6.4.3 Biological Environment – Aquatic Life

During the construction phase, the water flow of Sungai Murum will be expected as it was before. The river is still passable for fish as there is no damming yet, hence no upstream impacts during this period. Effects on aquatic organisms will, very likely, be caused by water quality deterioration in respect of its suspended solid and turbidity, particularly at the dam site and powerhouse construction site. Siltation due to erosion from road building, construction work in the dam site, from machine park area and construction workers living area is anticipated. Increased in silt loads in the river will increase the concentration of suspended solid (SS), which at present is already high. The silt will smother the substrates for periphyton to grow which potentially reduce their biomass and diversity. The primary production of the periphyton will also be negatively impacted due to reduced light penetration in the turbid water.

During the initial filling of the reservoir, the water level of Sg. Murum below the dam will significantly be reduced which will create a considerable stress for the river biota.

Mitigations:

- The siltation effects are believed to be significant only in the rainy season. In order to reduce such impact, some construction activities which may cause significant impact will need to be conducted only in the dry season. Soil erosion and subsequent siltation effects can also be minimised using soil protection measures such as plastic sheeting and installing silt traps or a series of silt trap for steep areas.

- A compensation flow, i.e. 10% natural baseflow (approximately 92 m³/s) is recommended that will, in general, secure the survival of aquatic life and minimise the adverse impacts associated with dry-up and stagnant water in Sungai Murum. Based on the results of the aquatic survey, it is concluded that the stretch of the river between the dam and the powerhouse is important from the perspectives of aquatic ecology. This stretch of the Murum River consists of very diverse habitats and among these habitats are the fast flowing waters of hard substratum (rapids) and pool areas (both hard and soft bottoms). In each of these habitats are diverse niches that are important for particular species of aquatic life that are both small (e.g., macroinvertebrates) and large (fishes). This stretch area is also an important fishing ground for the local Kenyah communities especially the 18 doors that have moved from Long Lawen to the area around Murum Camp 2.

6.4.4 Biological Environment - Flora

The main flora-related environmental impacts of the Murum Dam Project, are described in the following section, along with recommended mitigation measures aimed at reducing the environmental impacts. The main impacts during this phase are:
6.4.4.1 **Biodiversity and Habitat Loss**

The main environmental impacts related to the flora in the area will be caused by inundation of the 245 km² reservoir area upstream of the Murum Dam. A biomass removal plan that is proposed will consider the biodiversity and habitat loss issues when considering the best management practices for the biomass removal plan (see Section 6.4.4.3).

Inundation of the existing vegetation in the reservoir will results in:

1) Loss of biodiversity; and

2) Loss and fragmentation of wildlife habitat

The inundation of the reservoir area may lead to a decline in stocks of aquatic life (fish, etc.) as the inundated vegetation decomposes, depleting oxygen in the water of the reservoir.

**Mitigations:**

The objective is to reduce damage/degradation of flora in the catchment prior to, and during dam construction and reservoir filling operations.

- Conserve native flora species above the maximum inundation line of 547 meters by ceasing all logging operations in the Murum Dam catchment area.

- A Catchment Management Plan for Murum Catchment in particular and Bakun catchment in general should be considered by State Authorities. This would allow for a more centralised management of the agricultural, logging and forest plantation activity in the entire catchment area of the Murum Dam Project (particularly exotic tree such as Acacia, Oli Palm, Rubber, etc.).

- Control weeds and invasive species – e.g. Water Hyacinth, Lalong, etc.

- To locate rare and endangered flora species found above the reservoir area for recording and storage of seed of native plants.

6.4.4.2 **Depletion of Oxygen and Impeded Marine Navigation and Reduced Tourism Opportunities**

The inundation of flora in the reservoir area will result in significant environmental and economic impacts including loss of village land, community farmlands, and agriculture and forest plantations.

The decomposition of the inundated vegetative material will deplete level of oxygen in the water, often killing much of the aquatic life.

Consumption of oxygen by decomposing vegetation in the newly filled reservoir behind the Dam is believed to kill fish.
Chemicals released by decaying vegetation can damage turbine equipment.

Rotting organic matter leads to releases gases such as methane and carbon dioxide (greenhouse gases) and hydrogen sulphide, which will have a significant impact on global warming.

Impact from dam reservoirs may be higher than emissions from an equivalent coal or natural gas power station (McCully, 1996).

Hydro-electric reservoirs are commonly used for marine transport and for tourism activities (fishing, boating, sight-seeing etc.). However, the presence of flooded biomass along the shoreline detracts from these uses, impeding marine navigation and deterring tourism activities due to dead vegetation protruding from the reservoir surface.

**Mitigations:**

- Residual forest biomass and other non-utilisable materials generated from reservoir clearing and preparation will be considerable and proper management and disposal is crucial to prevent possible soil erosion, and air pollution from burning as well as land and river water pollution through inappropriate disposal of materials.

- Controlled open burning may be considered to dispose of the considerable biomass.

- The objective is to ensure that reservoir clearing is conducted in a way consistent with the principles of avoidance, reduction and recycling.

**6.4.4.3 Planning Guidelines for Biomass Removal from the Reservoir Area**

The following procedures describe measures to be taken for biomass removal are described in the following Guidelines for Biomass Removal.

**Objectives:** there are 4 main objectives for removing forest biomass from the reservoir area:

1. To avoid loss of economic value from valuable timber in the area to be inundated.

2. To reduce forest biomass inundated, therefore reduce oxygen depletion due to decomposition of this material, and thus reduce loss of aquatic life in the reservoir.

3. To ensure that the reservoir shoreline is free of dead vegetation which may impede marine transport and future tourism development in the reservoir area.

4. To remove the biomass in a timely manner, consistent with the schedule for dam construction and reservoir filling operations.
The planning guidelines are developed as responses to the following 4 questions:

i. What types of biomass should be removed?

ii. Over what time period should the biomass be removed?

iii. From what part of the reservoir should biomass be removed?

iv. How should the biomass be disposed of?

The following planning guidelines have been prepared to address the 4 objectives and answer the four questions listed above.

**Guideline 1: Removal of Timber with Commercial Value**

- Commercial timber trees should be removed first from all of the 24,500 ha reservoir area (up to—but not exceeding the maximum flood level 547 m). This is being done in the years preceding dam construction and can continue during the 6 year dam construction period.

- Timber should be harvested using conventional timber harvesting methods, as governed by existing forest legislation, regulated by staff of the Sarawak Forest Department (SFD) and the Sarawak Forestry Corporation (SFC).

**Guideline 2: Removal and Disposal of Residual Forest Biomass and Logging Residues from the Area between the High and Low Reservoir Water Levels**

- Following removal of timber of commercial value, selective removal of residual biomass (small diameter trees, shrubs and logging residues) from the shoreline portion of the reservoir, i.e. between minimum reservoir operating level (515 m) and the maximum flood water line (547 m).

- Clearing of residual biomass from the strip of land between high and low water levels, should not commence until start of the reservoir filling period (2 years) as biomass re-grows quickly and may have to be cleared again if clearing operations commence too early.

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*Maximum biomass decomposition (and related oxygen depletion) will take place in this zone where the biomass is alternately wet and dry, due to shoreline fluctuations. In areas below the minimum water level (515 m) biomass is permanently inundated and therefore decomposition and oxygen depletion are reduced. Studies have shown that wood permanently covered in water, remained relatively sound for long periods of time, compared to wood which was alternately exposed to air and water.*
Planning Parameters and Assumptions

The following are assumptions based on preliminary design given by Project Proponent

- Elevation difference between high (547 m) and low (515 m) water levels: 32 meters
- Estimated average horizontal distance between high and low water levels: 200 m
- Estimated length of reservoir shoreline (including all of the tributaries): 250 km
- Estimated area of shoreline to be cleared of residual biomass: 5,000 ha (a 200 m wide strip of shoreline-250 km long; or 25% of the 24,500 ha reservoir area)
- Clearing time from start to finish of reservoir filling: 2 years
- Average rate of clearing: 2,500 ha/year; or 200 ha/month
- Average dry weight of biomass to be removed monthly is 28,000 tons/month or about 1000 tons per day.

- Method of clearing and disposing of forest biomass – slash, pile with excavators and control burning during periods of suitable climatic conditions (to minimize air pollution).
- Should burning of biomass not be acceptable, the material should be chipped using mobile chippers and trucked to a site where it can be utilized for manufacture of reconstituted wood products. This option will be more costly, however a portion of the cost may be recovered through the sale of this material.

It should be noted that these guidelines are only a preliminary step in biomass removal planning. A detailed Biomass Removal Plan (BRP) – must be prepared to manage reservoir clearing operations once the detailed construction plan is finalised. The following section includes an Outline for Preparing of a Biomass Removal Plan (BRP).

Outline of Process for Preparing a Biomass Removal Plan (BRP)

There is a well developed process for planning and implementation for biomass removal. It entails preparation of a Biomass Removal Plan (BRP) according to an established series of steps. The BRP addresses and integrates procedures of

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5 Based on assumed average shoreline slope of 16% - i.e. 16 meters of elevation difference in each 100 meters of horizontal distance from the high-water line i.e. 200 meter horizontal distance between high (547 m) and low (515 m) water line (32 m). It is estimated that the dry weight of biomass on this strip will be about 700,000 tons.
least environmental impact to the physical, biological and the human components of the reservoir affected by the activities. The BRP is responsive to the spatial and temporal variations in the environment of the reservoir in order to meet the objective of optimum biomass removal. In the case of the Project, the objective is consistent with conservation of Project resources. The BRP precedes preparation of information for deployment and scheduling of work. The BRP is based on standards for compliance and guidelines for implementation. The BRP steps are listed in chronological order as follows:

**Step 1** - The BRP should be based on studies and inventories of physical conditions in the reservoir:

- Terrain, soil and surface hydrology.
- Wildlife and fisheries.
- Vegetation and commercial forest resources, concessions and licenses.
- Existing land use and infrastructure.

**Step 2** - The BRP will employ the inventory information and delineate operational areas (compartments) within the reservoir for implementation of specific procedures and practices based on proposed activities. Each compartment will:

- Classify biomass as salvage and non-salvage according to predetermined salvage standards.
- Classify terrain for slope, exposure of bedrock, erosive potential and stability.
- Delineate areas of fisheries, wildlife and cultural importance. Compartments will be defined by comparative uniformity in terrain and biomass where there is more uniformity within the compartment than between adjacent compartments of the same terrain or biomass.

**Step 3** - For each compartment, specific information pertaining to proposed activities, methods and procedures for carrying out biomass disposal operations will be developed. Information will include:

- Location of permanent camps and camps with administrative and emergency response capabilities.
- Location of depots, yards and other facilities for storage of non hazardous materials.
- Location of storage for hazardous materials.
- Alignment of access and crossings of watercourses.
• Location of water supply sources and intakes.

• Vegetation buffer strips and firebreaks.

• Location for collection of sewerage, solid waste and run-off, treatment and discharge.

• Location for infrastructure such as: boat docks, heliports and tourism sites.

Step 4 - The BRP will then assign a schedule of implementation, implementation procedures, methods and guidelines to each compartment for the activities and needs described above. Camps and administrative complexes will have structural plans including buffer strips and firebreaks.

• Service centres, depots and yards will have boundaries and dimensions identified, buffer strips and firebreaks marked and functions classified.

• Permitted hazardous materials will be identified for each authorized location.

• Main, secondary and feeder roads will have individual standards for construction.

• Salvage areas will have logging chance and preferred logging systems assigned.

• Scientific inventory and rescue of wildlife, and cultural artefacts will be scheduled.

• Fishery conservation will be addressed by location and procedure.

• Source of domestic water supply and method of abstraction or storage will be identified.

• Location of wastewater and sewerage will identify treatment, handling and discharge.

• Solid waste handling and disposal procedures will be identified.

• Scheduled waste products will be identified per location.

• Schedules and practices for monitoring and audit will then be assigned.

The BRP is an integral part of the Environmental Management Plan (EMP) for the Reservoir and both will form part of the contractual commitment between the Project Proponent and its contractors.
Implementing the Murum Biomass Removal Plan

Implementation involves translating the Biomass Removal Plan into actions. In order to implement the plan, rules, standards and guidelines must be established for, and as a response to, the effects of the following key implementation activities:

- Surveying standards and guidelines.
- Timber salvage standards for cut, skid, pile, sort and transport.
- Residue clearing standards and guidelines for slashing and piling.
- Residue disposal standards and guidelines for burning.
- Standards and guidelines for construction of access tracks – sub-grade, grade and drainage.

6.5 SOCIAL IMPACTS ASSESSMENT

6.5.1 Public Health

Public health impacts can be identified as those arising due to the project implementation and reservoir filling as well as those due to resettlement of the population.

Public health impact assessment of the Bakun HEP showed sero-evidence of Schistosoma malayensis among the Kayans of Lg. Murum (Sagin, 2001). There was no sero-evidence of S. japonicum or S. mekongi. Further field surveys conducted in collaboration with the London Natural History Museum failed to detect the presence of Robertsiella kaporensis snail host as the area had been severely flooded as a result of some technical problems with the Bakun diversion tunnels (Sagin, 2002). There was no sero-evidence of HIV infection, although there is relatively high sero-evidence of syphilis (Sagin 2002).

Malaria is apparently endemic to the Project area. In the last 12-months, a 3-months old infant in Lg. Singu had died of malaria, while two other infants (1-month old and 3-month old) in Lg. Tanggau had also died of malaria (based on fieldwork carried out in October 2007). The Plasmodium species responsible is not determined, however, the jungle environment in Ulu Kapit is known to be endemic with Plasmodium knowlesi (Singh).

6.5.1.1 Change of Biological Environment

More of the biological resources will be damaged and destroyed, and the nearest local communities such as the Penans of Lg. Luar, Lg. Tanggau and Lg. Pelutan may find it increasingly difficult to subsist on their proximate biological environment.
6.5.1.2 Change of Human Environment

Malaria and Schistosoma incidences at the Project area might be complicated by the reservoir filling which provides standing water for the breeding of mosquito-borne disease vectors and Schistosoma vectors, particularly snails.

Mitigations:

- Vector Survey: Periodic vector surveys should be made, mainly in the dwellings, and spraying carried out if necessary.

- The Project Proponent should support the Health Services Department in carrying out blood film screening for detection of malaria parasite as well as implement on-going health education and vector control programme. It may be necessary that when workers temporary camps are set up in the jungle area, the surrounding area may need to be sprayed.

- The formation of breeding sites for mosquitoes such as stagnant waters in containers, etc should be avoided as much as possible particularly near human habitation or working sites.

- Proper housekeeping at campsites to ensure potential mosquito breeding areas (e.g. water is discarded tins, bottles, plastic containers, etc.) are not present.

6.5.1.3 Health Impacts due to Resettlement

6.5.1.3.1 Physical Environment

The communities’ leaders and elders are aware of the need for their villages to be resettled elsewhere. There is some indication of resistance to resettlement, primarily because the community leaders and village elders have not been briefed and consulted on the proposed site of the resettlement area. Government agencies and NGOs are unwilling to implement or provide new “health” facilities to the villages such as gravity fed water supplies and toilet, due to the uncertainties of the proposed Murum HEP. There is opposition on resettlement, since resettlement means uprooting them from a physical environment they have become adapted to for generations to a different physical environment, which they will have to quickly learn to adapt to. This is, by no means, easy for communities that are largely illiterate.

Mitigations:

- Recommendations for the infrastructures in the resettlement area are summarised in Table 6.4.1. The institution of village health worker should be strengthened in order ensure that basic health infrastructure facilities are utilised properly and effectively.
Table 6.4.1 Infrastructure Requirements for the Resettlement Area

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site selection</strong></td>
<td>To be done with the active participation of the community leaders and elders (Table 1.10 in Annex 2.1).</td>
</tr>
<tr>
<td></td>
<td>Avoid drastic changes to their physical, biological, human and social environments.</td>
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<tr>
<td></td>
<td>May significantly affect their mental, social and cultural health.</td>
</tr>
<tr>
<td><strong>Resettlement</strong></td>
<td>Site preparation to be carried out with the active participation of the community leaders and village elders.</td>
</tr>
<tr>
<td><strong>Planning</strong></td>
<td>Ensure spiritual, cultural and social concerns are adequately addressed.</td>
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<tr>
<td></td>
<td>Enable the communities to earn their livelihood during the whole transition period.</td>
</tr>
<tr>
<td><strong>Clinic</strong></td>
<td>To provide a properly equip Klinik Kesihatan for the six longhouses.</td>
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<tr>
<td></td>
<td>Clinic should not carry patronising name such as “Penan Service Centre” but should carry standard name (e.g. Klinik Kesihatan Sg. Koyan).</td>
</tr>
<tr>
<td><strong>School</strong></td>
<td>There should be a primary school for the children (Table 1.12 in Annex 2.1).</td>
</tr>
<tr>
<td><strong>Longhouse</strong></td>
<td>Construction should be better than their existing longhouses.</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td>Should not be too different from their present longhouses as the mostly illiterate villagers will be unable to cope with too much modernity.</td>
</tr>
<tr>
<td></td>
<td>Longhouses should not carry patronizing name such as Rumah Penan.</td>
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<tr>
<td><strong>Water Supplies</strong></td>
<td>Provide adequate quantities and of good quality.</td>
</tr>
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<td></td>
<td>Should not come with a monthly bill (at least during the transition period) as their very low literacy rate and lack of income will force them to</td>
</tr>
<tr>
<td></td>
<td>go back to their roots (lesson learned from Sg. Asap and Sg. Koyan resettlement).</td>
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<tr>
<td><strong>Toilets</strong></td>
<td>Provide adequate toilet facilities.</td>
</tr>
<tr>
<td></td>
<td>Must be of robust construction, since the facilities will not be properly maintained (meaning pour flush type of latrine with short piping and</td>
</tr>
<tr>
<td></td>
<td>robust angle joint).</td>
</tr>
<tr>
<td><strong>Drainage</strong></td>
<td>Provide proper drainage for domestic wastewater to prevent development of unhygienic stagnant pools.</td>
</tr>
<tr>
<td><strong>Solid Waste</strong></td>
<td>Provide facilities for disposal of solid domestic waste (e.g. empty tins, plastic containers) to prevent breeding of mosquitoes.</td>
</tr>
<tr>
<td><strong>Electricity</strong></td>
<td>Should not come with a monthly bill (at least during the transition period) as their very low literacy rate and lack of income will forced them to</td>
</tr>
<tr>
<td></td>
<td>attempt to go back to their roots.</td>
</tr>
</tbody>
</table>

### 6.5.1.3.2 Biological Environment

Resettlement means that the affected communities will be uprooted from their present biological environment that they have adapted to for generations to a different biological environment that they may not be familiar with and which may be insufficient to sustain their way of life during the 5-10 years transition period. It will have significant impact on their quality of life.
Mitigation:

- It is impossible for the Project Proponent to provide the equivalent biological environment at the resettlement area. However, it is recommended that there should be significant forested area near the longhouses, and there should also be rivers. The Project Proponent should be able to learn some useful lessons from the Batang Air and Bakun HEP experience.

6.5.1.3.3 Human Environment

Resettlement means that the human environment will be significantly different from their existing human environment. Presently, they are living in remote longhouses separated by large tracts of jungle. In the resettlement area, their new longhouses will be much closer to each other and is accessible to outsiders. They will have electricity, adequate water supplies and toilet.

Mitigation:

- There should be sustainable and on-going public health and social education. Each family should be provided with their own 'bilek' to avoid overcrowding and the concomitant health risks.

6.5.1.3.4 Social Environment

Resettlement means that they will be in a different and more 'modern' social environment. Compensation monies may not be utilised properly. Instead, it may be misused for purposes that lead to negative health impacts such as gambling and alcoholism. At present, there is already some evidence of escapism through excessive drinking of alcohol.

Mitigation:

- The important issues have been discussed under previous sections.

6.5.2 Population Impacts and Mitigations

6.5.2.1 Local Area Population Change

This is the migration of people into the area over some period of time as a result of the Project. Population increase would occur during the construction and post-construction periods as the respective workforce move in. The use or presence of the road that provides access to the dam might also facilitate people moving into the project area later on. Furthermore, people from distant villages, for example, could move closer to the Project area as they would be enticed to settle along the access road.

The increase in population could become a determinant of other social impacts in the Project area. This includes increases in the cost of basic items (e.g. rice,
vegetables, etc.) and causing strains on existing services like transportation along Bintulu-Bakun road.

6.5.2.2 **Influx of Temporary Workers**

This is the temporary movement of people into the area. This is necessary because the Project would need workers of various skills as construction progresses. This includes the influx of foreign workers if local manpower is insufficient in meeting the needs of the Project. Influx of workers might involve several hundreds of people.

Table 6.5.1 Matrix Relating Project Stage to SIA Variable (Taylor et al, 1995; Burdge, 1999 & Vanclay, 1999)

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<tr>
<th></th>
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<tbody>
<tr>
<td>A. Population Impacts</td>
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<tr>
<td>1. Population change</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>2. Influx of temporary workers</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>3. Presence of seasonal residents</td>
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<td>1</td>
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<tr>
<td>4. Relocation of individuals &amp; families</td>
<td></td>
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<td>3</td>
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<tr>
<td>5. Dissimilarity in age, gender, ethnicity</td>
<td>2</td>
<td>1</td>
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<tr>
<td>B. Community Arrangements</td>
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<tr>
<td>6. Formation of attitudes toward Project</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7. Interest of group activity</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8. Alteration in size &amp; structure of local gov't</td>
<td>3</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9. Presence of planning &amp; zoning activity</td>
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<td>3</td>
<td></td>
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<tr>
<td>10. Industrial Diversification</td>
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<tr>
<td>11. Enhanced economic inequities</td>
<td>2</td>
<td>1</td>
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<tr>
<td>12. Job equity change of the Penan</td>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>13. Changing occupational opportunities</td>
<td>2</td>
<td>1</td>
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</tbody>
</table>
### C. Local People/Newcomers Conflicts

<table>
<thead>
<tr>
<th></th>
<th>Planning/Design</th>
<th>Construction</th>
<th>Maintenance</th>
<th>Abandonment</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. Presence of Outside Agency</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
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<tr>
<td>15. Introduction of New Social Class</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
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<tr>
<td>16. Change in Commercial Focus</td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
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<tr>
<td>17. Presence of weekend residents</td>
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<td>1</td>
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</tbody>
</table>

### D. Individual/Family Level Impacts

<table>
<thead>
<tr>
<th></th>
<th>Planning/Design</th>
<th>Construction</th>
<th>Maintenance</th>
<th>Abandonment</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Disruption in daily living &amp; movement patterns</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>19. Dissimilarity in religions practices</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>20. Alteration in Family Structure</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>21. Disruption in social networks</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>22. Perceptions of public health &amp; safety</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>23. Change in leisure opportunities</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

### E. Community Infrastructure Needs

<table>
<thead>
<tr>
<th></th>
<th>Planning/Design</th>
<th>Construction</th>
<th>Maintenance</th>
<th>Abandonment</th>
</tr>
</thead>
<tbody>
<tr>
<td>24. Change in community infrastructure</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>25. Land acquisition &amp; disposal</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. Effects on cultural, historical, sacred resources</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

1- Minor adverse impact; 2- Moderate adverse impact; 3- Significant adverse impact

### 6.5.2.3 Presence of Visitors

This is the occasional/seasonal increase in population of the area due to much improved accessibility in and to the Project area. This could lead to the influx of some visitors including foreign tourists, especially when the Project is in place or completed.

### 6.5.2.4 Dissimilarity in Age, Gender and Ethnicity

It is anticipated that the majority of workers would comprise males in their prime working age ranging from 25-45 years old. This might lead to certain social
problems. For example, unscrupulous people could exploit the situation by introducing vice activity.

6.5.2.5 Relocation of Penan People

This is the number of people who are relocated. Relocation due to the Project is expected to affect at least six Penan longhouse communities involving 207 families with a total population of 935 people. Relocated Penans will have to start new life in a new environment. Adjustment and adaptation to a new living environment could be stressful.

Mitigations for population impacts:

a) Employment Priority for Local Residents

This recruitment policy for the Project should provide opportunities to local communities as a priority in order to minimise the influx of non-local people and also population increase in the Project area. Thus, first priority is for the Project to recruit and employ local residents from nearby longhouses and from Asap. The second priority is to recruit and employ any non-local Sarawakians and Malaysians. The recruitment package of local workers should include the provision of relevant training to equip the local workers with required skills. Recruitment of foreign workers should be the last resort in accordance with the needs of the Project.

b) Implementing Project in Phases

From the observations of other mega projects in Sarawak, the implementation of a project in phases would require lesser influx of workers to the project site at any one time.

c) Choose Resettlement Site Acceptable to the Penan people

Refer to later discussion.

6.5.3 Impacts on Community Arrangement and Mitigations

6.5.3.1 Attitudes Formation

This is concerned with the positive or negative feelings, beliefs or positions expressed by the public including the affected Penan community. Public attitudes should be viewed as feedback for considerations in the design, implementation, operation and management of the Project. Certain initial negative feelings should be expected as the Penan people, in particular, ponder on how the Project would affect them. Uncertainties about the future can be stressful to think about and people could behave abnormally in the face of an uncertain future, whether imagined or otherwise.
6.5.3.2 Activity of Interest Group

This is the formal and informal interest groups and organizations stating positions for or against the Project. This is normal as the Project would be viewed as a politico-economic venture by a variety of strategic groups. For example, the NGOs in the Project area may eventually state their positions for or against the Project. NGO's greatest fear is that the Project may cause more harm than good to the affected Penan communities.

6.5.3.3 Change in Land Use and Zoning Activity

There will be a change in land use. It is anticipated that the Murum Catchment will be developed with substantial acreage of suitable non-inundated areas turned into plantations. The hilly areas shall be left to their natural cover. There is also proposal to zone Ulu Sg. Danum-Linau areas into the National Park. It is unlikely that the Penan people could live in the catchment area anymore.

6.5.3.4 Enhanced Economic Inequities

This is related to the degree to which the new opportunities created by the Project match the job skills of the unemployed/underemployed in the Project area. Field observations indicate that only a limited number of Penan people are capable of exploiting new job opportunities brought about by the Project. Because of their illiteracy and lack of skills it appears that the Penans are marginalized right from the beginning. But it is anticipated that on a short-term basis the more skilful and resourceful people would benefit most while the majority of the Penans might be mere spectators.

6.5.3.5 Changing Occupational Opportunities

This aspect relates to the degree to which the Project alters the occupational profile of the area. One aspect is that new opportunities introduced by the Project could draw people away from their traditional occupations. Some may abandon farming altogether, for examples, and become full time labourers at the Project. This represents a change from a traditional subsistence to a cash-economy lifestyle. Other spin-off opportunities may demand different sets of skills, which could attract outsiders coming in to do businesses (e.g. operating canteen). Younger people may be attracted to earn cash income and be discouraged from acquiring higher education levels and remain unskilled.

Mitigations for community arrangements impacts:

a) Disseminate and Solicit Information Regarding Project

Dissemination of Project information and solicitation of feed-backs from all affected people would portray a sense of transparency. This could lead to positive attitude formation toward the Project by the people and interest groups alike. These exercises should be initiated first before the commencement of any project.
component by organizing some dialogues with local residents and interest groups in the Project area.

Dialogues, in its various formats, would:

- Make people feel involved in the Project;
- Make people feel that their needs are considered;
- Make people feel that their minds are engaged and respected;
- Facilitate integrations of the needs of the Project with all stakeholders including local people and interest groups; and
- Facilitate formation of a community of people interfacing with one another.

Dialogue formats may comprise:

- Consultation with key informants such as the elected representatives and community leaders who can also assist in information dissemination to the community;
- Focus group discussions with headmen/opinion makers having knowledge of the community and respected by the public for their "stories";
- Community forums/public meetings to give direct to the people all necessary information and at the same time to receive opinions direct from them;
- Workshops with representatives of all stakeholders, which is also useful for mitigation and management not only during pre-construction but also during all phases of development.

b) Proactive Employment Policy Toward Penan People

This policy should facilitate the Project to play its roles to minimize economic inequities and enhance employment equity among the Penan people, as well as to minimize potential negative impacts of changing occupational opportunities in the Project area. Disadvantaged groups may comprise the unemployed, unskilled, illiterate, older people, women, youth not only from the Penan community but also from the surrounding people of different ethnicity. Being proactive is going beyond the practice of employing local-people-first policy. It is taking initiatives to go the "extra mile", being socially responsible and provide opportunities for these groups to work creatively so that they can have a sense of self-respect.

Proactive employment policy may include:

- Changing our own attitudes - not to look down and underestimate them;
- Allocating, say, 30% of required local manpower to Penan groups;
- Match job types with the potential of each person in these groups (e.g. women for office cleaning, Penan for supply of vegetables & truck divers, etc.);

- Conducting capacity building courses;

- Providing on-the-job training; and

- Setting up a Social Action Committee with mandate to focus on helping these groups to work creatively (e.g. subcontractors for construction of workers' camps and landscaping, canteen operators at site office, etc.).

### 6.5.4 Conflicts and Mitigations

#### 6.5.4.1 Resentment against Newcomers

In general, newcomers comprise those who are not normally living in the Project area such as other Sarawakians and Malaysians, and the foreigners. There were cases of conflicts at work sites in the past in due to drunkenness-related misunderstandings, or simply resentment against any people who are non-locals.

#### 6.5.4.2 Resentment against Outside Agency (Proponent/Contractor)

This is the residence in the Project area of the Proponent whose management and control is external to the area. It should be noted that Agency responsible for making decisions affecting the community and is not responsive to local needs and priorities may cause significant dissatisfaction among local population. For example, a contractor that pollutes rivers but not willing to provide alternative sources (e.g. water tanks to collect rainfall) of clean drinking water would be disliked and this could lead to real conflicts.

#### 6.5.4.3 Resentment toward New Social Group

This relates to the appearance of a group of people (Penan) that either expand an existing or establish a new social status based on position, education, income or occupation in the area. Some members of this new group could be people who were previously not influential but have established themselves as subcontractors, village shopkeepers and transport services providers. These business groups, for example, have climbed up the social ladder, have economic leverage, better exposure, more networks, different lifestyles and influences on some local decisions. More often than not, the new social group and local residents have different perceptions of each other. These might cause local resentment and social tensions.

#### 6.5.4.4 Change in Commercial Focus of Community

This is a change from traditional to commercial or private sector focus of the community. This change could be brought about by the presence of hundreds of workers who need various types of goods especially during construction. This
provides incentives to some to change their traditional occupation and diversify into non-farm occupations (e.g. handicrafts making) in order to exploit new opportunities. The local community would gradually become more business-minded and materialistic in outlook as a result of better accessibility and exposures to outside influences. Business rivalry could arise between certain groups.

**Mitigations for conflicts:**

a) During recruitment exercises, screen workers properly. Candidates with disputable behavioral records should not be employed in the Project;

b) Give proper orientation to all workers about the beliefs, customs and ways of life of local population to minimise misunderstandings and instil respects for the community;

c) Organise some dialogues with local community as suggested above. Dialogues can also be used to sort out any misunderstandings;

d) Integrate the needs and opinions of local Penan community into manners and ways of Project implementation;

e) Do not favour the well-to-do people only but respect the existing hierarchy of power in existing longhouses irrespective of economic standing, education, or occupation;

f) Sort out any conflict immediately, and any worker who is a troublemaker should be deported away from the Project area;

g) Extend goodwill to local community (e.g. repair access roads to longhouses, donate trophies to schools during sport occasions, etc).

6.5.5 Individual and Family Level Impacts

6.5.5.1 Disruption in Daily Living

These are changes in routine living and work activities of the people by alteration to the visual environment, water quality, forest habitats, communication modes, etc. resulting from the Project. The Project will inundate all Penan territory and its landscape that they are familiar with. They will be relocated to a new area and it will take time for them to adapt to new landscape. As it will take time to adapt and to familiarize with the new environment their daily living and working patterns will be greatly disturbed.

6.5.5.2 Dissimilarity in Religious Practices

This is the introduction into the Project area of people with religious values, beliefs and practices different from those of the local population. This could happen as
the influx population may have different religion and lifestyles that could influence local values and traditions causing misunderstanding and conflicts. For examples, disrespects of community elders and general rudeness are greatly despised by the Penan people. A new group that does not share or appreciate the beliefs and values of the area communities can cause resentments.

6.5.5.3 Alteration in Family Structure

This relates to the increase or decrease in one or more of the family status categories (e.g. married, single parent, divorcee). It is typical that the influx population for the Project could comprise many single people and those who are married but not accompanied by their families. Some of these workers might have social habits that violate traditional and religious norms of the community. Some Project workers could intermarry with the locals and after completion of the Project the marriages may end up in divorces resulting in single mothers. These have and are happening with the influx of logging workers in the Project area. In addition, many local young people could also work and live in the Project area to earn wage income. After completion of the Project, a significant number of these local workers, who by now are used to earn wage incomes, could migrate to the towns. Normally, they would leave behind both the old and young members of households. This could worsen the existing dependency ratio in the area.

6.5.5.4 Disruption in Social Networks

This is the disruption of normal community social interactions. Disruption would arise because the Project will relocate the Penans to a new area. Relatives and friends could be separated as a result.

6.5.5.5 Perceptions of Public Health and Safety

Health and safety aspect include mental well-being. The Penan people are now already beginning to worry because with the implementation of the Project they will lose everything they have – farmland, crops, longhouse, hunting and fishing ground, and their landscape they are familiar with. They know that in a new area they will have to start anew. The anxiety is more serious among the older generation. They also sense that if the longhouses are relocated too close to one another in a new area, there would be a lot of social ills especially among the youth. These include alcohol consumption that could lead to quarrels, for example.

6.5.5.6 Change in Livelihood and Leisure Opportunities

The respondents always refer to the experience of Asap resettlers. They know that given limited size of land their livelihood and leisure opportunities will decrease drastically. This is due to the anticipated changes in the management of natural resources within the area.
Mitigation of individual/family level impacts:

a) As farmers, who still practice hunting and gathering livelihood strategy, the Penan should be given adequate size of land for cultivation and a large area of natural forest for game opportunities. This will minimize cultural shock as they gradually adapt to modern style of livelihoods.

b) The Project should recruit more workers who have similar ways of life and/or tolerance to local ways of life; the workers should also respect local traditions and practices.

c) As mentioned earlier, all workers should be properly screened and those with criminal records should not be employed.

d) Wherever possible, adequate accommodation should be provided that facilitate workers to be accompanied by their families. This could reduce unwanted social problems that could arise.

6.5.6 Community Infrastructure Needs Impacts

6.5.6.1 Change in Community Infrastructure

This is the increase in the demands for and supply of basic infrastructure services and facilities in the Project area. Population influx that accompanies the Project construction would strain existing facilities and services such as existing clinic, schools, logging tracks and transportation. This is often at the expense of the local communities.

6.5.6.2 Land Acquisition

This refers to the acreage of land that will shift from present use as a result of the Project. As mentioned earlier, a large area would be acquired for the Project and no longer be used by the Penan communities. In addition, further land acquisition for commercial plantations, for conservation (e.g. Catchment and National Park) and for commercial development (e.g. resort hotel) at a later stage is envisaged, though each of these is not a direct Project component.

6.5.6.3 Impacts on Aesthetic, Cultural, Historical and Archaeological Resources

These refer to the potential destruction of the cultural, sacred, historical or archeological resources within the impacted area (Danum & Peliran catchment areas). These resources are often the pride and treasures of the local people. Inundation of the area not only the loss of historical data, cultural materials and aesthetic values but may incur the dissatisfaction of the community and NGOs as well. This includes the burial grounds established by each of the communities.
Mitigations for community impacts:

a) During the construction and maintenance stages the Project should set up its own basic facilities such as clinic, canteen, workshops, fuel depots, etc.

b) Damages to public and private roads must be promptly repaired. The Project could also have its own transportation system such as shuttle transport service for its workers and staff and make the service available to local communities.

c) Adequate and prompt compensation should be paid to all affected local people.

d) Every effort should be given to preserve all aesthetic, cultural and historical sites.

6.5.7 Issues to be Resolved

Developing Penan society is tantamount to leap-forging a hunter-gatherer community into a modern society. Although the Project provides the opportunities for social change there is no easy solution. Experience with Penan in other areas may give us some clues.

6.5.7.1 Some Principles and Approaches

i) There must be a definite and committed policy to develop Penan into a modern society;

ii) It requires the collaboration of all relevant agencies including churches, own ethnic organizational mechanism and NGOs;

iii) The focus should be on improving the quality of life (QOL) and capacity building such as providing education;

iv) On-the-ground supervision is required until Penan can stand on their own feet, or develop self-reliance livelihoods;

v) Penan must have cordial relations with their neighbors from whom they could learn better ways regarding modern livelihoods;

vi) Penan should be located at some distance from other community to avoid strong competition for land and various types of resources. This is because in any competition for resources the Penan lose out;

vii) Penan should own enough land for cultivation and for hunting and gathering of non-timber forest products, over which they have a sense of stewardship;

viii) The socio-psychological attributes and socio-anthropological variables could provide useful guidelines in transforming the Penan community into a modern society.
6.5.7.2 Resettlement

The Danum and Peliran valleys where the six Penan settlements are sited will be inundated. Thus, resettlement is unavoidable. It was mentioned by every longhouse representatives that the Penan does not want to be resettled in Asap area.

a) Site Options

i) Within the respective longhouse territory above the anticipated flood line.

During our dialogues the Penan expressed that they do not want to go and live in other area. “Let us live in the area we know”, they said, “in our own area where it is not flooding”.

It is likely that an area can be found of relatively hilly land that can be developed for hill padi/ tapioca, but which would not be particularly attractive for plantation development. Such an area is likely to also sustain intact forest on the steeper slopes.

ii) Lower Linau River

The area envisaged extends from the rapid right to Long Abit. Within this area it is estimated that about 25,000 hectares are suitable to marginally suitable (Class 3 & Class 4 land) for agriculture.

b) Population Options

i) Only the impacted six longhouse communities

Under this option the authority is obliged to resettle the six impacted longhouses only that involves 207 families, or 935 people.

ii) All Penan population in Belaga District except Penan Talun in Asap

Under this option a Penan “township”, or Penan “Heartland” would be established. This comprises 19 longhouse communities involving about 650 families or 3000 people. All development projects designed to improve QOL and for capacity building could be more effectively and efficiently implemented.

c) Income-generating Options/Projects

i) Smallholding Oil Palm – 2 hectares per household

ii) Smallholding rubber – 1 hectare per household

iii) Rattan cultivation – 1 hectare per household
iv) Hill rice/food crop cultivation – 5 hectares per household (one acre per season on a 12 year-fallow period)

d) **Supporting Sectors**

i) Projects that are geared to the improvement of QOL

ii) Capacity building projects on long-term basis.

iii) Communal Forest Reserve of about 20,000 hectares where the Penan can exercise good stewardship and exploit the fauna and flora resources on a sustainable manner. Some areas can be enriched with the planting of Sago, Rattan and Gaharu.
CHAPTER SEVEN

Environmental Impacts & Mitigating Measures II
Chapter 7

Environmental Impacts and Mitigating Measures II

7.1 INTRODUCTION

This chapter identifies potentially significant environmental impacts associated with the operation of Murum Hydroelectric Dam and recommended mitigating measures to prevent and/or minimise these impacts. It looks at the potential physical, biological and socio-economic impacts arising from the activities during the dam's operation.

7.2 IMPACTS ASSOCIATED WITH DAM OPERATION

7.2.1 Physical Environment - Reservoir Water Quality

7.2.1.1 Background

Pollution sources from the catchments will enter into the reservoir, contributing to water quality conditions. This includes terrestrial organic material entering the reservoir. The decay of this biomass will consume oxygen which, when considered in conjunction with stratification within the reservoir, can lead to oxygen depletion and anaerobic conditions. Under both aerobic and anaerobic conditions, there are carbon dioxide emissions from the decay of matter; however, with anaerobic conditions, additional compounds such as hydrogen sulphide and methane are produced. Furthermore, excessive plankton and zooplankton growth created by these loads can create eutrophic conditions, with algal blooms and emissions of noxious by-products. If not properly managed, poor quality water can be flushed into the downstream waterways, creating further environmental degradation.

Oxygen in the aquatic environment is produced by photosynthesis of algae and plants and consumed by respiration of plants, animals and bacteria, BOD degradation, sediment oxygen demand and oxidation of nitrogen compounds. In addition, dissolved oxygen is re-aerated through interchange with the atmosphere.

Density variations due to temperature differences in the reservoir water column can result in stratification. Shallower layers, influenced by sunlight and air temperatures, are warmer and have high dissolved oxygen concentrations from re-aeration with the surface and photosynthetic activity. Deeper layers are darker,
colder, less influenced by surface interactions, have less or no photosynthetic activity and are often oxygen depleted. With decaying biomass on the bed of the reservoir to generate oxygen demand, the lower layers are likely to become anaerobic.

To identify the risk of anaerobic conditions in the reservoir, a simplified equation describing the decay of biomass under aerobic conditions can be written as:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

This equation shows that for the decay of 180 units of organic matter, 192 units of oxygen are required, and this will produce 264 units of carbon dioxide. For a large reservoir, this firstly depletes the oxygen in the reservoir water and secondly generates carbon dioxide.

An estimate of the dry mass of biomass from dipterocarp forest that prevails in the impoundment area is 180 t/ha (discussed in greenhouse gas assessment). For an impoundment area of 350 km$^2$ (35,000 ha) and assuming that 50% of the biomass is harvested as timber, the maximum potential biomass retained in the reservoir is $3.15 \times 10^6$ t. A rapid decay scenario has been considered, where the decay of this biomass occurs constantly over a 10-year period ($0.315 \times 10^6$ t/year). This rate would depend upon (among other factors) the burial of biomass from siltation effects, the oxygenation of the reservoir and temperatures at the bed of the reservoir. It should be noted that the decay rate can be considered conservative as most organic matter from forest are likely to relatively stable (cellulose and lignin) with a slow decay rate.

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1. The molecular mass of each molecule is 180 g ($C_6H_{12}O_6$), 32 g (O$_2$), 44 g (CO$_2$) and 18 g (H$_2$O).
2. Reservoir area obtained from the modelling carried out in this EIA study.
From this, annual oxygen demand can be estimated to be $0.336 \times 10^6$ t/year. If this oxygen demand cannot be met, or if residence time is insufficient to flush the lower layers sufficiently, anaerobic processes will occur. As a rough comparison, the annual inflow rate from the catchment is $470 \text{ m}^3/\text{s}$ and, assuming that DO levels in the inflows are $7 \text{ mg/l}$, the annual oxygen load is approximately $0.104 \times 10^6$ t/year. This is significantly less than the oxygen demand from the biomass.

### 7.2.1.2 Assessment Scenarios

Assessment of reservoir water quality considers flushing characteristics and stratification of the reservoir under various operating conditions and catchment scenarios. Modelling of the complex processes associated with reservoir water quality, eutrophication and the decay of biomass has not been considered. Instead, two modelling components have been used:

- A simulation of the mass flow of BOD concentrations in the river system. In this simulation, interactive water quality processes are turned off (conservative parameter). This provides a simplified assessment of water quality based upon the input loads (including estimates of biomass decay), the volume of the receiving waters, reservoir flushing and advective and dispersive movements. A 1 year simulation period (2004) was performed for various scenarios:
  - Existing catchment conditions, without Murum Dam.
  - Existing catchment conditions, with Murum Dam operating with $8 \text{ m}^3/\text{s}$ residual baseflow.
  - Existing catchment conditions, with Murum Dam operating with 10% natural residual baseflow.
  - Future catchment conditions, with Murum Dam operating with $8 \text{ m}^3/\text{s}$ residual baseflow.
  - Existing catchment conditions, with Murum Dam operating with $8 \text{ m}^3/\text{s}$ residual baseflow, with biomass loading$^3$.

- A vertical stratification simulation, assessing the levels, persistence and temperature variations of layers in the reservoir. A simulation period representing constant dam operations was performed for various scenarios:
  - Reservoir at normal operating level (540 m amsl), with an $8 \text{ m}^3/\text{s}$ residual baseflow.

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$^3$ Biomass loads were estimated by assuming a constant BOD supply to the Murum reservoir ($0.315 \times 10^6$ t/year or $10 \text{ kg/s}$, distributed through the reservoir branches).
➢ Reservoir at normal operating level (540 m amsl), with a 10% natural residual baseflow.

➢ Reservoir at minimum operating level (515 mAMSL), with an 8 m³/s residual baseflow.

A longitudinal profile of conservative BOD concentrations for the various scenarios, from Murum Reservoir to downstream of Bakun Dam, is shown in Figure 7.2.1. The vertical temperature profiles along a typical reach of the Murum Reservoir are shown in Figure 7.2.2. Figure 7.2.3 to Figure 7.2.5, which show predicted stratification of temperature and DO in Bakun and Batang Ai Reservoirs, is similar in character to these results. It is expected that there will be some local mixing in the vicinity of the hydropower intake and dam structure, which is not represented in these simulations.

![Longitudinal Profile of Conservative BOD Concentrations](image)

**Figure 7.2.1 Longitudinal Profile of Conservative BOD Concentrations**
Figure 7.2.2 Temperature Profiles in Reservoir for Normal Operating Level + 8 m³/s Residual Baseflow (top), Normal Operating Level + 10% Natural Residual Baseflow (middle) and Minimum Operating Level + 8 m³/s Residual Baseflow (bottom)
Figure 7.2.3 Simulated Vertical Profiles of DO in Bakun Reservoir (from Electrowatt, 1994)

Figure 7.2.4 Temperature Profile in Batang Ai Reservoir (from Electrowatt, 1994)
Figure 7.2.5  DO Profile in Batang Ai Reservoir (from Electrowatt, 1994)

7.2.1.3  Discussion

Results show that BOD concentrations will increase in the reservoir, which are then discharged through the hydropower waterways and into the downstream environment. When considering biomass decay, BOD concentrations increase by a factor of 3. This indicates that biomass could be a significant pollutant source in the system.

Figure 7.2.2 shows that there will be a marked variation in temperature within the reservoir structure, particularly in the deeper reaches. In the shallower tributaries, there will be some mixing as the colder inflows move along the bed. The rate of residual baseflow does not appear to affect the stratification in the reservoir as a whole. Variations in catchment inflows and water levels do appear to make some differences to the temperatures, but the overall trend of a pronounced thermoclinic boundary in the top 10% of the water column still persists. This would indicate that the natural variability of catchment inflows into the reservoir would not affect the deeper layers in the reservoir significantly. This implies that there would be relatively undisturbed colder layers in the reservoir.

The previous studies show vertical profiles of temperature and DO; there is a clear correlation between the two. Hence, low temperature zones will likely be poor quality zones.

In conclusion, the assessment indicates that the combination of BOD loads from the catchments combined with biomass decay within the reservoir will result in poor water quality conditions in the reservoir. This will be exacerbated by stratification, which will reduce circulation and flushing in the deeper layers.
Mitigations:

- If necessary, Project Proponent to incorporate measures to improve reservoir water quality such as re-aeration using pumps to improve reservoir circulation.

- Ongoing monitoring of water quality, sediments, flows and habitats.

- Development of operational rules by Project Proponent to ensure that the water quality of the hydropower discharge is consistently good, with mitigation measures considered in case of poor water quality.

7.2.1.4 Reservoir Sedimentation

The land use activities in the catchment (logging and clearing for agricultural purposes) typically generate significant quantities of suspended sediment (see Figure 7.2.6). Batang Rajang is highly turbid due to these activities, and settled sediments create navigation and maintenance dredging issues, such as in the navigation channels downstream of Sibu. Most of the suspended sediments are generated from the upper catchments; the Murum Dam will act as a barrier to the movement of these sediments downstream, resulting in an accumulation in the reservoir.

The major effects of reservoir sedimentation are:

- A reduction in active storage capacity, which can reduce the capability of the reservoir to generate hydropower in the long-term;

- Flood response in the reservoir can change, which may affect dam operation and safety; and

- Turbines and other underwater structures can be damaged due to the abrasive action of silt.

The estimated annual sediment load from the Murum Catchment, based on existing land use activities, is $6.8 \times 10^8$ t/year. The fraction of this load likely to deposit into the reservoir will depend upon the flushing mechanisms of the dam structure. A reasonable estimate of entrainment into the reservoir is 80% of the total load; the rest remains in suspension or is flushed through the dam structure. A rough calculation, assuming 80% entrainment and a porosity of 40%, gives an annual volume of sediments of $3.4 \times 10^6$ m$^3$/year entering the reservoir. Much of the Murum Catchment area has been allocated for agricultural land use activities. If all allocated land was utilised for this purpose, the future sediment load from the catchments could be much higher ($26 \times 10^6$ t/year, equivalent to approximately $13 \times 10^6$ m$^3$/year entrainment in the reservoir). The total reservoir volume is $14,700 \times 10^6$ m$^3$. The analyses suggest that sedimentation could reduce the reservoir volume by 10% in the next 100 to 1000 years, depending upon catchment land use practice.
However, due to the dendritic nature of the reservoir, the sediments will settle further upstream at the reservoir’s edge. Sediment accumulation from the catchments will not be spread uniformly across the reservoir. There will be an initial accumulation at the upper reaches of the reservoir, where the reduction in flow velocities will result in sediments dropping out of suspension and onto the bed. Remobilisation and redistribution will transport the sediments further downstream, but it is expected that the bulk of deposited sediments will remain and accumulate in the upper reaches, particularly upstream of some of the narrower necks in the various tributaries. This trend is corroborated by preliminary morphological modelling, which suggests that 85% of the total accumulation of sediments will occur in the upper 10 km reaches of the reservoir.

Mitigation:

- It is recommended that a Murum Catchment Management Plan be carried out to look into the management of the catchment since it involves other parties who have started their activities. This plan could draw upon existing regulatory structures, plus many of the procedures that are adopted for Environmental Impact Assessments (EIAs), including approval processes, monitoring plans, emergency response plans, etc so that the upstream activities are managed properly.

7.2.1.5 Downstream Riverine Water Quality and Sediments

As demonstrated in Section 6.4, river discharges downstream of the hydropower waterway outlet are lower than the existing case, which could affect water quality locally. However, the riverine environment downstream of the Murum Dam will be largely dominated by conditions in the Bakun Reservoir. Concerns raised about reservoir water quality in Murum Dam (discussed in Section 7.2.1.3) are equally valid for the Bakun Reservoir.

There is potential for poor water quality from Murum Reservoir to impact upon water quality conditions in Bakun Reservoir, assuming that the Bakun Reservoir has better reservoir water quality. As discussed in Section 7.2.1.3, avoidance of discharging from the deeper layers of Murum Reservoir would minimise adverse water quality conditions downstream.

The entrainment of sediments in Murum Reservoir will have a marginal benefit to the entrainment of sediments in Bakun Reservoir. Murum Catchment is estimated to contribute $6.8 \times 10^8$ t/year of sediment to the Bakun Reservoir, compared to $37 \times 10^8$ t/year from the remainder of the Bakun Catchment; complete entrainment of sediments in Murum Reservoir would therefore reduce the overall loads into Bakun Reservoir by approximately 20%.

Mitigations:

- For downstream water quality, further aeration of released water can be achieved through artificial rapids or other appropriate designs/structures at the tail bay. These structures would also facilitate the release of hydrogen sulphide from the water.
• Refer Section 6.3.3.2 for the control of downstream riverine water pollution caused by soil erosion and sedimentation.

• Intake structures shall be operated at top 40m to allow for surface withdrawal during operations of the reservoir and also during Full Service Level and Minimum Operational Level. Surface withdrawal will maximise discharge of aerated waters to the downstream river.

7.2.2 Physical Environment – Flow Regime

7.2.2.1 Flow Regime between Hydropower Waterway and Bakun Reservoir

Between the hydropower waterway and the Bakun Reservoir, flow rates are as shown in Figure 7.2.7. A summary of the changes in flow regime is provided in Table 7.2.1.

![Graph showing flow rates over time](image)

Figure 7.2.7 Flows Downstream of Hydropower Waterway

Murum Hydropower operation is expected to be continuous; therefore, flows into Bakun Reservoir will not change significantly in the long term. What will change however is the variability of flows in the shorter term.

Table 2.7.1 shows a reduction in flow variability with the dam in operation. The lower the baseflow, the more dependence on the hydropower discharges flows are, and thus the more consistent the flows.
Table 7.2.1 Summary of Flows Downstream of Hydropower Waterway

<table>
<thead>
<tr>
<th>Condition</th>
<th>Discharges (m$^3$/s) for Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1: No dam</td>
</tr>
<tr>
<td>Minimum</td>
<td>55</td>
</tr>
<tr>
<td>10% Low Flow</td>
<td>98</td>
</tr>
<tr>
<td>20% Low Flow</td>
<td>129</td>
</tr>
<tr>
<td>Mean</td>
<td>260</td>
</tr>
<tr>
<td>20% High Flow</td>
<td>366</td>
</tr>
<tr>
<td>10% High Flow</td>
<td>434</td>
</tr>
</tbody>
</table>

Note: The discharges are downstream of the hydropower outlet, not the reach between dam wall and hydropower outlet.

Average flow conditions remain similar for all scenarios. Flow variability is reduced, particularly the flood peaks which are contained within the Murum Reservoir (i.e. the dam spillway does not operate).

Bakun Dam is situated 50 km downstream of the Murum site and, as discussed in Section 7.2.1, the upper extent of the Bakun Reservoir is immediately downstream of the hydropower waterway outlet. The natural environment will already have changed significantly and this change in flow regime is likely to be only a minor impact (when comparing to conditions with Bakun Dam, which is the case here).

The storage capacity of the Bakun Reservoir is sufficiently large to absorb any short term changes in flow characteristics as a result of Murum Dam operation.

Operational arrangement in regard to flow releases to ensure that Bakun Dam HEP operation is not affected by Murum Dam (especially during reservoir fill). The operational arrangement of Bakun will not be significantly affected by Murum operations during normal operations.

7.2.3 Biological Environment – Aquatic Fauna

The dam will be fully operational when the reservoir reaches the full service level of 540 m. The potential impacts at the operational stage can be categorised into downstream area, reservoir area and area upstream that is not flooded areas.

Various environmental impacts on the fish fauna and riverine fisheries are postulated to occur as a result of the construction of the Murum Dam. Some species of fish will disappear from certain portion of the river (inundated area) due to the changes in the newly formed lacustrine water body (lake environment). However, with the exception of the two species which are neither unique nor endangered, all the other species are found in the area that will not be flooded.
7.2.3.1 Downstream Area

In the downstream area, there will be a reduction in water flow and volume depending on the impoundment stages of Bakun Dam. If the river condition is as present, this will lead to reduction in the depth of the water and many rapids areas will become very shallow or dry. Some of the exposed sand banks will be colonised by earthworms during this period when there will be minimum flushing effects even during the rainy period. Fish migration will be impaired and this will lead to congregation of fish at certain parts of the river. Without proper regulation and enforcement by the relevant authorities, they are vulnerable to overexploitation.

Water flowing downstream will also have reduction of suspended solids and leaf litter. Rivers in the higher order are strongly influenced by riparian vegetation (Vannote et al., 1980) and although primary production is low because of shading, vegetation provides large amounts of allochthonous detritus. Cummins et al. (1973) showed the importance of terrestrial debris especially leaves as a food web base for stream invertebrates and subsequently fish.

7.2.3.2 Reservoir

The reduced water flow in the reservoir will encourage the deposition of suspended solids especially around the areas of the inflowing water supply. The water will be more transparent, thus encouraging the growth of phytoplankton in the newly developed lacustrine environment (one that pertains to lakes/reservoirs). Enhanced primary productivity in the lacustrine environment will lead to rapid increase in selected fish species, particularly planktivorous and herbivorous species. These species will be preyed upon by carnivorous species particularly Mystus spp. Migration of fish downstream will be restricted depending on the volume discharged downstream during this period.

The formation of lacustrine habitat will undergo a period of stabilisation as the reservoir is being filled up. With the reduction of water flow, the primary productivity of the lake will increase. Certain species of fish that are well adapted to lacustrine habitat will flourish while other species that have specialised adaptations for living in fast-flowing waters will either move to other suitable areas upstream or perish. Therefore, species composition and relative abundance of fish species will change.

The relatively deep nature of the reservoir would mean that benthic organisms important as one of the sources of food will only thrive in shallow areas of less than 10 m. Food resources for fish will be limited at the main reservoir area although the possibility of aquatic weeds developing is low due to the absence of this species and the steep slopes of the area. Therefore, with the water intake base plate at 496 m (or 44 m below the FSL reservoir surface), the turbine mortality, if occurs, would be minimal since the fish population would be minimal at this depth in a tropical lake environment. However, the reservoir needs to be monitored so that appropriate management strategies could be implemented if aquatic weeds start to grow in the area.
7.2.3.3 **Areas Upstream Not Flooded**

The formation of lacustrine condition will favour some fish species while others that prefer running water conditions will move to upstream areas that will not be flooded. The movement of the latter species will start during the initial impoundment of reservoir. Whether they can breed successfully upstream depends on the prevailing habitats and the quantity and types of food available.

Species that prefer or are well-adapted to living in fast-flowing waters such as *Tor* spp. and those from the family Balitoridae and Sisoridae will move to the areas upstream that are not flooded. Some of the catchments at upstream areas that will not be flooded should be rehabilitated and conserved to act as breeding areas for these fish.

**Mitigations:**

- Rehabilitation of aquatic habitat and lake-side vegetation at the vicinity of the dam

As all the areas have been logged, planting of trees that produce either fruits or seeds eaten by fish is recommended (e.g., *Ficus* spp. (pokok ara), *Syzygium* spp. (jambu air) and *Dipterocarpus oblongifolius* (ensural)). Similar tree species should be planted by the lake side. Replanting should be carried out at the commencement of dam construction as these trees may take several years before they start bearing fruits.

- Conservation of the catchment area of Murum Dam

All the areas within the catchment have been logged. However, there are some watersheds that have shown some kind of recovery and should be conserved for the habitat of aquatic organisms including fish and macroinvertebrate. These watersheds include Sg. Saing, Sg. Pap, Sg. Belep, upstream tributary of Sg. Luar and Sg. Bora which flow through peat swamp forest which is a unique and fragile ecosystem. Therefore, a catchment management plan should be drawn up by the authorities to monitor and regulate the upstream activities.

- Maintain constant minimum residual flow

In order to maintain the aquatic life in the stretch between the dam and powerhouse outlet, it is recommended that a constant residual flow of 10% baseflow is maintained.

- Natural fish production and aquaculture development

It is common that tropical reservoirs in Asia have been developed into fish production area through the management of a sustainable captured fishery and the introduction of cage aquaculture (Chookajorn, 1992; De Silva, 1992). **Appendix 2 of Annex 2.10** shows the natural production in different tropical reservoirs in Thailand and Sri Langka. Yield varies from 10 – 70
kg/ha/yr mainly due to differences in species composition and prevailing environmental conditions.

The Murum reservoir will provide a large water body which can be exploited for various forms of aquaculture, including the farming of fish in floating cages. These activities will generate additional employment opportunities for local inhabitants displaced by the Project (Appendix 3 of Annex 2.10).

7.2.4 Biological Environment - Macroinvertebrate Fauna

Based on the existing community structure of macroinvertebrate and the present condition of river systems, five biological metrics were selected to predict the impacts of the proposed Murum Dam. The biological metrics are summarised in Table 7.2.2. It is postulated that macroinvertebrate community will be most affected in the inundated areas and few kilometres downstream of Sg. Murum below the dam site. Macroinvertebrate community in the rivers above the inundated areas will not be affected. This area will serve as shelter for some species of macroinvertebrate fauna.

Total species richness (total number of macroinvertebrate species) is a straightforward biological metrics that is able to indicate the impacts of Murum Dam. Since the study area had been affected by deforestation, the species richness of macroinvertebrate will continue to decline particularly in the inundated areas and below the dam site. All of crustacean species recorded in this study (including endemic and threatened species) are shallow-habitat species. They were recorded from the inundated areas such as Sg. Pap, Sg. Belepu, Sg. Sunan and Sg. Sap. Indeed, they will be wiped out by the Murum Dam reservoir. Some aquatic insect orders except for Order Odonata and Hemiptera entirely live in water most part of their life cycle. The majority of them live in shallow water with high concentration of dissolved oxygen. Therefore, they also will be affected by the increasing water level which results in the declining of dissolved oxygen (anaerobic condition).

<table>
<thead>
<tr>
<th>Biological metrics</th>
<th>Existing impacts of logging activities</th>
<th>Predicted responses to the Proposed MHED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below dam site</td>
<td>Inundated</td>
</tr>
<tr>
<td>Species richness</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Taxa richness of EPT</td>
<td>Very poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Taxa richness of Odonata</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>Functional Feeding Group</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>ASPT Index</td>
<td>Fair</td>
<td>Fair</td>
</tr>
</tbody>
</table>
Some species of macroinvertebrate will not be affected by the Murum Dam reservoir. For instance, several species of dragonflies from the family of Libellulidae (except Zygonyx sp. and Onychothemis coccinea) prefer stagnant water including man-made habitats. This group will establish along the reservoir margins where vegetation provides shelter and source of food. Another group of insects that will possibly establish in the reservoir are of Gerridae and Veliidae Families. All of this macroinvertebrate fauna (both adults and larvae) will indirectly support fish population in the reservoir, and also other animals such as birds, reptiles and amphibians particularly important in the islands where habitats are disconnected.

It is presumed that only few species of macroinvertebrate will be able to establish right below the dam site and a few kilometres downstream of Sg. Murum. Gray & Ward (1982) found that densities of macroinvertebrates at few kilometres downstream Guernsey and Whalen Dams in Wyoming, U.S.A are influenced by the suspended solids concentration during the sediment release from the reservoirs. In the case of Murum Dam where the water catchments had been logged and bottom sedimentation had already occurred, the same scenario is expected. The total species richness below the dam will decrease.

Another important biological metrics are taxa richness of Order Ephemeroptera-Plecoptera,-Trichoptera (EPT), Order Odonata and Functional Feeding Groups. The first three orders are useful as the indicator for the degree of disturbance of deforestation. Impact of deforestation on macroinvertebrate fauna is important to be assessed because it will contribute to the overall decision making and management measures for the reservoir. Total number of species of EPT was very low in all categories of study sites. Taxa richness of this insect probably will increase in the rivers above the inundated areas after logging activity has stopped. Few species from the families of Baetidae, Isonychiidae and Hydropsychidae will adapt to shallow habitats where fast flowing water meets with the reservoir. It is expected that taxa richness of EPT below the dam will decrease.

Taxa richness of Order Odonata are useful to monitor the quality of biotope along the reservoir margins because they respond readily to the environmental changes and are easy to measure (Clark & Samways, 1996). It was observed that dragonfly species had congregated at man-made habitats such as ponds and puddles nearby the rivers. Therefore, they were not much affected by the logging activity especially during high flash flood. This aquatic insect group will benefit from the Murum Dam reservoir. It is presumed that species richness of odonates below the dam site will be less affected.

The composition of functional feeding group in all study sites was similar where shredders, collectors, predators and scrapers were dominant. Composition of functional feeding group in inundated areas will be dominated by piercers, predators and parasites. It is expected that the same functional feeding groups will be dominant below the dam site. Functional feeding groups above the inundated area will be dominated by shredders, collector and predators provided that logging activity has completely stopped.
Average Score per Taxon is useful biotic index and have been widely used in water quality assessment of river ecosystem in many countries. Tolerance values used in calculating of ASPT score have been developed at family and class levels. The similarity of macroinvertebrate fauna at family or class level in the Southeast Asia is very high. Therefore, the tolerance values developed by Mustow (2003) for rivers in Thailand are acceptable to be used in this study. All study site categories have high scores of ASPT which indicate no heavy source of pollution. However, scores of ASPT for several rivers such as Sg. Auk, Sg. Belepu, Sg. Sap, Sg. Sunan, Sg. Singu and tributary of Sg. Danum were relatively low. Scores of ASPT will decrease in the inundated areas and below the dam site whereas probably will increase above the inundated areas.

Mitigations:

This study proposes two potential mitigating measures to minimise the impacts of the proposed Murum Dam such as below:-

- River rehabilitation right below the dam to the powerhouse is highly important. The 10% baseflow shall be maintained to achieve this. The river rocks should be left untouched as much as it will serve as habitats for some macroinvertebrate fauna. Some trees preferably *Ficus spp* (pokok ara) and *Syzygium spp.* (jambu air) are ecologically important to be planted along the riverbanks to provide river cover that will stabilise the water temperature from the reservoir. The plants also support the riverbanks stability and serve as source of food for fish and other animals.

- Littoral zones in the reservoir (areas where the depth is 4m or less) are very important habitats for many species of macroinvertebrate to re-establish. This includes the areas where fast flowing water meets the reservoir at the river mouth. It is suggested that a number of littoral zones to be conserved.

- A few river basins areas should be protected such as Sg. Saing, Sg. Pap, Sg. Belepu and tributary of Sg. Luar. These rivers have high diversity of macroinvertebrate and serve as important habitats especially for the threatened species.

- Sungai Bora which flows through swamp forest is a unique and fragile ecosystem, therefore it should be protected.

### 7.2.5 Biological Environment – Flora

#### 7.2.5.1 Aquatic Flora - Upstream of the Dam

The development of the dam will result in the loss of over 40 km of natural river, associated sand banks and river bank which will be replaced by a lake. The creation of a reservoir is expected to transform the species composition from that of riverine to that of lacustrine. The adverse impact from the loss of the riverine habitat cannot be adequately quantified or compensated.
Reservoir reduces water flow velocity and enhances sedimentation. As soon as dam is operational, it will begin to trap sediment within its storage volume and reservoir sedimentation will progressively alter the character of discharges downstream. Reservoir will permanently store almost the entire sediment load supplied by the Sungai Plieran and Sungai Danum drainage basin. Thus, many habitats presently available for periphyton such as boulders, rock and pebbles will be smothered by the silt. It should be noted that there is no exhaustive survey done on periphyton community, thus precise impacts are hard to determine. However, the periphyton will survive in the upstream part of Sungai Danum and Sungai Plieran, and in their tributaries which are not flooded.

Eutrophication will not be a problem in the Murum Dam reservoir as, at present, there are low human population and low agricultural activities in the surrounding catchments areas. However, as time progressed, it is expected that the reservoir is somewhat more productive due to nutrient being released from the inundated terrestrial catchment. The slow-moving water of the reservoir is often an ideal habitat for phytoplankton, thus the dam can be expected to promote higher phytoplankton population which will become an important group of primary producer. The water in the reservoir is likely to become thermally stratified and in the lower level, oxygen depleted.

Fluctuation of water level in period with no operation in the power station and large discharge during peak hours is expected to adversely impact all life in the littoral zone of the lake due to periodical dry-ups. Large magnitude and frequent fluctuation in water levels in reservoirs can cause erosion of the shores and add to deposition. It is estimated that between 0.5% and 1% of the storage volume of the world’s reservoirs is lost annually due to sediment deposition (Mahmood 1987).

**Mitigation:**

- The presence of rapids in the downstream river of the dam would redress potentially low levels of dissolved oxygen in water from the reservoir by natural aeration. To this end, the 10% baseflow (97 m$^3$/s) would be maintained for downstream flow.

### 7.2.5.2 Aquatic Flora - Downstream of the Dam

In the first years after damming, there will be a lot of erosion taking place in the reservoir. The silt and clay fraction of this erosion material will also impact the river downstream.

Reservoir operations produce artificial discharge variations. These often involve extreme fluctuations of water depth and flow velocity, having unnatural rates of change, unnatural duration and unnatural frequencies. There may be stagnant water in some stretch of the regulated river in periods of no operation in the power station and large discharge during peak hours. The combination of severe water-level fluctuations and high content of suspended solids can devastate the benthos population. Artificially high or low flow can have a major effect upon the composition of periphyton (e.g. Mc Intire, 1966; Biggs, 1996) by eliminating or favouring flow specific species. The generation of high turbidity and extreme flow...
velocity during dam releases can be an important factor causing the devastation of periphyton as they will be dislodged from substratum by a rapid current and mechanical movement of larger grains of deposit. However, artificially induced reduction in flow downstream of a dam will give rise to physicochemical conditions which may lead to periphyton growth. This in turn will have a considerable impact on the population of invertebrates and energy relationship (Biggs, 1996, Nichols et. al, 2006).

Mitigation:

- During operational stage, compensational flow of 10% normal baseflow (97 m³/s) will be maintained downstream of the dam. This may secure possibility for the survival of aquatic life and minimise the adverse impacts from the large diurnal flow and water level variation in Sungai Murum.

7.2.5.3 Increased Incidence of Invasive and Exotic Plants due to Habitat Change

7.2.5.3.1 Exotic and Invasive Flora Upstream of the Dam (Murum Reservoir Area)

Aquatic weeds such as water hyacinth can invade and quickly cover the reservoir surface, leading to clogging of water intakes, reduced marine navigation and reduction in aquatic life by preventing solar radiation from penetrating the water surface.

Non-indigenous and/or invasive species introduced into the reservoir and then inadvertently released into the river system.

Chemicals leaching from the plants can lead to corrosion of turbines and other dam equipment.

Mitigations:

Aquatic weeds and/or algal blooms are often linked with eutrophication⁴, and management should involve tackling both removal of the species involved, and the underlying water quality issues:

- To deal with this impact, management must incorporate management of exotic / invasive species into dam operation, with staff trained to identify such species and prevent their introduction, and to remove them when they occur.

- Aquatic weeds can be manually removed with mechanical floating harvesters.

⁴ Natural eutrophication is the process by which lakes gradually age and become richer in nutrients. It normally takes thousands of years to progress. However, the creation of a dam and a reservoir can greatly accelerate this process. Eutrophication in these situations can be water pollution caused by the decomposition of excessive plant nutrients.
• Biological controls of water hyacinth include introducing weevils such as Neochetina eichborniae and Neochetina bruchi – into reservoirs accidentally infested with water-hyacinth. However, the option has its disadvantage; the weevils may move on to other plants, including plantations of agricultural crops in the area.

7.2.5.3.2 **Exotic and Invasive Flora Downstream of the Dam**

Since dams eliminate peak discharges that naturally flush river systems, certain species may gain a foothold, or cause others that normally occur at low levels to proliferate and invade large areas including the river downstream. In this case, the area immediately downstream of the Murum Dam is the Bakun Hydro Electric Project Reservoir, therefore the threat of escape of invasive species from the Murum Reservoir area, into downstream areas is less likely. However, it is possible in the long term.

**Mitigations:**

• Monitor the downstream areas for such incidences and assess on its significance. If significant, Proponent do remediation such as removing using manual harvestors.

7.2.6 **Human Environment - Greenhouse Gas Impact**

Due to the inundation of a significant amount of forest, the loss of a carbon sink and the resulting greenhouse gas exchanged, in this case carbon dioxide (CO₂) emitted may be significant. In view of this development, air quality during operations is assessed based on the amount of CO₂ released into the atmosphere.

7.2.6.1 **Greenhouse Gas Emission**

This section discusses the amount of CO₂, a greenhouse gas released into the atmosphere resulting from the proposed Murum Hydroelectric Project.

The methodology for estimating the amount of CO₂ released was based on the latest published **Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories**.

The IPCC Guidelines for National Greenhouse Gas Inventories are approved internationally and developed through an international process which has included:

• Wide dissemination of drafts and collection of comments from national experts;
• Testing of methods through development of preliminary inventories;
• Country studies which ensure that methods are tested in a wide variety of national contexts;
Technical and regional workshops; and

Informal expert groups convened to recommend improvements on specific aspects of the methodology.

**Methodology**

The following methodology was employed to compute the net carbon dioxide balance resulting from activities of the Project:

1) The total amount of dry matter in above-ground biomass (existing biomass stock) was calculated based on the type of existing forest at the Project site, the size of the forest inundated and default above-ground biomass values provided by the IPCC document for the type of existing forest. In this case, the existing vegetation inundated by the waters of the hydroelectric dam is dipterocarp forest and the dry matter biomass of this type of forest is 180 tonnes per hectare (Source: Table 5.5: Aboveground Biomass Estimates for Various Tropical Forest Types by Country, Page 5.38, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook Volume 3). This is in comparison to the value of between 280 and 330 tonnes per hectare for undisturbed mixed dipterocarp forest in flat to mountainous area. From the vegetation characteristics in Murum Catchment field surveys, the average biomass quantity ranges from 40 t/ha to 230 t/ha and an average of 140 t/ha. However, the 180 tonnes per hectare estimate was used based on the existing type of forest that will be inundated which is logged hill dipterocarp forest in very moist climatic zone in Malaysia and to reflect the worst case situation in terms of CO₂ released.

2) As the Project may involve the harvesting of some of the forest before the construction of the dam, the rate and method of harvest and the main used of the timber was defined. Based on this information, the rate of carbon released was computed.

3) During the damming stage of the Project, the remaining above-ground biomass is inundated, the rate of inundation was determined. With the estimated rate of decay and the amount of biomass remaining under water, the rate of carbon released was also computed based on this rate. However, this amount was estimated to be negligible as the Project proposes that all the vegetation is cleared before the dam is flooded and all the above ground biomass is accounted for in the removal of all vegetation in the area flooded;

4) Finally the net carbon removed from the atmosphere or emitted into the atmosphere over the Project period was computed and this was then converted to the amount of carbon dioxide; and

5) The carbon dioxide inventory for each year of the project period was computed and presented.
Computation

The amount of carbon emitted into or removed from the atmosphere was computed based on data provided by the Project Proponent.

In instances where no data was available, default values from the IPCC Guidelines were used in the calculations.

Information and default values which were used in the computation are:

- Project location: Murum, Belaga District, Sarawak;
- Project area (flooded): 245 km² or 24,500 hectares (maximum);
- Present forest type at the Project site: logged dipterocarp forest;
- Natural regeneration: As the area will be permanently inundated, annual increment in biomass from natural regeneration is zero;
- Carbon fraction of biomass dry matter: 0.5 (IPCC default value);
- Harvest method: clear felling and removal;
- Disposal method: Zero burning (assumed for this computation); and
- Weight ratio of waste wood to harvested timber: 1:1.

Harvested wood releases its carbon at rates dependent upon its method of processing and its end-use. Waste wood in this case is left to decay and is estimated to oxidise in roughly a decade (IPCC, 1996) and the end product of the timber decays in 10 years as well (IPCC, 1996).

The climate at the Project site is defined as tropical, moist with short dry seasons, mean average temperature of above 25°C and annual precipitation between 2,800 and 4,600 mm. This is based on meteorological data from the Bintulu Meteorological Station.

7.2.6.2 Results

The maximum size of the forest area inundated is 245 square kilometres or 24,500 hectares and this is expected to take between one and two years. Based on these values and approximately 50 percent of the forest harvested prior to flooding is converted to end products which have a decay time of more than 10 years (IPCC default value). However, the rapid decay period of 10 years was selected in this study to reflect the worst case scenario. The remaining 50 percent is left to decay at the site over a period of 10 years⁵ (IPCC default value). As the harvested forest area will be flooded, there will be no regeneration of forest at the

⁵ The 10 year period is to signify worst case scenario. Timber immersed in deep reservoir may take 10 times as long to completely decay.
flooded area of the Project site, so there is no uptake of atmospheric carbon in this case.

The net amount of carbon dioxide released into the atmosphere during the first year and subsequent years is computed. A spreadsheet was used for the computations.

Tabulated below are the results of the amount carbon dioxide released into or removed from the atmosphere for a period of 11 years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount of carbon dioxide released into the atmosphere (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>808,500</td>
</tr>
<tr>
<td>2</td>
<td>808,500</td>
</tr>
<tr>
<td>3</td>
<td>808,500</td>
</tr>
<tr>
<td>4</td>
<td>808,500</td>
</tr>
<tr>
<td>5</td>
<td>808,500</td>
</tr>
<tr>
<td>6</td>
<td>808,500</td>
</tr>
<tr>
<td>7</td>
<td>808,500</td>
</tr>
<tr>
<td>8</td>
<td>808,500</td>
</tr>
<tr>
<td>9</td>
<td>808,500</td>
</tr>
<tr>
<td>10</td>
<td>808,500</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>8,085,000</td>
</tr>
</tbody>
</table>

Positive values indicate release of carbon dioxide into the atmosphere while negative values mean carbon dioxide is removed from the atmosphere. As there is no forest regeneration, there is no uptake of carbon from the atmosphere. This means that from year one to year ten of the Project, there is a release of 808,500 tons of carbon dioxide per year and by year eleven there is no carbon dioxide released and the carbon dioxide emission is in equilibrium.

### 7.2.6.3 Discussions

As Malaysia is not subjected to any carbon dioxide emission limits or ceilings under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, the economic impact of the carbon dioxide released is not a major issue.

The amount of carbon dioxide released by this Project per annum is about 0.5 percent in comparison to the 144 millions of tons of greenhouse gas emitted in
Malaysia in the year 1994, the latest available data extracted from Malaysia Initial National Communication submitted to the United Nations Framework Convention on Climate Change, Ministry of Science, Technology and Environment, July 2000. Currently the amount of green house gases emitted in Malaysia is expected to more than double the 144 million tons emitted in 1994.

7.2.6.4 **Other Greenhouse Gases**

The carbon and other greenhouse gases such as methane flux from below ground were not computed as the amount is considered insignificant because there will be very little soil tillage and over-turning of the soil at the Project site.

As there may be controlled burning of the wood waste at the site, gases such as methane, carbon monoxide, nitrous oxide and oxides of nitrogen which are greenhouse gases as well is also emitted should such activity occur.

7.3 **DAMBREAK**

7.3.1 **Probable Maximum Flood (PMF)**

The PMP estimates were applied to the models to generate the probable maximum flood event (PMF). Two simulations were performed, using the 1994 estimates of PMP and the revised estimates (see Annex 2.7). The resulting water levels at the dam site are shown in **Figure 7.3.1**, and the spillway flows over the dam structure are shown in **Figure 7.3.2**.
Figure 7.3.1  Peak Water Level at Dam for PMF Based on 1994 Study PMP (Top) and Revised PMP (Bottom)

The predicted peak water level at the dam site is 543.5 m amsl for the 1994 PMP and 545.1 m amsl for the revised PMP. Both are below the design dam crest level of 547.5 m amsl. Peak discharges over the spillway during these events are 1,860 m$^3$/s and 2,960 m$^3$/s.

Note that the PMP investigations undertaken for the present study are not rigorous, and these predictions and quoted values should not be adopted in dam design.
Figure 7.3.2 Spillway Discharge at Dam for PMF Based on 1994 Study PMP (Top) and Revised PMP (Bottom)

7.3.1.1 Dam Structure

The proposed dam structure is a roller compacted concrete dam (RCC), with a height of 146 m above natural ground levels and a crest length of 500 m. The reservoir impoundment volume is approximately $15,290 \times 10^6 \text{ m}^3$.

Roller Compacted Concrete (RCC) is a special blend of concrete that has the same ingredients as conventional concrete but is drier and essentially has no slump. RCC is increasingly used to build concrete dams since the low cement content causes less heat to be generated while curing than typical for conventionally placed massive concrete pours.