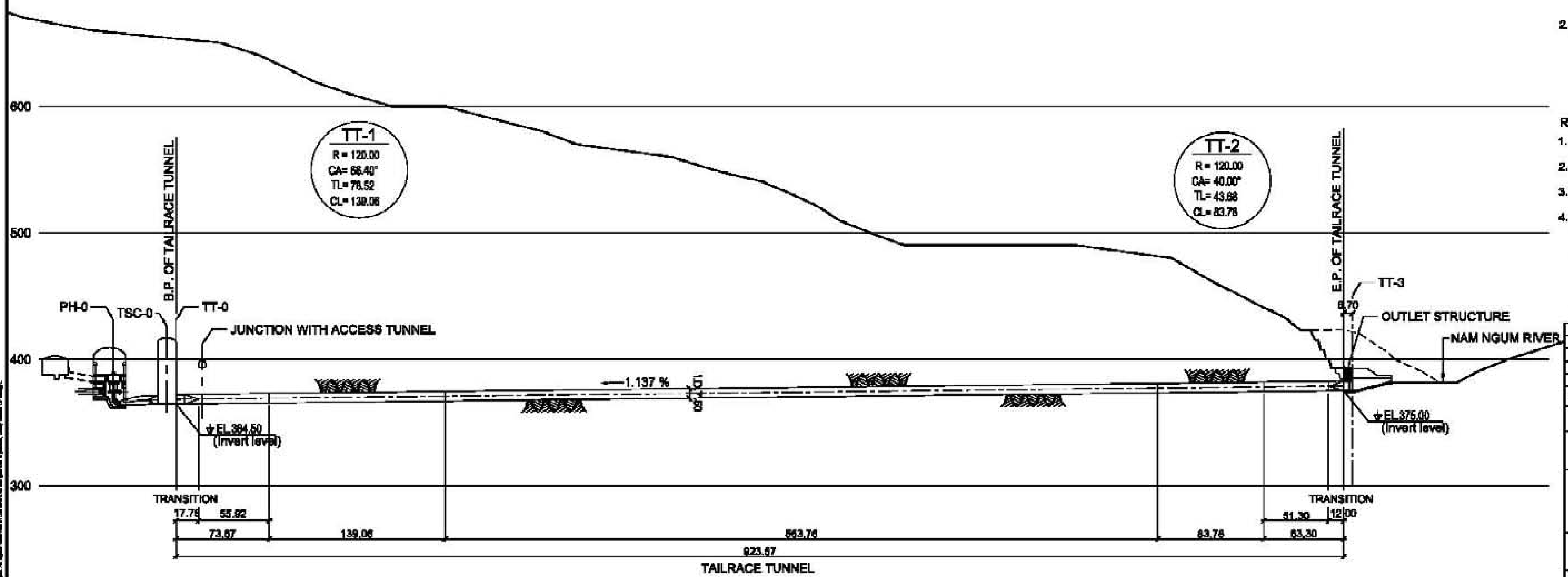
PLAN VIEW



COORDINATES

POINT	E	N
TT - 0	18,271,586.0928	2,103,156.8051
TT - 1	18,271,581.6266	2,103,008.1504
TT - 2	18,270,885.5568	2,102,893.1123
TT - 3	18,270,812.0767	2,102,806.3765

SECTION



GENERAL NOTES:

1. Typical sections of the Tailrace Tunnel are the same as the typical sections of Types I, II, III, IV-1, and V-1 of the Headrace Tunnel shown on 1032/DWG/3103 and 1032/DWG/3104. The application of tunnel type will be directed or approved by the Engineer to meet with actual geological condition.
2. For other coordinates see drawing 1032/ DWG/ 3201

REFERENCE DRAWINGS:

1. For typical section of Headrace Tunnel, see 1032/DWG/3103 to 3105.
2. For Temporary Road, see 1032/DWG/8601 to 8607.
3. For Access Tunnel, see 1032/DWG/3001 to 3008.
4. For Power Complex, see 1032/DWG/3201 to 3205.

FOR TENDERING PURPOSES ONLY

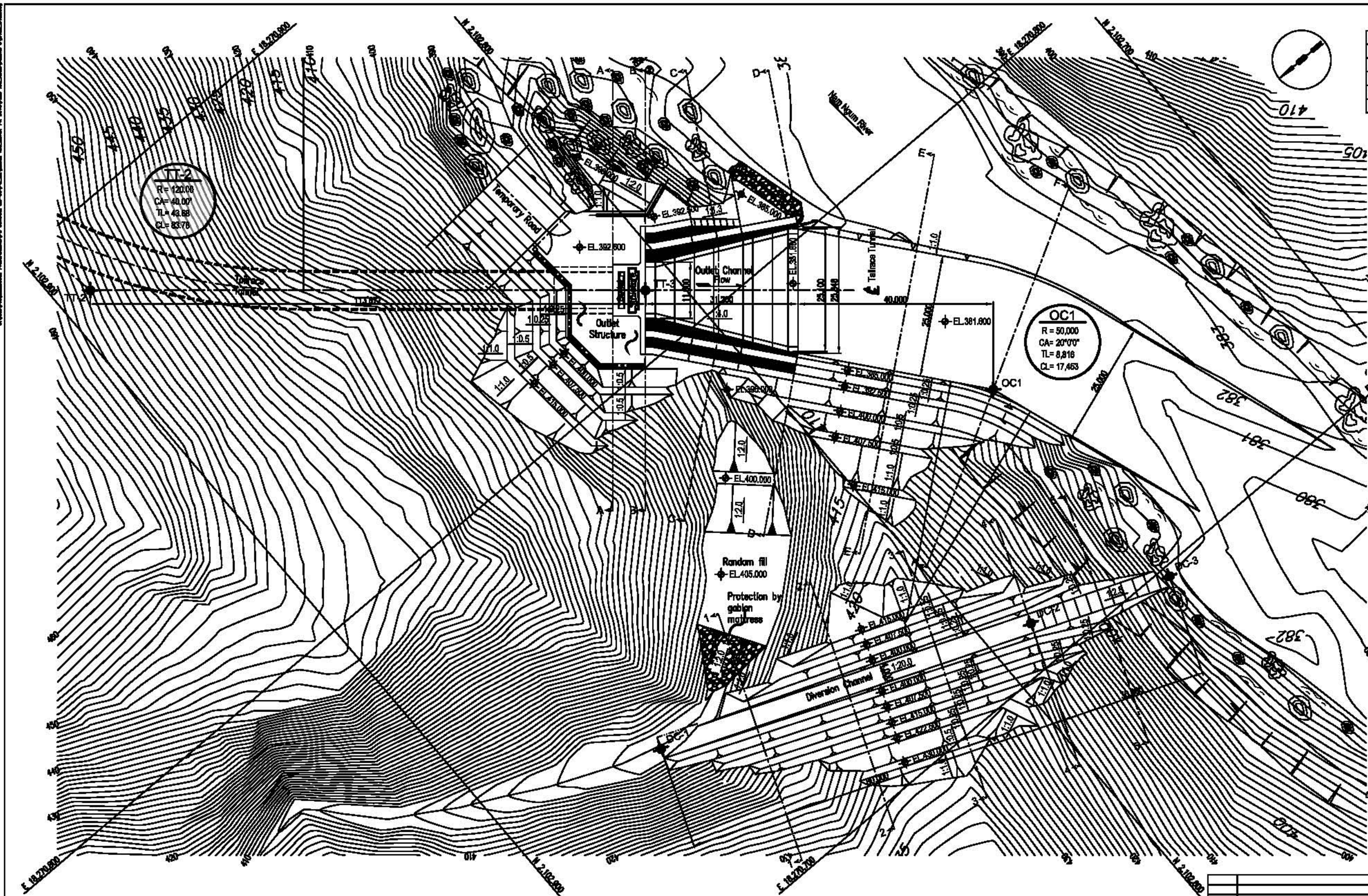
NAM NGUM 3 POWER COMPANY LIMITED

NAM NGUM 3 HYDROPOWER PROJECT
TENDER DESIGN

TAILRACE TUNNEL
GENERAL PLAN AND PROFILE

NN3PC | COLENCO | NIPPON KOEI

Drawing No. 1032/DWG/3401/0



COORDINATES

Point	E	N
TT-2	18,270,886.5583	2,102,893.1122
TT-3	18,270,812.0767	2,102,808.3765
DC-1	18,270,738.3333	2,102,884.8965
DC-2	18,270,709.0000	2,102,790.2683
DC-3	18,270,688.0000	2,102,762.3577

NOTES:

1. For general notes, see 1032/DWG/3401.
2. Open cut excavation line and slope may be modified by the Engineer according to the actual geological conditions.
3. Excavated surface shall be protected by shotcrete or sod planting but not shown. Application of them will be determined by the Engineer at the site.
4. Berm drains are required but not shown.
5. Reinforcement bars and construction joints are required for concrete structures but not shown.

SCALE A 0 8.0 16.0 40.0 METRES

FOR TENDERING PURPOSES ONLY

Rev.No.	Description	CPE-NK Approval	NN3PC Approval	Date

NAM NGUM 3 POWER COMPANY LIMITED

NAM NGUM 3 HYDROPOWER PROJECT
TENDER DESIGN

TAILRACE TUNNEL
OUTLET STRUCTURE
GENERAL PLAN

NN3PC | COLENCO Colenco Power Engineering Ltd. | NIPPON KOEI Challenging mind, Changing dynamics

Project Manager	Drafted	Dr. Check	Design	Des. Check
Managing Director	Pr. Manager		Pr. Director	

ACAD File 3402_3408.DWG | Drawing No. 1032/DWG/3403/0