This document presents the findings of the Environmental Impact Assessment (EIA) for the proposed Hydroelectric Power Plant at Vaca Falls in Cayo District. Two site options were investigated and the site that presented the least environmental impacts was selected, for detailed impact assessment. Several impacts have been identified and mitigation measures presented.
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*Belize Electric Company Ltd.*

*Vaca Hydroelectric Project*
EXECUTIVE SUMMARY

This report constitutes the Environmental Impact Assessment (EIA) for the Vaca Hydroelectric Project proposed for the Macal River in the Cayo District, Belize. The Vaca project is proposed as the third in a series of hydroelectric schemes on the Macal River. The first at Mollejon was commissioned in 1995 and the second, the Chalillo Dam, located upstream of Mollejon was commissioned in September 2005. This EIA was commissioned by the Belize Electric Company Limited (BECOL) the developer, and conducted by ESL Management Solutions Ltd. (EMSL), an agency of Environmental Solutions Ltd. (ESL), after an international competitive bidding process. The study was commissioned in April 2005 and conducted over a six month period.

The Proposed Project

BECOL proposes to develop a hydroelectric facility of approximately 18 MW on the Macal River above the Vaca Falls. BECOL has submitted a proposal to the Belize Electricity Limited (BEL) and to the Public Utilities Commission (PUC) for this scheme to be evaluated, in response to a request for proposals for new generation additions from BEL. If found to be technically and environmentally feasible, and subject to regulatory approval, BECOL will proceed with this project.

- The Vaca Hydroelectric Project would be the third in a series of hydroelectric projects on the Macal River and would complete the series of dams and generating stations proposed for the Macal River from the early 1990’s.
- The Vaca Hydroelectric Project consists of a run-of-the-river dam, power house, penstock, switchyard, tailrace channel and transmission lines connecting to the main line from Mollejon.
- Two main sites have been considered for the placement of the dam.
- Site A is located immediately below the confluence of the Macal River and the Rio On and Site B, approximately 1 km above the Vaca Falls on the Macal River.
- BECOL has provided a technical and economic justification for the proposed Vaca project based on a least cost generation evaluation. Their project justification is reproduced in its entirety in Section 1.4.
- The EIA has been prepared for submission to the Department of the Environment (DOE) for their environmental evaluation of the project and approval.
- The EIA process has involved the collection of baseline data by the EMSL team comprising both local and international professionals.
- The Terms of Reference (TORs) for conducting the EIA were approved by the DOE before initiation of the study. After a series of meetings with EMSL, DOE and BECOL,
and after DOE review of the draft against the approved TOR, this final report has been prepared for submission.

Main Conclusions

In summary, below, are the main conclusions of this Environmental Impact Assessment report:

1. Preferred Site
   - After BECOL’s identification of four potential sites, two sites were selected for detailed study (Site A and Site B)
   - The EIA team concluded that ecological impacts at Site B would be greater than at Site A due to the greater area of inundation involved with Site B
   - However, physical impacts particularly related to geology/geotechnics, the uncertainty of tunneling, and construction works would be greater at Site A
   - Based on a qualitative and quantitative analysis of all the environmental aspects, Site B was assessed to present overall less significant impacts
   - Although environmental analysis has indicated that Site B has fewer environmental impacts than Site A, neither site is ruled out as being unsuitable for the development.
   - Two options for construction of the dam at Site B were evaluated. The Concrete Dam (Option 1) presents less environmental impacts than the Rockfill Concrete Face Dam (Option 2). However, both options are considered environmentally acceptable.

2. Geology/Geotechnics
   - In general terms the geological and geotechnical conditions are favourable for the construction of the dam.
   - Geological baseline data was based on site investigations and available geological and geotechnical reports particularly that produced by Rodio-Swissboring in 2005.
   - The project site is located on granites and metamorphosed granites (gneiss). These intrusive igneous rocks comprise the Mountain Pine Ridge area.
   - The bedrock at Dam Site B is porphyry granite with a variable content of orthoclase (feldspar mineral).
   - This rock is fractured and sometimes microfaulted, however, based on borehole investigations and the unconfined compressive strength test from the dam axis area, the rocks were classified as strong to very strong, and well suited for dam construction. However, where highly weathered rock and superficial deposits occur on the bedrock, these should be removed prior to construction.
   - Similar tests done at the proposed powerhouse and quarry sites indicated equally suitable rock types for building and quarrying.
   - The geotechnical report found no evidence of faulting in the rock outcrops along the river channel at Site B.
3. **Hydrology**

- Operation of the Vaca Dam as a run-of-the-river dam should not significantly alter downstream flows on the Macal River under normal wet, dry and average year conditions.
- Flows over the Vaca Falls would not be negatively impacted by operation of the Vaca Dam at Site B.
- With implementation of the Chalillo, Mollejon and Vaca Hydroelectric projects floods below the Vaca Dam would not be eliminated altogether but would be reduced in frequency and intensity. Dry weather flows would generally be increased.
- The rate of sedimentation above the Vaca dam would be low and would not be expected to affect the effective capacity and life of the reservoir, nor require significant maintenance.
- Instantaneous total dam failure under probable maximum flood (PMF) conditions would not significantly increase the extent of flooding at Cristo Rey and San Ignacio. However, flood heights above Cristo Rey, for example at Negroman, would be increased by approximately 1m.
- Similar dam failure under dry and average year conditions would result in increased flood heights at Cristo Rey and San Ignacio, but would remain within annual flood plain contours.
- Inundation contours have been presented based on flood plain calculations for total dam failure under PMF and fair-weather conditions.

4. **Water Quality**

- Water quality parameters most likely to undergo changes as a result of project implementation would be temperature, dissolved oxygen and suspended solids. These changes may impact the life cycles of aquatic species.
- There is the potential for mercury contamination in water and fish as a result of methylation effects. Close monitoring of this parameter in the early years after project implementation would be required, as for Chalillo, and as recommended in a report by PAHO in 2005.
- Flushing of the reservoir whenever it occurs would require close monitoring and compliance with DOE standards.

5. **Ecology**

- Inundation would result in the loss of 52-62 ha (125 -150 acres) of vegetative cover
- The main types of habitat that would be impacted are Lowland Riparian Shrubland of approximately 16 ha (40 acres) or less than 0.6% of national coverage) and Tropical Evergreen Broadleaf Forest over Steep Calcareous Hills (less than 0.06 to 0.07% of national coverage).
- All the Riparian Shrubland (along the river within the reservoir) would be inundated but would not result in loss of any critically endangered species of flora or fauna.
- Inundation of Tropical Broadleaf Forest would also not result in loss of any critically endangered species of flora or fauna
- Species of international conservation interest were identified within the Vaca project area. These include reptiles (Morelet’s Crocodile and the Boa Constrictor), birds (Keel-billed Motmot, Greater Currassow and the Golden-winged Warbler) and mammals (Yucatan Black Howler, Baird’s Tapir, Juguari, Puma and the Neotropical River Otter).
- Construction impacts would result in some habitat loss, fragmentation and/or disruption. However, highly mobile species such as mammals, birds and reptiles would be expected to relocate into forested areas once site preparation activities begin.
- The Orange-breasted Falcon sighted regularly within the project area is highlighted as being vulnerable in its Central American range. Nesting sites observed on cliff faces could be impacted during the site preparation and construction phases.
- Overall negative impacts on these critical species are expected to be minimal.
- Fragmentation of the riverine habitat would result in separation of niches upstream and downstream of the dam.
- The reservoir area would alter the existing habitat for fish and may affect abundance and diversity.

6. Archaeology

- The Rapid Archaeological Assessment as required by the Terms of Reference for the EIA, revealed only a limited number of features of archaeological interest.
- Prior to construction a detailed archaeological survey should be conducted to determine the nature and extent of the features identified, particularly at the travertine dams and the Cophune ridges.
- Prior to construction excavation of these features should be considered.

7. Socio-economics

- Public Consultations were conducted during the course of the EIA and included individual consultations, stakeholder meetings, community meetings and the dissemination of project information.
- The consultations revealed a number of concerns of both a technical and non-technical nature, which were addressed in various public consultations.
- Technical concerns relate mainly to the potential hydrological impacts including monthly flows, Vaca Falls, wet season flooding, and dam failure as well as ecological impacts related to the loss of flora and fauna and alteration of existing habitat structures, as well as water quality related to the potential accumulation of mercury in fish.
- Non-technical concerns relate mainly to the openness and transparency in the EIA and bidding processes, the cost of electricity, and responsibility for the management of flows in the Macal River.
- Regulated flow of the Macal River would result in year round potential for some water sports activities such as tubing and canoeing. The potential for whitewater activities would be reduced.
- Stakeholders in the tourism industry are concerned about the safeguarding of their interests on the Macal River and request their continuing participation in all phases of the process.
- Domestic users of the Macal River should not be negatively impacted by project implementation but should benefit from more regular flows and the controlled flood plain throughout the year.
- There should be no negative public health impacts such as impairment of water quality, or proliferation of pests and vectors as a result of project implementation.
- Inundation for the reservoir and construction of the dam would not result in the displacement or relocation of any communities or villages.

8. Decommissioning

- Decommissioning of dams may be total or partial, and may involve the cessation of the production of energy, the removal of various components of the operation or total demolition of the dam and restoration of the former riverine environment.
- If the Vaca project is implemented a decommissioning plan would in time need to be developed and subjected to its own environmental assessment.

9. Cumulative Impacts

- The cumulative impacts of having three hydroelectric plants in the Macal River basin have been evaluated under hydrology, water quality, ecology, archaeology and socio-economics.
- The main hydrological impacts relate to regulation of river flows and flood controls. The Vaca Hydroelectric Project would contribute to both, but would be minimal compared to the influence of the Chalillo dam. Overall, the river flow and flood control impacts are considered to be positive but some downstream changes are inevitable.
- Overall, water quality impacts are expected to be negligible. However, the potential for mercury accumulation in fish needs to be further investigated and the monitoring of mercury levels in the Vaca reservoir should be incorporated in the Mercury Risk Management Programme for the Chalillo Dam.
- Some habitat loss in the Macal River Basin as a result of the construction of all three dams is inevitable and cannot be mitigated. However, on the national scale the flora and fauna that would be impacted, including those of conservation concern, is not significant. Rehabilitation of construction sites should take place and this would facilitate the regeneration of natural habitats within five years.
- Archaeological knowledge of the Macal River Basin has increased considerably as a result of the assessments conducted for the dams. The Rapid Archaeological Assessment of the Vaca site revealed no features of archaeological significance, however a detailed survey is recommended of the travertine dams and Cohune ridges, before construction begins.
- Socio-economic concerns in relation to having three hydroelectric schemes relate to
  the regulation of flood flows on the downstream communities, the potential for year
  round water sport activities, the overall control of Macal River flows, the public
  perception of the benefits and risks associated with three dams, cost of electricity,
  extent of public participation and the evaluation and approval process as administered
  by the DOE and ultimately by the PUC.

10. Climate Change

- Future climate change could affect the Vaca project in a number of ways:
  1. Changes in rainfall patterns affecting hydrological projections and therefore power
     generation expectations
  2. Increased hurricane events affecting the frequency of large floods; and also the
     possibility of reduced operations due to structural damage resulting from sediment,
     debris and wind forces
  3. Increase in ambient temperatures affecting temperature and other water quality
     parameters

- BECOL needs to take precautionary mitigation measures which should include the
  following:
  1. Awareness of the implications of climate change
  2. Establishment of capabilities for and participation in climate monitoring networks
  3. Incorporation of appropriate engineering designs for extreme events
  4. Training for and participation in hazard management networks
  5. Development and maintenance of an Early Warning System

11. Disaster Management

- Evaluation of the seismic risk hazard for Site B indicates that there are no active faults at
  the site and the area may be stated as being of moderate seismic risk.
- Flood mapping has been carried out for dam failure under PMF and fair-weather
  conditions. In the event of dam failure under PMF conditions the area of flooding would
  not be significantly different from that under natural flood conditions in the areas of
  Cristo Rey and San Ignacio. However, flood heights above Cristo Rey would be
  increased by 1m or more.
- It has been recommended in the EIA that BECOL should prepare an Emergency
  Preparedness Plan (EPP) in conjunction with the National Emergency Management
  Organization (NEMO) and all stakeholders. This plan should be finalized before
  completion of the Vaca dam and should include communication with the National
  Oceanographic and Atmospheric Administration (NOAA) to ensure immediate satellite
  transmission of signals.
- Due to the possibility of floods originating from the Vaca area (Macal River and Rio On)
  a Flash Flood Early Warning System (FFEWS) should be incorporated in dam
  operations, which is linked to the FFEWS established at Chalillo. This FFEWS would
  be operated by BECOL in association with the National Meteorological Service. If all
three dams are equipped with a FFEWS a positive cumulative impact in flood management should be realized.

- The handling and storage of hazardous materials including petroleum products and explosives, would be required to facilitate construction of the dam.
- Mitigation Measures have been presented to minimize the risks associated with the handling and storage of materials including the implementation of proper handling and storage techniques, provision of berms and barriers, and the use of appropriate safety gear for relevant workers.

12. Potential Impacts, Mitigation Measures and Mitigation Plan

- Impacts have been identified for the Site Preparation and Construction Phases as well as for the Operation Phase, and have been identified as positive or negative; long, medium or short term; and reversible or irreversible.
- The main impacts have been summarized in the above sections for geological/geotechnical aspects, hydrology, sedimentation, water quality, hazard management, flora, fauna, archaeology and socio-economics.
- Where negative impacts have been identified EMSL has recommended one or more mitigation measures to minimize these impacts.
- While some of the impacts are inevitable and long-term, most of the impacts can be mitigated through careful planning and monitoring.
- Mitigation measures relate to all aspects of the physical, biological and socio-economic components of the environment.
- A Mitigation Plan has also been developed which details specific potential impacts and the identified mitigation measures.
- A Mitigation Matrix has been prepared which summarizes and shows the interrelationships between the potential impacts and the proposed mitigation measures, and this is reproduced below (Table 9.2).
- Construction activities need to be carefully controlled and should follow the Mitigation Plan as well as a Monitoring Plan which should be approved by the DOE.

13. Monitoring Plan

- An outline Monitoring Plan has been presented in the EIA Report and includes key environmental parameters and project aspects that should be monitored during the Site Preparation and Construction Phase, as well as during the Operation Phase.
- These include riverine water quality, ecology, and the construction camp during the Site Preparation and Construction Phase, and water quality, ecology, hydrology and meteorology during the Operation Phase.
- If the project is approved a detailed Monitoring Plan should be prepared, and should include any other aspect recommended by the DOE. The Monitoring Plan will also be subject to DOE approval before implementation.
### Reproduced from EIA Report: Table 9.2: Mitigation Matrix

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14. **Analysis of Alternatives**

- Several alternatives for the project were considered and included alternative engineering design, alternative sites for the dam, and alternative sites for the quarry.
- A geotechnical investigation of four initial sites was followed by a detailed environmental evaluation of the two sites selected.
- An environmental evaluation of alternative engineering design has been summarized above.
- The No Option Alternative has also been discussed. The EIA report does not recommend a decision one way or another and the decision whether or not the Vaca Hydroelectric Project proceeds, is subject to regulatory approval.

15. **Agency and Public Participation**

- Public participation has been a part of the EIA data gathering process throughout the study. Several meetings have been held with individuals, stakeholder groups and communities, and the issues raised at these meetings have been summarized in the Appendices.
- The public will continue to be involved in the EIA process as copies of this Final EIA Report will be made available for public review and comment.
- Comments on the EIA Report will be received by the DOE and taken into consideration during the DOE review process.
1.0 Introduction

1.1 The Report

This document presents the findings of the Environmental Impact Assessment (EIA) for the proposed Hydroelectric Power Plant in the vicinity of the Vaca Falls, in the western Cayo district of Belize (Figure 1.1). The EIA was commissioned by Belize Electric Company Ltd. (BECOL), and ESL Management Solutions Ltd. (EMSL) was commissioned to undertake the study, after responding to a request for proposals, and submission of tender documents, in an open bid process.

In fulfillment of contractual arrangements, several reports have been prepared and submitted to BECOL prior to the completion of the EIA. These reports served to facilitate the continuous exchange of information between BECOL and EMSL, ensured an iterative process in the rationalization of issues, and served to indicate the preferred site for the implementation of the proposed project.

1.2 Background

The hydroelectric potential of the Macal River was studied in 1990 (Canadian International Power Services Inc., 1990); 1992 (CI Power, 1992); in 1999 (AGRA CI Power/BEL, 1999); and in 2001 (Canadian International Power Services Inc., 2001). These studies determined that the optimal development strategy to be implemented for the Macal River was two run-of-the-river facilities with minimal storage and regulation capabilities, supported by an upstream water storage scheme. The first facility to be put in place was the Mollejon Dam, which has been operational since 1995 and has an installed capacity of 25 MW. In 1998, using environmental criteria, BECOL compared the options of establishing a storage facility at Rubber Camp and at Chalillo. That
assessment concluded that the construction of a dam at Chalillo, formally called the Macal River Upstream Storage Facility, was the better of the two options.

An EIA was conducted for the Chalillo storage facility, and completed in August 2001 (AMEC E&C Services Ltd., 2001). The Chalillo Dam was completed and commissioned in September 2005. At full supply level the maximum depth of the reservoir at Chalillo is 35 m, with live storage of 120.3 million m$^3$. The Chalillo facility generates 7.3 MW of power. The Chalillo Dam is designed to work in conjunction with the existing Mollejon Plant and also with the proposed Vaca Facility.
Figure 1.1: Map of Central Belize showing the Study Area for the proposed Vaca Hydroelectric Project
1.3 The Proposed Project

The proposed Vaca Hydroelectric Project is to be located on the Macal River downstream of the existing Mollejon hydroelectric facility and the Chalillo dam recently constructed. This third facility forms part of a larger integrated system designed to increase the supply of electricity to meet the needs of Belize.

The hydroelectric potential of the Macal River was first investigated in the 1970’s as part of the search for solutions to meet the need for safe and reliable energy production. Completion of the Mollejon plant and current construction of the Macal Upstream Storage facility at Chalillo has tapped some of that potential. The Vaca Facility would include a run-of-the-river dam, small reservoir, penstock, a powerhouse, and a switchyard for the generation of electricity.

Two alternative sites on the Macal River are being considered as shown in Figure 1.3.
Figure 1.3: The Macal River showing the Location of the Mollejon Power Plant, the Confluence with Rio On, Proposed Site A, Proposed Site B and Vaca Falls
The first alternative at Site A includes a low dam with a tunnel leading to a powerhouse about 3 km downstream. Alternative A would include the following components:

- A concrete diversion dam on the Macal River just downstream of the Rio On confluence, with a storage depth of about 15 m
- A temporary diversion facility for river handling during construction
- An uncontrolled overflow spillway
- A low-level-outlet facility
- An intake facility on the east bank of the river
- A low pressure tunnel approximately 3 km long
- A surge tunnel and construction adit
- An underground high pressure/penstock tunnel
- A surface powerhouse, downstream of the Vaca Falls, with an installed capacity of approximately 18 MW
- An excavated tailrace channel
- Access roads from the existing Mollejon Road to the new dam and powerhouse facilities, including a road bridge over the dam
- A construction camp and construction roads
- A sub-station and transmission line

The second alternative, at Site B includes a higher dam but with no tunnel and a powerhouse just downstream of the dam. Alternative B would include the following components:

- A dam on the Macal River about 2.5 km downstream of the Rio On confluence. This dam would be either a concrete dam, or a concrete-faced-rockfill-dam (CFRD)
- A temporary diversion facility for river handling during construction
- An uncontrolled overflow spillway
- A low-level outlet facility
- An intake facility in the dam adjacent to the west abutment of the river
- A penstock embedded in the body of the dam, and extending to the
1.4 Project Justification

Justification for the implementation of the VACA Hydroelectric Project has been developed by Belize Electric Company Limited (BECOL) and submitted to the environmental consultants (ESL Management Solutions Limited (EMSL)) for inclusion in this Environmental Impact Assessment (EIA) Report. This justification is presented in its entirety below, as documented by BECOL (2005 b). Details of the Vaca Hydroelectric Project being investigated in this EIA report have been submitted by BECOL to the Public Utilities Commission (PUC) and Belize Electricity Limited (BEL) in response to the invitation to tender for the supply of 15 MW.

PART 1

This segment of the project justification has been developed with information from BEL’s most recent Request for Proposals (RFP) and the Cost of Service and Tariff Study of June 2005 and summarizes the electrical energy market and the need for additional generation sources to meet a growing demand within Belize.

The country of Belize is developing, and with this development has come an increased
demand for energy to service industries, tourism, housing expansion and others. The country needs greater energy self-sufficiency as it currently imports almost half of its energy requirements. The preference is to utilize local renewable resources which would reduce dependency on imports and exposure to rising cost of fuel while reducing greenhouse gas emissions.

In the National Energy Policy (available on-line at www.puc.bz/nep.asp) developed by the PUC and approved by the Government of Belize (GOB), hydroelectric power has been identified as one of the main sources of electricity to be developed over the long term to meet Belize’s present and growing energy needs. Quoting from Section 7.0 of the Energy Sector Diagnostic Report from the Energy Policy, the following bullets extracted from page 59 reads:

- The current electricity mix with 50% imported from Mexico is not sustainable given that demand is growing at 9% p.a. The Mexican supply is currently limited, and if additional supply can be negotiated (under a new contract) it is likely to be significantly more expensive.

- The use of renewable energies is technically, environmentally and economically feasible and given the exigencies of the internal and external environment, is highly recommended.

Other sources in the energy equation are diesel driven generators, purchase of energy from Mexico, and biomass schemes using agricultural by-products such as the bagasse fired generation project being developed by BELCOGEN.

The objective of this project justification is to demonstrate the rational, as presented by BEL and approved by the PUC, for viable generation alternatives for meeting the electrical energy requirements of Belizean consumers. It is structured in the following manner:

Section 1.4.1, which describes the Current Energy Sources of Belize;

Section 1.4.2, which summarizes the results of the Cost of Service and Tariff
Study for Belize undertaken by Stone & Webster Management Consultants Inc; (SWMCI).

Section 1.4.3, which presents the country’s Generation Plan.

The Public Utilities Commission (PUC), a Government of Belize agency, has responsibility for the regulation of utilities including water, telephone services and electricity. Based on the projected energy demands for the nation, BEL under the PUC’s oversight is currently seeking to realize additional electrical generating potential of 40 MW and have invited international bids in two tranches – one for 25 MW (to be available by 2006/7) and one for 15 MW, (to be available early 2009) from different types of generation.

The PUC (Pers. Com., July 2005) has approved a transparent bidding process to be employed with set criteria for selection. The weighting of the criteria is as follows:

- Pricing (70 percent)
- Technical Aspects (15 percent)
- Socio-economic Aspects (15 percent)

The socio-economic aspects will include fulfillment of the EIA requirement and approval by the Department of the Environment. The final approval for any new generation source rests with the PUC.

1.4.1 CURRENT ENERGY SOURCES

1.4.1.1 The Belize Energy Supply
The energy requirements of Belize are currently met using a combination of generation sources, including approximately 35 MW of thermal diesel fired units, the 25 MW run-of-river Mollejón hydroelectric plants, which now has storage provided by the Chalillo (Macal River Upstream Storage Facility (MRUSF)) storage dam which doubles the available energy from the Macal River. Chalillo also increases the average hydro
capacity by about 7.3 MW. Additionally, Belize has a 25 MW supply from CFE in Mexico via a single circuit 115 kV transmission line. Because of the high cost of peak power supplied from Mexico, every effort is made not to dispatch it during the peak hours – which are between 18:00 and 21:00 hours, Monday through Friday. The Mollejón facility is dispatched on a first priority basis during the peak period because of its cost advantage over the Mexican peak and diesel generation costs. Mollejón is used during other periods to optimize hydro production and the use of available water and to minimize cost of power.

A number of other generation plants are under construction or have signed agreements with BEL and are programmed to come on line in later years. Hydro Maya Limited is developing a hydroelectric facility on the Rio Grande River in Toledo that will provide as much as 3.4 MW of capacity to the grid early in 2006. BELCOGEN, a company with Belize Sugar Industries as the primary shareholder, will be developing a bagasse fired generation facility at the Tower Hill sugar factory in Orange Walk Town and have signed a Power Purchase Agreement (PPA) for the supply of up to 13.5 MW of capacity to the grid in 2007.

However, for the country to achieve long-term sustainable development, it needs to secure alternative in-country generation sources into the future that are least cost, economic, reliable and that will become the primary base load sources of electricity supply to consumers, reducing reliance on more costly energy sources indexed to world oil prices.

Details of the existing supply and the dispatch procedures are presented in the “No Action Plan” also included in this section.

1.4.1.2 Issues Related to the Purchase of Energy from Mexico

Currently, Belize relies heavily on Mexico for electricity. In 2004, 62 percent of the annual electricity requirements were met through purchases of electricity from CFE of Mexico. The dependence on Mexico is of considerable concern when considering the security of energy supply in Belize. Due to its dependency on the CFE supply, Belize
experiences rotating power interruptions whenever the supply from Mexico is unavailable and in-country sources are less than system peak demand requirement. The 22.8 MW ISO rated gas turbine unit installed in 2003 to reduce the reliance on Mexico has been effective, but the rising demand (with projected growth rate of 6.2 percent per annum and high side potential of 8.2 percent in the 10 year planning period) along with rising fuel prices makes it necessary to seek additional in-country sources.

Apart from the security and reliability concerns, BEL considers the present contract with CFE to be good. However, it is limited to 25 MW and CFE has opted to exercise an early exit clause in 2004 for the contract to expire in 2006. Early indications to BEL are that CFE is interested in renewing the supply contract but at a new price that could be at least 30 percent higher than the existing contract and at a tariff that will still be linked to the world oil/gas price. Whatever the outcome of current negotiations for a new supply contract, the results will have a very important effect on the energy sector in Belize. Without Mexican electricity supply or with a CFE contract meeting only a part of what is needed, the resulting energy shortfall will be added to the additional energy which the country has to produce. Whether or not an agreement can be struck between Mexico and Belize will depend on factors such as:

The availability of excess electricity in Mexico for export (depending on Mexican production, internal needs and political will);

An acceptable purchase price for electricity.

Within this context, it will be very important for the country to have electrical generation sources ready to be put on line in the short term if an agreement cannot be reached.

Under the contract which expires in 2006 Mexico provides favorable off-peak rates. But the price on peak is over 5 times the off-peak rate and alternate supply is dispatched by BEL to shelter consumers from these very high on-peak prices. Up to the time of the preparation of this report, indications are that the peak and off-peak energy rate will be eliminated and that CFE will offer a tariff that is insensitive to time of use. Due to the current configuration of the equipment installed at the Xulha substation, no more than
40 MW of power can be transferred to Belize from Mexico, but this constraint might be removed and power transfer availability may increase. The term of the last power supply contract was 15 years, and BEL believes that any new contract is likely to be similar.

Capacity problems arise during the dry season when the Mollejón plant output is reduced due to the lack of storage and low river flows, considerably reducing the energy output of the plant. The MRUSF will considerably improve the dry season output of Mollejón; however, new generation will still be required into the future as this added capacity is absorbed by rapid growth and as older diesel plants are retired.

1.4.2 LEAST COST GENERATION - STONE & WEBSTER STUDY

1.4.2.1 Electricity Sales Forecast for Belize

In 2004, SWMCI was contracted by BEL to conduct a cost of service and tariff study which includes a forecast of electricity sales for the period 2004 – 2014 for BEL’s interconnected grid which includes the areas of Belize City, Belmopan, Corozal, Orange Walk, Dangriga, San Pedro, Independence, Punta Gorda, and for the off grid area of Caye Caulker. Results of this study were released in the SWMCI report *Cost of Service and Tariff Study*, dated April 2005.

In this study, a two-stage process was employed by SWMCI to produce BEL’s energy forecast which was then compared with the electricity sales growth forecast provided by BEL and the sales forecast from the 1999 GE least cost expansion study. A multivariable regression analysis was conducted on a national level considering the total energy sales as the dependent variable and population and gross domestic product (GDP) as the independent variables. Additionally, the GDP as a measure of the country’s economy is generally correlated with the electricity sales, since electricity supply is one of the basic services required for the development of the majority of the activities that contribute to the GDP. This initial approach only provided results on a national level, and the generation and transmission planning component of the SWMCI study required the separation of the results by load center. Therefore, a zone-by-zone regression analysis
was conducted. With the results at the national and zone level analysis, three energy sales scenarios were defined and load forecasts for each zone were generated.

The following scenarios were considered for the electricity energy sales forecast.

**Base Scenario:** A linear multivariable model with the forecast for the independent variables based on the GDP annual growth according with Belize Central Bank average expectations (5.375 percent), and on the population historical average growth rate (2.811 percent).

**Low Scenario:** A linear multivariable model with the forecast for the independent variables based on the GDP annual growth according with International Monetary Fund expectations (4.4 percent) and on the population historical average growth rate (2.811 percent).

**High Scenario:** Based on the linear multivariable model with the polynomial forecast for the independent variables.

Using the real sales data up to September 2004, the expected value at the end of 2004 was estimated to be 330,000 MWh. This last value was used as the basis for the rest of the forecast using the annual growth rates calculated by the model.

Figure 1.4.2.1 shows the final total results and compares them with BEL forecast.

The annual rates of growth were obtained for each scenario and are given in Table 1.4.2.1.

**Table 1.4.2.1: Annual Rates of Growth for Three Scenarios**

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>BASE</th>
<th>HIGH</th>
<th>LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERIOD 2004-2009</td>
<td>6.28%</td>
<td>8.92%</td>
<td>5.48%</td>
</tr>
<tr>
<td>PERIOD 2009-2014</td>
<td>5.85%</td>
<td>7.88%</td>
<td>5.19%</td>
</tr>
<tr>
<td>PERIOD 2004-2014</td>
<td>6.10%</td>
<td>8.40%</td>
<td>5.30%</td>
</tr>
</tbody>
</table>

BEL’s historical average annual growth rate in electricity sales for the 1983-2003 period is 9.92 percent. The fact that the forecast rates for all the scenarios are below the
historical trend reflects the expectation that the Belizean economy will grow more moderately in the future.

Figure 1.4.2.1 (b) shows the base scenario forecast for each zone or load center.

Figure 1.4.2.1 (b) Base Scenario Zone Forecast


In summary, according to SWMCI, based on the expected population and GDP projection for the country of Belize, electricity sales for the total country are expected to grow at a future rate somewhat slower than was historically experienced, but as this growth is based on a larger sales base, it is still significant. Total electricity sales should achieve a level of about 600,000 MWh by the year 2014, with a potential upside of approximately 740,000 MWh.

The three scenarios shown in figure 1.4.2.1 served as a basis for a generation and transmission cost analysis which was one of the inputs to cost allocation procedure for the tariff design developed by SWMCI as a part of the study.

The above data shows that even under the pessimistic scenario, electricity sales will have
doubled between 2004 and 2014. These projections clearly indicate that improved and/or additional production capabilities will be necessary to meet the expected demand.

1.4.3 GENERATION EXPANSION PLAN

1.4.3.1 The Need for an Expansion Plan
The available generation capacity existing in Belize in mid 2005 is comprised of: Mollejon Hydro 25 MW; existing diesel engines 16 MW and a diesel fired gas turbine of 22.8 MW ISO rating. The power supply is completed with the international transmission link with CFE with a 25 MW capacity (the power purchase contract of which expires in 2006) and the Chalillo scheme that will add 7.3 MW of capacity in the later part of 2005. The need for an expansion plan to meet future demand requirement is based on the projected demand into the future, the high cost of the fossil fuel generation sources available to the country, and the limitations and risks associated with reliance on energy imports from Mexico or any outside country. Technically and economically speaking, the selection of the means to be put in place to meet the expected demand is based on a least-cost approach, as recommended by SWMCI.

1.4.3.2 Peak Demand Growth Forecast
Table 1.4.3.2 (a) and 1.4.3.2 (b) show the energy and peak load forecast used as the basis for the system planning. Average annual growth rates are shown at the bottom of the tables.
Table 1.4.3.2.a Annual Energy Forecast Generation Level

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total System Generation (GWh)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Base</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>315.244</td>
<td>315.244</td>
<td>315.244</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>347.757</td>
<td>347.757</td>
<td>347.757</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>373.291</td>
<td>373.291</td>
<td>373.291</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>408.261</td>
<td>397.910</td>
<td>394.386</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>445.340</td>
<td>423.218</td>
<td>416.400</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>485.033</td>
<td>449.691</td>
<td>439.262</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>527.340</td>
<td>477.387</td>
<td>463.003</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>572.262</td>
<td>506.365</td>
<td>487.661</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>619.798</td>
<td>536.688</td>
<td>513.271</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>669.950</td>
<td>568.423</td>
<td>539.872</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>722.717</td>
<td>601.640</td>
<td>567.503</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>778.099</td>
<td>636.411</td>
<td>596.206</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>836.096</td>
<td>672.815</td>
<td>626.023</td>
<td></td>
</tr>
</tbody>
</table>

|       | Total System                  |       |       |       |
|       | Generation (%)                |       |       |       |
|       | High                          | 8.468% | 6.522% | 5.884% |


Table 1.4.3.2 b Peak Load Forecast Generation Level

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total System Peak Load (MW)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Base</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>53.720</td>
<td>53.720</td>
<td>53.720</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>57.381</td>
<td>57.381</td>
<td>57.381</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>67.886</td>
<td>66.157</td>
<td>65.565</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>74.093</td>
<td>70.410</td>
<td>69.270</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>80.741</td>
<td>74.859</td>
<td>73.119</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>87.830</td>
<td>79.515</td>
<td>77.117</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>95.361</td>
<td>84.388</td>
<td>81.269</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>103.333</td>
<td>89.488</td>
<td>85.583</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>111.746</td>
<td>94.826</td>
<td>90.063</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>120.602</td>
<td>100.414</td>
<td>94.718</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>129.901</td>
<td>106.265</td>
<td>99.554</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>139.641</td>
<td>112.392</td>
<td>104.579</td>
<td></td>
</tr>
</tbody>
</table>

|       | Total System                  |       |       |       |
|       | Peak Load (%)                 |       |       |       |
|       | High                          | 8.286% | 6.345% | 5.708% |


The peak demand forecast in Table 1.4.3.2 c shows the need for generation addition that must be made during the 10 year planning period (on a gross generation basis), especially
given the uncertainty surrounding the Mexican supply and the excess of available capacity over the existing demand needed to ensure the reliability of supply to consumers as expressed by the Loss of Load Probability (LOLP) target set by the regulatory authority. The SWMCI study proposes to meet this demand growth recommending the installation of the generating units shown in Figure 1.4.3.2 c below. Uncommitted to sources such as GT-2 to GT-4 and VACA are assumed to be the least cost options but may change during more rigorous economic analysis.

Figure 1.4.3.2 c Supply – Peak Load Balance

1.4.3.3 Conclusions from SWMCI Study

Major conclusions of the April 2005 Stone & Webster study are:

. The most economic plan for BEL at this time is to pursue a new contract with Mexico as long as the new price is cheaper than that of other alternative sources.

. The additional capacity and associated energy from the Chalillo scheme has been factored in but new generation additions will still be needed during the planning period.

. The additional capacity and associated energy from the Hydro Maya scheme has been factored in but new generation additions will still be needed during the planning period.

. The additional capacity and associated energy from the BELCOGEN bagasse fired plant has been factored in but new generation additions will still be needed.

. For peaking and emergency back-up, BEL should continue to concentrate on adding gas turbine generator units at the time period indicated in the plan. (However, this would only be a viable option if BEL could be assured of a continued and reliable supply of cheap off-peak energy from CFE).

1.4.3.4 No Action Plan

This section provides a “No Action Plan” for Belize with regards to the economic advantages/disadvantages in the event that the proposed RFP for additional supply is not implemented. This plan commences in Section 1.4.3.4.1, with a description of the Belize energy situation in which the existing supply, the energy sales and demand forecasts, and the current planning criteria are discussed.
The “No Action Plan” is presented and the capacity deficit of the country, with and without new generation additions after BELCOGEN, is discussed. The various options for increasing capacity are summarized and, finally, the conclusions reached as to the necessary developments in the event of the RFP not proceeding.

1.4.3.4.1 Belize Energy Situation

1.4.3.4.1.1 Existing Supply

The energy requirements of Belize are currently met using a combination of generation sources, including the 35 MW of diesel fired thermal generators, the 25 MW run-of-river Mollejón hydroelectric plant and a 25 MW supply from CFE in Mexico via a single circuit 115 kV transmission line. Because of the high cost of peak power supplied from Mexico, every effort is made not to dispatch it during the peak hours – which are between 18:00 and 21:00 hours, Monday through Friday. The Mollejón facility is dispatched on a first priority basis during the peak period because of its cost advantage over the Mexican peak and diesel generation costs. Mollejón is used during other periods to avoid spilling water.

A number of other generation plants are under construction or have signed agreements with BEL and are programmed to come on line in the near future. The Macal River Upstream Storage Facility (MRUSF) at Chalillo is in the final phase of construction and is expected to come on stream in the later part of 2005 which will add 7.3 MW of capacity, provide needed regulation for the Mollejon run-of-river scheme and result in a doubling of the annual energy production from that plant. Hydro Maya Limited is developing a hydroelectric facility on the Rio Grande River in Toledo that will provide as much as 3.4 MW of capacity to the grid early in 2006. BELCOGEN, a company with Belize Sugar Industries as the primary shareholder, will be developing a bagasse fired generator facility at the Tower Hill sugar factory in Orange Walk Town and have signed a memorandum of understanding for the supply of up to 13.5 MW of capacity to the grid in 2007.
For the country to achieve long-term sustainable development, it needs to secure other alternative in-country generation sources far into the future that are economic, more reliable and that will become the primary base load sources of electricity supply to consumers and reduce its reliance on more costly energy sources with rates linked to world oil prices.

**Table 1.4.3.4.1: Sources of Energy and Dispatch Criteria**

<table>
<thead>
<tr>
<th>Source</th>
<th>Dispatch Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>Two diesel plants exist, one at Belize City, the other at Belmopan and two standby plants are located at San Pedro and Independence. A diesel fired gas turbine unit is also available for dispatch near the West Substation. Use is minimized during off peak hours and maximized during peak hours.</td>
</tr>
<tr>
<td>Mollejón</td>
<td>The Mollejón hydroelectric plant has a nominal rating of 25.2 MW and can reliably supply about 80 GWh annually. During the dry season the continuous base load capability is 0 MW and the 3-hour capability is 6.5 MW. Dry season continuous base load capability should increase to 5 MW after Chalillo goes into operation. During the wet season the continuous base load capability is 15 MW and the 3-hour capability is 28 MW. The plant is dispatched first for peak and otherwise to take advantage of available water.</td>
</tr>
<tr>
<td>Mexico</td>
<td>The Mexican supply can provide 25 MW at all times, but the rates during peak hours, which are 5 times the base rate, require that dispatch during peak hours be limited.</td>
</tr>
</tbody>
</table>
The energy supply capability of existing and generation sources already programmed to come on stream are:

<table>
<thead>
<tr>
<th>Source</th>
<th>Capability in GWh</th>
<th>Year available</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFE</td>
<td>220</td>
<td>On-line</td>
</tr>
<tr>
<td>Diesel</td>
<td>110</td>
<td>On-line</td>
</tr>
<tr>
<td>Mollejón run-of-river</td>
<td>80</td>
<td>On-line</td>
</tr>
<tr>
<td>Mollejón with Chalillo</td>
<td>80 (additional)</td>
<td>2006</td>
</tr>
<tr>
<td>Hydro Maya</td>
<td>13</td>
<td>2006</td>
</tr>
<tr>
<td>BELCOGEN</td>
<td>70</td>
<td>2008</td>
</tr>
</tbody>
</table>

1.4.3.4.1.2 Energy Sales And Demand Forecast

Sales growth over the 1993 – 2003 period averaged approximately 9.92 percent. This relatively high level of growth, fuelled by continued strong economic performance, is not expected to be sustained in the future. The latest projections from a Cost of Service and Tariff Study conducted in June 2005 are that both energy sales and demand will grow at about 6 percent on average over the next 10 years. The gross generation required to meet energy sales and demand forecast based on projected increases in the Belize GDP and Population Growth Rate for the period 2005 to 2014 are shown below.
Table 1.4.3.4.1.2 a: Gross Generation Required to Meet Energy Sales and Demand Forecast

<table>
<thead>
<tr>
<th>Year</th>
<th>Total System Gross Generation GWh - Growth %</th>
<th>Grid Peak Demand MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>397.9 - 6.59%</td>
<td>66.1</td>
</tr>
<tr>
<td>2006</td>
<td>423.2 - 6.36%</td>
<td>70.4</td>
</tr>
<tr>
<td>2007</td>
<td>449.6 - 6.25%</td>
<td>74.8</td>
</tr>
<tr>
<td>2008</td>
<td>477.3 - 6.16%</td>
<td>79.5</td>
</tr>
<tr>
<td>2009</td>
<td>506.3 - 6.07%</td>
<td>84.3</td>
</tr>
<tr>
<td>2010</td>
<td>536.6 – 5.99%</td>
<td>89.5</td>
</tr>
<tr>
<td>2011</td>
<td>568.4 – 5.91%</td>
<td>94.8</td>
</tr>
<tr>
<td>2012</td>
<td>601.6 – 5.84%</td>
<td>100.4</td>
</tr>
<tr>
<td>2013</td>
<td>636.4 – 5.78%</td>
<td>106.3</td>
</tr>
<tr>
<td>2014</td>
<td>672.8 – 5.72%</td>
<td>112.4</td>
</tr>
</tbody>
</table>

It is important to note that the forecast above is for the base case only, wherein the growth rate for both energy and demand averages 6 percent. There is an upside growth rate potential for both energy sales and peak demand of 8 percent which would produce the projections as shown in Table 1.4.3.4.1.2 b:

Table 1.4.3.4.1.2 b: Energy Sales and Demand Forecast

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Sales System Grid Generation GWh - Growth %</th>
<th>Grid Peak Demand MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>408.2 – 9.36%</td>
<td>67.8</td>
</tr>
<tr>
<td>2006</td>
<td>445.3 – 9.08%</td>
<td>74.1</td>
</tr>
<tr>
<td>2007</td>
<td>485.0 – 8.91%</td>
<td>80.7</td>
</tr>
<tr>
<td>2008</td>
<td>527.3 – 8.72%</td>
<td>87.8</td>
</tr>
<tr>
<td>2009</td>
<td>572.2 – 8.52%</td>
<td>95.3</td>
</tr>
<tr>
<td>2010</td>
<td>619.7 – 8.30%</td>
<td>103.3</td>
</tr>
<tr>
<td>2011</td>
<td>669.9 – 8.09%</td>
<td>111.7</td>
</tr>
<tr>
<td>2012</td>
<td>722.7 – 7.87%</td>
<td>120.6</td>
</tr>
<tr>
<td>2013</td>
<td>778.0 – 7.66%</td>
<td>129.9</td>
</tr>
<tr>
<td>2014</td>
<td>836.0 – 7.45%</td>
<td>139.6</td>
</tr>
</tbody>
</table>
1.4.3.4.1.3 Planning Criteria

The existing generation criterion is to provide system reliability to a target Loss of Load Probability (LOLP) of 2 days per year, which is a target generally accepted and used by utilities for generation planning. An additional criterion was added after a series of outages on the 25 MW intertie with CFE. CFE has confirmed that Belize is assigned a lower priority than CFE’s customers in Mexico. As a result, the interconnection to Belize is cut at the first sign of problems and, on several occasions, power to Belize has been curtailed over peak so Mexico could meet their own requirements. The revised generation planning criteria is that adequate base and peak load generation must be available in Belize to meet peak demand less generation capacity available from industrial customers with ability to self generate (approximately 3 MW) and that a system LOLP target of 2 days/yr or less shall be maintained.

Once the capacity criterion is met the next step is to meet the energy needs of the system instantly and continuously on demand at minimum cost. To meet the energy needs of the system, base load and peaking units are employed. These units are dispatched at all times under the minimum cost criteria. With the energy capability of the existing sources limited to the values shown in the section Existing Energy Supply Capability, additional plants are required to meet the energy demanded by customers after 2009 (taking into account a suitable reserve margin).

1.4.3.4.2 Capacity Deficit without Generation Additions after Belcogen

If additional capacity is not built, the system capacity deficit is shown in the table below:
### Table 1.4.3.4.2 a: Base Demand Forecast Scenario

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand MW</th>
<th>Capacity Reserve/Deficit W CFE MW</th>
<th>Capacity Reserve/Deficit W/O CFE MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>66.5</td>
<td>5.5</td>
<td>-19.5</td>
</tr>
<tr>
<td>2006</td>
<td>69.8</td>
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<td>-27.0</td>
<td>-50</td>
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<td>-26.3</td>
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<td>114.4</td>
<td>-32.4</td>
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<tr>
<td>2014</td>
<td>120.7</td>
<td>-38.7</td>
<td>-61.7</td>
</tr>
</tbody>
</table>

*Notes: Hydro Maya (0.5 MW capacity) added in 2006, Mollejon/Chalillo upgraded to 27 MW capacity in 2006, 2 MW of diesels retired in 2007, BELCOGEN added in 2008 and 2 MW of diesels retired in 2009.*

### Table 1.4.3.4.2 b: High demand Forecast Scenario

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand MW</th>
<th>Capacity Reserve/Deficit W CFE MW</th>
<th>Capacity Reserve/Deficit W/O CFE MW</th>
</tr>
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<tr>
<td>2014</td>
<td>123.0</td>
<td>-39.0</td>
<td>-64.0</td>
</tr>
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</table>

*Notes: Hydro Maya (0.5 MW capacity) added in 2006, Mollejon/Chalillo upgraded to 27 MW capacity in 2006, 2 MW of diesels retired in 2007, BELCOGEN added in 2008 and 2 MW of diesels retired in 2009.*
With only CFE and the programmed generation additions of Hydro Maya and BELCOGEN, the peak demand of the system will be met using available sources until 2008 after which there will be a capacity deficit, which increases each year. Delaying new generation addition past 2009 imposes a serious shortfall of capacity which will inevitably cause power interruptions.

Without generation additions and in the base case scenario, the system capacity goes into a deficit in 2007, which can be met with short term diesel rental. The addition of BELCOGEN in 2008 will provide temporary reprieve, but the system goes into deficit again in 2009. In the high-growth scenario the capacity deficit is exacerbated. At these levels high-speed diesels are not an attractive option as they are expensive to operate as base load units. The Mexican supply is utilized during off peak hours because of competitive rates and will continue to be so utilized as long as the existing rate structure and associated price signal justifies this mode of dispatch. Therefore, the generation source chosen next must be capable of providing capacity during peaking hours and backup should the Mexican supply fail during off-peak hours.

If a new supply contract with Mexico does not materialize or if the Mexican supply fails, the problem is further exacerbated and there would be hourly energy shortage during off peak hours amounting to 25 MW. This deficit is more than 50% of Belize’s current demand and is not easily met.

1.4.3.4.3 Capacity Deficit With New Generation Addition

The following tables show the system capacity deficit (for base case and high growth scenarios) both with and without CFE and with the addition of new generation sources to complement future capacity. The addition of a new source of generation would clearly provide the reserve capacity that the system needs to ensure a high level of in-country supply to support the economic growth of the country.
Table 1.4.3.4.3 a: Base Case Scenario

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand</th>
<th>Capacity</th>
<th>W CFE</th>
<th>W/O CFE</th>
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<tbody>
<tr>
<td></td>
<td>MW</td>
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<td>2005</td>
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<td>120.7</td>
<td>98</td>
<td>-22.7</td>
<td>-47.7</td>
</tr>
</tbody>
</table>

Note: New generation source on-line by 2009 adding 14 MW (net) of capacity to system (some capacity removals)

Generation excess capacity increases to 14.5 MW if 18 MW generation source is added in 2009. But there will be a need for additional generation additions in ensuing years as this reserve is absorbed quickly by demand growth, as shown in the base case scenario above.

Table 1.4.3.4.3 b: High Growth Scenario

<table>
<thead>
<tr>
<th>Year</th>
<th>Grid Peak Demand</th>
<th>Minimum Available Capacity</th>
<th>Capacity Reserve/Deficit W CFE</th>
<th>Capacity Reserve/Deficit W/O CFE</th>
</tr>
</thead>
<tbody>
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<td>123.0</td>
<td>98</td>
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<td>-50.0</td>
</tr>
</tbody>
</table>

Note: New generation source on-line by 2009 adding 14 MW (net) of capacity to system
In the high-growth scenario and with the addition of 18 MW of new generation capacity, the capacity deficit is more pronounced and suitable base load generation options must be pursued which will conform to the least cost generation planning criteria.

1.4.3.4.4 Conclusions of the No Action Alternative

1. In the event that a new source is not built, the resulting capacity deficit would be 14.8 MW in 2010 with the CFE interconnection. This deficit must be met at the least cost.

2. Simple cycle gas turbines can address this deficit in the short term but would not meet the least cost generation criteria due to the high cost of fuel. Thermal plants would also not comply with the National Energy policy stress on the minimization of green house gas emissions.

3. Without CFE the capacity deficit would have been approximately 19.5 MW in 2005 and this increases to 61.7 MW by 2014 in the base case scenario. In the upside growth scenario the capacity deficit may be 3 – 4 MW higher.

4. If available, increasing Mexico’s supply for capacity means depending on a foreign supply for more than 50 percent of capacity. This is an unacceptable planning criteria, and Mexico will only be considered for part of the energy deficit.

5. Peak capacity and energy charges from Mexico are prohibitively expensive under the current cost structure. There is much uncertainty on the availability of supply from Mexico as the current contract expires in 2006. Early indications are that a tariff structure insensitive to time of day might be offered to replace the current contract. But the new price is likely to be at least 30 percent above the current average tariff or higher.
The dispatching strategy will need to be adjusted when the situation is clearly known. Moreover, increasing the supply beyond the existing 25 MW requires a study of the interconnection constraints both in Mexico and Belize to determine if existing substations and transmission lines need to be upgraded.

PART 2

*This segment of the No Action plan was developed by BECOL*

1.4.4 THE VACA HYDROELECTRIC PROJECT

1.4.4.1 Need for Additional Generation

As highlighted in Part 1 of this Project Justification section, the energy demand in Belize has grown at a rate of about 10 percent per year and is forecast to continue at about 6 percent per year for the next five years.

In order to meet growing energy needs, Belize will have to increase its power generation capabilities in the medium term and, in addition, compensate for any energy shortfall that could result from termination or reduction of supply from external contracts. Over the years, BEL has been using different methods for power generation and proposes to meet energy needs with different tools selected from internal sources on the basis of least cost as determined by an RFP process.

1.4.4.2 The Options

It appears to BECOL that various options are available to BEL to meet the energy needs to increase the installed capacity in Belize. To meet the additional requirement, the generation source selected must be the next least cost option. Some of the options along with associated considerations are noted below:

1. Develop the hydro potential of Vaca Falls.
Considerations for this option are:

a) With the Chalillo reservoir in place, Vaca seems to meet the requirements for the least cost base load generation option.

b) A new hydro facility such as Vaca reduces air emissions.

c) A new hydro facility reduces country dependence on imported oil.

d) A new hydro facility reduces dependence on foreign energy sources.

e) A new hydro facility at Vaca is a renewable energy source.

2. Purchasing more than the 25 MW from Mexico. The following issues pertaining to this option would need to be considered:

a) Increased reliance on energy from foreign sources.

b) Mexican prices are tied to world market fuel prices, which have increased 35 percent over the past years.

c) Security of supply is questionable based on recent performance.

d) Substations and transmission lines capability may need upgrading.

3. Install an additional 20 MW site-rated, diesel-fired gas turbine on the electrical grid in Belize. Considerations for this option are:

a) High fuel costs which make these units unsuitable for base load dispatch.

b) Increased air emissions.

c) Quick start capability.

d) Non-renewable resource.

e) Production costs tied to world oil prices.

4. Other small hydro potential of hydro sites countrywide, especially in the Southern districts. Considerations include:
a) Good balance with load distribution
b) Long lead time to construct
c) Very small in capacity which typically increases cost.
d) A renewable resource

1.4.4.3 BECOL’S Response
BECOL has submitted the Vaca Hydroelectric Project in response to a RFP from BEL and the PUC and feels it should be accepted based on the following key issues.

1) The Vaca Hydroelectric Project is likely to be the most economical option for supply of the almost 18 MW of installed capacity of all the options available within Belize. The RFP process will confirm this point.

2) The Vaca Hydroelectric Project is technically viable and will maximize the hydroelectric potential of the Macal River given that the Mollejón dam and the Chalillo Upstream Storage Facility are already in place.

3) The Vaca Hydroelectric Project will help decrease energy reliance on sources outside of the country, decrease requirements for imported fuel, and minimize greenhouse gas emissions.

4) The Vaca Hydroelectric Project will decrease the need for imported fuel oil.

5) The Vaca Hydroelectric Project will help stabilize electric energy prices in Belize as the output cost is not tied to world oil prices.

6) The Vaca Hydroelectric Project will minimize greenhouse gas emissions associated with electric power production.

7) The Vaca Hydroelectric Project offers flexibility to BEL that will translate into better
overall service to its customers.

8) The Vaca Hydroelectric Project, in conjunction with the MRUSF and Mollejon, will provide flood control benefits to downstream area stakeholders.

As with any other power generation option, the Vaca Hydroelectric Project does entail environmental and social impacts. These are the subject of the full Vaca Hydroelectric Project EIA of which this Project Justification forms a part. It is the objective of the EIA to detail the consequences, both positive and negative, and to propose a strong project Mitigation and Management Plan to help offset and reduce negative impacts to acceptable feasible levels.

1.4.4.4 The Public Utilities Commission

The foregoing section presents BECOL’s justification for the Vaca Hydroelectric project with significant input from BEL. The Public Utilities Commission (PUC), a Government of Belize agency, has responsibility for the regulation of utilities including water, telephone services and electricity. Based on the projected demands for the nation the PUC is seeking to realize electrical generating potential of 40 MW, and have invited international bids in two tranches – one for 25 MW and one for 15 MW, (to be available early 2009) from different types of generation. Details of the Vaca Hydroelectric Project being investigated in this EIA report may be submitted by BECOL to the PUC when the invitation to tender is given for the supply of 15 MW.

The PUC has indicated to ESL Management Solutions Ltd., (July 2005) that a transparent bidding process will be employed with set criteria for selection. The weighting of the criteria is as follows:

- Pricing (70%)
- Technical Aspects (15%)
- Socio-economic Aspects (15%)
The socio-economic aspects will include fulfillment of the EIA requirements, and approval by the Department of the Environment. The PUC is the agency responsible for the ultimate decision on the selection of the power generating scheme to be implemented. This final decision rests entirely with the Public Utilities Commission, and not with BECOL.
2.0 Potential Areas of Impact

2.1 Study Area – Footprint of the Project and Sphere of Influence

The Vaca Hydroelectric Project is a run-of-the-river scheme proposed to be constructed either 3.5 km downstream (Site A) or 5.8 km downstream (Site B), from the existing Mollejon Power House. The project if situated at Site A would comprise a diversion dam, with an uncontrolled overflow spillway, a 2.96 km tunnel and an 18 MW powerhouse situated just below the Vaca Falls. At Site B, the project, would involve a diversion dam with an uncontrolled overflow spillway, a penstock and an estimated 17.8 MW powerhouse situated at the toe of the dam. The specific location of the dam at either Site A or Site B will be determined by BECOL, and will be based on the environmental assessment of both sites as well as on other technical considerations.

A significant stretch of the Macal River is being considered for the two site alternatives under investigation. (See Plate 2.1, a-e)
Plate 2.1 a, b, c, d & e – Aerial Photos of Macal River Looking Upstream from Vaca Falls to Mollejon Power Station

Plate 2.1 a: Macal River at Site B above Vaca Falls

Plate 2.1 b: Macal River above Site B.

Plate 2.1 c: Macal River between Site A and Site B
Plate 2.1 d: Site A. Confluence of Macal River (right) and Rio On (left)

Plate 2.1 e: Macal River just above confluence with Rio On

Plate 2.1 f: Macal River below Mollejon Power Generating Plant
It is expected that the channel sides in the vicinity of the impoundment would be occupied by elevated water levels, while the spillway, possible tunneling and generating facility would require the modification of several hectares of land.

As a run-of-the-river facility, the direct area covered by the Vaca project is not expected to be very large. Attendant facilities for the construction and operation of the project would include quarries, access roads and transmission lines.

The sphere of influence of the project has been considered in the context of the drainage basin and watershed of the Macal River immediately upstream and downstream of the facility. The EIA attempts to delineate and describe the sphere of influence in the context of projected impacts of the project on the natural as well as the built realms of the environment. Assessment of the sphere of influence indicates the following aspects:

- The Macal River area south of the Mollejon powerhouse to the area north of Vaca Falls
- The Mollejon Dam
- The Macal River Basin
- The Macal River Channel
- The surrounding forests and habitats
- Communities upstream and downstream

### 2.2 The Macal River Basin

The Macal River is a major tributary of the Belize River. It originates at Baldy Sibun on the western flanks of the Maya Mountains at an elevation of approximately 800 m and flows northerly to drain the Mountain Pine Ridge and eastern slopes of the Vaca Plateau. The watershed boundary for the Macal River is shown in Figure 2.2.

The river and its tributaries in the upper watershed have typically flat gradients of between 0.2% and 2% in the reaches down to the Guacamallo Bridge, which is some 58
km from the source at Baldy Sibun. The main valley is generally wide with flat lower banks and gently rising upper slopes.

The middle reach of the channel extends from the confluence with the Raspaculo tributary to Vaca Falls. The section is bedrock controlled, and towards the lower end the valley narrows and is characterized by extensive rapids and small waterfalls. The river gradient increases to around 3%.

Downstream of Vaca Falls, the Macal River gradient flattens to an average of 0.13% as it meanders through the foothills of the Mountain Pine Ridge past the village of Cristo Rey. The Macal River joins the Mopan River to form the Belize River at about 3 km north of San Ignacio. The total drainage area of the Macal above this confluence is about 1,463 km². (See Plate 2.2, a-g).

Much of the uppermost watershed area is remote and undisturbed, but the central section of the basin, in which lies the project, exhibits land clearing, tree cutting, logging camps and trails, some of which have been abandoned.

Plate 2.2 a-g shows areas of the Macal River Basin within the sphere of influence of the project.

Plate 2.2 a: Mollejon Reservoir and Upstream
Plate 2.2 b: The Mollejon Reservoir

Plate 2.2 c: Macal River at Black Rock

Plate 2.2 d: Macal River at Chaa Creek
Plate 2.2 e: Macal River at Cristo Rey

Plate 2.2 f: Macal River at San Ignacio

Plate 2.2 g: Macal River (right) at confluence with Mopan River to form the Belize River
Figure 2.2: Macal River Watershed Boundary
3.0 Policy, Legal and Administrative Framework

The main statutory instrument to be applied to this Environmental Impact Assessment is the Environmental Protection Act, No. 22 of 1992 – Environmental Impact Assessment Regulations, and revised in 2000. This instrument details the minimum requirements for the EIA, categories of projects requiring an EIA, the details of the EIA report and the identification of significant environmental impacts. The Environmental Impact Assessment Regulations made by the Minister of Tourism and the Environment are administered by the Department of the Environment (DOE), established under Section 3 of the Act.

The Terms of Reference (TOR’s) for conducting this EIA, approved by the Department of the Environment, are presented in Appendix II. The Curricula Vitae of the EIA preparers, as requested by the DOE in the TOR’s, are given in Appendix III.

3.1 Pertinent Regulations, Standards and Policies

The laws and regulations of Belize were reviewed, in an effort to identify those that are relevant to the proposed development. These laws have been sorted to provide a timeline to the project proponent as to when they are most crucial during the project cycle. Four phases of the project cycle are taken under consideration. These include:

1) The Planning and Development Phase
2) Construction and Implementation Phase
3) Operation and Maintenance Phase
4) Decommissioning and Abandonment Phase
3.1.1 PLANNING AND DEVELOPMENT PHASE

Environmental Protection Act:
Primary to the preparation process being undertaken by the proponent is the Environmental Protection Act, Chapter 328 of the Substantive Laws of Belize. Part III of the Environmental Protection Act is applicable to the proposed development as its focus is on the prevention and control of environmental pollution. Of greatest significance is Section 8, which prohibits the discharge of pollutants into the environment inclusive of lithosphere, hydrosphere and atmosphere and the related Pollution Regulations (S.I. 56 of 1996). The Pollution regulations are particularly important during the construction phase of the project, particularly in matters related to the establishment of workers facilities, solid waste and liquid effluent disposal and fuel/chemical storage.

Part V Section 20 (Subsection 1) indicates the need for an EIA, “Any person intending to undertake any project, programme or activity which may significantly affect the environment shall cause an environmental impact assessment to be carried out by a suitably qualified person, and shall submit the same to the Department for evaluation and recommendations.”

Subsections 2 through 5 provide an overview of the requirements of an EIA and are to act as a guide for the contracted preparers. The Department of the Environment took this guide into consideration in the development of the Terms of Reference.

(2) An environmental impact assessment shall identify and evaluate the effects of specified developments on-

(a) human beings;
(b) flora and fauna;
(c) soil;
(d) water;
(e) air and climatic factors;
(f) material assets, including the cultural heritage and the landscape;
(g) natural resources;
(h) the ecological balance;
(i) any other environmental factor which needs to be taken into account.

(3) An environmental impact assessment shall include measures which a proposed developer intends to take to mitigate any adverse environmental effects and a statement of reasonable alternative sites (if any), and reasons for their rejection.

(4) Every project, programme or activity shall be assessed with a view to the need to protect and improve human health and living conditions and the need to preserve the reproductive capacity of ecosystems as well as the diversity of species.

(5) When making an environmental impact assessment, a proposed developer shall consult with public and other interested bodies or organizations.

Section 21 of the Act allowed for the development of regulations to further guide the process. Under Section 5 and 6 of the Environmental Impact Assessment Regulations (S.I. 107 of 1995), sets out the requirements for the preparation of an EIA are as follows:

“An environmental impact assessment shall include at least the following minimum requirements---

a) a description of the proposed activities;

(b) a description of the potentially affected environment, including specific information necessary to identify and assess the environmental effect of the proposed activities;

(c) a description of the practical activities, as appropriate;
(d) an assessment of the likely or potential environmental impacts of the proposed activities and the alternatives, including the direct and indirect, cumulative, short term and long term effects;

(e) an identification and description of measures available to mitigate the adverse environmental impacts of proposed activity or activities and assessment of those mitigative measures;

(f) an indication of gaps in knowledge and uncertainty which may be encountered in computing the required information;

6. Whenever the Department determines that there is a need for an environmental impact assessment on a project, the environmental impact assessment process shall include:

(a) a screening of the project;

(b) a review by the National Environmental Appraisal Committee as provided in regulation 25 of these regulations;

(c) the design and implementation of a follow-up program. ”

Sections 14 through to 28 of the EIA Regulations describe the stages required to be undertaken by the proponents. Highlighted are those components deemed to be most critical by the reviewer.

Section 15 (1) The developer shall submit draft terms of reference in writing to the Department for the purposes of an environmental impact assessment.

Section 17 Where the terms of reference for the environmental impact assessment have been agreed between the developer and the Department, and approved in writing by the Department, the developer shall commence the environmental impact assessment and submit the same to the Department by the specified date.
The process described above was successfully undertaken allowing for the contracting of ESL for EIA preparation. (Approved Terms of Reference attached as Annex 1)

Section 18 (1) During the course of an environmental impact assessment, the developer shall provide an opportunity for meetings between the developer and interested members of the public, especially within or immediately adjacent to the geographical area of the proposed undertaking, in order:

(a) to provide information concerning the proposed undertaking to the people whose environment may be affected by the undertaking; and

(b) to record the concerns of the local community regarding the environmental impact of the proposed undertaking.

(2) At any time during an environmental impact assessment of a proposed undertaking the Department may invite written comments from interested persons concerning the environmental impact of an undertaking.

(3) The Department may forward the written comments under subsection (1) to the developer who shall answer any pertinent questions raised in such written comments.

(4) The procedure for public contact and involvement shall be determined by the Department.

Section 18 of the EIA Regulations provides for the participation of all stakeholders within the EIA process. Whilst the Regulations make reference to those persons within the immediate sphere of project implementation, the scope for consultations was expanded to include other areas as it was recognized that projects of this nature are of national importance and impacts may be far reaching. The procedure for public contact was prepared in consultation with the Department of Environment and the project developers.
Section 20 (1) A person who has submitted an environmental impact assessment shall, as soon as may be, publish in one or more newspapers circulating in Belize a notice:

(a) stating the name of the applicant;

(b) the location of the land or address in respect of which the environmental impact assessment relates;

(c) stating that application has been made and indicating the location and nature of the proposal to which the application relates;

(d) stating that an environmental impact assessment has been prepared in respect of the proposal;

(e) naming a place where a copy of the environmental impact assessment may be inspected free of charge;

(f) specifying the times and the period (being the prescribed period) during which the environmental impact assessment can be so inspected;

(g) stating that any person may during the prescribed period make objections and representations to the Department in relation to the effects of the proposed project activity on the environment;

(h) the date which the environmental impact assessment shall be available to the public;

(i) the deadline and address for filing comments on the conclusions and recommendations of the environmental impact assessment.
(2) An environmental impact assessment submitted by a developer shall be accompanied by a copy of a newspaper in which there has been published a notice in accordance with sub-regulation (1).

In the December 19th 2002 Supreme Court ruling of the honorable Chief Justice Conteh, the seemingly inconsistencies between Section 20 (1) of the EIA regulations and Section 20 (2) was assessed. In order to avoid difficulties which may be caused by perceived conflicts between these sections, it is proposed that an initial draft copy of the EIA document be submitted to the Department of Environment, upon the approval of the EIA, the required notifications be prepared and published. These notices should then accompany the Formal/ Final EIA document submitted to the department of the environment.

Section 24 (1) The Department, on the recommendation of the National Environmental Appraisal Committee, may require a public hearing in respect of any undertaking, project or activity in respect of which an environmental impact assessment is required pursuant to these regulations.

It is ultimately the decision of the Department of Environment in Consultation with the National Environmental Appraisal Committee to determine the need for a Public hearing. If deemed necessary by the DOE, the hearing may focus not only on the EIA but on the development being proposed.

Ancient Monuments And Antiquities Act (Chapter 330 Substantive Laws of Belize, Revised Edition 2000)
Under the Act an ancient monument refers to, “any structure or building erected by man or any natural feature transformed or worked by man, or the remains or any part thereof, whether upon any land or in any river, stream or watercourse or under the territorial waters of the country, that has been in existence for one hundred years or more” and an antiquity refers to, “any article manufactured or worked by man, whether of stone, pottery, metal, wood, glass, or any other substance, or any part thereof.”
Past Archeological mapping in the area have unearthed many such features heightening the importance of this act to proponents. Based on the Act, “All ancient monuments and antiquities however situate, whether upon any land or in any river, stream or watercourse, or under territorial waters of the country, and whether or not before the date of the commencement of this Act in private ownership, possession, custody or control, shall absolutely vest in the Government.” And subject to this Act, “no person shall possess or have in his custody or control any ancient monument or antiquity except under a licence in writing granted by the Minister in the prescribed form.”

Section 12 stipulates that any findings are to be reported to the Government of Belize.

“If any person finds any ancient monument or antiquity he shall within fourteen days of such finding report the details of the finding to the Minister.” This is important for contracted workers on project site.

Based on the initial assessment of the area to be carried out under the EIA, Section 16 of the Ancient Monuments and Antiquities Act provides for the recommendation for preservation of the area and the carrying out of the relevant excavation exercises or for the call for the demolishing of the structure/antiquity allowing development to proceeded as planned.

Proponents are to be mindful that under section 34 of the Act, “The Archaeological Commissioner may direct any land owner, lessee, concessionaire, contractor or any other person who is about to engage in any operation which in the opinion of the Archaeological Commissioner is liable to destroy, damage, interfere with or otherwise be to the detriment of any ancient monument or antiquity—

(a) not to proceed with any operation until the Archaeological Commissioner shall have had an archaeological exploration and survey carried out; and

(b) to take or to refrain or desist from taking any such action as part of the operation as the Archaeological Commissioner may decide
to be fair and reasonable for the proper protection of the ancient monument or antiquity.”

### 3.1.2 PERMITTING

Environmental Clearance of a project does not negate the need for relevant permits from the various permitting agencies overseeing various facets of development. Key to the permitting processes are the Department of Petroleum and Mines, Forest Department,

**Forest Act (Chapter 213 Substantive Laws of Belize, Revised Edition 2000, Subsidiary Laws 2003)**

As the planned facility is located within lands and is surrounded by lands declared as Forest Reserves under Part II Section 3 of the Forest Act, it must be ensured that all regulations under this Act be taken under consideration. The project lies within the boundaries of the Vaca Forest Reserve designated by SI 165 of 1991.

Section 3 of the **Forest (Protection of Trees) Regulations (S.I. 49 of 1992)** found in the Forest Act Revised Edition 2003, prohibits the conversion of certain species without obtaining a license. This is further reinforced under the Forest Rules, Part II Section 4.

*In any forest reserve or in national land or in any private land to which the provisions of the Act have been applied, no person shall except by virtue of and subject to the conditions of any licence granted in that behalf-

(a) cut, girdle, burn or injure any tree;

(b) collect, prepare, use or remove any forest produce.*

Section 5 refers to the type of licenses granted by the Forest Department. As clearance of tree cover is expected in preparation for the construction and impoundment phase of dam development, based on the options provided, the proponents based on the planned activities will require the license described under option “b” that is a **“forest licence not on a sustained yield basis for the working of timber or other forest produce, except chicle or crown gum and whether in a timber salvage area or not.”**
“No person shall convert any species of primary hardwoods, secondary hardwoods or softwoods as specified in the First Schedule to these regulations into lumber without first having obtained a License in accordance with Rule 5 of the Forest Rules.”

Specific species to which this regulation applies is scheduled within the regulations, some of which are expected to be found at the project site.

As the proposed development site is located away from the coastal areas of Belize, the Mangrove Regulations are not applicable.


As the proposed project will involve some excavation/movement of earth, the Mines and Mineral Act and its corresponding regulations should be considered of great importance in guiding project development. The stipulations made under this act are made in reference to all minerals in any land in Belize referring to both terrestrial areas and those lands submerged under water. As the proponents will be engaged in the mining of construction minerals this must be noted for inclusion within the regular mining permit. Part I Section 4 of this act clearly states that, “No person shall prospect or mine except in accordance with the rights granted under this Act.”

Part II Section 12 of the act restricts mineral rights to Belizean entities, “No mineral right- being a mining licence, shall be granted to a body corporate unless the body corporate is a company or corporation incorporated in Belize”.

The proponents in accordance to Section 36 of the Laws will be required to submit for a Mining licence for approval before extraction of Material and will be responsible for the
prescribed royalties. Applications for such a licence should be directed to the Inspector of Mines within the Geology and Petroleum Department.

Part VII Section 93 of the Act also calls for an EIA in order to ensure protection of the environment. “The Minister may, pursuant to section 37 (4), require environmental impact assessment studies to be carried out.”

Section 95 of the act deals with matters regarding the rehabilitation of mined areas.

1) There may be included in a prospecting or mining licence such conditions relating to-

(a) the reinstatement, leveling, regrassing, reforesting and contouring of any part of the prospecting or mining area that may have been damaged by prospecting or mining operations; and

(b) the filling in, sealing or fencing off, of excavations, shafts and tunnels, as may be prescribed, or as the Minister may, in any particular case, determine.

2) There may be included as a condition on which a claim is registered any condition, of a kind referred to in subsection (1), which may be prescribed for the purposes of that subsection.

3) Where any condition is to be included in a prospecting or mining licence pursuant to subsection (1), the Minister may require the applicant for the licence to lodge with the Inspector, within such time as the Minister may require, security for the performance of the condition in such amount and form as the Minister deems appropriate.

Mines and Minerals (General) Regulations

Part IV of these regulations describes the procedure for quarry permitting. This is key in the establishment of quarry sites necessary for the provision of raw material necessary for Dam construction.
Also of importance is Part VII of these Regulations, which deals with Royalties and Transfers. According to Section 28, 3% of the value of the materials utilized is to go to the Government of Belize.

Section 58 of these regulations empowers the Minister to make final decisions about dam construction, and water flow diversion into machines etc.

**Mines and Minerals (Safety, Health, and Environment) Regulations**

Part II Section 4 of these regulations directly identifies “The cracking or Subsistence of any dam” as a “dangerous occurrence” and empowers the inspector of Mines to investigate such an occurrence in an effort to assess damage to the environment.

Section 15 makes provisions for the establishment of an Operation Safety and Health Committee in regards to mining/ quarry operations.

Part II Section 17 emphasizes the need for an Environmental Impact Assessment. Main issue of concern under this section is hydro geological resources and the effect of operations on these resources.
Based on the Mines and Minerals Regulations the ambient standards are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved oxygen</td>
<td>Not less than 90% of the seasonal natural value</td>
</tr>
<tr>
<td>Temperature</td>
<td>To be within 1 degree Celsius of the natural level</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Not more than 5 Jackson Turbidity Units above the natural value</td>
</tr>
<tr>
<td>Floatable Solids</td>
<td>None</td>
</tr>
<tr>
<td>pH</td>
<td>No change</td>
</tr>
<tr>
<td>Toxicity</td>
<td>Below detectable</td>
</tr>
<tr>
<td>(96 hr static bioassay)</td>
<td>Limit</td>
</tr>
<tr>
<td>Colour</td>
<td>No Change</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>No Decrease</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>Not less than 20% natural value</td>
</tr>
<tr>
<td>Chloride</td>
<td>Not more than 25 mg/L</td>
</tr>
<tr>
<td>Fecal Coliforms</td>
<td>Less than 1/100 ml</td>
</tr>
</tbody>
</table>

Objectives for discharge of final effluents to marine and freshwater systems are presented below, as taken from Table II of the DOE Guidelines. It should be noted that these guidelines are currently being amended.
### Table 3.1.2 b: Objectives for the Discharge of Final Effluents to Marine and Fresh Waters (DOE Guidelines)

**TABLE II**  
Objectives for the Discharge of Final Effluents to Marine and Fresh Waters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dissolved</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>[mg/L] is effluent unless otherwise stated</td>
<td></td>
</tr>
<tr>
<td>Suspended solids</td>
<td>25-75</td>
</tr>
<tr>
<td>Toxicity</td>
<td>80-100%</td>
</tr>
<tr>
<td>pH</td>
<td>6.5-10</td>
</tr>
<tr>
<td>Radioactivity</td>
<td></td>
</tr>
<tr>
<td>Gross Alpha picoCuries/Liter</td>
<td>10-100</td>
</tr>
<tr>
<td>Radium 226 picoCuries/Liter</td>
<td></td>
</tr>
<tr>
<td>Aluminium</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Ammonia</td>
<td>1.0-10.0</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.25-1.0</td>
</tr>
<tr>
<td>Arsenic (as Trivalent)</td>
<td>0.05-0.25</td>
</tr>
<tr>
<td>Arsenic (total dissolved)</td>
<td>0.10-1.0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.01-0.1</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.05-0.3</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Copper</td>
<td>0.05-0.3</td>
</tr>
<tr>
<td>Cyanide (as CN)</td>
<td>0.1-0.5</td>
</tr>
<tr>
<td>Fluoride</td>
<td>2.5-10.0</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3-1.0</td>
</tr>
<tr>
<td>Lead</td>
<td>0.05-0.2</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.1-1.0</td>
</tr>
<tr>
<td>Mercury</td>
<td>0-0.005</td>
</tr>
<tr>
<td>Molybdenium</td>
<td>0.5-5.0</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.2-1.0</td>
</tr>
<tr>
<td>Nitrite/Nitrate</td>
<td>10.0-25.0</td>
</tr>
<tr>
<td>Phosphate (Total P)</td>
<td>2-10.0</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.05-0.5</td>
</tr>
<tr>
<td>Silver</td>
<td>0.05-0.5</td>
</tr>
<tr>
<td>Uranil (UO2)</td>
<td>2.0-5.0</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.2-1.0</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>10-15</td>
</tr>
</tbody>
</table>

Although this law deals primarily with developments regarding the subdivision of lands it does reflect some relevance to the project specifically in regards to its regulations regarding utilization and protection of areas such as watersheds. Under the Act, the Cayo District West has been named a Special Development Area requiring planned development and a consultative process. Investigations have proven that the proposed site falls outside the boundaries of the proposed special Development Area so the provisions of this ACT are not applicable.


Section 46 Where a person fails to carry out an environmental impact assessment or any other duty imposed by this Act or any Regulations made there under, the Commissioner or the person referred to in section 3 may issue an order in writing to such person directing him to cease, by such date as specified in the order, the activity in respect of which the environmental impact assessment or duty, as the case may be, is required.

Part III Section 33 of the National Land Rules associated with the National Lands Act allows for the maintenance of a sixty-six feet vegetative buffer along all water frontages. This rule will require some action by proponents as some of this buffer will be lost due to land clearance for construction and impoundment of water by the dam. Special permission for this clearance must be granted by the Department of Lands and Survey.
3.1.3 CONSTRUCTION AND IMPLEMENTATION PHASE


The Labour Act of Belize guides the recruitment and the hiring of individuals as well as lay out the rights of these individuals and their employer.

Part XIII Section 149 of this act deals specifically with provision of housing and Requirements associated with the general safety and health of the employees. This section is called upon as it sets the guidelines in place in the event that worker camps are deemed necessary.

“Every employer who provides or arranges accommodation for workers to reside at or in the vicinity of a place of employment shall provide and maintain-

(a) sufficient and hygienic house accommodation;
(b) a sufficient supply of wholesome water; and
(c) sufficient and proper sanitary arrangements, for every worker who resides at the place of employment. Such house accommodation, water supply and sanitary arrangements shall conform to such requirements and standards of health and hygiene as may be prescribed.”

“(2) No employer shall house any worker or other person in a building the state of which or the surroundings of which are, in the opinion of the Commissioner or health officer, such as to endanger the health of such worker or other person and should it appear to the Commissioner or health officer that the accommodation provided is likely, by reason of its site, construction, size, or otherwise, to endanger the health of any worker or of any person, the Commissioner may serve the employer with an order in writing requiring him to remove, alter, enlarge or reconstruct such accommodation within a reasonable time to be stated in such order; and such order may also, if necessary, declare that no worker or other person shall be permitted to occupy any building the subject of such order pending removal, alteration, enlargement or reconstruction.”
Environmental Impact Assessment

**Immigration Act (Chapter 156 Substantive laws of Belize, Revised Edition 2000, Subsidiary Laws 2003)**

This Act and its regulations become pertinent to the proponent in the selection of a contracting firm for dam construction. A lack of local capacity in terms of dam construction has driven a need to contract non-national firms who by extension employ non-nationals to aid construction efforts.

The Immigration Act indicates procedures and qualifying elements of securing entry permits as well as make allocation for the securing of temporary employment permits (Section 16 of the Act).


The Wildlife Protection Act controls hunting of various faunal species in Belize. The ACT also serves to restrict hunting of scheduled species based on the importance of the species, endangered status, and the reproductive cycle of the species. This Act is relevant as the proposed project will likely increase the amount of human interaction in the area. As a forest reserve the Vaca area and the surrounding protected areas have been closed for hunting.

The Act however does not prohibit defending oneself against attacks by animals.

**Forest Rules (Chapter 213 Subsidiary Laws of Belize 2003)**

Part III Section 23 of the Forest rules disallows squatting, building, cultivation, grazing and hunting within the boundaries of a Forest Reserve without the approval of the Chief Forest Officer. This section is key in the establishment of work camps during the dam construction phase. Every attempt should be made to site camps outside the reserve area and to ensure that the rules governing the management of the reserve are enforced.
Section 24 prohibits the lighting of fires within the boundary of the forest reserve and indicates that all precautions should be taken by individuals to prevent the starting of fires and to extinguish fires which may erupt.

Forest Fire Protection Act (Chapter 212 of the Substantive laws of Belize, Revised Edition 2000)

The extensive drought situation currently being faced throughout Belize requires that attention be paid to the areas vulnerability forest fires and to ensure that planned activities do not increase the risk of forest fires in the area. The prescribed Forest Fire Protection Plan (FFFP) has not yet been developed for the Vaca region however such a plan does exist for the surrounding Mountain Pine Ridge Forest Reserve and this plan should be taken under consideration by developers. The FFFP is to be prepared by the forest department in conjunction with the project proponent. As a part of the Forest Reserve Order Chapter 213 Laws of Belize the project proponents have the responsibility to take preventative actions. This will be important for the site preparation and construction phase where clearing of land is required.

Section 6 of this act make the responsibility to carry out recommended prescription that of the landowner. “Each landowner shall at his own expense carry out the prescriptions of the fire protection plan in so far as they relate to land over which he enjoys rights, provided that he may require the Chief Forest Officer to carry out the prescriptions of the fire protection plan on such land in which case the landowner shall pay the cost of carrying out each prescription as estimated in the fire protection plan, to the Chief Forest Officer, not later than thirty days after the completion of the prescription.”

Section 11 of the Forest Protection Act states, “In the event of the outbreak of a forest or bush fire, whether within or without a fire protection area, the Chief Forest Officer may, with or without assistants, enter upon any land or direct any person to enter, with or without assistants, upon any land and there take such measures, including the building of fire lines and the destruction of trees, as the Chief Forest Officer or, as the
case may be, the person so directed may consider necessary for fighting such outbreak of fire.

3.1.4 OPERATION AND MAINTENANCE PHASE

Environmental Protection Act
Section 11 sub section 1 on the EPA is key during the operation phase of the proposed hydroelectricity facility. Project is expected to be monitored based on its compliance in this area.

“11.-(1) No person shall emit, import, discharge, deposit, dispose of or dump any waste that might directly or indirectly pollute water resources or damage or destroy marine life.”

3.1.5 DECOMISSIONING AND ABANDONMENT PHASE

Mines and Minerals Act
The Mines and Minerals Act is the only act which makes reference to the rehabilitation of the natural environment after use/ exploitation of a resource. Part VII of this act deals explicitly with the protection of the environment and allows for the inclusion of conditions for the protection of the environment in its permitting process.

Section 95 of the Act calls for the rehabilitation of areas damaged by Prospecting or mining:

“Section 95.-(1) There may be included in a prospecting or mining license such conditions relating to-

(a) the reinstatement, leveling, regrassing, reforesting and contouring of any part of the prospecting or mining area that may have been damaged by prospecting or mining operations; and
(b) the filling in, sealing or fencing off, of excavations, shafts and tunnels, as may be prescribed, or as the Minister may, in any particular case, determine.”

Environmental Protection Act
Although not stated explicitly in the EPA or in the EIA regulations, it is standard that the Department of Environment address the decommissioning of a project and mitigatory actions related to decommissioning in the Environmental Compliance Plan, a legally binding document signed between the Department of Environment and the proponent.

Investigations with the Department of Environment indicates that although no reference of an Environmental Compliance Plan is made within the laws and the regulations, the DOE can legally request this plan under Section 26 subsection 2 of the EIA regulations.
4.0 Approach and Methodology

4.1 General Approach

For this Environmental Impact Assessment, ESL Management Solutions Ltd. assembled a qualified team of environmental scientists and assessment specialists including local and international professionals. An integrated and iterative approach was adopted in the review of relevant documents, field studies, data collection and interpretation of laboratory analyses. A Charette-style approach was used, where appropriate, during field studies and in the identification of impacts and the recommendation of mitigation measures. The Charette-style approach involves a series of iterative meetings with all team members representing various disciplines, where issues are identified and an interactive approach is employed to address the issues raised.

The methodology employed was divided into three phases. Phase I included the collection and analysis of baseline data, including ground-truthing and aerial surveys. Phase II focused on the interpretation of the data collected to determine the preferred site for project implementation. Phase III focused on the assessment of potential negative and positive impacts and the recommendation of mitigation measures to minimize negative impacts.

Baseline data was assembled for the physical, biological, archaeological and socio-economic components of the environment relevant to the project site alternatives. Consideration of dry, intermediate wet/dry and wet season conditions was essential, given the variability in physical and ecological parameters, as well as flood hazard vulnerability indices. The data was assessed in the context of making recommendations for the alternative that presented fewer environmental impacts. Impact assessment utilized internationally accepted techniques following closely the TOR’s approved by the
Belize Department of the Environment as well as the World Bank Guidelines for assessing the impact of hydroelectric facilities.

Presentation and discussion of the project among relevant stakeholders was also integral to data gathering and analysis.

Standard research and data gathering methods were employed and included the following:

- Site reconnaissance
- Review of existing documentation
- Access to information from relevant agencies
- Detailed site assessments (wet, dry, intermediate wet/dry seasons)
- Assessment of maps, plans, photographs
- Aerial survey
- Laboratory analyses
- Qualitative and quantitative evaluations
- Impact assessment

### 4.2 Phase I – Collection of Baseline Data

Baseline data was collected for parameters related to the physical, biological, archaeological and socio-economic aspects of the environment.

#### 4.2.1 PHYSICAL ENVIRONMENT

##### 4.2.1.1 Topography

Information was gathered on the topographical features of the area within the footprint of the development and the sphere of influence. Information was gathered from topographical maps, documented literature and verified by site assessment and ground
truthing. Details were gathered on topographical features including slopes and drainage patterns.

### 4.2.1.2 Climate and Meteorology

Information on climate and meteorology is presented for Belize in general terms and the Cayo District. Detailed information on rainfall for the Macal River watershed and other connecting watersheds is also included where relevant. Sources of data include published reports, web site searches and the National Meteorological Service.

### 4.2.1.3 Geology/Geotechnics

Geomorphological and geophysical information for the project area was provided by Rodio-Swissboring (2005) and multiVIEW Geoservices Inc. (1991). This information included a detailed description of the characteristics of landform, land surface including exposed rock types, types of unconsolidated materials exposed (sediments), rivers, tributaries, ridges, valleys, and geological structures including faults and folds. Additionally, a review of the geological/geotechnical studies on the Macal River basin, including the Vaca site, done by the Geology and Petroleum Department (Cho and Moore, 2004), was also examined.

Geological and Geotechnical information was also provided by Rodio-Swissboring, and included a detailed description of the stratigraphy of the rocks or unconsolidated materials within the project site, focusing on the site where the diversion structure and power house would be built, as well as detailed information of rock type(s) in locations where the dam and appurtenant structures would be constructed.

Several other reports were consulted including a review of seismic events within the general project area and the Macal River valley.
Detailed reviews were made of the project documentation made available to the project team, as well as other reports relevant to site location.

4.2.1.4 Hydrology

Previous feasibility study reports and EIAs for the Mollejon and Chalillo projects have described the basic hydrological features for the Macal River from above Chalillo, past Mollejon and Vaca down to its confluence with the Mopan River where it forms the Belize River north of San Ignacio. These have included various analyses of the river flows using historical records from Cristo Rey, supplemented by data obtained at Mollejon since the construction of the dam and power station. The three most recent analyses have been by AGRA CI Power/BEL (1999) and Gilbert-Green and Associates (2005 b and c) and these reports were provided for EMSL to review and incorporate in this EIA report.

The analysis of monthly flows at Cristo Rey located 16 km downstream of Vaca has been based on stream gauge records from there (1984 – 2003) as well as from recent measurements at Mollejon comprising spillway and turbine flows. Specifically, flows from 1984 to 1995 have been derived mainly from twice daily staff gauge readings at Cristo Rey while flows from 1996 to 2000 have been estimated from more recent Cristo Rey records supplemented by the Mollejon data. Flows from 2000 to 2003 have been derived mainly from daily flow records at Mollejon. In the most recent analyses, the results have been cross checked against downstream flows on the Belize River and, to a lesser extent, against historical rainfall data. These have provided what is now regarded as reliable stream flow projections for the Macal River along its length from Chalillo to Cristo Rey and San Ignacio.

4.2.1.5 Water Quality

Environmental Management Solutions Ltd. provided additional baseline data on water quality within the project area. The first set of water samples to establish baseline water
quality conditions for the Macal River during the dry season, was collected in May, 2005. The second set of samples, in the wet season, was collected in August 2005.

Five sampling stations were initially selected, four along the Macal River and one on the Rio On just upstream of its confluence with the Macal River. Additionally, a sixth station was selected between Mollejon and Chalillo. The sampling stations were selected based on several criteria which included proximity to the existing dam at Mollejon, the potential for impairment of water quality from likely localized impacts from the proposed Vaca dam, as well as the potential for cumulative impacts from all three dams. Station 1 is located at the Mollejon dam whereas Stations 6 and 3 are located upstream and downstream respectively, of Mollejon. Stations 3 and 4 are located on the Macal downstream of the Mollejon dam at the two sites proposed for the Vaca dam. Station 5 on the Rio On was selected to provide baseline data for this river which would be impacted if either Site A or Site B were chosen. The site locations are given in Table 4.2.1.5 and are shown on Figure 4.2.1.5.

Table 4.2.1.5: Water Quality Sampling Stations on the Macal River and the Rio On

<table>
<thead>
<tr>
<th>STATION NUMBER</th>
<th>STATION NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mollejon Dam</td>
</tr>
<tr>
<td>2</td>
<td>Mollejon Power Station</td>
</tr>
<tr>
<td>3</td>
<td>Rio On</td>
</tr>
<tr>
<td>4</td>
<td>Site A on Macal River</td>
</tr>
<tr>
<td>5</td>
<td>Site B on Macal River</td>
</tr>
<tr>
<td>6</td>
<td>Guacamallo Bridge</td>
</tr>
</tbody>
</table>
Figure 4.2.1.5: Water Quality Sampling Stations on the Macal River and the Rio On
Water quality determinations, an important component of any environmental assessment, provide critical data on the condition of the water resource. The major objectives of the present water quality sampling programme are outlined below:

◊ To determine baseline water quality conditions of the major surface water systems in the project area.
◊ To determine the nature and extent of existing land use impacts,
◊ To determine compliance with local and international water quality standards.

Samples were collected in the middle of the river at the water’s surface. Sample collection at Site A and upstream the Rio On was facilitated by use of a canoe. All samples were collected in pre-cleaned 2 litre polyethylene sample bottles. Bacterial samples were collected in sterilized 100 ml glass bottles and BOD samples were taken in opaque polyethylene containers.

The following parameters were analysed on the water samples:
◊ Ph
◊ Salinity/conductivity/temperature
◊ Dissolved Oxygen
◊ Turbidity
◊ Nitrate
◊ Phosphate
◊ Chemical Oxygen Demand (COD)
◊ Biochemical Oxygen Demand (BOD₅)
◊ Total and Faecal Coliform
◊ Total dissolved solids
◊ Total suspended solids
◊ Calcium
◊ Magnesium
◊ Manganese
◊ Mercury
◊ Iron
◊ Alkalinity
◊ Hardness
◊ Sulphate
Salinity, temperature, and dissolved oxygen were measured *in situ* at all sampling stations using a YSI Model 57 Salinity/Conductivity/Temperature (SCT) meter and YSI Model 33 oxygen meter respectively. Measurements were taken at the surface (0.5m depth) of the water column.

Environmental Solutions Limited Laboratory performed or supervised the analysis of all parameters. Laboratory analyses used certified methodology, primarily from the text Standard Methods for Examining Water and Wastewater (Eaton et al 1995).

### 4.2.1.6 Natural Hazards

Relevant information was obtained from literature, maps and other sources to assess the vulnerability of the proposed project to natural phenomena such as hurricanes, earthquakes and floods.

### 4.2.2 BIOLOGICAL ENVIRONMENT

#### 4.2.2.1 Ecosystems

Prior to this EIA, a Rapid Ecological Assessment (REA) was conducted in the region of the Vaca Falls by Tunich-Nah Consultants & Engineering (2005), on behalf of BECOL. The main objectives of that REA included:

1. The development of an understanding of the main ecosystems of the area,
2. A rapid wet season field assessment of the main faunal populations, particularly of sensitive or endangered species, and
3. The identification of keystone/flagship species on which to base future monitoring programmes.

As part of this current EIA, ecologists from Environmental Management Solutions Ltd. conducted extensive literature research and field surveys during the dry, intermediate wet/dry and wet seasons. Reviews included the use of the current

Habitat homogeneity along the course of the potential inundation area(s) was assessed, lists of predominant characteristic plant species were developed, and topographical gradients of plant community composition and structure noted within the valley of the project site.

Ecosystems were identified and mapped through ground-truthing transects located between the area immediately downstream of Site B and the Mollejon Power Station.

The following methods were employed in the data collection process, during the dry, wet / dry intermediate, and wet seasons:

- Transects were undertaken longitudinally through the forest approximately 15-20m above the floodwater level of the river, largely following existing narrow access trails. Vegetation point surveys were also undertaken, running parallel to the river within the projected inundation zone, to include plant species inventory and habitat structure and condition.

- A series of vegetation transects running perpendicular from the river up the first ridge of the valley, to include plant species inventory and habitat structure and condition. These included three on the western bank of the river, and two on the eastern bank, two following the access tracks to sites A & B, and two stretching from the water’s edge to approximately 110-120 m up the ridges on either side of the river.
• Data collection on the transects included average canopy height and structure, species composition, and relative abundance.

4.2.2.2 Flora

Predominant and characteristic plant species were identified within each ecosystem, both along the transects described above, and at numerous additional point surveys within the study area. Changes in species predominance and relative abundance were recorded within and between each sample site.


4.2.2.3 Fauna

Dry, intermediate and wet season surveys were conducted of the fish, amphibians, reptiles, birds and mammals. Comprehensive literature reviews on each vertebrate group and past research in the area provided further supporting information.

4.2.2.3.1 Fish

A review of the literature included location records collated by Greenfield and Thomerson, (1997), Myvette G. (2005) - incorporating species records from Glaholt (1992), and BECOL (2001)). The species distribution data contained in these reports was then compared with data collected in the field.
Work on the aquatic fauna concentrated on a comparison of fish diversity at a number of sampling sites within the project area, with particular focus on Site A and Site B (Figure 4.2.2.3.1). Methods used included netting within pools, snorkeling transects, use of cast nets, baited fish traps, hook and line, and nocturnal point surveys in a variety of aquatic habitats (primarily isolated rock pools, shallow riffles, deeper flowing channels, and pools) throughout the study area. Species nomenclature followed Greenfield and Thomerson (1997), which was also used in species identification.

4.2.2.3.2 Amphibians and Reptiles

Extensive literature research was conducted on the likely presence of reptiles and amphibians within the project areas at Site A and Site B, and surrounding areas. Of primary value in this are the works of Lee, J.C. (1996, 2000), Stafford and Meyer (2000), BECOL (2001), Tunich Nah / Walker, P. (2005), and the web-based Global Amphibian Assessment (2004).

Field surveys included diurnal and nocturnal Visual Encounter Transects along routes used for the vegetation survey, the location and visual surveying of identified amphibian breeding sites in isolated rock pools along the riverbed. Additional opportunistic records and observations were made throughout each of the vegetation surveys. Particular effort was given to the surveying for the potential presence of amphibian species of conservation concern.
Figure 4.2.2.3.1: Location of Fish Survey Sites
4.2.2.3.3 Birds

A literature review included distribution data from Jones (2003), Jones and Vallely (2000), baseline information from BECOL (2001), the National Protected Areas Systems Plan for Belize: Volume 3. Zoological Report (1995), and the Belize Biodiversity Information System. Additional species-specific information was also sought on-line.

Two surveys were conducted in the area in 2005, in conjunction with Tunich-Nah Consultants and Engineers, timed to coincide with wet and a dry seasons. These were supported by the addition of opportunistic sightings during the fieldwork on other taxa.

4.2.2.3.4 Mammals

A literature review was conducted covering the mammal species of the Vaca area, including regional distribution data (Reid, 1997), previous reports (BECOL, 2001) and Tunich Nah (2005), as well as data from the Belize Biodiversity Information System.

Mammals were surveyed using diurnal and nocturnal visual encounter transects at both Site A and Site B (Table 4.2.2.3), and also opportunistically throughout the survey area, with examination of tracks, faeces, and recording of sightings.
### Table 4.2.3.4: Visual Encounter Transects for Mammal Survey of Vaca Area

<table>
<thead>
<tr>
<th>Transect</th>
<th>UTM Starting Co-ordinates</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vaca Site A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transect One</td>
<td>0282 672; 1881 022</td>
<td>Length: 1hr timed transect Transect perpendicular to river through <strong>Tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills</strong>. 2 diurnal and 2 nocturnal transects</td>
</tr>
<tr>
<td>Transect Two</td>
<td>0282 672; 1881 022</td>
<td>Length: 800m Transect parallel with river, running south south west along river bank through <strong>Deciduous broadleaf lowland riparian shrubland in hills</strong>. 1 diurnal, 1 nocturnal transect</td>
</tr>
<tr>
<td>Transect Three</td>
<td>0282 672; 1881 022</td>
<td>Length: 3,350m (approx.) Transect parallel with river, from Site A to Mollejon power station through <strong>Deciduous broadleaf lowland riparian shrubland in hills</strong>. 1 diurnal transect</td>
</tr>
<tr>
<td>Transect Four</td>
<td>0282 672; 1881 022</td>
<td>Length: 2,500m (approx.) Transect parallel with river, from Site A to Site B through <strong>Tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills</strong> and <strong>Deciduous broadleaf lowland riparian shrubland in hills</strong>. 1 diurnal transect</td>
</tr>
<tr>
<td><strong>Vaca Site B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transect One</td>
<td>0280 936; 1882 575</td>
<td>Length: 600 m Transect parallel with river, running northwest through <strong>Tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills</strong>. 2 diurnal and 1 nocturnal transect</td>
</tr>
<tr>
<td>Transect Two</td>
<td>0281 328; 1882 583</td>
<td>Length: 1 hr timed transect Transect perpendicular to river, through <strong>Tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills</strong>. 1 diurnal and 1 nocturnal transect</td>
</tr>
</tbody>
</table>
4.2.3 PARKS AND PROTECTED AREAS

Information was obtained from documented literature on the Parks and Protected Areas of Belize, and in particular the Vaca Forest Reserve and the Mountain Pine Ridge Reserve which are separated by the Macal River.

4.2.4 ARCHAEOLOGY

Previous archeological mapping within the Cayo District has unearthed many archaeological features heightening the importance of the Ancient Monuments And Antiquities Act (Chapter 330 Substantive Laws of Belize, Revised Edition 2000) to the project proponents. Based on the Act, “All ancient monuments and antiquities however situate, whether upon any land or in any river, stream or watercourse, or under territorial waters of the country, and whether or not before the date of the commencement of this Act in private ownership, possession, custody or control, shall absolutely vest in the Government.” And subject to this Act, “no person shall possess or have in his custody or control any ancient monument or antiquity except under a license in writing granted by the Minister in the prescribed form.”

A Rapid Archaeological Assessment (RAA) of the project area within the middle Macal River Valley encompassing Site A and Site B was carried out in July 2005. The purpose of the RAA was threefold:

1) To determine if any ancient monuments or features of archaeological significance were located within the survey area
2) To recommend which of the two sites would have less impact on the archaeological resources in the region
3) To describe what potential impacts dam construction would pose to the archaeological features of the proposed dam area.

Standard procedures for most surveys generally rely on the cutting of a central baseline from which are established several perpendicular traverses at consistent intervals. Given
the nature of the terrain within the Macal River valley, the Macal River itself was used as the baseline. Traverses were subsequently cut at 100 metre intervals. The traverses extended from the river bank up to the 220 metre contour line, on either side of the river. By extending the traverses up to the 220 metre contour line it allowed for the survey to be conducted well above the intended flood zone.

During and after the cutting of the traverses the work crew reconnoitered the area for any visible, archaeologically significant features. When these were identified they were later ground proofed and certified by the Principal Surveyor and Field Archaeologists.

Location data was acquired utilizing a handheld Garmin II plus GPS receiver. Features were mapped utilizing the tape and compass method where applicable. All data collected were inputted into a Geographical Information System (GIS) Database for further insights into geographical relationships and patterning. The British Ministry of Defense Topographical Maps (1993) were utilized as a base map layer for the construction of the project cartography. Because these maps were produced in North American Datum 1927 projection, NAD-27 was used as the native projection for all geographical information subsequently collected.

4.2.5 SOCIO-ECONOMIC CHARACTERISTICS

4.2.5.1 General Approach

The working definition of Social Impact Assessment (SIA) put forth below has been given as this was used to guide the SIA methodologies and techniques that were employed during the EIA.

“SIA includes the process of analyzing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions. Its primary purpose is to bring about a more sustainable and equitable biophysical and human environment” (IAIA, 2003).
The methodology employed for the socio-economic assessment is in compliance with Section 18 (1) of the Environmental Impact Assessment Regulations:

“During the course of an environmental impact assessment, the developer shall provide an opportunity for meetings between the developer and interested members of the public, especially within or immediately adjacent to the geographical area of the proposed undertaking, in order:

(a) to provide information concerning the proposed undertaking to the people whose environment may be affected by the undertaking; and

(b) to record the concerns of the local community regarding the environmental impact of the proposed undertaking”.

The SIA portion of the EIA was guided by the Principles of Stakeholder Involvement set forth by Bissett (1987).

Public participation in an EIA can take various forms. Stakeholders are engaged to improve understanding of the potential impacts of proposed projects; identification of alternative sites or designs, and mitigation measures; clarification of values and trade-offs associated with these different alternatives; identification of contentious issues (and a possible forum to resolve them); establishment of transparent procedures for implementing proposed projects; and creation of accountability and a sense of local ownership during project implementation.

Of the methodologies available to ensure public participation, EMSL has utilized the following:

- **Public Meetings** (these are 'open' with no restriction as to who may attend); and
- **Focal Group Discussions** (a group of individuals, chosen to represent stakeholder groups)
4.2.5.2 Secondary Research

Review of existing literature has been conducted and includes literature from similar projects or projects in same geographic area, including the EIA Reports for the two previous dam phases (Mollejon and Chalillo). Pertinent research documents, graduate theses/dissertations, relevant magazine and newspaper articles have all been included. Collection and collation of secondary data (from the census data and poverty data) has also been included.

The key variables that formed the assessment framework have been grouped into the following main headings:

- Demographic Characteristics
- Institutional Structures/Arrangements
- Political and Social Governance
- Individual and Family Changes and
- Community Resources

These variables have been measured and cross-referenced within the project lifecycle of the Vaca Hydroelectric Project, which includes four phased components: (1) planning, (2) construction, (3) operation and (4) decommissioning.

4.2.5.3 Primary Research

The collection of primary data, and information on public sentiment, was facilitated though the following means:

- Stakeholder meetings (doubled as public involvement sessions)
- Key stakeholder interviews
Employed techniques and methods for data analysis included the following:

- **Ad hoc discussion**
- Checklist method
- Matrix methods (goals achievement, Leopold, stepped)
- Basic overlay method
- Network diagrams

### 4.3 Phase II – Identification of the Better Site Option

Issues related to the proposed project at both potential sites were identified. A qualitative assessment was then conducted of the environmental aspects for Site A and Site B in order to determine which of the two sites would result in the least environmental impact. Additionally, a quantitative assessment was also conducted to support the qualitative findings. The environmental aspects for physical, biological, archaeological and socio-economic components of the environment were assessed against design criteria, construction works and the operation phase. A rating was assigned with +5 having the most significant positive impact and –5 having the most significant negative impact.

### 4.4 Phase III - Assessment of Potential Impacts

After discussions with BECOL on the selection of the site which would result in the least environmental impacts, detailed assessments and analyses were conducted on all the issues identified and the site specific and project specific impacts were identified. Where negative impacts were identified mitigation measures were determined that would minimize these negative impacts.
5.0 Baseline Data

5.1 Topography

The Vaca project is located at latitude 17° N in the mountainous interior of Belize on the Macal River (Figure 5.1). Located in the north-west of the Cayo District and within the Vaca Forest Reserve, the area is also adjacent to the Mountain Pine Ridge Forest Reserve, which lies to the east of the Vaca Forest Reserve. The Macal River originates in the Mountain Pine Ridge at an elevation of 800 m, and flows westerly, then northerly to join the Mopan River. Topographical features of the Macal River Basin are shown in Plate 5.1 a (aerial image), and Plate 5.1 b, c, d, e and f.
Figure 5.1a: Aerial Photograph of the Macal River and Topographical Setting in the Vicinity of Vaca Dam Sites A and B.
Plate 5.1  b, c, d, e and f: The Macal River Basin Showing River Bank Topography
5.1.1 REGIONAL TERRAIN

The terrain in this area of Belize is strongly controlled by the underlying geology. The limestone plateau to the west of the site is characterized by karstic topography (landforms created by the dissolution of limestone by water, and the progressive development of underground drainage systems).

The Paleozoic sediments of the Santa Rosa Group and the plutonic intrusions (granites) comprise the Maya Mountains, which are characterized by a very mountainous and rugged topography. The granite on which the study site is located is also characterized by very rugged topography that is deeply incised by the river valleys. The ridges on the right (east) bank of the Macal have a NE-SW trend, and those on the left (west) bank trend E-W, indicating a strong structural control. The Vaca dam site B is located approximately 3 km south of Black Rock on the Macal River at an elevation of 95 m above sea-level. The Macal River is a major tributary of the Belize River. The catchment of the Macal River is heavily vegetated, and encompasses a large area of the Maya Mountains.
Figure 5.1.1: Site Location Map of Belize and the Vaca Area © edigol ediciones
5.1.2 SITE TERRAIN

The Geotechnical Report (Rodio-Swissboring, 2005) identified four zones in the study area, which were largely based on slope angle.

(a) **Zones with an abrupt slope (>70°)**. These are related with limestone outcrops. Generally they are located in the upper part of the valley slopes and along the main tributary sides of the Macal River. To a minor degree they also appear on the granite and granite gneiss outcappings of the river bed. They form vertical cliffs that in some cases can reach up to more than 50 m in height. This zone is considered potentially unstable due to joints, leaching of the fracture walls and the weathering process which has unlatched blocks of up to 10 m and has deposited them in zones with a lesser slope and sometimes as far down as the river bed. At the dam site none of these blocks is observed due to the elevation of the limestone outcappings.

(b) **Very strong slope zone (50 – 70°)**. These are located at the foot of the cliffs over the Macal River banks where talus detritus deposits have formed. They are characterized by being accumulations of various sized rocks, ranging from 50 cm to several meters in diameter. The erosive processes have only taken place in the fine fraction that has filtered through the interstices and blowholes of inferior beds. This zone is considered moderately stable.

(c) **Strong slope zone (25 – 50°)**. These are colluvial deposits which have a wide distribution but have a relatively small thickness that can reach up to 4 m. These deposits are covered by soils and dense vegetation, which gives them stability by preventing the erosion of the materials. The matrix of these deposits is mainly clay.

(d) **Low slope zone (5 – 12°)**. This zone is restricted to the alluvial terraces and the river-bed and is considered stable. Some of the terraces existing due to slope change on both sides can be observed along the river valley. These terraces are related to the upper part of the limestone rocks, where it is common to observe karstic relief with valleys lacking natural drainage, possibly with sinkholes.
5.2 Climate and Meteorology

In general, the climate in this area can be described as a subtropical climate with a pronounced dry period between February and May. Towards the end of the year (October-December) the weather is cooler and wetter. East and Southeast prevailing winds occur in February to September, while winds from the North and Northeast dominate in winter.

Historical total annual rainfall data obtained for Bull Run between 1980 and 1994 show a total annual rainfall greater than 1900 mm. The distribution of this rainfall is distinctly uneven through the year (Figure 5.2). During the months January to August rainfall generally remains below 160 mm per month, with an exception in June (when rainfall is expected to be greater than 200 mm). The driest months occur between February and May, when mean monthly rainfall can be less than 100 mm. In general, the period September through December is the main rainy season, with average monthly rainfall approaching 250 mm.

Temperature readings recorded at Spanish Lookout (17° 10’N, 89° 00’ W) over the past 21 years and reported by the online WeatherBase.com website indicate average temperatures between 22°C and 27°C. Average monthly temperature figures show that November and December are the coolest months with a steady rise in temperature through the dry season until May/June and the advent of the wet season. Higher elevations in the mountainous interior can be expected to have cooler temperatures (16 °C to 18 °C) in the coldest months November and December.
The FAO reports high water saturation levels during November and December in Belize. These conditions probably arise as a result of higher precipitation levels and lower rates of evapo-transpiration.¹

5.3 2005 Seasonal Variations in Rainfall

In April 2005 the National Meteorological Service formally announced that the country of Belize was experiencing drought conditions. The possibility of a drought was first announced in 2000 with records indicating water deficit over most parts of the country.

The months of January to March 2005 according to a national report to CDERA have registered marked deficits in rainfall. This release indicated that the rainfall is less than 50% of the average rainfall normally recorded in the month of March with the Northern Districts of Corozal and Orange Walk being the hardest hit. As of Mid May 2005, the

¹ http://www.fao.org/ag/agl/aglw/aquastat/countries/belize/print1.stm
forecast was for the western district (inclusive of Project site) to experience mild drought conditions, with intense conditions being alleviated by the early start of the rainy season (Table 5.3).

Table 5.3: Status of Drought in Districts

<table>
<thead>
<tr>
<th>DROUGHT STATUS</th>
<th>AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mild</td>
<td>Cayo and Belize Districts</td>
</tr>
<tr>
<td>2. Moderate</td>
<td>Corozal and Orange Walk</td>
</tr>
<tr>
<td>3. Severe</td>
<td>The intense drought conditions have been moderated.</td>
</tr>
</tbody>
</table>

Climate models for May, June, and July 2005 have indicated that the areas in which the project site lies has a 25% likelihood of below normal rainfall, 50% likelihood of normal rainfall and a 25% likelihood of above average rainfall.
Figure 5.3 gives the probability of rainfall and is a prediction model based on climatic data. Based on these reflections it is likely that flow rates of the Macal River will not vary significantly from current recorded rates. The rainfall pattern since May has confirmed the accuracy of the model.
5.4 Geology/Geotechnics

The geological baseline data is based on site investigations and the review of available geological and geophysical reports and maps including Rodio-Swissboring (2005), Burkart (1994), Multiview Geoservices Inc. (1991) and Bateson and Hall (1977). The most detailed information was contained in the Geotechnical Report prepared by Rodio-Swissboring (2005). Their investigations included:

- Reconnaissance of the geology of the site of the Mollejón Dam upstream of the proposed project site to Black Rock located downstream of the project site.

- Geotechnical Assessments including Unconfined Compression Tests of rock specimens and petrographic analysis of 11 thin sections from samples obtained from 8 boreholes located at the dam site (6), powerhouse and the proposed quarry site. The detailed geotechnical assessment was undertaken to assess the suitability of the foundation at the project site. Water pressure tests were done where ground conditions permitted.

5.4.1 Lithologies

The following geological description includes the major superficial deposits found along the riverbanks, as well as three major bedrock lithologies found in the study area (Figure 5.4.1 a).
These bedrocks include:

1. Cretaceous limestones. These are the youngest rocks in the area, and mainly occur to the west and comprise the Vaca Plateau. These limestones also outcrop locally on either side of the river valley.

2. Granites and metamorphosed granites. These intrusive igneous rocks comprise the Mountain Pine Ridge area. The project site and the area to the south of it are located on this lithology.

3. Paleozoic sediments, including mainly shale and siltstones in the vicinity of Vaca. These are the main types of sediments found in the Maya Mountains.

Figure 5.4.1 a: Regional Geology of the Site (reproduced from Penn et al, 2003)
Figure 5.4.1b below is a schematic section across the Macal River, illustrating the stratigraphic relationships between the main formations.

![Schematic section across the western flank of the Mountain Pine Ridge and the Northern Vaca Plateau](image)

**Figure 5.4.1 b:** A generalized section across the western flank of the Mountain Pine Ridge and the Northern Vaca Plateau (reproduced from Reeder et al 1996)

(a) Cretaceous Limestones

These limestones belong mainly to the Campur Formation consisting of thick (850 m, according to Reeder et al, 1996) limestones and dolomitic limestones which have been deposited over the granites and gneiss rocks. The limestones may be interbedded with calcareous lutite and marls up to 1 m thick. The Coban and Campur formations extend westwards into eastern Guatemala. The surface of these rocks is highly weathered (Rodio-Swissboring, 2005) and can include massive intraformational breccias and conglomerates (Burkart, 1994, Reeder et al, 1996). Vinson (1962, in Reeder et al, 1996) describes the Campur Formation as composed of principally gray, gray-brown, and tan...
limestones associated with reef environments. This formation is locally interbedded with thin beds of shale, siltstone, and limestone breccia or conglomerate. According to Rodio-Swissboring (2005) none of the project structures including the reservoir and the dam would be constructed on these limestones.

(b) Granites and Metamorphosed Granites (Gneiss)

The granite and gneiss in the area are interpreted as corresponding to the final part of the Pine Ridge granite intrusion located east of the area. According to the Rodio-Swissboring (2005) mapping, the study area from Mollejón to Vaca Falls (south of northing 1883600) is underlain by granite. Downstream of Vaca Falls, the intrusive body disappears and a body of clayey gray shale outcrops. Over this shale lies a fine-grained sandstone with abundant mica with light to moderate schistosity. Fresh outcrops of granite are reported from along the valley sides. This bedrock “is generally covered by the colluvial deposits, residual soils and by the dense vegetation” (Rodio-Swissboring, 2005).

The geological mapping does not differentiate between granite and gneiss. Rodio-Swissboring (2005) also treats the unit as a single lithology with “profuse variations, from granite with abundant orthoclase phenocrystals that in some places exhibits the crystals direction and an incipient foliation to a clearly defined gneiss”. However, the report indicates that the gneiss tends to be predominant from Mollejón to upstream from the confluence of the Rio On and Macal rivers. Below the confluence “to the originally selected site for the construction materials”, Rodio-Swissboring (2005) reports a “granite predominance over the gneiss”. Although lithologically different and with different geotechnical properties, both the granite and the gneiss have been determined by Rodio-Swissboring (2005) as being suitable for dam construction. Granite is defined as “crystalline igneous rock, consisting mainly of quartz, potash feldspar, and a feldspar containing both soda and lime, also of a small amount of either white or black mica or both, and sometimes of hornblende, more rarely of augite, or both”\(^2\). Gneiss consists of the same suite of minerals, re-aligned by intense pressure (metamorphosed). This parallel

\(^2\) See: http://www.cagenweb.com/quarries/geology/disc_granites.html
re-alignment of minerals into planes, may create discontinuities. Rodio-Swissboring (2005) reports that the bedrock at the dam site is porphyry granite with a variable content of orthoclase (feldspar mineral). It is also reported that “In some parts there are intercalations of gray-green colored granite with abundant micas in its matrix. These intercalations exhibit quartz crystals with a banded texture and flow structures (augen). This feature can be described as cataclastic metamorphism (gneiss)”. This rock is fractured and sometimes micro-faulted. Site borings through the cataclastic gneiss suggest a limited distribution forming 3 m layers. On the boring logs they are reported as gray-green colored granite with abundant quartz. On the boreholes of the left bank these strata are found in greater number and have a greater thickness in relation to the ones on the right bank. The basement rock shows intercalations of cataclastic gneiss of varied width. A more detailed geological mapping is given at the proposed dam site, where a 400-m wide geological cross-section is drawn, based on data from six boreholes with 3 on the left side and 3 on the right side. However, a report by Cho and Moore (2004) also discusses the granite / gneiss relationship and confirms the predominance of granite at the site.

Rocks from the recommended quarry site downstream of the dam, on the left bank of the Macal River) (co-ordinates 1882598.812, 280774.244) were also determined to be granite.

(c) Palaeozoic Sediments

These sediments are named the Santa Rosa Group (Bateman and Hall, 1972, cited by Bateman and Hall 1977). These rocks form the Maya Mountains and can include conglomerates, sandstones, siltstones and shales. Downstream of Vaca Falls, these sediments outcrop along the river valley and mainly comprise non-calcareous black shales underlain by metamorphosed fine-grained sandstones. As a result of the metamorphism these sandstones (60 to 100 m thick) are characterized by the presence of micas, and may be locally developed into schists. The schists are described as gray to brown colored with a low to moderately hard strength, and moderately hard, sometimes
presenting a foliation. The dam and proposed structures would not be founded on this bedrock.

5.4.2 GEOTECHNICAL CHARACTERISTICS

Six bore-holes were drilled by Rodio-Swissboring (2005) in the area of the proposed dam Site B, three on either side of the river. In addition, boreholes were done at the proposed powerhouse and quarry sites.

Table 5.4.2 a: Borehole Locations, Elevations, Depths, etc.
(Source: Rodio-Swissboring, 2005)

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Location</th>
<th>Elevation (m) asl</th>
<th>Depth of investigation (m)</th>
<th>Coordinates</th>
<th>Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-1</td>
<td>Dam – left side (near bed)</td>
<td>92.66</td>
<td>57.45</td>
<td>1882564.208, 281012.9636</td>
<td>45º</td>
</tr>
<tr>
<td>L-2</td>
<td>Dam – left bank</td>
<td>117.675</td>
<td>40</td>
<td>1882526.05, 281006.0221</td>
<td>80º</td>
</tr>
<tr>
<td>L-3</td>
<td>Dam – left bank (highest)</td>
<td>145.035</td>
<td>60</td>
<td>1882495.398, 2811005.8387</td>
<td>90º</td>
</tr>
<tr>
<td>R-1</td>
<td>Dam – right side (near bed)</td>
<td>93.857</td>
<td>50</td>
<td>1882617.919, 281017.6649</td>
<td>45º</td>
</tr>
<tr>
<td>R-2</td>
<td>Dam – right bank</td>
<td>122.283</td>
<td>40</td>
<td>1882656.62, 281017.0399</td>
<td>70º</td>
</tr>
<tr>
<td>R-3</td>
<td>Dam – right bank (highest)</td>
<td>146.784</td>
<td>60</td>
<td>1882685.59, 281022.0149</td>
<td>90º</td>
</tr>
<tr>
<td>L-4</td>
<td>Power House - downstream of the dam - left bank</td>
<td>94.70</td>
<td>25.00</td>
<td>1882553.384, 280964.477</td>
<td>70º</td>
</tr>
<tr>
<td>L-5</td>
<td>Quarry - downstream of the dam - left bank</td>
<td>133.135</td>
<td>30.00</td>
<td>1882598.812, 280774.244</td>
<td>70º</td>
</tr>
</tbody>
</table>

(a) Dam Site
In general 100% of all six cores were recovered. All cores were classified as granites. The degree of weathering is a descriptive term that classifies the rock from completely fresh rock (sound rock) through to slightly weathered (SW), moderately weathered (MW), highly weathered (HW) and completely weathered (CW) rock. Table 5.4.2 b summarizes the percentage of the borehole segment that was classified as fresh rock (Rodio-Swissboring, 2005 gives more details regarding this classification). The boreholes (L-1 and R-1) at nearest the valley floor (river bed) showed an increase in the percentage of fresh rock with depth ranging from 0% to 62% in the upper 21 m. Below
this depth the percentage of fresh rock exceeded 80%. Boreholes L-2 and L-3 contained more than 69% fresh rock below depths of 18 m. Boreholes R-2 and R-3 were both overlain by overburden. Borehole R-2 contained more than 81% fresh rock below the upper 13 m, whilst R-3 contained more than 90% fresh rock below the upper 26 m.

The percentage of the core with discontinuities less than 20 cm is an indicator of density of large size spacing in the rock fabric (<20 cm is close to very close). Table 5.4.2b indicates that there is considerable variability in this parameter, with a range across all sections of 9% to 100%.

The Rock Quality Designation (RQD) is defined as the cumulative length of core pieces longer than 10 cm in a run divided by the total length of the core run. This index is used in determining the rock mass rating (RMR) along with other indices. The percentage of the core with a RQD greater than 75% (good to excellent) is summarized in Table 5.4.2b. Borehole L-1 (near river bed) shows some variability in the upper 21 m, but appears to be better below this depth. Similarly the upper 17 m of Borehole R-1 (also located near the river bed) was variable, but approximately 70% of the core was classified in this range below the 17 m depth. More than 78% to 85% of the cores from boreholes L-2 and L-3 were classified in this range below the first four meters. Similarly, the 83% of the core of Borehole R-2 was given this classification below the first six metres. R-3 was classified as having less than 26% of the core in this RQD range for its entire length.
Table 5.4.2 b: Geotechnical Parameters of the Boreholes from the Proposed Dam Site B

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Petrographic/lithological classification</th>
<th>Depth (m)</th>
<th>%RQD &gt;75%</th>
<th>% Core of Sound Rock</th>
<th>% Core with Discontinuities &lt;20cm</th>
<th>Permeability</th>
<th>Strength Test kg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-1</td>
<td>Porphyritic granite @46 m</td>
<td>0-17.75</td>
<td>38</td>
<td>62</td>
<td>34</td>
<td>Low to moderate</td>
<td>None done</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.75-20.8</td>
<td>0</td>
<td>41</td>
<td>59</td>
<td>Low to very low</td>
<td>None done</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.8-50</td>
<td>96</td>
<td>85</td>
<td>9</td>
<td>Very low</td>
<td>None done</td>
</tr>
<tr>
<td>L-2</td>
<td>Colluvial deposit</td>
<td>0-0.5</td>
<td>0</td>
<td>0</td>
<td>62</td>
<td>Moderate</td>
<td>No test done</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5-4.0</td>
<td>0</td>
<td>0</td>
<td>62</td>
<td>Moderate</td>
<td>No test done</td>
</tr>
<tr>
<td></td>
<td>Granite @11.95 m</td>
<td>4-18.1</td>
<td>78</td>
<td>69</td>
<td>30</td>
<td>Very low to moderate</td>
<td>UCS = 695.03 EM = 255536.14</td>
</tr>
<tr>
<td></td>
<td>Granite porphyry</td>
<td>18.1-60</td>
<td>85</td>
<td>79</td>
<td>9</td>
<td>variable</td>
<td>UCS = 789.81 EM = 244888.8* granite gneiss</td>
</tr>
<tr>
<td>L-3</td>
<td>Colluvial deposit</td>
<td>0-0.5</td>
<td>0</td>
<td>0</td>
<td>62</td>
<td>Moderate</td>
<td>No test done</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5-4.0</td>
<td>0</td>
<td>0</td>
<td>62</td>
<td>Moderate</td>
<td>No test done</td>
</tr>
<tr>
<td></td>
<td>Granite porphyry</td>
<td>17.15-50</td>
<td>70</td>
<td>81</td>
<td>21</td>
<td>Very low to moderate</td>
<td>None done</td>
</tr>
<tr>
<td>R-1</td>
<td>Colluvial</td>
<td>0-0.275</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>Low to very low</td>
<td>None done</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3-3.3</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>Low to very low</td>
<td>None done</td>
</tr>
<tr>
<td>R-2</td>
<td>Colluvial</td>
<td>0-2.75</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>Low to very low</td>
<td>None done</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.75-5.85</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>Low to very low</td>
<td>None done</td>
</tr>
<tr>
<td></td>
<td>Granite @24.6 m</td>
<td>5.85-12.8</td>
<td>83</td>
<td>0 (SW)</td>
<td>17</td>
<td>Very low to moderate</td>
<td>UCS = 871.95 EM = 248337.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.8-40</td>
<td>70</td>
<td>81</td>
<td>21</td>
<td>Very low to moderate</td>
<td>UCS = 871.95 EM = 248337.93</td>
</tr>
<tr>
<td>R-3</td>
<td>Muddy sand</td>
<td>0.3-3.3</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>Low to very low</td>
<td>None done</td>
</tr>
<tr>
<td></td>
<td>Granite porphyry @7.75 m</td>
<td>3.3-26.4</td>
<td>26</td>
<td>0</td>
<td>57</td>
<td>Low to very low</td>
<td>UCS = 707.67 EM = 226051.93</td>
</tr>
<tr>
<td></td>
<td>Granite porphyry @57.05 m</td>
<td>26.4-60</td>
<td>1</td>
<td>90</td>
<td>9</td>
<td>Low to very low</td>
<td>UCS = 1168.82 EM = 559745.82</td>
</tr>
</tbody>
</table>

EM = elastic module; UCS = unconfined compression test; SCT = simple compression test
Permeability was also considerably variable, ranging from very low to moderate. Only at the L-3 borehole along the segment of 20 to 30 m is the permeability very high. Based on the proposed height of the dam, the water column will apply hydrostatic pressures of up to 6 kg/cm² to the ground.

From the Unconfined Compressive Strength tests performed on samples from the dam axis area values that range from 695 kg/cm² (68.16 MPa) to 1579.62 kg/cm² (154.9 MPa) were obtained. This corresponds to Strong to Very Strong rock.

(b) The Powerhouse Site and Quarry Site

Rocks recovered from both boreholes were 100% recovered and were all classified as granite. The powerhouse site consisted of a good solid bedrock foundation, whilst at the quarry site the rock appeared to be more weathered (Table 5.4.2c).

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Lithology</th>
<th>Depth (m)</th>
<th>%RQD &gt;75%</th>
<th>% Core of Sound Rock</th>
<th>% Core with Discontinuities &lt;20cm</th>
<th>Strength (kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-4 (Powerhouse)</td>
<td>Granite</td>
<td>0-10.03</td>
<td>73</td>
<td>92</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Granite gneiss (milonitic)</td>
<td>10.03-22.65</td>
<td>53</td>
<td>69</td>
<td>25</td>
<td>UCS = 1446.95 EM = 511072.27</td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td>22.65-25</td>
<td>0</td>
<td>85</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>L-5 (Quarry)</td>
<td>Colluvial deposit</td>
<td>0-2.35</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td>2.35-9.65</td>
<td>0</td>
<td>12</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flaser granite</td>
<td>9.65-22.30</td>
<td>42</td>
<td>0 (100% SW)</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td>22.3-25.15</td>
<td>31</td>
<td>0</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td>25.15-30</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
5.4.3 ROCK MASS RATING

The investigated parameters (uniaxial compressive strength of the intact rock, RQD, spacing of discontinuities, condition of discontinuities, ground water conditions and orientation of discontinuities) can be used to determine the Rock Mass Rating (RML). For the dam site a rock mass characterization was done based on the information obtained in the geotechnical boreholes and complemented with superficial observations. The RML method proposed by Bieniawski (1989) was used. Based on the data obtained, a classification was made for both units superior and inferior on both banks. Rocks were classified as either II or III (good to fair), with ratings increasing with depth below the surface.

Dams require competent foundations with the strength to withstand the loads imposed by both the structure and the reservoir. It is generally recognized “that very seldom are foundations made up of a single type of rock of uniform strength and that this is only an average "effective" value for the entire foundation” (USACE, 1994). The Geotechnical Report recommended that the highly weathered rock and superficial deposits of the right banks found on the R-2 and R-3 boreholes must be removed to a depth of approximately 5 m.

5.4.4 STRUCTURAL GEOLOGY

5.4.4.1 Regional Considerations

Belize is located on the Maya/Yucatan Block, on the North American Plate, which is one of the major plate tectonic elements in the region. The Maya/Yucatan Block occurs to the northwest of the Chortis Block, which is the western margin of the Caribbean Plate (Burkart, 1994). Movements along the North American Plate relative to the Caribbean Plate or the Cocos Plate (a major subduction zone on the Pacific side) can result in earthquakes.

The Maya Mountains are described as a horst block bounded by northeast trending faults. The Maya Mountains have been interpreted as an extension of the Libertad Arch, which is an east/west striking antiform extending along the width of north-central Guatemala (Weyl, 1980).
cited by Reeder et al, 2004). The structure of the western boundary of the Maya Mountain fault block is obscured by the Cretaceous limestones.

(a) Faulting

According to the Geotechnical Report (Rodio-Swissboring, 2005), there was no evidence of faulting in the rock outcrops along the river channel at the Site B boreholes. Other evidence for faulting within the region such as the orientation of the river (fault-controlled lateral displacement) and the occurrence of waterfalls (probably due to fault related vertical displacement) is suggested, and is supported by the Rodio-Swissboring (2005) assessment given below:

The Geotechnical Report specified that “The clear presence of faults could not be established during the field work. However, there is some evidence and alignments that can be related to the presence of faults. In the aerial photographs of the area two alignments can be observed. They have an approximate length of 1500 to 1800 m with a N 70 E and N 50 E direction respectively (see geologic map 9 and 10); these are located near two drainages that outlet into the Macal River. No evidence for faulting could be established along the river channel outcrops. The regional fault system controlling the river coincides with the alignments (Cayo Trench System and others). The river course changes almost at 90° angles, this can be related to faults or main joints that in some cases have carved channels by the eroding action of water and have formed a rectangle drainage. The water falls can be related to local faults as at Vaca Falls, but in the outcrops on both banks of the river there is no evidence of such movement.”

Studies conducted by multiVIEW Geoservices Inc. (1991) at dam Site A and the alignment for the tunnel indicated the presence of a fault/shear zone along the tunnel alignment. According to a review of the Macal River Hydroelectric Development Feasibility Study (Volume III - Report on the Geology and Geotechnical Conditions by Geo-Engineering MST Ltd.) done by Cho and Moore (2004), there are fault/shear zones within 850 m of dam Site A. Additional mapping along the Macal River by Cho and Moore (2004) confirmed the presence of two shear zones within the study area (one located within UTM N188739, E0282244, and N1881765 E0282452 and the other located within UTM N1881812, E0282169 and N1881840 E0282134). The first
fault zone is a 15 m wide normal fault zone trending NE, and the second is a 28 m wide normal fault zone trending NE.

(b) Fractures

The Geotechnical Report (Rodio-Swissboring, 2005) states that the fractures are defined by the joint sets, which can be classified into three groups. These joint sets result in the creation of blocks in the granite, some of which can be seen in the riverbed. On borehole L-1 (riverbed) 102 joint readings were taken; on borehole L-2 (riverbed) 42 joint readings were obtained. Sixty-one (61) separate fracture data readings were taken on the right side of the valley (dam axis site).

Analysis of this data by Rodio-Swissboring (2005) lead to the conclusion that “the rock has a joint spacing predominance from moderate to wide with an RQD of Good quality from (75 – 90%). The fractures are closed to slightly open due to their own decompression, the superficial weathering and the insertion of roots within the fractures. At depth the fractures do not have the same behavior because they are not exposed to the agents indicated above. The main fracturing has moderate to high longitudinal continuity of about 10 to 20 m.” The dominant direction of the joints is NEE-SWW and NNW-SSE on the left bank. The dominant direction of the joints on the right bank is NW-SE.

Cho and Moore (2004) reported numerous joints in the study area, and that these appeared to be more densely concentrated in the fault zones.

Fernandez (2004) reported that “No faults or major shear zones were observed along a 150 metre long river stretch on the proposed dam site. Three sets of tight, well defined joint systems were observed in the river valley exposures. In two sets the joints run semi-parallel to the river valley and dip steeply to the south, while joints in the other set run in a direction semi-perpendicular to the river flow and dip upstream. In general the joints are tight, moderately to widely spaced and with no significant weathering along the joint surface.

With respect to dam abutments, Fernandez (2004) noted that on the ‘left abutment, the rock exposures consist of relatively massive and very strong granite with only slight surface
weathering. No shear or fault zones were observed in the exposed rock. A few, near vertical, widely spaced, tight joints running semi-parallel to the river were observed in the steeply inclined rock walls.” On the right abutment similar bedrock was observed, with “more pronounced and closer spaced joints”. According to Fernandez (2004) “a set of persistent, rough joints, striking perpendicular to the river flow and with a flat dip upstream, were observed in the right valley walls. These joints appear to be relatively open in the vicinity of the valley walls.

5.4.5 SUPERFICIAL MATERIALS

Four types of superficial materials are discussed in the Geotechnical Report (Rodio-Swissboring, 2005). These include:

a) Slope detritus, overburden, residual soils. These are found on the valley slopes, and are typically vegetated. This soil consists of yellow brown clayey sands. The thickness of this unit can be as much as 2.3 m (found in borehole R-3).

b) Alluvial Deposits. These consist of material transported by the river, and are usually found at the lower elevations (accessible by flood waters). In the study area four alluvial terraces are noted. These deposits comprise abundant granite and gneiss rounded boulders (up to 70 cm in diameter), with sands and gravels.

c) Colluvial Deposits. These are materials transported down a slope as a result of weathering and erosion processes (including landslides). This unit is composed of blocks and gravel of diverse size and composition in a silty or clayey sand matrix. This material has the widest distribution on both flanks of the Macal River. The thickness of this deposit is variable and depends on factors such as the slope, fracturing and weathering degree. The thickness of these deposits at the dam site axis varied from 0.50 m to 2.35 m. The Geotechnical Report concluded, “The thickness of these deposits does not imply movement or landslides that can affect the dam site or the reservoir area”. Whilst it is true that the stability of slopes comprising this material may be improved by vegetative cover, the presence of this material suggests the potential for slope failure in the parent
rocks comprising the valley slopes. There is insufficient investigation of slope stability to draw a conclusion that the area would not be subject to landslides.

d) Carbonate Crusts (travertine or tufa). This layer has a relatively ample presence on the left bank (western) of the dam site. It is a product of the precipitation of carbonate rich fluids that flow from natural springs found on the karstic limestones. These thin surficial travertine crusts are mainly distributed from the dam axis to 140 m upstream from the borehole L-1, and are only associated with surface water flow pathways.

### 5.5 Hydrology

#### 5.5.1 BASIN DIMENSIONS
The Macal River is divided into four smaller sub-catchments corresponding to the area drained by each existing or proposed dam site and river gauge station (Table 5.5.1.).

Table 5.5.1 Catchment Sub-division of Macal River Basin

(Source: AGRA CI Power/BEL, 1999)

<table>
<thead>
<tr>
<th>Dam/Gauge *</th>
<th>Sub-catchment area (km²)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber Camp (P)</td>
<td>813</td>
<td></td>
</tr>
<tr>
<td>Challilo (P)</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Mollejón (E)</td>
<td>156</td>
<td></td>
</tr>
<tr>
<td>Vaca (P)</td>
<td>~ 250</td>
<td>Subset of the 426km² for Cristo Rey</td>
</tr>
<tr>
<td>Cristo Rey (F)</td>
<td>426</td>
<td></td>
</tr>
<tr>
<td><strong>Total Catchment</strong></td>
<td><strong>1465</strong></td>
<td></td>
</tr>
</tbody>
</table>

(Existing – E; Proposed – P; Flow Gauge Station - F)

There are five hydrometric stations around the considered watershed, one of which is within the Macal River watershed – Cristo Rey – from which discharge/water level records are available for different timeframes.
5.5.2 HYDROGEOLOGY

The hydrogeology of the Macal River basin is described in the geotechnical summary document (AGRA CI Power/BEL, 1999). The report described the hydrogeology as ‘complex’ due to the litho-stratigraphic distribution and consequently it was difficult to derive a hydrogeological classification for the independent rock types. The permeability (obtained by the Lugeon method) ranged between $10^{-6}$ to $10^{-9}$ m/s, which characterises moderate to lower permeability materials. However, one borehole (L-3) reported permeability values greater than $10^{-6}$ m/s at a depth of 20-30m which is attributed to fracturing. No groundwater abstraction points were noted in the report.

The presence of several springs was observed in the area of interest occurring mostly at around 300 m above sea level. Dry season discharges from these springs were measured at between 0.5 to 3 l/s. The report suggested that these springs were a result of the geological contact between the limestone and the granite at that level. This suggests that groundwater surface expression is geologically controlled in river basin.

Boreholes installed at river-bed level and above indicated that relative to bed level, groundwater level is approximately 26 m – 32 m above river bed level, suggesting that the river, at least in portions, receives some groundwater as baseflow. Looking at the hydrograph the baseflow contribution is likely to be less than 10% of the total monthly water budget. No rainfall-groundwater hydrographs were developed due to the scarcity of such groundwater data.

5.5.3 EXISTING MACAL RIVER FLOWS

Flows on the Macal River at Vaca Site A just downstream of its confluence with Rio On and at Site B above the Vaca Falls have been calculated by Gilbert-Green and Associates (2005 c) based on the flows derived for Cristo Rey and adjusted for their differential drainage areas and incremental run-offs. The resulting flows at Vaca Site B have been estimated at 1.6% higher than at Site A, as shown in Table 5.5.3 a, adapted from Gilbert-Green and Associates (2005 c).
Table 5.5.3 a: Mean Annual Flows on the Macal River for Different Time Periods
(Source: Gilbert-Green and Associates, 2005 c)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalillo</td>
<td>Flow m³/s</td>
<td>16.2</td>
<td>13.4</td>
<td>12.2</td>
</tr>
<tr>
<td>Mollejon</td>
<td>Flow m³/s</td>
<td>19.4</td>
<td>16.4</td>
<td>15.0</td>
</tr>
<tr>
<td>Vaca Site A</td>
<td>Flow m³/s</td>
<td>25.7</td>
<td>21.9</td>
<td>20.1</td>
</tr>
<tr>
<td>Vaca Site B</td>
<td>Flow m³/s</td>
<td>25.7</td>
<td>22.2</td>
<td>20.4</td>
</tr>
</tbody>
</table>

Based on similar data and analyses, the mean annual flow at Cristo Rey has been estimated at 31.4 m³/s (AGRA CI Power/BEL, 1999). However, as is typical for the entire Macal River basin, flows are highly variable from month to month with a well defined wet and dry season. In addition, long term wet and dry years occurring in cycles are evident with a maximum annual average for the 1984 to 1998 period of 50.2 m³/s in the wet year of 1990 and a minimum annual average of 13.9 m³/s in the dry year of 1987. Table 5.5.3 b sets out the monthly flows derived for Cristo Rey for the period 1984 to 1998.
Environmental Impact Assessment

ESL Management Solutions Ltd.

Table 5.5.3 b: Historical Monthly Flow Estimated at Cristo Rey (m³/s) Based On Stage Discharge Relationship By AMQ/Acres 1999 and Completed Based on Big Falls and Double Run Records (dmd w/o 1981-83 Oct. 86-Dec 88)  Source: AGRA CI Power/BEL, 1999

\[
Q = 6.685 (H - 0.43)^{2.486} \text{ for } H<1.09 \text{ m}
\]

\[
Q = 10.42 (H - 0.55)^{2.397} \text{ for } 1.09<H<3.22\text{m}
\]

\[
Q = 3.457 (H + 0.99)^{2.406} \text{ for } H>3.22\text{m}
\]

<table>
<thead>
<tr>
<th>YEAR</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>32.7</td>
<td>31.1</td>
<td>8.8</td>
<td>2.9</td>
<td>6.3</td>
<td>27.3</td>
<td>44.5</td>
<td>43.8</td>
<td>72.2</td>
<td>37.7</td>
<td>29.1</td>
<td>36.9</td>
<td>31.1</td>
</tr>
<tr>
<td>1985</td>
<td>32.4</td>
<td>13.1</td>
<td>9.3</td>
<td>10.3</td>
<td>5.4</td>
<td>19.8</td>
<td>36.8</td>
<td>21.4</td>
<td>26.7</td>
<td>66.8</td>
<td>34.5</td>
<td>23.6</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>26.9</td>
<td>34.8</td>
<td>28.5</td>
<td>37.7</td>
<td>22.5</td>
<td>60.2</td>
<td>47.2</td>
<td>38.9</td>
<td>63.4</td>
<td>35.9</td>
<td>25.5</td>
<td>8.5</td>
<td>35.7</td>
</tr>
<tr>
<td>1987</td>
<td>5.7</td>
<td>4.6</td>
<td>4.3</td>
<td>1.9</td>
<td>7.4</td>
<td>8.4</td>
<td>33.1</td>
<td>27.8</td>
<td>40.1</td>
<td>13.0</td>
<td>10.4</td>
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<td>4.3</td>
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</table>

RIVER FLOW (m³/s)
Gilbert-Green and Associates (2005 c) have applied flow equations based on Cristo Rey data to derive Chalillo, Mollejon and Vaca flows under dry, intermediate and wet conditions. The derived results are in good agreement with the flows measured at Mollejon from 1996.

5.5.4 PROJECTED MACAL RIVER FLOWS WITH THE VACA PROJECT

The Vaca project is proposed as the third and furthest downstream of the series of dams on the Macal River. Figure 5.5.4 a shows the longitudinal profile of the Macal River and the relationship between the Vaca, Mollejon and Chalillo Hydroelectric Projects, as illustrated in the Gilbert- Green and Associates (2005 a) Vaca Project Proposal Document.

Figure 5.5.4 a: Macal River Hydroelectric Projects: Longitudinal Profile
(Extracted and unmodified from 1999 AGRA CI Power/BEL, 1999)

The Chalillo dam will store surplus flood water during the wet season and release it during the dry season. The outflows from Chalillo will pass through a small powerhouse before continuing downstream for use at Mollejon. The outflows from Mollejon, plus the additional inflows from the Rio On and small spring fed streams between Mollejon and the Vaca dam, will then generate additional energy at Vaca.
Two possible dam sites have been identified at Vaca. At Vaca Site A, a dam with full supply level at elevation 143.5 m would be built just below the confluence of the Macal River and Rio On. This would create a reservoir with a gross storage of 2.0 hm$^3$ which would extend 3.5 km up the Macal River to the toe of the Mollejon powerhouse and about 0.7 km up the Rio On to an equivalent elevation. At full capacity a discharge of 33 m$^3$/s from the reservoir would be made via a 2.96 km tunnel to the powerhouse located below the Vaca Falls. There would also be a continuous riparian release of 1 m$^3$/s or the total inflow, whichever is less, to the reach of the river between Rio On and the foot of the Vaca Falls. This means that the falls would flow near minimum flow except when the discharge capacity of the turbines (33 m$^3$/s) is exceeded as, for example, during flood flows (about 20% of the time) (Gilbert-Green and Associates Inc., 2005c).

At Vaca Site B, a 48.5 m high dam with full supply level also at elevation 143.5 m would create a larger reservoir of 13.1 hm$^3$ storage, extending from the dam, past Site A and up to the same elevations as the Site A reservoir on the Macal River and Rio On. The total inundated length on the Macal River from Site B would be approximately 5.8 km. With a powerhouse operating at the toe of the dam on a continuous run of the river basis, there would be a regular flow to the river of up to 33 m$^3$/s, rejoining the river immediately below the powerhouse. The plant would generally operate 24 hrs per day at an average flow of 20 m$^3$/s. Hence, there would be no significant reduction in flow on the Macal River downstream of the dam and the facility would serve to better regulate the river flow downstream of Vaca. On the other hand, at full generating capacity and with the reservoir level at full height during periods of extreme flood conditions, downstream flow would exceed 33 m$^3$/s due to additional flow over the spillway.

The general arrangement for the Vaca Site A and Site B options are illustrated in Figure 5.5.4 b.
Figure 5.5.4 b: General Arrangement of Vaca Site A and Site B Options
The Vaca Project Options as provided by Gilbert-Green and Associates (2005 a and c) are detailed in Table 5.5.4.

Table 5.5.4: Vaca Project Option Details  
(Source: Gilbert-Green and Associates, 2005 a and c)

<table>
<thead>
<tr>
<th>Item</th>
<th>Vaca Alt. A</th>
<th>Vaca Alt. B</th>
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<tr>
<td>Dam Crest Elevation, m</td>
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<td>157.0</td>
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<tr>
<td>Reservoir Full Supply Level, m</td>
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<td>143.5</td>
</tr>
<tr>
<td>Assumed Riverbed Elevation, m</td>
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<td>95.0</td>
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<tr>
<td>Dam Height at Full Supply Level, m</td>
<td>19.5</td>
<td>48.5</td>
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<tr>
<td>Gross Storage at Full Supply Level, hm³</td>
<td>2.0</td>
<td>13.1</td>
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<tr>
<td>Total Tunnel Length, m</td>
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<tr>
<td>Powerhouse Tailwater Elevation, m</td>
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<td>82</td>
</tr>
<tr>
<td>Gross Head, m</td>
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<td>3</td>
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<tr>
<td>Installed Capacity MW</td>
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<td>17.8</td>
</tr>
<tr>
<td>Riparian Release, m³/s</td>
<td>1.0</td>
<td>0</td>
</tr>
</tbody>
</table>

5.5.5 INUNDATION AND FLOOD PLAINS

Based on the proposed dam design parameters, it is possible to project the extent, areas, and depth of the reservoirs that would result, given implementation of either the Site A or Site B dam option. Gilbert-Green and Associates (2005 a) has shown the inundated areas for each dam site (See Figure 5.5.4 a) and Gilbert-Green and Associates (2005 c) has produced elevation storage curves for both (Figure 5.5.5 a). Table 5.5.4 above also gives details of the reservoirs.
Figure 5.5.5 a. Vaca Elevation Storage Curves (Source: Gilbert-Green and Associates, 2005 c)
Of special note is the fact that a Site B dam would create a reservoir that is larger than a Site A dam. The inundation length of a Site B dam would be approximately 6.5 km (5.8 km on the Macal River plus 0.7 km on the Rio On) while the inundation length of a Site A dam would be 4.2 km (3.5 km on the Macal River and 0.7 km on the Rio On). The Site B dam would incorporate all of the area of the Site A dam, on both the Macal River and Rio On. In addition it would be more than twice the depth at its deepest point and would have a storage capacity more than six times. On the other hand, the potential generating capacity at Site B would be approximately 0.2 MW less than at Site A (Gilbert-Green and Associates, 2005c).

Immediately downstream of the dam, the floodplain features would also be different. Of special note is the fact that a Site A dam would create significantly reduced flows between the dam and the powerhouse below Vaca Falls as most of the flows would be directed to the powerhouse by a tunnel and only 1 m$^3$/s would be returned directly to the river at the toe of the dam as a riparian release. Hence, while a Site A dam would inundate a smaller area above the dam, it would also create a larger dry area below the dam.

With the Chalillo, Mollejon and Vaca dams operating in series, the downstream flows in the Macal River would be transformed from being highly variable and flashy to more controlled and predictable. Projections for flows at Cristo Rey after implementation of the Chalillo Hydroelectric Project have been made for a number of flow regimes (average, wet and dry years) as shown in Figures 5.5.5 b, c, and d, produced by AMEC E & C Services Ltd. (2001).
Figure 5.5.5 b Projected Flows on the Macal River after Implementation of Chalillo Scheme (AMEC E&C Service Ltd., 2001) – Average Year
Figure 5.5.5 c: Projected Flows on the Macal River after Implementation of Chalillo Scheme (AMEC E&C Service Ltd., 2001) – Wet Year
Figure 5.5.5 d Projected Flows on the Macal River after Implementation of Chalillo Scheme (AMEC E&C Service Ltd., 2001) – Dry Year
As the figures illustrate, the upstream dams would reduce downstream peak flows in the wet season and increase low flows in the dry season. At the same time, there would be no significant changes in annual total or average flows. This, however, would result in changes in the extent of inundation of the flood plain during the wet and dry seasons and would create more stable flood contours year round.

Wagenseil (1999) has analysed the extent and nature of peak flows on the Macal River at Cristo Rey and has described the duration and flashy nature of the floods, some of which would continue during operation of the upstream dams (see Figures 5.5.5 b and c, which project future flows in average and wet years). According to Wagenseil (1999), impoundment on the upper Macal River would retard some of the flood waters but not eliminate them altogether. This is shown in Figures 5.5.5 b and c.

Based on the above, it can be expected that some flood plain features other than water level would change over time. This would include the riparian vegetation, wildlife habitats and access, domestic uses and hazard vulnerability (these will be discussed in the section on impacts).

While the above pertains to usual, wet and dry season flows, two other situations require special mention. The first is extreme flood flows or Probable Maximum Floods (PMF), and the second is Dam Failure.

PMFs occur under exceptional circumstances such as hurricanes and are generally unpredictable, generating extreme flows over a relatively short period of one to a few days (peaking in a few hours and receding over a few days). During this time, water levels at the dam may exceed the normal spillway height and approach the level of the dam crest. With adequate design, the dam crest should hold back most of the flood water and release it more gradually over time. However, with inadequate design, the PMF could overtop the crest and result in severe downstream flooding. For this reason, dam engineers are extremely conservative in designing dam crests to ensure that the Inflow Design Floods include
provision for the PMF. The proposed Vaca dam incorporates this consideration in its preliminary design.

The other situation is dam failure which may occur with structural damage to the dam. In such a situation, the dam may release unregulated flows which could cause severe downstream flooding. Again, these flows to a certain extent are unpredictable so dam engineers make provision for possible total dam failure during PMFs. In the case of Vaca, preliminary dam break analyses have been carried out for each dam option by Gilbert-Green and Associates (2005 b and c) (see Appendix IV).

For a Site A dam, given an inflow design of 0.5 PMF, failure of the dam at maximum water level would produce a peak discharge of 8,770 m$^3$/s and the following flows at Cristo Rey and San Ignacio as shown below:

Table: 5.5.5 a: Flows at Cristo Rey and San Ignacio in the event of Dam Failure at 0.5 PMF at Site A (Source: Gilbert-Green and Associates, 2005 c)

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<th>Height</th>
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<tr>
<td>Cristo Rey</td>
<td>5620m$^3$/s</td>
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<tr>
<td>San Ignacio</td>
<td>5590m$^3$/s</td>
<td>57.7m</td>
<td>0.1m</td>
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</table>

Both increases in flood inundation are less than the 0.6 m criterion set by the US Federal Energy Resource Commission (FERC), for dam failures, so the 0.5 PMF is suitable as the Inflow Design Flood (IDF) for this site.

For a dam at Site B, failure at maximum level during the PMF would produce a peak discharge of 24,600 m$^3$/s and the following flows at Cristo Rey and San Ignacio:
Table: 5.5.5 b: Flows at Cristo Rey and San Ignacio in the event of Dam Failure at PMF at Site B (Source: Gilbert-Green and Associates, 2005 c)

<table>
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<th></th>
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<th>Height</th>
<th>Increase</th>
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<tr>
<td>Cristo Rey</td>
<td>13407 m³/s</td>
<td>76.91 m</td>
<td>1.17 m</td>
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<tr>
<td>San Ignacio</td>
<td>13242 m³/s</td>
<td>60.60 m</td>
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</table>

The increase at Cristo Rey would be above the FERC criterion. Therefore the dam design must use the Probable Maximum Flood as the Inflow Design Flood in order to minimize flood increases in case of dam failure.

Gilbert Green and Associates (2005 b) have provided a comprehensive analysis of flood flows below the Vaca dam with and without dam failure. Their report, with flood flow data and hydrographic graphs (Appendix IV), shows that at PMF, dam failure would not significantly change the extent of the flood plain. However, under fair weather conditions there would be an increase in the flood plain, but not such to result in hazardous flooding. Flood plain contours for dam failure under PMF and fair-weather conditions are shown in Figure 5.5.5 e (see insert in back pocket).

Wagenseil (1999) has concluded that given the dynamics that obtain the upper Macal River Basin ‘runoff surges’, once the soil reaches saturation, can reach populated areas within ‘three days or less’ (Figure 5.5.5 f). Wagenseil (1999) further suggested that impoundment control could retard the effects of the hydrograph response on the Macal. This impoundment facility would require:

- Careful design to ensure that the impoundment “would have to provide adequate storage to delay high flow surges” and,
- Possess sufficient reserve empty capacity to ensure public safety downstream during a significant flood event while addressing electricity generation requirements.

The Vaca dam preliminary designs incorporate all these features.
5.5.6 SEDIMENTATION

Sedimentation studies conducted for the Chalillo project along with direct observation and measurements of sedimentation at Mollejon have been used to estimate sedimentation levels at the proposed Vaca dams. These include suspended sediment loads as well as reservoir bedloads in the reservoirs.

The AGRA CI Power/BEL (1999) EIA report for Chalillo has provided the following catchment areas for selected sub-areas on the Macal River:
From these figures, we calculate a catchment area of Mollejon to Cristo Rey of 426 km$^2$ and Mollejon to Vaca Site B (including Rio On) of approximately 300 km$^2$.

Based on theoretical considerations as well as practical experience of sediment loadings in tropical forested areas such as the Macal watershed, AGRA CI Power/BEL (1999) applied an annual erosion rate of 0.2 mm for the Chalillo catchment area of 883 km$^2$. This gave an annual sediment runoff to the river above Chalillo of 215,000 m$^3$, which is equivalent to a deposited reservoir load of 300,000 tons.

When these figures are compared with the deposited sediment load actually observed at Mollejon after ten years operation, it can be seen that there is a significant over-estimation even given possible inaccuracies in the Mollejon estimate. Nevertheless, to be conservative, the theoretical values have been retained for estimation of the Vaca reservoir loads.

Based on the above formula, we may conservatively estimate an annual deposited sediment load of 73,046 m$^3$ or 102,000 tons in a Vaca reservoir. Compared with the theoretical sediment load at Mollejon of 238,858 m$^3$ or 353,260 tons and matching this against the actual observed deposition in that reservoir, we may conclude that sediment deposition of sediment at Vaca is likely to be much less and neither a significant problem for water quality nor reservoir life.

A sample taken of the suspended sediment deposits at Mollejon for the Chalillo Feasibility Study (Agra CI Power/BEL, 1999) showed the sediments to be composed of 4% Organics, 20% Sand, 69% Silt and 4% Clay. Three more samples taken in April 2004 (BECOL,
2004), showed a similar composition of 5.9% Organics, 47% Sand, 48% Silt and 5% Clay. These analytical results are given below in 5.5.6.

Table 5.5.6: Analytical Results of Sediment Samples taken from Mollejon in April, 2004 (BECOL, 2004)

<table>
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<th>Sample No.</th>
<th>% Clay</th>
<th>% Silt</th>
<th>% Sand</th>
<th>Liquid Limit %</th>
<th>Plastic Limit %</th>
<th>Plasticity Index %</th>
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<td>54</td>
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<td>19.5</td>
<td>10.7</td>
<td>2.66</td>
<td>6.1</td>
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</table>

Note: Clay size means particles finer than 0.002 mm. Silt size is between 0.002 mm and 0.075 mm.

On both sampling occasions, the sediment thickness generally varied from 300 to 500 mm. (See Plate 5.5.6)
Plate 5.5.6 a, b, c: The Mollejon Reservoir Showing Shoreline Sedimentation and Riparian Vegetation

Plate 5.5.6 a:

Plate 5.5.6 b:

Plate 5.5.6 c:
It seems reasonable to expect, given the nature of the Macal and Rio On basins, that deposited sediments in the Vaca reservoir would have a similar composition as at Mollejon and be deposited in a similar pattern. Therefore, we would expect the problem free Mollejon experience to be repeated at Vaca.

With regard to likely bedload transport and deposition in a Vaca reservoir, the Mollejon experience can again be used as a useful guide. At Mollejon, bedload comprising about 500 m$^3$ of sand, gravel, stones and cobbles was observed in 2004 mainly at the upper end after drawdown of the water level (AGRA CI Power/BEL, 1999). Estimating an additional 500 m$^3$ for sand that may have gone further into the reservoir, a total of 1000 m$^3$ bedload material was derived for the ten years operation of the project. This amount may also be regarded as insignificant and unlikely to affect dam operations or its effective life.

By using similar methods to those applied above, AGRA CI Power/BEL (1999), estimated that without flushing it would take 500 years for the Chalillo reservoir to become filled with sediment. Our study suggests that a Vaca reservoir would likely take as long or longer. During this time, however, and based on reservoir bed inspection as an annual maintenance operation, flushing of deposited sediment would take place to reduce its accumulation. If this flushing were done as required, the flushed material would not be expected to affect downstream water quality for more than a few hours. However, this would need to be carefully monitored and controlled according to DOE standards.

The Chalillo EIA investigated likely effects of the Macal River impoundment on aggregate sand supply at Belize River mouth, mangrove shore development in the Belize District coastal plain and movement of the saline wedge in the Belize River, and concluded that the impoundment would have no impact. This EIA study agrees with these conclusions.
5.6 Water Quality

Baseline data for dry season water quality conditions was collected May 17 and 18, 2005. Water quality sampling was also conducted on August 18, in order to establish baseline conditions for the wet season. Both data sets are given in Table 5.6.

In summary the quality of the water in the Macal River is quite good. Dissolved Oxygen levels are lower at Mollejon dam but the river rapidly rejuvenates itself and downstream dissolved oxygen levels were quite good. The accumulated effect of the three dams will be considered when evaluating the impact of the Vaca dam on the Macal River.

The following discussion is based on data generated from one sampling exercise during the dry season in May 2005 and one exercise during the wet season in August 2005, and four historical sampling exercises (August 2001 and December 2004 - April 2005). The historical data are presented in Appendix IV. The present and historical data show good correlation.

During the wet season the opportunity was taken to investigate one additional station between Mollejon and Chalillo, to determine parameters further upstream of the Vaca Falls. Further investigation of some of the parameters investigated during the dry season was also done during the wet season.
## Table 5.6.1: Water Quality Data for the Macal River and Rio On May 17 & 18, 2005 (Dry Season Sampling) and August 18 (Wet Season Sampling)

<table>
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<tr>
<td>Dissolved Oxygen (mg/L)</td>
<td>5.1</td>
<td>-</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>13.0</td>
<td>-</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>15.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Nitrate (mg/L)</td>
<td>7.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Phosphate (mg/L)</td>
<td>0.27</td>
<td>2.1</td>
</tr>
<tr>
<td>Sulphate (mg/L)</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Total Coliform MPN/100ml</td>
<td>93</td>
<td>-</td>
</tr>
<tr>
<td>Faecal Coliform (MPN/100ml)</td>
<td>21.0</td>
<td>-</td>
</tr>
<tr>
<td>Total dissolved solids mg/L</td>
<td>23*10³</td>
<td>12,800.0</td>
</tr>
<tr>
<td>Total suspended solids mg/L</td>
<td>5.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Hardness mg Ca/L</td>
<td>47.5</td>
<td>-</td>
</tr>
<tr>
<td>Calcium (mg/L)</td>
<td>15.3</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium (mg/L)</td>
<td>4.4</td>
<td>3.6</td>
</tr>
<tr>
<td>Manganese (mg/L)</td>
<td>&lt;20.0</td>
<td>-</td>
</tr>
<tr>
<td>Mercury (mg/L)</td>
<td>&lt;0.5</td>
<td>-</td>
</tr>
<tr>
<td>Iron (mg/L)</td>
<td>103</td>
<td>750</td>
</tr>
</tbody>
</table>
A discussion of the variation of the critical parameters follows.

◊ **pH, Conductivity, Salinity and Temperature**

The pH levels indicate that the waters are somewhat alkaline in nature. Conductivity measurements show a marked decrease from the reservoir downstream to Vaca falls. The data suggest that evaporation could be the cause of the higher conductivity and marginal salinity readings recorded at the reservoir. The system is naturally adjusting itself as it moves downstream resulting in the lower conductivity levels recorded.

◊ **Dissolved Oxygen (DO) and Oxygen Demand**

Dissolved Oxygen (DO) levels in the Macal River at the Mollejon reservoir were lower than that further downstream at Site A and Site B. DO levels improved moving away from the dam from fair at the dam to very good at Station A and the Rio On. The rapid mixing at the confluence is directly responsible of the high oxygen levels at Site A and in the Rio On.

Significant oxygen demand was recorded along the Macal River. This is in direct contrast to the low oxygen demand for the Rio On. The data suggest that biological constituents are responsible for the oxygen demand as chemical oxygen demand levels were relatively low. The biological population in reservoirs is usually high and hence the demand for oxygen is not surprising. Dissolved oxygen levels are not currently below accepted norms and so there is no cause for concern. Historical water quality data show that dissolved oxygen levels are better upstream of the existent reservoir. When the Chalillo dam is commissioned and later the Vaca facility, it is likely that the oxygen demand will increase significantly. Oxygen reduction in the reservoirs must therefore be managed to prevent them becoming anoxic.

◊ **Total Dissolved and Suspended Solids**

Total suspended and dissolved solids were low at all the stations sampled when compared with the standards. However, it should be noted that for each station sampled, the wet season levels of total suspended solids was higher than the dry season. This is expected as terrestrial run-off
and faster flows would generate more sediments in the wet season. The historical data records similarly low levels upstream of the present reservoir. The run of the river dam at Mollejon is therefore not impacting sedimentation in the river channel. Vaca though a run-of-the-river dam would be influenced by the release of impounded waters from Chalillo. These waters would typically have low suspended sediments and therefore suspended solids should not increase in the system.

◊ **Total and Faecal Coliform**

Total and faecal coliforms are used as indicators of pathogenic organisms and by extension pollution. Coliform bacterial levels are low when compared to international standards such as the USEPA standard of 400/100 ml, although they exceed the DOE more stringent standard of 1/100 ml. However, the levels detected can still be considered an indicator of good water quality.

◊ **Nitrate and Phosphate**

Nutrient levels are low and indicate that there is no accumulation of nutrients in the surface waters tested. Similar low nutrient levels were recorded for the stations sampled upstream of the Mollejon, as may be expected. It should be noted that nitrates are lower for each station, during the wet season, which could be due to dilution effects. Conversely, phosphate levels are higher at each station during the wet season which may signal increased inputs of phosphates into the river system or from terrestrial run-off.

◊ **Metals**

The concentration of calcium, manganese, magnesium and iron were at or just above detection levels. The hardness data confirm that the waters in this river system are soft.

◊ **Mercury**

Mercury levels at all stations sampled were low. Mercury has the ability to bio-accumulates in aquatic organisms in reservoirs. No data was available for review of mercury levels in biota in the Macal River.
Mercury was not sampled during the wet season. The levels detected during the dry season were low and well within the national standard. During the wet season, increased flow in the river system would create a dilution effect that would reduce these levels even more.

In response to concerns raised on levels of mercury reported in the Macal River Upstream Storage Facility (Chalillo) EIA Report, the Ministry of Health, Fisheries Department, and the Department of the Environment, with the technical cooperation of the Pan American Health Organisation (Flores et al, 2005) conducted a study to assess levels of mercury in selected fish species in the Macal, Mopan and Sibun Rivers (Flores et al, 2005). Levels of mercury were detected in predatory and non-predatory fish species at levels below the FAO/WHO limit for both groups. The Flores et al (2005) report stated that an assessment of mercury levels in fish from other water bodies countrywide should be conducted, and a plan of action including mitigation measures, public awareness, monitoring and enforcement should be developed and implemented involving the relevant stakeholders.

The report concluded with a reminder that BECOL is responsible for developing and implementing a Mercury Risk Management Program, under the Environmental Compliance Plan for the Chalillo Dam.

The emerging trends from the historical data correlate with the dry season results for the present study. Further analysis will be conducted after completion of the wet season sampling. The quality of the water in the Macal River is good. Dissolved oxygen levels are lower at the Mollejon dam but the river rapidly rejuvenates itself and downstream of the dam the waters are fairly well oxygenated.

5.6.1 POTABLE WATER SOURCE

The above water quality data indicates that the Macal River in the Vaca area is suitable as a source of potable water. This is supported by the experience of several individuals and some resort facilities that claim to use river water as a safe water supply, following only basic treatment of settling and/or filtration. It is the recommendation of this EIA report that the Macal River be tapped as a source of potable water to supply the requirements of the residential
construction campsite. However, it is also recommended that chlorination be added as further treatment.

5.7 Natural Hazards

5.7.1 FLOODING

Details on the potential for flooding are given in Section 5.5 Hydrology.

5.7.2 EARTHQUAKES

The seismic hazard risk (i.e. the incidence of earthquake epicenters within a 300 km radius) of the Chalillo dam site was evaluated (AGRA CI Power, 1999) using the available record for the past 400 years. Six hundred and ninety eight (698) earthquakes occurred between 1856 and 1994 (USGS records) in the 300 km radius of Chalillo. Of these, only two were estimated to have a magnitude greater than 6 on the Richter Scale (6.8 on June 12, 1912 and 7.5 on August 4, 1856). The seismic data suggests that there are no active faults in the study area.

The Geotechnical Report (Rodio-Swissboring, 2005) used a 1984 study to characterize the seismic hazard at the site. From extrapolation of macro-zonation of that study into the Vaca Falls project area, it was concluded that there was “a low seismic hazard”. It was suggested that this was due to the project being located approximately 150 km from the seismically active zones. Figure 5.8.2 a, below shows an updated analysis from the USGS Earthquake Hazards Project. This analysis illustrates that the area is assessed as having 10% probability of exceeding a Peak Ground Acceleration 1.6 m/s² in 50-years.

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4 http://neic.usgs.gov/neis/world/central_america/gshap.html
Figure 5.7.2 a: Peak Ground Acceleration (m/s$^2$) with 10% probability of exceedence in 50-years.

The USGS database does not record any significant events as having occurred in this area. Figure 5.7.2 b shows the 10-year seismicity for Central America (USGS website) for the period 1990-2000. From all the above data it would appear that the conclusion of a moderate seismic risk is valid when compared to the intensity of seismicity in the region. Earthquake activity in the Central American region appears to concentrate along plate tectonic margins. The Montaguan Fault which separates the North American Plate from the Caribbean Plate is located more than 150 km to the south of the project area.
Belize, like much of the Latin American states fronting the Caribbean Sea and the Trade Winds, has been repeatedly affected by hurricanes. Hurricanes that have impacted Belize directly since 1961 include Hattie (1961), Francelia (1969), Edith (1971), Fifi (1974), Greta (1978) and Mitch (1998). Of the hurricanes striking Belize prior to 1995, the most devastating was Hurricane Hattie, which struck Belize on October 31st, 1961, tracking over the central part of the country, before weakening over the Maya Mountains. The most recent hurricanes hitting Belize were Hurricane Keith (2000), and Hurricane Iris (2001), and Hurricane Mitch in 1998. Hurricane Keith made landfall in Belize as a Category 3 hurricane, passing over the north-eastern tip of Belize. Hurricane Iris (Figure 5.8.3) made landfall in southern Belize in the vicinity of Monkey River Town (October 9th 2001). Hurricanes are likely to impact the area with torrential rainfall which could result in flooding as well as damage from hurricane force winds.

Figure 5.7.2 b: Seismicity of Central America 1990-2000
5.7.4 SLOPE STABILITY

Factors affecting the slope stability in this area include:

1. **Weathering**: Landsliding in granitic rocks in humid areas has been well documented (Chigira, 2003). Understanding the vulnerability of these areas to slope failure hinges on the extent of weathering in these rocks. Weathering affects slope stability in two main ways, specifically in terms of (1) water infiltration, and (2) the distribution of strength of the rocks. Based on the borehole data, the extent of weathering at the lowest points in the river valley (R-1 and R-2) seems very variable, with between 24% and 85% solid rock noted in the boreholes. Weathering at depth in the area at sites above the valley seems to vary, with solid rock percentages varying between 69% and 91% below the overburden.
Weathering may range from slight weathering to a situation where there may only be core-stones of solid rock in between weathered earth.

2. **Permeability**: The permeability of the rocks is likely to vary with the degree of weathering. The Geotechnical Report indicated low permeability through the borehole sections.

3. **Slope Angle**: The Geotechnical Report indicates that the reservoir area will be on granite and gneiss. Slopes with dipping joints in weathered rock may be more susceptible to slope failure events.

4. **Jointing Pattern**: Joints are known to occur in the granites. The stability of the slope at the final selection of dam site will depend on the dip amount and dip direction (upstream or downstream) of these joints. In the Chigira (2003) study, it was found that the most common types of landslide consisted of “loosened, medium to coarse grained granite with dense, low-angle microjoints with similar textual features and are identified as micro-sheeting”

5. **Trigger factors**: Natural landslide triggers include intense rainstorms that would overload a slope, and earthquake events.

Interpretation of Figure 5.7.4 (satellite image showing sites A and B) would suggest that Site B is more prone to slope failure than Site A. Examination of the geological maps of the area (Figures 7 and 10 in the Rodio-Swissboring (2005) investigation, for B and A respectively, shows in general there is less evidence of landslides at Site A (near confluence with Rio On) as compared to Site B, where there is a large scarp, likely to be caused by landsliding in the granite. This may be related to the steeper slopes (and possibly jointing characteristics) at Site B.

Fernandez (2004) observed that the pronounced curve in the river located 800 m upstream of the dam site was associated with “a sharp, concave shaped line in the vegetation which could mimic a scarp in the rock below. A close inspection of the rock in this area was not possible, but it is recommended to perform a field reconnaissance of the area to assess the potential for localized instability, if any, during fluctuations of reservoir elevation. The zone is sufficiently removed from the dam site, and any potential sliding wouldn’t present a menace to the structure, but it could have an effect on dam operations and maintenance.”
Figure 5.7.4: Satellite Imagery of the Proposed Dam Sites
Landslides with significant amounts of landslide debris potentially occurring behind the dam structure could pose two major problems, a reduction of the storage capacity of the dam, and an increase in the flooding levels predicted behind the dam. However, the potential amounts that would come down in a landslide are relatively insignificant based on the size of the dam and the length of the inundation area (6.5 km).

5.8 Biological Environment

5.8.1 ECOSYSTEMS

Research demonstrates the presence of four (4) ecosystems within the study areas at Sites A and B, and along the Macal River in these areas. These four ecosystems are described below and presented in Figure 5.8.1:

- **Tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills**
  
  this is the predominant ecosystem throughout most of the study area. Significant localized variation in plant species assemblages and forest structure occurs, associated with gradient, soil depth, drainage and, in at least one location, in wind exposure. Canopy height varies from 12-25m, and is generally broken – especially so on the steeper slopes. Gradients vary from a minimum of approx 45 degrees to almost vertical. Generally thin soil and rapid drainage lead to very dry soil conditions during the dry season, and intermittently through the wet season – having a significant impact on the flora. Predominant plant species identified during the survey include: *Attalea cohune, Bernoullia flammea, Bucida buceras, Bursera simaruba, Calophyllum brasiliense, Chrysophyllum mexicanum, Coccoloba belizensis, Cryosophila stauracantha, Desmoncus orthacanthos, Euterpe precatoria, Manilkara zapota, Metopium brownei, Plumeria obtuse, Philodendron sp., Pouteria campechiana, Protium copal, Schippia concolor, Spondias radikoferi, Stemmadenia donnell-smithii, Swartzia cubensis, Vitex gaumeri and Xylopia frutescens.*

5 Although the bedrock in this area is not limestone the forest structure and type is influenced by calcareous material from above, that is brought down as a result of the process of weathering. The international nomenclature assigned to the forest type is based on this influence.
Figure 5.8.1: Ecosystem Map Showing the Four Ecosystem Types Identified in the areas of the proposed Dam Sites A and B
This is the predominant ecosystem type to be inundated by the proposed project. For the estimated 52-62 ha (125-150 acres) of vegetation to be lost by the inundation of Site B, approximately 85% (42-52 ha or 100-125 acres) will be of this habitat type. This area represents approximately 0.06-0.07% of the total extent of this ecosystem (as mapped in the Belize Ecosystem Map, Meerman & Sabido (2004). The area likely to be impacted by road construction, power-line alignment and quarrying activities cannot yet be calculated as all the details for these aspects have not been finalized. However, these impacts can be determined when applications are made to the relevant authorities for the permission to proceed with the specific activities.

- **Tropical evergreen seasonal broadleaf lowland forest over calcareous soils:**
  
  **Tehuantepec-Peten Variant** – initially identified as being present in the Vaca area (Herrera, 2005), this quite distinct ecosystem is located on the less steep terrain on the hill-top to the west of the main valley of the Macal, in the more southerly reaches of the survey area, and is most easily accessible on the access track to Site A. It is a taller forest (up to 30m), with a less broken canopy than that of the forest on the steep calcareous hills. Soils are deeper and more humid in this ecosystem and in the forests on the steep calcareous hills. It appears to be the ecosystem most impacted by the recent land allocations within the Vaca Forest Reserve, with not-insignificant areas being cleared for milpa farms / land claims. Whilst there is significant plant species overlap with the broadleaf forest on steep calcareous hills, relative abundances differ significantly, and a significant proportion of the canopy is made up of (as yet unidentified) tree species not or rarely found on the steeper terrain. Identified predominant trees include: *Astronium graveolens, Attalea cohune, Brosimum alicastrum, Calophyllum brasiliense, Castilla elastica, Cedrela odorata, Chamaedorea ernesti-augustii, Chamaedorea oblongata, Coccoloba sp., Desmoncus orthacanthos, Guazuma ulmifolia, Philodendron sp., Protium copal, Pseudolmedia sp., Sabal mauritiiformis, Schizolobium parahyba, Simarouba glauca, Spondias radlkoferi,*
Stemmadenia donnell-smithii, Swietenia macrophylla, Terminalia amazonia, Vitex gaumeri and Zanthoxylum sp.

Whilst none of this ecosystem would be flooded by the proposed inundation, some would be lost to road construction and power-line alignment if construction were to take place at Site A.

- **Deciduous broadleaf lowland riparian shrubland in hills** – restricted to a narrow belt along both sides of the rivers (Macal and Rio On), within the normal seasonal flood zone. Vegetation generally ranges up to 3-5m in height, and has a far more limited species richness than does the forest above the flood zone. Lying within the zone that is flooded annually and repeatedly, within the study area the soils of this ecosystem are often very thin, are generally sandy and lacking significant organic content. Soils are often limited to small pockets within the fissures in the granitic rock. This riparian shrubland occurs on both sides of the rivers, generally stretching 5-15m away from the main river course, depending largely upon the gradient of the banks – it rarely extends more than approx 8m above dry season water levels. The woody shrub *Calptranthes sp.* is very prevalent within this ecosystem, along with a relatively sparse ground cover of graminoids, *Hamelia patens, Lantana camara, and Solanum sp.*. Stunted specimens of *Lysiloma latisiliquum* are dotted amongst *Inga affinis*, with tall *Bucida buceras* being dominant in the ecotone between the riparian shrubland and the taller broadleaf forest on the steep calcareous hills.

All of this ecosystem within the proposed inundation area of the Macal River and the Rio On will be inundated. This is the main ecosystem type to be inundated if Site A is selected. Within the maximum inundation area (if Site B is selected) a total of somewhat less than 16.67 ha (40 acres) of this ecosystem will be lost – representing approximately 0.6% of the total extent of this ecosystem (as mapped in the Belize Ecosystem Map, Meerman & Sabido (2004). In reality, throughout much of the national occurrence of such riparian shrubland (as in the case of this section of the Macal), the extent of the
ecosystem was too small to have been mapped (in the Belize Ecosystems Map), so it can be concluded that the actual percentage of the national coverage of this ecosystem lying within the proposed inundation area is likely to be significantly less than the 0.6% calculated here.

- **Agro-productive systems** – primarily unimproved pasture and old ‘milpa’ farms on the less steep terrain to the west of the main valley, between the Mollejon Road and the steep ridge of the valley. In a few more remote areas (upstream from Site A), regenerating milpas extend right down to the river-bank, and appear to have been cleared 2-3 years ago. These are presumed to be associated with land claims for lands within the Vaca Forest Reserve. Established pasture is located in the vicinity of Chechem Ha Resort (above Site B). Milpa farms are being cleared within the approximately 108 ha (260 acres) of forest recently allocated within the Vaca Forest Reserve in the vicinity of Site A, an area encompassing approximately 1,800m of frontage onto the Macal.

Some of this ecosystem will be inundated, but there will be no loss of viable, or currently used farm lands. There is, however, significant potential for erosion, agricultural runoff, pollution and sedimentation as a result of these farming activities within the immediate watershed area.

Whilst identified as occurring within the survey area (Herrera, 2005), it is the conclusion of the current survey that the ecosystem *Tropical evergreen seasonal broadleaf lowland forest over rolling calcareous hills* does not in fact occur here. Characteristically this ecosystem – with a canopy reaching up to 40m in height (Meerman & Sabido, 2001) - is associated with the forest ecosystem found on steep calcareous hills and is located on less steep gradients in the valleys between the steep hills. The topography of the Macal valley in the study area does not generally include such areas – the steep slopes rise directly from the riverbed. Elsewhere, where it occurs, this ecosystem can be considered as a continuum of that occurring on the steep calcareous hills, with a significant species overlap. Within the survey area, the forest habitats more closely fit the classification and definitions for those on steep calcareous hills.
5.8.2 FLORA

A total of 109 plant species (78 identified to species level), from 51 families, have been recorded to date in the surveys of the project area (Appendix V). Whilst the majority of species were recorded at both Site A and Site B, it was noted that there is significant patchiness in the size distribution of species throughout the tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills within the study area. Most differences can be directly attributed to gradient, soil moisture and exposure. Interestingly, cohune palms were noted to be less abundant in the gullies running down the slopes, than on the ‘ridges’ in between. Overall, species richness within the tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills is lower at upper elevations / exposed locations than on the mid- to lower- slopes. Drought-resistant species including Plumeria obtusa, Manilkara zapota, Metopium brownei and Pouteria campechiana are more predominant in more exposed locations. The Belize endemic Schippia concolor palm is locally abundant within the area, predominantly in the mid- to upper- reaches of the slopes, and particularly on drier slopes where it is sometimes the predominant under-story species – largely above the inundation level for the proposed reservoir.

Plant species of conservation concern found within the vicinity of the project area include:

Cedrela odorata – (IUCN, Vulnerable), occurring at very low densities within the project area. The population within the survey area is not considered of national significance.

Schippia concolor – (IUCN, Vulnerable) endemic to the Maya Mountains of Belize, and possibly neighbouring northern Guatemala. As noted above, this species is locally common within the vicinity of the project area – generally above the level of inundation of the proposed dam and reservoir. Quite widely distributed throughout the broadleaf forests of the Maya Mountains, the population within the survey area is not considered of national significance, and is largely outside the footprint of the
project area. Nonetheless care should be taken during construction to minimize habitat disturbance / damage outside the immediate footprint of the proposed dam, reservoir and support facilities.

*Swietenia macrophylla* – (IUCN, Vulnerable), occurring at quite low densities within the project area. The population within the survey area is not considered of national significance.

*Vitex gaumeri* – (IUCN, Endangered), occurring throughout much of the project area. This is an very common species, broadly distributed throughout lowland and mid-elevation forests of widely varying condition and stature in Belize. Its listing as an endangered species is considered erroneous (Meerman, J., pers com., Walker, P. pers obs.). The population within the survey area is not of national significance.

*Zamia sp.* (Z. polymorpha) – (IUCN, Near Threatened), occurring at quite low densities within the project area. The population within the survey area is not considered of national significance.

Three out of seven of Belize’s *Zanthoxylum* species are IUCN red-listed as Endangered, though it is not feasible in the context of an EIA to determine whether the specimens of this genus observed within the project area, are of one of these three species. Whilst it is prudent to steer on the side of caution, the population within the survey area is not considered of national significance – based upon current taxonomy and distributions.

Whilst not yet considered a species of conservation concern, it is noteworthy that virtually all specimens of xate palm of the *Chamaedorea* genus within the project area have had leaves harvested. Part of a far larger scale issue of illegal extraction of xate leaves by Guatemalan xateros, it is evident that even on the very steep slopes of the Vaca Forest Reserve the xate palms are under pressure. Harvest rates are considered unsustainable (Hererra, pers. comm., Walker, pers. obs), with likely reduced photosynthetic ability, disease resistance, reproductive capacity and overall vigour.
5.8.3 FAUNA

5.8.3.1 Fish

During the present survey, seven species of fish were confirmed, six of which occurred at both Vaca (A) and Vaca (B). The most noticeable difference was the absence of *Xiphophorus helleri* in all three upstream sites at Vaca (A), though previous surveys have shown its presence further upstream where Mollejon is now situated (Glaholt, 1992).

Sites A and B showed little variation in fish population, with over 85% of those species identified in Site A being present in Site B (Table 5.8.3.1 a).

Table 5.8.3.1 a: Fish Species Identified Within the Vaca Project Area and the Mollejon Dam

<table>
<thead>
<tr>
<th>Fish Identified</th>
<th>Survey Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site A</td>
</tr>
<tr>
<td>Common Name</td>
<td>A(1)</td>
</tr>
<tr>
<td>Central Tetra, Billum</td>
<td>Astyanax aeneus</td>
</tr>
<tr>
<td>Two-spot Livebearer</td>
<td>Heterandria bimaculata</td>
</tr>
<tr>
<td>Mountain Molly</td>
<td>Poecilia teresae</td>
</tr>
<tr>
<td>Green Swordtail</td>
<td>Xiphophorus helleri</td>
</tr>
<tr>
<td>Yellowbelly Cichlid</td>
<td>Cichlasoma salvini</td>
</tr>
<tr>
<td>Blue-eye Cichlid</td>
<td>Cichlasoma spilurum</td>
</tr>
<tr>
<td>Mountain Mullet</td>
<td>Agonostomus monticola</td>
</tr>
</tbody>
</table>

The results are consistent with the previous work conducted in the area. Reviewing data from previous surveys, it would appear that the series of falls along the section of the Macal (also known as the Belize River (Eastern Branch) between Black Rock and downstream of Site B act as an effective barrier to fish movement upstream, with species diversity decreasing upstream towards the confluence of the Rio On and Macal rivers. Species diversity in the lower Macal River, near its confluence with the Belize River (Western Branch), is greatest, with a total of 21
species. This decreases to only four species \((A. \text{aeneus}, H. \text{bimaculata}, P. \text{teraeae}, \text{and } X. \text{helleri})\) in the fast flowing upper portions of the river systems. (Greenfield and Thomerson, 1997). The area to be inundated therefore lies within these two extremes (Table 5.8.3.1 b).

<table>
<thead>
<tr>
<th>Species</th>
<th>Cristo Rey¹</th>
<th>Survey Site A²</th>
<th>Survey Site B³</th>
<th>Tunich Nah⁴</th>
<th>Upper Macal⁵</th>
<th>Mollejon⁶</th>
<th>Rio Frio⁷</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorosoma petenense</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astyanax aeneus</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x*</td>
<td></td>
</tr>
<tr>
<td>Astyanax fasciatus*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ictalurus furcatus</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhamdia guatemalensis</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhamdia laticauda</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belonesox belizanus</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gambusia lumia</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gambusia sexradiata</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gambusia yucatana</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterandria bimaculata</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poecilia mexicana</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poecilia teraeae</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cichlasoma intermedium</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cichlasoma meeki</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cichlasoma robertsoni</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cichlasoma salvini</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cichlasoma spilurum</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Cichlasoma synspilum</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petenia splendida</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Xiphophorus helleri</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agonostomus monticola</td>
<td>x</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Atherinella sp. 1</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophisternon aenigmaticum</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anguilla rostratus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>No. of Species</strong></td>
<td>21</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>
Only two *Cichlasoma* species were identified at Site A and Site B. A catfish species was also observed during a nocturnal survey, but not caught. These three species have therefore been omitted from the resulting species inventory, but future surveys should be aware that they are flagged as potentially present, requiring verification.

It has been shown that Caribbean streams are dominated by a shrimp and fish assemblage for which amphiromy (eggs or larvae carried to the ocean followed by migration of juveniles upriver) is thought to be predominant. Effects of dam structure on this assemblage are thought to dramatically alter species composition upstream, if there is no provision for a marine-headwater link (Holmquist 1998). The only truly migratory fish species of the Macal, the mountain mullet, was recorded during the survey in both the slow and rapidly flowing sections as adults, but the spawn and larvae are thought to be swept downstream to the sea, where the larval stage develops.
with the young returning upstream. This species is found throughout Belize, in the rivers flowing down from the Maya Mountains, being recorded from Cockscomb Basin Wildlife Sanctuary (Walker, 2005) and Bladen Nature Reserve Esselman (2001), and is a favoured food fish, being preferentially sought by local fishermen. The presence of the Mollejon dam effectively fragments the *Agonostomus* population into those above the dam, and those below.

Another species of note is *Poecilia teresae*, one of Belize’s few endemic species (www.fishbase.org), being largely confined to the fast flowing streams of the Maya Mountains that flow into the Macal River. This species is one of a species-assemblage of four that inhabit the species-poor upper reaches of the Mountain Pine Ridge streams such as Rio On and Rio Frio, above waterfalls considered to be barriers to most fish movement (Greenfield and Thomerson, 1997). Whilst abundant in isolated pools and the main river in the focal area of the Macal, these individuals are probably at the downstream limit of their environmental range, as this species is prefers the colder, fast flowing waters further upstream.

The fish fauna in the Vaca project area (Site A and Site B), appeared to be relatively stable – diversity was as would be expected, and abundance appeared good for this type of river, with only one incidence of disease being noted (in an *Astyanax aeneus*). The condition of the populations of all species appeared good, with extensive dry-season breeding activity by both species of cichlids and *X. helleri*. It should be noted that the study sites ranged from 500m to 2,500 m downstream from the existing Mollejon dam powerhouse, (downstream from the Mollejon dam itself), suggesting recovery from impacts during the construction phase in 1992, and minimal impact from the continued operation of the dam (though there is no baseline against which to measure the diversity and abundance of the fish population in this area). This corresponds with findings presented by Craig (2000), which suggest that fish populations downstream can recover within months from the immediate impacts from dam construction, despite initial declines in abundance and health.
5.8.3.2 Amphibians and Reptiles

Species and habitat surveys, coupled with analysis of known ranges and habitat preferences, indicate the likelihood of a total herpetofaunal species richness of approximately 83 species. Initial estimates during the field research for this EIA had been higher, but subsequent habitat surveys demonstrated a significant limitation of non-riparian aquatic habitats – a factor likely to significantly impact species occurrence within the vicinity of this section of the Macal River.

A total of 28 species of amphibian and reptile were recorded within the survey area (Appendix V), representing 18 families: 1 species of salamander, 7 anurans, 1 crocodilian, 1 turtle, 10 lizards and 8 snakes. This represents approximately 33% of the potential overall herpetofauna of the area. Morelet’s Crocodile is the only species of conservation concern recorded in the study area.

Of Belize’s thirty-nine (39) amphibian species, six (6) are IUCN red-listed as endangered or threatened as follows: 1 critically endangered (CR), 3 endangered (EN), and 2 listed as vulnerable (VU). A further six (6) are classified as near-threatened (NT). None of these species was recorded during the field surveys for this EIA. Whilst all twelve (12) of these threatened and near threatened species are largely restricted to the broadleaf-forested portions of the Maya Mountains, known distributional ranges tend to be restricted to the higher elevations (250+ m above sea level) to the south and east of the Vaca Falls area of the Macal. Thus whilst several of these threatened species (including the critically endangered Morelet’s Treefrog) were recorded in the Chalillo area (CI Power, 2001), they are unlikely to occur in the lower elevations of the Vaca area. Nonetheless, of particular concern for the Vaca locality was the question of the potential presence of two of these species of international concern: Morelet’s Treefrog and the Maya Mountain Frog. Field search time was allocated specifically to look for the presence of either of these species:

- Belize’s only Critically Endangered terrestrial vertebrate¹, Morelet’s Treefrog (*Agalychnis moreletii*) was not recorded during the surveys, despite specific searches of the most likely habitats. Whilst the known range of this species extends over this general...
area of the Maya Mountains, this portion of the Macal River valley is below the known elevational range (300-1500m above sea level) of this species – so it is unlikely to be found there. Morelet’s Treefrog has been recorded from the Chalillo area (Canadian International Power Services Inc., 2001), and at Caracol (Walker, P, pers obs), both sites being of higher elevation. It can therefore be concluded that the proposed Vaca Hydroelectric Project is highly unlikely to have any impact upon the conservation status of this species.

- Belize’s only endemic frog, the Near Threatened Maya Mountain Frog (*Rana juliani*) was also not recorded during the surveys, despite specific searches of the most likely habitats. The known range of this species does not extend as far northwest in the Maya Mountains as this portion of the Macal River, though a range extension would not be entirely surprising over this distance. The recorded altitudinal range for this species is 100-600m asl, so the Macal River within the survey area does fall within this range. In summary therefore, whilst *Rana juliani* was not observed during the survey, it could occur there. If this species is present within this portion of the Macal River, it would be in low numbers (being beyond the known range of the species) and it can therefore be concluded that the proposed Vaca Hydroelectric Project is highly unlikely to have any impact upon the conservation status of this species.

The conservation status of Neotropical reptiles is not yet well understood or documented. Whilst the amphibian fauna of the region was subjected to extensive examination under the Global Amphibian Assessment (Stuart S. et al. 2004), reptiles have not yet received similar attention. The IUCN red-list for reptiles is limited in its coverage, and cannot be considered comprehensive. Nonetheless it is the most authoritative such listing, and as such remains the primary reference. Of Belize’s 122 species of reptile, 6 are IUCN red-listed as endangered or threatened, and 5 are classed as near-threatened. Of the 6 threatened or endangered species, 5 are marine species; the Central American River Turtle (or hicatee) being Belize’s only endangered non-marine reptile. None of these six threatened or endangered reptiles was recorded in this survey, nor are they likely to occur in the area. The granitic bed of this portion of the Macal River, paucity of aquatic vegetation, and seasonally strong water-flow makes this habitat unsuitable for the hicatee.

Of the 5 near threatened reptiles found in Belize, one is the Morelet’s Crocodile, and the remaining 4 are freshwater turtles (though it should be noted that this is more a reflection of research on conservation status on these groups, rather than being truly indicative of lizards and snakes not being of conservation concern). Of these five near-threatened reptiles, the Morelet’s Crocodile is the only one to have been recorded within the development area for the proposed
Vaca Hydroelectric Project. One specimen (measuring approx 1.5m) was observed approximately 1.0km downstream from the Rio On confluence, at around mid-day on 22/7/05 – probably the same specimen that was observed in the same location at night in an earlier survey (Walker, P., 2005). The lack of sightings of crocodiles during nocturnal transects at other locations along the river, during dry and intermediate season surveys, indicates that the population is not high in this section of the river – probably a few individuals at most. Three, or probably all four of the near-threatened freshwater turtles are unlikely to occur in this locality, as their habitat requirements (in terms of adequate pools / marshes) are not present. The fourth species, *Kinosternon acutum*, could possibly co-exist with *Kinosternon leucostomum* (a species of ‘least concern’) – which was recorded close to the small pools within the river flood-zone.

The condition of the forest habitat, in terms of herpetofauna, is excellent, with only very limited sites having been structurally impacted by human activity. Primary constraints on herpetofaunal species richness within this site (and of course within the context of geographical distribution and elevation) are likely to be associated with the frequently dry soil and leaf-litter conditions (resulting from the steep topography and rapid drainage), and the paucity of small ephemeral pools. The soil and leaf layers are therefore less well suited to the terrestrial-breeding *Eleutherodactylid* frogs than further upriver in the Chalillo area where a wide floodplain extends on either side from the river. No temporary seasonal pools (preferred breeding site for the majority of Belize’s non-*Eleutherodactylid* frogs, and also an important environment for many reptiles) were found beyond the upper reaches of the riverbed, a factor potentially limiting amphibian presence and distribution within the area. *Bufo marinus* is one of the few amphibians to breed within the main body of the river, its tadpoles being toxic to fish predation. Whilst rain-filled (and flood-filled) pools are common in the fissured granite forming the riverbed and immediate banks, most are devoid of surrounding groundcover – and are used as breeding sites primarily by amphibian generalists such as *Bufo valliceps* and *Smilisca baudini*. Vegetated temporary rain pools, free of fish predators, and above the level of regular floodwaters are very limited in occurrence. One area rich in such prime amphibian breeding sites is located approximately 200m upstream from the Rio On confluence – *Agalychnis callidryas*, *Hyla microcephala* and *Rana vaillanti* were found breeding at this locality, along with *Bufo valliceps* and *Smilisca baudini*. 
It can be concluded that the amphibian fauna of this section of the Macal River valley can be considered as effectively being at the upper elevational limit of the lowland species. The amphibian fauna comprises primarily of lowland generalist species rather than of the more specialized species (in terms of habitat requirements) occurring at higher elevations further upstream on the Macal and elsewhere in the Maya Mountains. It can also be concluded that whilst the Vaca site harbours a rich herpetofauna, Morelet’s Crocodile is the only herptile of conservation concern to have been recorded, or likely to occur, within the project area. The Vaca area of the Macal River is rather marginal habitat for this species, with population densities being far higher in freshwater pools, swamps, cenotes, and slower flowing vegetated streams and rivers elsewhere in Belize (Walker, P., Pers. Obs.).

Footnote.

¹ Accepting the conclusion of the Global Amphibian Assessment (2004) that a specimen from Toledo, purportedly of *Hyla valancifer* (also rated as Critically Endangered) is in fact of another species, and that *Hyla valancifer* does not in fact occur in Belize.
5.8.3.3 **Birds**

A total of 183 bird species was recorded in the Vaca project area during the two surveys (wet and dry season) conducted in conjunction with Tunich-Nah Consultants and Engineers (Gentle, 2005). The majority of these species are characteristic of broadleaf forest (Table 5.8.3.3 a) with some riverine species such as the bare-throated tiger-heron, great and little blue herons, great egret, and green heron, present along the river itself. Also recorded are a small number of species that are more indicative of pine forest, this area being adjacent to the Mountain Pine Ridge (for example, the blue-gray gnatcatcher and yellow-backed oriole).

**Table 5.8.3.3 a: Characteristic Bird Species of Broadleaf Forest, Vaca Project Area, 2005**

<table>
<thead>
<tr>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Tinamou</td>
</tr>
<tr>
<td>White Hawk</td>
</tr>
<tr>
<td>Great Curassow</td>
</tr>
<tr>
<td>Short-billed Pigeon</td>
</tr>
<tr>
<td>Gray-cheeked Dove</td>
</tr>
<tr>
<td>Mealy Parrot</td>
</tr>
<tr>
<td>Spectacled Owl</td>
</tr>
<tr>
<td>Central American Pygmy-Owl</td>
</tr>
<tr>
<td>Violet Sabrewing</td>
</tr>
<tr>
<td>Collared Trogon</td>
</tr>
<tr>
<td>Slaty-tailed Trogon</td>
</tr>
<tr>
<td>Tody Motmot</td>
</tr>
<tr>
<td>White-whiskered Puffbird</td>
</tr>
<tr>
<td>Chestnut-colored Woodpecker</td>
</tr>
<tr>
<td>Scaly-throated Leaf-tosser</td>
</tr>
<tr>
<td>Black-faced Antthrush</td>
</tr>
<tr>
<td>Sepia-capped Flycatcher</td>
</tr>
<tr>
<td>Eye-ringed Flatbill</td>
</tr>
<tr>
<td>Thrush-like Schiffornis</td>
</tr>
<tr>
<td>Red-capped Manakin</td>
</tr>
<tr>
<td>Tawny-crowned Greenlet</td>
</tr>
<tr>
<td>Green Shrike-Vireo</td>
</tr>
<tr>
<td>White-breasted Wood-Wren</td>
</tr>
<tr>
<td>Nightingale Wren</td>
</tr>
<tr>
<td>Golden-crowned Warbler</td>
</tr>
<tr>
<td>Black-throated Shrike-Tanager</td>
</tr>
<tr>
<td>Orange-billed Sparrow</td>
</tr>
</tbody>
</table>
Three IUCN-redlisted international species of concern have been highlighted for this area (Table 5.8.3.3 b), with a fourth, the orange-breasted falcon, also being included as a species of national concern. The scarlet macaw (*Ara macao*) is not recorded as resident within the Vaca project area.

**Table 5.8.3.3 b: IUCN Bird Species of International Concern of Vaca Project Area**

<table>
<thead>
<tr>
<th>Vulnerable</th>
<th>Keel-billed Motmot</th>
<th><em>Electron carinatum</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Risk/Near Threatened</td>
<td>Great Curassow</td>
<td><em>Crax rubra</em></td>
</tr>
<tr>
<td></td>
<td>Golden-winged Warbler</td>
<td><em>Vermivora chrysoptera</em></td>
</tr>
</tbody>
</table>

*IUCN Red List, 2005*

The keel-billed motmot (IUCN status: Vulnerable), is rare or absent from most of its range (southeastern Mexico to western Costa Rica), with remaining populations being largely concentrated in Belize and Nicaragua. It requires large areas of contiguous, undisturbed habitat to ensure viable populations, where it occurs in low densities. In Belize, it appears to show a preference for steep terrain in the Maya Mountains, intersected by streams, where it is thought to nest in excavated holes in the banks of the rivers. The global population is facing a continuing decline as the habitat becomes fragmented and destroyed (Birdlife International, 2005), but it is still present in isolated patches in the Maya Mountain corridor of connected protected areas - including Cockscomb Basin Wildlife Sanctuary, Chiquibul Forest Reserve, and Bladen Nature Reserve. The Vaca project area is contiguous with this, but is only marginal habitat for this species, especially with the increasing disturbance from incursions by farmers, and can therefore probably not be considered critical for the survival of a viable population of this species, in view of the presence of large, adjacent, protected areas of less human-impacted habitat.
Two species are of IUCN “Near Threatened” status – the great curassow \((Crax ruber)\) and the golden-winged warbler \((Vermivora chrysoptera)\). The great curassow is not considered endangered yet within Belize as it is currently doing well in the national parks, where it is considered protected from hunting (Jones and Vallely, 2001). It is however heavily hunted throughout the rest of Central America, with significant population decline (Birdlife International, 2005). Within the Vaca project area, the population is thought to have declined, following increasing incursions, with clearing for milpa production within the immediate catchment area, xate harvesting by xateros, and direct hunting pressure (as also indicated by the depressed game species populations (Herrera, 2005). This has been exacerbated by Mollejon road, giving access to hunters from adjacent communities.

The second near-threatened species, the golden-winged warbler, is one of many transient species that pass through the area, traveling southwards from Canada to as far south as Venezuela. As it moves into Central and South America, it is reliant on broadleaf tropical forest in both the countries it migrates through, and at its overwintering sites. It is known to be a winter resident in Cayo District (Jones and Vallely, 2001). The small potential impact area of the Vaca project is not considered critical to the continued viability of this species.

The orange-breasted falcon \((Falco deiroleucus)\) is highlighted as vulnerable (by the Peregrine Fund) in the Central American portion of its range, and very rare, perhaps extinct, south of Belize and Petén, Guatemala (Jones and Vallely, 2001; The Peregrine Fund, 2005). It is only known to nest in four areas in Belize, one of these areas being in the Vaca area (Jones and Vallely, 2001). Two pairs have been recorded nesting on cliffs between Black Rock and Mollejon (Whitacre, 1994 (cited in BBIS), and this species has been regularly sighted in the area over the years since then (also being recorded within this survey, (Gentle, 2005). The Peregrine Fund monitors known nesting sites within Belize, and has been engaged in a release programme in the Maya Mountains to try and boost the Belize population (The Peregrine Fund, 2005).
5.8.3.4  Mammals

A total of twenty-two mammals is confirmed as present within the focal area (Appendix V). Eleven mammal species have been recorded directly from sightings or signs (tracks etc.) during fieldwork. An additional four species were identified during the Rapid Ecological Assessment of the area conducted by Tunich-Nah (2005). Discussions with local hunters and farmers also confirmed the presence of a further seven species (Table 5.8.3.4 a).

<table>
<thead>
<tr>
<th>Table 5.8.3.4 a: Mammal Species confirmed as present within the Vaca Project Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species recorded by Survey Crew</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Baird’s Tapir  Tapirus bairdii</td>
</tr>
<tr>
<td>Yucatan Howler    Alouatta pigra</td>
</tr>
<tr>
<td>Puma            Puma concolor</td>
</tr>
<tr>
<td>Grey Fox      Urocyon cinereoargenteus</td>
</tr>
<tr>
<td>Kinkajou    Potos flavus</td>
</tr>
<tr>
<td>Neotropical River Otter Lutra longicaudis</td>
</tr>
<tr>
<td>Central American Agouti Dasyprocta punctata</td>
</tr>
<tr>
<td>Paca         Agouti paca</td>
</tr>
<tr>
<td>Deppe’s Squirrel  Sciurus deppei</td>
</tr>
<tr>
<td>Big-eared Climbing Rat Ototylomys phyllotis</td>
</tr>
<tr>
<td>Hispid Pocket Gopher Orthogeomys hispidus</td>
</tr>
<tr>
<td>Additional Species recorded by Allan Herrera (2005)</td>
</tr>
<tr>
<td>Red Brocket  Mazama americana</td>
</tr>
<tr>
<td>Jaguar       Panthera onca</td>
</tr>
<tr>
<td>Puma         Puma conolor</td>
</tr>
<tr>
<td>Nine-banded Armadillo  Dasypus novemcinctus</td>
</tr>
<tr>
<td>Additional Species Reported by Local Community Members</td>
</tr>
<tr>
<td>Virginia Opossum Didelphis virginiana</td>
</tr>
<tr>
<td>Grey Four-eyed Opossum Philander opossum</td>
</tr>
<tr>
<td>Mexican Porcupine Sphiggurus mexicanus</td>
</tr>
<tr>
<td>Yucatan Squirrel  Sciurus yucatanensis</td>
</tr>
<tr>
<td>Collared Peccary Pecari tajacu</td>
</tr>
<tr>
<td>White-tailed Deer  Odocoileus virginianus</td>
</tr>
<tr>
<td>White-nosed coati Nasua narica</td>
</tr>
<tr>
<td>* Gopher tunnel mounds seen in re-growth areas</td>
</tr>
<tr>
<td>No data collected on bat species</td>
</tr>
</tbody>
</table>

This list indicates that the area supports a mammal diversity expected of a typical broadleaf forest ecosystem. Indications are that the mammal densities, however, are low, particularly of the game species such as collared peccary and white tailed deer. Farmers in the area confirm that white-lipped peccary (an indicator species with reduced populations in areas of hunting pressure and habitat disturbance), though present, are found in far fewer numbers than in the past, and are
generally found further from human settlement than the focal area. Similarly, the Tunich-Nah (2005) survey suggests that the low numbers of white-tailed deer in the area are symptomatic of heavy hunting pressure. The presence of active hunting pressure within the protected area from local communities, of hunting by xateros moving through the area, and the presence of small farms, all combine to reduce game species populations, and therefore also the abundance of predatory species such as puma and jaguar.

Of the twenty-two mammals confirmed within the project area, four are considered to be of international concern (Table 5.8.3.4 b). Two species, the Yucatan black howler and Baird’s tapir, are listed as Endangered (IUCN Redlist: ‘…facing a very high risk of extinction in the wild in the future’), and two (the jaguar and puma) are listed as near threatened species, (‘close to qualifying or is likely to qualify for threatened category in the near future’ IUCN ). There are also two species listed as Data Deficient in the IUCN Redlist – the Neotropical river otter and red brocket deer. This is not a threat category in itself, but highlights species with ‘inadequate information to make a direct, or indirect assessment of its risk of extinction’. Species listed as data deficient are generally acknowledged as possibly being classed as threatened once further information becomes available.

<table>
<thead>
<tr>
<th>Table 5.8.3.4 b: Mammal Species of International Concern (IUCN: Red list 2005) of Vaca area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endangered</strong></td>
</tr>
<tr>
<td><strong>Lower Risk / Near Threatened</strong></td>
</tr>
</tbody>
</table>

Baird’s Tapir (*Tapirus bairdii*) is becoming increasingly rare throughout its range, with primary threats being deforestation and hunting. At the present time it is thought to be maintaining viable populations within Belize, being present in the majority of protected areas, though numbers are thought to be reduced from habitat destruction. Whilst not hunted to any great extent by Belizeans, the presence of Guatemalans within the area that reap the xate palm (locally referred to as xateros), increases the chances of the tapir becoming a target.
Tracks and faeces were seen at various points within the focal area, always accessing or leaving the water. The lack of a flood plain within the area, and lack of footprints following the river itself suggests that this species is using the river primarily for drinking and bathing, but spending the majority of the time elsewhere. As long as the tapir is able to access the water (whether it is in a reservoir or as a river), and the water flow and water quality are good, both above and below the dam, there should be little significant impact on this species, if human disturbance in the surrounding watershed is kept to a minimum. A comprehensive literature review of this species is given in Macal River Upstream Storage Facility Environmental Impact Assessment – Part 2 (CI Power, 2001).

Yucatan black howler monkeys (*Alouatta pigra*), endemic to a small area of the Yucatan Peninsula, Belize and the Peten, were decimated by a yellow fever epidemic in 1956/1957 that swept through the *Alouatta* population throughout most of Belize. With increasing habitat fragmentation and loss, it has recently been upgraded to Endangered in the IUCN Redbook.

In the Vaca project area, there appears to be a healthy howler monkey population, with at least five troops active in the area (Herrera, 2005). During the survey, troops were heard calling primarily from the ridge tops, both at Site A and Site B. This species is not actively hunted within Belize, and has shown good recovery over the past years.

Nationally, the jaguar (*Panthera onca*) is impacted primarily by land clearance and reduction of prey base by hunters. This species is present in the Vaca project area (Herrera, 2005; Archaeology Survey Crew, Pers. Com.), but surveys indicate a probable reduction in prey base because of increased hunting activity within the area. It is thought that as a result of this lower prey abundance, and the increasing human impacts (land use change, noise, hunting), the jaguar presence in the immediate area may be declining. There is also some pressure on the Cayo population, with jaguars reportedly being shot and traded illegally with the Chinese Community in San Ignacio for medicinal purposes, though it is not known whether this has affected any individuals within the Vaca project area itself (Mansard, Pers. Com.).
The area to be potentially impacted is too small to support a single jaguar, as an average male territory being thought to be between 25 and 38km² (about twice that of the female (Rabinowitz and Nottingham, 1986), but may be included in the territory of more than one individual.

The puma (*Puma concolor*), more of a generalist than the jaguar in both terms of habitat requirements and prey, is recorded from several locations within the project area from tracks (EIA, 2005), and from calls (Herrera, 2005). This species is not considered to be of concern at a national level, particularly as it is not as dependent on large tracts of broadleaf forest. As with the jaguar, the potential impact of the potential Vaca dam development is likely to be far lower than the sum of the present level of incursions, with associated land clearance and increased hunting pressure of the prey base, if some forms of active protective measures are put in place within the immediate area.

### 5.8.3.5 Species of International Conservation Interest

No amphibian species of international conservation concern (as listed on the International Union for the Conservation of Nature (IUCN) red-list) were recorded at Vaca, nor are likely to occur there. None of the species found is listed on the Convention for International Trade in Endangered Species of Flora and Fauna (CITES).

The only reptile of international conservation concern recorded at Vaca is Morelet’s Crocodile, no other IUCN red-listed reptile species is likely to occur there. Table 5.8.3.5 shows the category of restriction in international trade under CITES as well as the IUCN conservation status, where applicable.

Three IUCN-redlisted international species of concern have been highlighted for this area (Table 5.8.3.3 b), with a fourth, the orange-breasted falcon, also being included as a species of national concern. The scarlet macaw (*Ara macao*) is not recorded as resident within the Vaca project area. The keel-billed motmot (IUCN status: Vulnerable), is rare or absent from most of its range (southeastern Mexico to western Costa Rica), with remaining populations being largely concentrated in Belize and Nicaragua. Two species are of IUCN “Near Threatened” status – the
great curassow (*Crax ruber*) and the golden-winged warbler (*Vermivora chrysoptera*). The great curassow is not considered endangered yet within Belize as it is currently doing well in the national parks, where it is considered protected from hunting (Jones and Vallely, 2001). The second near-threatened species, the golden-winged warbler, is one of many transient species that pass through the area, traveling southwards from Canada to as far south as Venezuela. As it moves into Central and South America, it is reliant on broadleaf tropical forest in both the countries it migrates through, and at its overwintering sites.

Of the twenty-two mammals confirmed within the project area, four are considered to be of international concern (Table 5.8.3.4 b). Two species, the Yucatan black howler and Baird’s tapir, are listed as Endangered (IUCN Redlist: ‘…facing a very high risk of extinction in the wild in the future’), and two (the jaguar and puma) are listed as near threatened species, (‘close to qualifying or is likely to qualify for threatened category in the near future’ IUCN ). There are also two species listed as Data Deficient in the IUCN Redlist – the Neotropical river otter and red brocket deer.
Table 5.8.3.5: Category of Conservation Status (IUCN) and of Restriction in International Trade under CITES

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>English Name</th>
<th>IUCN</th>
<th>CITES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reptiles</td>
<td><em>Crocodylus moreletii</em></td>
<td>Morelet's Crocodile</td>
<td>LR</td>
<td>I</td>
</tr>
<tr>
<td>Reptiles</td>
<td><em>Boa constrictor</em></td>
<td>Boa constrictor</td>
<td></td>
<td>II</td>
</tr>
<tr>
<td>Birds</td>
<td><em>Electron carinatum</em></td>
<td>Keel-billed Motmot</td>
<td>VU</td>
<td></td>
</tr>
<tr>
<td>Birds</td>
<td><em>Crax rubra</em></td>
<td>Great Currassow</td>
<td>LR/NT</td>
<td></td>
</tr>
<tr>
<td>Birds</td>
<td><em>Vemrivora chrysoptera</em></td>
<td>Golden-winged Warbler</td>
<td>LR/NT</td>
<td></td>
</tr>
<tr>
<td>Mammals</td>
<td><em>Alouatta pigra</em></td>
<td>Yucatan Black Howler</td>
<td>EN</td>
<td>I</td>
</tr>
<tr>
<td>Mammals</td>
<td><em>Tayassu bairdii</em></td>
<td>Baird’s Tapir</td>
<td>EN</td>
<td>I</td>
</tr>
<tr>
<td>Mammals</td>
<td><em>Panthera onca</em></td>
<td>Jaguar</td>
<td>LR/NT</td>
<td>I</td>
</tr>
<tr>
<td>Mammals</td>
<td><em>Puma concolor</em></td>
<td>Puma</td>
<td>LR/NT</td>
<td>II</td>
</tr>
<tr>
<td>Mammals</td>
<td><em>Lontra longicaudis</em></td>
<td>Neotropical River Otter</td>
<td></td>
<td>I</td>
</tr>
</tbody>
</table>

KEY FOR CITES AND IUCN Listing in Table 5.8.3.5

IUCN Red-listing indicates conservation status:
- CR denotes ‘Critically Endangered’
- EN denotes ‘Endangered’
- VU denotes ‘Vulnerable’
- NT denotes ‘Near Threatened’
- LR denotes ‘Lower Risk’
- LC denotes ‘Least Concern’

CITES listing indicates restrictions in international trade:
- Appendix I includes species threatened with extinction. Trade in specimens of these species is permitted only in exceptional circumstances.
- Appendix II includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival.
- Appendix III includes species that are protected in at least one country, which has asked other CITES Parties for assistance in controlling their trade.
5.8.4 ASSESSMENT OF THE EFFECT THAT THE EXISTING MOLLEJON HYDROELECTRIC PLANT HAS ON POPULATIONS OF ENDANGERED AND THREATENED WILDLIFE SPECIES

Threatened or endangered species in the Macal River valley around the Mollejon facility include:

**Endangered:**
- Yucatan Black Howler Monkey
- Baird’s Tapir

**Near Threatened:**
- Morelet’s Crocodile
- Great Curassow

Field surveys around the Mollejon reservoir, and downstream as far as the Vaca Falls area indicate that these four species have recovered from any negative impacts they may have suffered from the construction and subsequent operation of the facility.

**Baird’s Tapir:** the steep terrain and general absence of flat floodplains and riparian forest within the Mollejon – Vaca Falls section of the Macal River evidently limit population densities of tapirs in this locality. They are present in the valleys, but tracks indicate that most foraging is done on the steep forested slopes in the absence of the species’ preferred habitat of relatively flat alluvial floodplain. The western bank of the Mollejon reservoir, that was the location of the aggregate crushing / storage, construction storage and machinery facilities, now effectively provides a flat riparian habitat, largely dominated by assorted grasses, a riparian belt of (planted?) *Ficus sp.* and *Inga affinis*, and assorted shrubs grading into the forest immediately behind the impacted area. Tracks indicate frequent / continual use by at least one tapir, along with white-tailed deer and paca. It appears that in terms of tapirs at least, this flattish grassy wetland adjacent to the Mollejon reservoir may be a better habitat than that which was there before inundation. Tracks and wildlife paths in the Site A and Site B locations downstream show the ability of tapirs to move through / along steep escarpments, indicating that the Mollejon Power Station and Dam facility should not significantly negatively impact connectivity in terms of use of the area by tapirs. This species is certainly capable of ascending and descending slopes to skirt around the structures and move upstream or downstream.
The protection of both the tapirs directly, and of their habitat, provided by the gated and restricted access to the site is unquestionably beneficial to the species. Only 500m downstream, uncontrolled access and unplanned allocation is already impacting tapir habitat.

**Yucatan Black Howler Monkey:** two troops of howler monkeys were heard vocalizing during a brief survey of vegetation regeneration around the Mollejon Dam and reservoir – one close to the ridge-top immediately west of the inundation and the second to the south, approximately 700m from the tip of the reservoir. Staff and management of the Mollejon facility report regular / daily vocalization of the howler monkeys. Whilst troop size was not evaluated, the relative position of the two troops mirrored (in terms of separation and position on the escarpments) that of groups encountered downstream in the vicinities of Sites A & B; there was no indication of any differences in behaviour or abundance. It is concluded that the population of howler monkeys has not been significantly impacted by the presence of the Mollejon Dam.

However, the access roads to both the Mollejon Dam and Power Station have potentially negatively impacted connectivity of howler monkey habitat. The roads are sufficiently wide as to necessitate the monkeys descending to the ground to cross from one forest block to the other. For this reason, consideration could be given to the installation of aerial rope walkways installed at Mollejon and Vaca, to enable the monkeys to cross without having to make the risky ground-level crossing.

**Morelet’s Crocodile:** the often swift-flowing Macal River in the reaches immediately upstream and downstream of the Mollejon Hydroelectric facility, largely devoid of vegetation, is somewhat marginal habitat for this species – an observation supported by the recording of only a single specimen during the surveys. Whilst a nocturnal survey was not conducted at Mollejon itself, it is evident that the still waters and abundant edge-vegetation provides a rather better habitat for crocodiles than was previously there. The fish survey of this assessment indicates healthy fish populations – ie food resources for crocodiles within the Mollejon reservoir. The presence of large crocodiles within the reservoir is reported by others (Garcia, J. pers comm.; Gonzalez, O. pers comm.). In terms of quality of habitat, it is concluded that the Mollejon
facility has had a positive impact on the population of Morelet’s Crocodile, though habitat connectivity for this species has been negatively impacted. Crocodiles are capable of terrestrial movements from one water-body to another, but movements of this species around the Dam wall can be expected to be infrequent / minimal.

**Great Curassow:** The only record for this species was an adult male inside the Mollejon compound, crossing the road to the dam. The protection afforded by the gated entrance has probably had a significant positive impact on this species, as it appears to have been heavily hunted elsewhere downstream in the valley, and will be negatively impacted by the progressive clearance of land for agriculture, and resulting fragmentation of forest habitat.

**Fish populations:** A visual point survey of the fish fauna of the Mollejon reservoir showed that the fish population appears to have adapted well to the still water conditions – large shoals of *Astyanax aeneus* congregated at bait, along with *Cichlasoma salvini* and *C. spilurum*. Of the smaller fish, *Poecilia teresae* and *Xiphophorus helleri* were recorded in the shallow waters, though neither was particularly abundant. As a general conclusion, the creation of a reservoir in this area may alter the population structure of the fish community, but the component species do seem to be able to adapt to the still conditions. *Astyanax* and the *Cichlasoma* species are generalists found in a variety of habitats throughout much of Belize, whilst the *P. teresae* and *X. helleri* are both more restricted, being associated more with the fast flowing streams and rivers.

Though not a threatened or endangered species, green iguanas are generally associated with riparian habitats in Belize. Green iguanas were observed in the ‘riparian’ habitat – the grassy wetland area to the west of the Mollejon reservoir, and breeding was confirmed by the observation of a 2005 hatchling. Evidently this species has adapted well to the habitat transformations resulting from the construction and operation of the Mollejon Hydroelectric facility.

### 5.9 Parks and Protected Areas - Vaca Forest Reserve

The proposed locations for the dam at Vaca are within the boundary of the Vaca Forest Reserve (VFR), and lie near the convergence of the boundary of the VFR with two other protected areas.
These are the Mountain Pine Ridge Forest Reserve (MPRFR) and the Elijio Panti National Park (EPNP). The Vaca Forest Reserve and the Mountain Pine Ridge Forest Reserve were among the earliest Belizean protected areas to be declared, while the Elijio Panti National Park was declared more recently in 2001.

![Parks and Protected Areas in Belize](image)

**Figure 5.9: Parks and Protected Areas in Belize**
(Source of map: Tunich-Nah Consultants & Engineering, February, 2005)

Management arrangements exist within the protected areas, but security of habitat cover does not suggest security of species, as it is known that hunting occurs within these areas. Incursions into the forest reserve were observed during site investigations and aerial surveys. Watershed degradation is obvious and on-going and is mostly a result of inappropriate agricultural practices.

The majority of the activities for Site B are located within the Vaca Forest Reserve but Site A is within the Mountain Pine Ridge Forest Reserve. The proposed project sites (A and B) are
located on the Macal River which forms the boundary between the two reserves. The Rio On and the Macal River both rise in the Mountain Pine Ridge Forest Reserve.

Plate 5.9 a, b, c, d shows aspects of the Vaca Forest Reserve and the Mountain Pine Ridge Forest Reserve.

Plate 5.9 a, b, c, d:

Plate 5.9 a: Site A. Vaca Forest Reserve on left; Mountain Pine Ridge Forest Reserve on right

Plate 5.9 b: Site B. Vaca Forest Reserve on right; Mountain Pine Ridge Forest Reserve on left
Plates 5.9 c and d: Watershed Degradation in Vaca Forest Reserve

Plate 5.9.c

Plate 5.9.d
5.10 Archaeology

5.10.1 REVIEW OF MAYAN PRESENCE IN THE MACAL RIVER BASIN

The primary purpose of the archaeological survey was to search for evidence of past human occupation or activity in the area proposed for development of the Vaca dam. In the Maya sub-area of Mesoamerica, prehistoric human activity generally encompasses three major time frames. These are:

1. Paleo-Indian to Archaic occupation - that is occupation by modern homosapiens, who culturally are pre-Maya (10,000 – 2000 B.C.).

2. Prehistoric Maya occupation - remnants of settlements, structures and materials associated with the period of ancient Maya occupation in Belize, from approximately 2000 BC to AD 1500.

3. Historical occupation - occupation by people living in the area after the end of the prehistoric Maya period. In Belize, this includes a span of time that extends from Spanish contact (A.D. 1500) through the early British colonial occupation (A.D. 1800).

A complete review of the archaeological aspects of the Macal River Basin between Vaca and Mollejon is given in Appendix VI.

5.10.2 CURRENT DATA

The full report on the archaeological survey is given in Appendix VI. The geographic region covered by the survey is dominated by the Macal River Gorge and consists of a narrow alluvial valley flanked by steep limestone hills. The only breaks in the gorge are located where minor and major tributaries join the Macal River in places such as the confluences of the Rio On and
Rio Frio rivers. Soils in the narrow valley are predominantly sandy loams that form a relatively thin layer above granitic and slate bedrock. A few sections of the gorge, however, contain stands of Cohune palm. These trees generally grow in fertile soils that were exploited for agriculture by the ancient Maya.

The survey of the entire project area (from the proposed powerhouse at Vaca Falls, to the existing Mollejon generating station) did not identify any major feature of archaeological significance. This differs from both the Lower Macal and the Chalillo to Raspaculo section of the Macal River Valley where several ancient Maya communities have been identified and investigated by the Belize Valley Archaeological Reconnaissance Project, and by a number of other research programmes.

Interestingly, the only areas where possible archaeological features were noted were along two small streams that flow into the Macal River, and within narrow strands of Cohune forest. It must be noted, however, that the study conducted was a rapid archaeological assessment, as is required at this stage by the Department of the Environment.

Features of dubious archaeological significance were noted in several seasonal creek beds. These features (see photos in Appendix VI) look like agricultural wiers (or channel) terraces. Channel terraces are usually located in areas suitable to capture soils eroding from hill sides and have been recorded throughout the Chiquibul Forest and Vaca Plateaus. Alternatively, the possible terraces could likely be what geologists refer to as Travertine or Rim-stone dams. The latter are natural features that form in streams which flow through soft limestone. They are also commonly found in caves within the Vaca area and often look like agricultural terraces.

The only other features of possible archaeological significance were noted in the sections of the valley with Cohune palm trees. The features in question include a few small mounds that may have served as platforms for ancient thatched buildings. Photographs of the eastern and western banks of the Macal River show that there is the presence of both Cohune palms and hard wood forest, both of which grow exceptionally well in limestone soils. The latter environments were
traditionally favoured for milpa or swidden agriculture by the ancient Maya, and they normally contain evidence for prehistoric settlements.

Most of the terrain within the survey area is dominated by sandy soils and non-sedimentary rock. Previous archaeological surveys throughout Belize suggest that these regions were never settled by the ancient Maya because their acidic soils were inadequate for farming. Despite this it is known that the Maya extracted granite for use in the production of manos and metates (grinding stones), and that they did hunt and fish in these locations. Pine forests were also exploited for wood and pine needles that were used for torches and ritual purposes in caves. Any archaeological remains in this environment will therefore only be represented by surface finds and will only be recovered by extensive clearing of the survey area.

5.11 Socio-economic Surveys

5.11.1 REVIEW OF EXISTING LITERATURE

The existing literature reviewed for this SIA is diverse in nature ranging from a national energy diagnostic to poverty assessment data. The geographic “sphere of influence” for the project has been delimited to include several settlements in the Cayo District considered within the project’s hinterland area and therefore probable impacts to these communities are being primarily assessed within the SIA. These settlements include Benque Viejo del Carmen, San Jose Succotz, San Ignacio, Santa Elena, Cristo Rey and San Antonio.

However, taking into account that the proposed project is part of a larger hydroelectric scheme and by extension the national electricity grid, it should also be considered as having national impact due to the close linkage between national economic development and reliable and affordable energy sources. Energy, in this case electricity, is closely linked to key socioeconomic development issues namely poverty alleviation and leveraging foreign direct investment. A key concern for local citizens is whether or not the facility will enable the reduction of electricity rates while for district residents, employment creation and accessibility might be a critical issue. Based on the previous advocacy efforts against the Challilo project, it is expected that some civil
society groups, particularly selected environmental lobby organizations, will most likely be highly critical and demonstratively negative about the Phase III dam project. Initial impacts within communities will most likely occur by simply introducing new project information into the local daily discourse.

5.11.2 RESULTS TO DATE

Pertinent Socio-economic data and information on the Cayo District has been gathered and is presented in the sections below:

5.11.2.1 Population

The total population of Cayo is approximately 60,000 persons (2005 population estimates) and was identified as the country’s fastest growing district. Cayo is notable for having 57.6% of its residents being male and predominantly Mestizo (58%). The district’s median age is 17 years with the age cohort (0-17) representing 21.5% of the population. The mean household size for the Cayo District is 5 persons per household placing as the district with the second highest mean household size. Comparatively, the national average was 4.6 persons per household. Cayo also has the largest proportion of foreign-born residents in the country.

5.11.2.2 Poverty

In terms of poverty, as Figure 5.11.2.2 shows, the Cayo District has the second lowest overall percentage of poor persons by district nationally with 27.4% of the district’s population being classified as poor. 20.5% of all households in Cayo are poor. The district has the lowest indigent line ($3.03) based on minimum costs of buying a basic food basket comprising of food items that yield 2400 calories of nutrients required by an average adult daily. Therefore, 4.8% of individuals were considered indigent or whose consumption is below the indigent line thereby being considered extremely poor. Cayo also had the lowest poverty line at $150.89 reflecting that an individual would be considered poor if their monthly consumption was below this figure.
The poverty gap is 6.6% indicating that it would cost that much of the poverty line to move each poor person in Cayo out of poverty and close the gap between the poor and non-poor. The poverty severity index for Cayo is 2.8% (distance from poverty line). In terms of wealth distribution and resource inequality, the Gini index for the district is measured at 0.33 which is below the national Gini of 0.4. Six percent (6%) of children 5-17 years old were identified as being “economically active” in Cayo indicating that the district had the second highest level of child labour in the country. Twenty-nine percent (29.1%) of youths 14-24 years of age and 24.6% of the elderly (65+ years) were also considered poor.

In terms of financial difficulties experienced by households, 59.6% of all Cayo households had problems meeting their monthly utility bills which were identified as the number one financial difficulty for households in the district. Due to considerable rural to urban commuting in the district, Cayo had 28% of it households naming transportation costs as a significant financial difficulty.

Overall, however, Cayo has one of the lowest levels of poverty in Belize in terms of districts. Considerable targeting of development interventions such as microcredit provision, agricultural extension and training in the district has enabled the social and economic spheres of the district. It is further surmised that relatively high levels of subsistence and commercial agriculture, tourism and cross-border mercantile activity sustains a fairly robust domestic economy in the district that while impacted by the national macro-economic situation, it is not unduly influenced.
5.11.2.3 **Health**
The Cayo District reported the highest mean days of illness (9.4 days per annum) of all districts. 67% of Cayo respondents in the 2002 LSMS reportedly sought health care after reporting ill and generally were proactive in seeking health care internally or externally.

5.11.2.4 **Education**
The Cayo District reported that 45.2% of those not attending school had no form of educational qualification reflecting a high level of illiteracy. Primary net enrolment stood at 99.5% however.
5.11.2.5  Recreational Facilities in General Vicinity of Dam Site

There are several recreational facilities and tourist properties within the project area. Some of the key tourist properties/resorts which would use the surrounding area are given below:

1. Chaa Creek Lodge
2. Black Rock River Lodge
3. Che Chem Ha Resort
4. Cahal Pech Resort
5. Five Sisters Lodge
6. Blancaneaux Lodge
7. Duplooy’s Jungle Lodge
8. Clarissa Falls Resort
9. San Ignacio Hotel
10. Maya Mountain Lodge
11. Mopan River Resort
12. Pine Ridge Lodge
13. Crystal Paradise Resort
14. Windy Hill Resort

5.12 Public Consultations - Initial Stakeholder Views on Proposed Project

5.12.1 BACKGROUND AND CONTEXT

Initial stakeholder consultation sessions have been held with selected individuals from the local government\(^6\), tourism\(^7\) and environmental conservation NGO\(^8\) spheres in order to share project information and elicit initial feedback on perceptions, concerns and issues surrounding the proposed project. Information shared during these consultations is given in Appendix VII. Additionally, several persons have been interviewed individually and their names are given in Appendix VII. Overall, since this proposed project is the final phase of the three phase Macal Hydroelectric Scheme, there are preconceived perceptions based on the experiences of the

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\(^6\) San Ignacio Town Board
\(^7\) Belize Tourism Industry Association-Cayo Chapter and the Belize Eco-Tourism Association
\(^8\) Belize Institute for Environmental Law and Policy
previous two phases that are influencing the views of stakeholders on this proposed project. With regard to the Phase 1-Mollejon Dam, the consensual view is that the development of the project was largely shrouded in secrecy with a resultant lack of information dissemination that led to speculation about undue political control and the lack of transparency. The general belief held by many that the Phase 1 Mollejon dam was not a good investment, is based on its relatively low electricity generation output compared to its development costs. This has been countered by the argument that each dam phase has to be evaluated as part of the whole scheme rather than simply as a “stand-alone” project.

Further along, the intense lobbying efforts of the environmental conservation activists against the Phase 2 Chalillo Dam led to the scrutiny of various aspects of the project’s development including safety issues surrounding the possibility of dam failure due to conflicting technical interpretations of the geologic foundations of the dam site, its economic viability from a cost-benefit analytical perspective, the possible loss of certain threatened species and the ongoing debate of how present dam construction is following the Environmental Compliance Plan issued by the Department of the Environment as part of the project’s approval process. The feelings of “bad faith” from some stakeholders’ perspective stem from perceptions of the withholding of critical data and information from stakeholders opposed to the dam and the purposefully misleading technical interpretations of critical data related to geology and biodiversity in the dam area. A positive outcome of the development debate about the Chalillo project is that there has been widespread cross-fertilization of ideas and comprehensive discussions of the pros and cons of the development of dams on a whole, and in particular dams with reservoir capacity that would have inevitable environmental impacts at a wider scale than regular “run of river” dam projects. This bodes well for the proposed Phase 3 Vaca Hydroelectric Project as many of the fundamental issues have been dealt with in the previous phases.

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9 Discussions centred around whether or not the dam would eventually lower electricity costs
10 It was asserted by environmental activists that significant populations of scarlet macaws would have been impacted
5.12.2 INITIAL STAKEHOLDER FEEDBACK

Initial stakeholder consultation sessions have been held with selected individual representatives (6) from the local government\textsuperscript{11}, tourism\textsuperscript{12} and environmental conservation NGO\textsuperscript{13} spheres and with community groups\textsuperscript{14} (total number of individuals: 46) in order to share project information and elicit initial feedback on perceptions, concerns and issues surrounding the proposed Vaca Hydroelectric project. Stakeholder discussions have been frank in nature and in-depth in terms of coverage of issues. There has been stated approval of the consultation process to date which has been deemed more participatory at the “front-end” of the process than the previous two phases of the Macal River Hydroelectric project. Core threads running through initial stakeholder feedback are that (1) there is an understanding of the need to balance development with conservation and (2) it is acknowledged that there can be errors made in the development of projects and interpretation of data. Many stakeholders, particularly villagers and ecoresort owners along the Macal River, have extensive anecdotal knowledge of the riverine environment, its evolving geophysical state and its fluctuating hydrological conditions. Extensive use of the river and many years of living along its banks have allowed the accumulation of this knowledge base and there is a “connection” with the river that influences perceptions and views about development interventions that will alter the river’s state in even a small way. Overall, it should be noted that although this EIA is focused on the Vaca Hydroelectric project, almost all of the stakeholder input was contextualized with and related to the overall Macal River Hydroelectric Developments.

\textsuperscript{11} San Ignacio Town Board
\textsuperscript{12} Belize Tourism Industry Association-Cayo Chapter, the Belize Eco-Tourism Association and the Cayo Tour Guides Association
\textsuperscript{13} Belize Institute for Environmental Law and Policy
\textsuperscript{14} Community public meeting in Cristo Rey Village (July 27, 2005) and joint Executive Village Council Committee/Health Committee meeting in San Jose Succotz Village (July 24, 2005)
6.0 Recommendations for the Preferred Site

6.1 Identification of Issues

Based on discussions with BECOL, the Department of the Environment and Charette-Style consultations among the EIA team the following environmental issues were identified as being relevant to the selection of the dam site:

**Physical Aspects**
1. Storage capacity and extent of inundation
2. Seismic risk of tunneling at Site A
3. Identification of quarry sites
4. Slope stability

**Hydrological Aspects**
5. Combined effect of Chalillo, Mollejon, and Vaca projects on downstream flows
6. Peak flows and flood flows
7. Potential dam failure
8. Inundation area
9. Flood control
10. Sedimentation effects of the proposed dams
11. Upstream effects
12. Downstream effects

**Water Quality**
13. Potential for mercury contamination in stored water

**Biological Aspects**
14. Loss of habitat and ecosystems
15. Alterations in riparian, aquatic and terrestrial ecology
16. Impact on various groups of fauna
17. Increasing access to the area
18. The presence of sensitive / endangered species of flora and fauna
19. Vaca Forest Reserve as a protected area
20. Watershed degradation

 **Socio-economic Aspects**
21. Land use and land tenure
22. Access to Site A and Site B
23. Potable Water Supply
24. Recreational, domestic and other uses of the Macal River
25. Public Perception and Sentiment
26. Local employment opportunities

 **Other Aspects**
27. Consideration of alternatives
28. Cumulative impacts

### 6.2 Comparative Assessment of Sites

A qualitative assessment was done of the environmental aspects for Site A and Site B in order to determine the site with the lower potential for environmental impact. Additionally, a quantitative assessment was also conducted to support the qualitative findings. The environmental aspects for physical, ecological, archaeological and socio-economic components of the environment were assessed against design criteria, construction works and operation phase. A rating was assigned with +5 having the most significant positive impact and –5 having the most significant negative impact. The qualitative assessment is given in Table 6.2 a and the quantitative assessment is given in Table 6.2 b.

The results show that Site B is the preferred site for dam construction, due to better design parameters, less construction impact, less intrusion into habitats and less potential operational impacts.
A similar comparative analysis was conducted for Option 1 (Concrete Dam) and Option 2 (Concrete Face Rock Fill Dam) at Site B. The comparisons are shown in Table 6.2c and 6.2d.

The results show that Option 1 requires less modification of the existing environment and has less potential negative environmental impacts. However, it should be stressed that both options are environmentally acceptable and, given consideration of other factors such as economic costs and benefits, any of the two options could be eventually chosen as the overall preferred one.
### Table 6.2a: Qualitative Assessment of Site A and Site B

<table>
<thead>
<tr>
<th>Environmental Aspect</th>
<th>Site A</th>
<th>Site B</th>
<th>Preferred Site</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYSICAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geology</td>
<td>Abutment site presents no issues as indicated in the Geotechnical/Geology Reports (Rodio-Swissboring, 2005) and the GPD Report (Cho &amp; Moore, 2004).</td>
<td>As for Site A</td>
<td>No geological/geotechnical preference</td>
</tr>
<tr>
<td>Geotechnics</td>
<td>Requires construction of a 3 km tunnel through structures with faults which could create unknown difficulties.</td>
<td>No tunnel is required as powerhouse will be sited at the toe of the dam.</td>
<td>Site B</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>No issues regarding sedimentation</td>
<td>No issues regarding sedimentation. A larger reservoir area would create a greater surface area for collecting sediment, thereby reducing accumulation effects. A deeper dam would also result in a lower percentage of sediment to volume of water.</td>
<td>Site B</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Inundation area smaller. Maximum storage depth for Site A is significantly less at 15m. The need for a tunnel would result in a greater stretch of river with significantly reduced flow (3km).</td>
<td>Inundation area of Site B, would include the inundation area for Site A and extend to the existing Mollejon Power Plant. Maximum storage depth would be deeper at 48m. Tailrace considerably shorter.</td>
<td>Site B</td>
</tr>
<tr>
<td>Water Quality</td>
<td>A smaller storage depth has slightly less potential to alter water quality parameters.</td>
<td>A greater storage depth has the potential to alter some water quality parameters such as DO and Temperature</td>
<td>Site A</td>
</tr>
</tbody>
</table>
## Table 6.2a: Qualitative Assessment of Site A and Site B

<table>
<thead>
<tr>
<th>Environmental Aspect</th>
<th>Site A</th>
<th>Site B</th>
<th>Preferred Site</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tourism</strong></td>
<td>Site A inundates approximately 5km of potential river activity areas up to the Mollejon Power Plant. However, Site A would severely alter the white water activity potential from Site A to below the power house tailrace at the end of the tunnel $\approx 3$ km. This area would be unavailable for river activities.</td>
<td>Site B inundates white water activity areas up to Mollejon Power Plant (8-9 km) but would increase potential for year round white water activities downstream due to steady flows. Site B could create opportunities for alternative recreational activities.</td>
<td>Site B</td>
</tr>
<tr>
<td><strong>BIOLOGICAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ecosystems</strong></td>
<td>Smaller storage depth and smaller inundation area would result in the loss of less acreage of ecosystems. The main type of ecosystem impacted would be riparian classified as Deciduous Broadleaf Lowland Riparian Shrubland in Hills. Smaller acreage of Tropical Evergreen Broadleaf Forest would also be impacted.</td>
<td>Greater storage depth and greater inundation area would result in more acreage of ecosystem lost. Site B would result in the loss of more acreage of two types of ecosystem. The main type of ecosystem impacted would be riparian classified as Deciduous Broadleaf Lowland Riparian Shrubland In Hills; with larger acreage of Tropical Evergreen Broadleaf Forest. The acreage of area to be inundated is 0.7 km$^2$ or 70 ha.</td>
<td>Site A</td>
</tr>
<tr>
<td><strong>Mammals</strong></td>
<td>Mammals identified in the area would be impacted less by the selection of Site A as this results in a smaller inundated area and</td>
<td>Site B is a greater inundation area, which includes Site A and would result in more loss of habitat.</td>
<td>Site A</td>
</tr>
</tbody>
</table>
Table 6.2a: Qualitative Assessment of Site A and Site B

<table>
<thead>
<tr>
<th>Environmental Aspect</th>
<th>Site A</th>
<th>Site B</th>
<th>Preferred Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reptiles</td>
<td>Reptiles identified in the area would be impacted less by the selection of Site A as this results in a smaller inundated area and less habitat lost.</td>
<td>Site B is a greater inundation area, which includes Site A and would result in more loss of habitat.</td>
<td>Site A</td>
</tr>
<tr>
<td>Amphibians</td>
<td>Amphibians identified in the area would be impacted less by the selection of Site A as this results in a smaller inundated area and less habitat lost.</td>
<td>Site B is a greater inundation area, which includes Site A and would result in more loss of habitat.</td>
<td>Site A</td>
</tr>
<tr>
<td>Fish</td>
<td>Site A would result in a smaller area of inundation and less water for fish proliferation.</td>
<td>Site B would encourage greater density of species within the inundated area and increased species density in areas previously separated by rapids.</td>
<td>Site B</td>
</tr>
<tr>
<td>Birds</td>
<td>Birds identified in the area would be impacted less by the selection of Site A as this results in a smaller inundated area and less habitat lost.</td>
<td>Site B is a greater inundation area, which includes Site A and would result in more habitat lost.</td>
<td>Site A</td>
</tr>
<tr>
<td>Inundation area</td>
<td>Smaller inundation area. Flood plain impacts would be less at Site A than at Site B. Greater area would be allowed to run dry. Less impacts in the event of dam failure</td>
<td>Greater inundation area, more water stored and potential for greater downstream impacts in the event of dam failure.</td>
<td>Site A</td>
</tr>
</tbody>
</table>
Table 6.2a: Qualitative Assessment of Site A and Site B

<table>
<thead>
<tr>
<th>Environmental Aspect</th>
<th>Site A</th>
<th>Site B</th>
<th>Preferred Site</th>
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<tr>
<td><strong>ARCHAEOLOGY</strong></td>
<td></td>
<td></td>
<td>No preference</td>
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<td>Archaeological Features</td>
<td>Only a limited number of features of archaeological significance were observed in the rapid assessment.</td>
<td>Only a limited number of features of archaeological significance were observed in the rapid assessment.</td>
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<tr>
<td><strong>SOCIO-ECONOMIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Use</td>
<td>Intrusion at Site A would create more difficulties and potential for intrusion into forested areas currently not accessible</td>
<td>Site B is very accessible, not pristine and already shows signs of intrusion and human activity.</td>
<td>Site B</td>
</tr>
<tr>
<td>Employment</td>
<td>Opportunities for employment would increase during the construction phase</td>
<td>Opportunities for employment would increase during the construction phase.</td>
<td>No preference</td>
</tr>
<tr>
<td>Access</td>
<td>Site A access would have to be created for construction works. Currently access is through disputed private property and would create access to pristine areas. Also more points of access would be required to facilitate construction camp site, tunnel to the power house, bridge to the power plant.</td>
<td>Site B already has an established access road which would need improvement, not through pristine forest.</td>
<td>Site B</td>
</tr>
<tr>
<td>Security</td>
<td>No security issues identified.</td>
<td>No security issues identified</td>
<td>No preference</td>
</tr>
<tr>
<td>Parks &amp; Protected Areas</td>
<td>Potential for human intrusion impacts would be greater at Site A than at Site B.</td>
<td>Has less potential for human intrusion impacts at Site B as this site is already accessible.</td>
<td>Site B</td>
</tr>
<tr>
<td>Environmental Aspect</td>
<td>Site A</td>
<td>Site B</td>
<td>Preferred Site</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------</td>
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</tr>
<tr>
<td><strong>HAZARD</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>VULNERABILITY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope Stability</td>
<td>Less evidence of landslides at Site A</td>
<td>Satellite imagery suggests that Site B is more prone to slope failure than Site A.</td>
<td>Site A</td>
</tr>
<tr>
<td>Dam Failure</td>
<td>Dam failure at Site A poses less risk to downstream communities due to lower volume of water and further river reach.</td>
<td>Dam failure at Site B would be more disadvantageous to downstream conditions, due to greater volume of water and closer proximity to communities (shorter river reach).</td>
<td>Site A</td>
</tr>
<tr>
<td>Natural Floods</td>
<td>Construction of the dam should create a more regular flow and reduce peak flows.</td>
<td>Construction of the dam would result in greater flood control due to the larger potential for retaining flood water.</td>
<td>Site B</td>
</tr>
<tr>
<td>Seismic Risk</td>
<td>Potential for seismic risk may be greater at Site A as a result of the tunnel through structures with faults. No identified seismic risk at the dam site, the same as for Site B.</td>
<td>No tunnel required. No identified seismic risk at the dam site, the same as for Site A.</td>
<td>Site B</td>
</tr>
<tr>
<td><strong>CONSTRUCTION</strong></td>
<td></td>
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</tr>
<tr>
<td>Camp Site</td>
<td>Less potential residential camp site locations nearer to Site A.</td>
<td>More potential residential camp site locations nearer to Site B.</td>
<td>Site B</td>
</tr>
<tr>
<td>Construction Activities</td>
<td>Construction work presents more environmental challenges in the creation of a tunnel and bridge to power plant. Creation of access road required, bridge, tunnel and residential camp site. Two</td>
<td>Dam with power house at the toe of the dam would result in one construction site. Less potential for environmental damage.</td>
<td>Site B</td>
</tr>
<tr>
<td>Environmental Aspect</td>
<td>Site A</td>
<td>Site B</td>
<td>Preferred Site</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>----------------------------------------------------</td>
</tr>
<tr>
<td>Transmission Line</td>
<td>separate construction sites would be required for the dam and for the powerhouse.</td>
<td>The existing access route could be used to connect the powerhouse to the Mollejon power plant. This would be a shorter access road. The right-of-way for the transmission line would sterilize this area for future land use and lower adjacent property values.</td>
<td>Site B</td>
</tr>
<tr>
<td>Quarry</td>
<td>Aggregate could be obtained from tunneling activities and a smaller quarry site would be required. A bridge would have to be built to transport aggregate across the river.</td>
<td>All aggregate would be supplied from one quarry, if possible sited within the footprint of the inundation area.</td>
<td>Site A (If quarry within Site B inundation area is not feasible)</td>
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<tr>
<td>Equipment Storage Maintenance</td>
<td>Site A has fewer suitable areas available.</td>
<td>Site B has more suitable areas available.</td>
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</tr>
<tr>
<td>Ecological Impacts</td>
<td>Site A has fewer options for construction activities to be sited in less disturbed areas.</td>
<td>Site B provides more options for construction activities to be either within the footprint of the inundation area or in more disturbed areas.</td>
<td>Site B</td>
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Table 6.2 b: Quantitative Comparison of Site A and Site B

<table>
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<td>Reptiles</td>
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<td>Amphibians</td>
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</tr>
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<td>Access</td>
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<td>Parks &amp; Protected Areas</td>
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<td>Displacement</td>
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<td>Operation Phase</td>
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</tr>
<tr>
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<td>Domestic Uses of the River</td>
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<td>Quarrying</td>
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<td>Total Option B1</td>
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Table 6.2c: Qualitative Assessment of Site B, Option 1 (Reinforced Concrete Dam) and Option 2 (Concrete Face Rock Fill Dam)

<table>
<thead>
<tr>
<th>Environmental Aspect</th>
<th>Site B Option 1</th>
<th>Site B Option 2</th>
<th>Preferred Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam and Appurtenant Structures</td>
<td>Less modification to existing environment, maintain existing flow path of river</td>
<td>Wide impact areas, more forest damage, greater modification to valley, greater river bed modification, cutting in the mountain, transport of material and people across the river.</td>
<td>Option 1</td>
</tr>
<tr>
<td>Hydrology</td>
<td>River bed course would be maintained and flow over the spillway would maintain stream flow in the river at the toe of the dam.</td>
<td>Spillway channel and tailrace would discharge further downstream of the dam. Flows would be maintained downstream of the tailrace.</td>
<td>Option 1</td>
</tr>
<tr>
<td>Construction Material</td>
<td>A quarry would be required to provide 150,000 m³ of the aggregate requirements. 100,000 m³ would be supplied from excavation of the tailrace channel A total of 250,000 m³ would be required.</td>
<td>Spillway channel excavation would provide 600,000 m³ of the aggregate requirements. 100,000 m³ would be supplied from excavation of the tailrace channel A total of 700,000 m³ would be required.</td>
<td>Option 2</td>
</tr>
<tr>
<td>Ecology</td>
<td>Would require less modification of the riverbed and gorge.</td>
<td>Option 2 would require more modification of the riverbed and gorge to accommodate the width of the base of the dam (approx. 132m) and the spillway channel (approx. 50m)</td>
<td>Option 1</td>
</tr>
<tr>
<td>Archaeology</td>
<td>Only a limited number of features of archaeological significance were observed in the rapid assessment.</td>
<td>Only a limited number of features of archaeological significance were observed in the rapid assessment.</td>
<td>No preference</td>
</tr>
<tr>
<td>Environmental Aspect</td>
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<td>Site B Option 2</td>
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<td>----------------------</td>
<td>----------------</td>
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<tr>
<td>Power House</td>
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<td>No preference</td>
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<td>Transmission line</td>
<td>No environmental difference</td>
<td>No environmental difference</td>
<td>No preference</td>
</tr>
<tr>
<td>Socio-economic</td>
<td>High level of imported material and expertise.</td>
<td>Greater use of local material, expertise and labour.</td>
<td>Option 2</td>
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</table>
### Table 6.2d: Quantitative Comparison of Site B, Option 1 (Reinforced Concrete Dam) and Option 2 (Concrete Face Rock Fill Dam)

<table>
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<tr>
<th>GEOTECHNICS/GEOLOGY</th>
<th>Design Features</th>
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<tr>
<td>Slope Stability</td>
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<td>Foundation Material</td>
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<tr>
<td>Quarrying</td>
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**HYDROLOGY**

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<td>Inundation Area</td>
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<td>Inundation Depth</td>
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<tr>
<td>Dam Failure</td>
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<tr>
<td>Flood Control</td>
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<td>Dry Area</td>
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<td>Regulated Downstream Flow</td>
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**WATER QUALITY**

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| Total Option B1                 | -4        |
| Total Option B2                 | -8        |
7.0 Potential Environmental Impacts

7.1 General Environmental Impacts

In general, the environmental impacts that would occur in the event of implementation of the proposed Vaca Hydroelectric Project at Dam site B would include both positive and negative impacts that would occur over the short, medium and long term. These impacts would include alteration of the existing terrain at the dam site, establishment of a reservoir, flood control, alteration in downstream flows, loss of vegetation and habitat and provision of employment in the medium term. Details of the various impacts including the nature and duration of these impacts are discussed in the following sections. Mitigation measures to minimize the negative impacts are also presented below in italics.

7.2 Physical Environmental Impacts

7.2.1 SITE PREPARATION AND CONSTRUCTION PHASE

During the site preparation and construction phase the main impacts on the physical environment would include long-term irreversible impacts, medium-term reversible impacts on the topography and terrain, and short-term impacts on air and water quality.

Topography and Terrain

Impact: During the site preparation and construction phase the main impacts on the physical environment would be long-term and irreversible on the topography. These would occur as a result of activities related to clearance of vegetation and earth movement for road construction, right-of-way for the alignment of the transmission line, abutment of the dam, excavation of the tailrace, blasting and quarrying.
**Mitigation Measures:** As far as possible all construction related activities should remain within the footprint of the development so as to minimize the potential negative impacts on the environment. This includes storage of equipment and machinery and no side-tipping of excavated spoil, and land clearing only within the right-of-way for the transmission line (30m) and access roads (20m). Plant debris should be piled along the edge of the right-of-way pending removal to a suitable disposal site. Any required burning should be carried out under the supervision of the Forest Department. Fire extinguishers should be on site at all times. Regarding the quarry site, if material were excavated from upstream of the abutment site, within the footprint of the inundation area this would reduce the impact of long-term irreversible changes on the topography. If the quarry site is outside the footprint of the inundation area, best quarrying practices would be required to ensure successful post construction rehabilitation. All access roads should be built in conjunction with the Ministry of Works and the Forest Department.

**Impact:** Medium-term reversible impacts would occur in the establishment of the work site, the residential camp, storage site and office facilities, batching plant and equipment maintenance. These impacts are considered medium-term and reversible as they would only last for the duration of the construction activities.

**Mitigation Measures:** Best practices for construction should be employed and site-rehabilitation should be performed at the end of the construction phase. Site rehabilitation should include removal of decommissioned buildings and structures that have not been identified as having future beneficial use, removal of equipment, vehicles and machinery, remediation of soils in the event of petroleum spills, removal of solid and liquid waste for disposal at an approved designated facility, and replanting/re-grassing of areas as appropriate to minimize the impact of scarring of the landscape. Site
rehabilitation should also include the realignment of any altered drainage channels, to pre-construction natural flows. Long-term maintenance of the operational roads and transmission line right-of-way are recommended to maintain service quality as well as aesthetic appeal.

Air Quality

Impact: Short-term impacts would occur in the creation of noise, dust and vibration, and the release of emissions. These impacts would arise due to excavation and blasting activities, operation of the batching plant, use of heavy machinery and general construction works. No major towns or villages have been identified in close proximity to the proposed dam site. Impacts should be contained within the construction zone.

Mitigation Measures: In order to minimize these short-term impacts proper maintenance of machinery and equipment is necessary to limit poor vehicular emissions and noise. Periodic wetting of stripped dry areas, periodic wetting of stockpiles of fines, and covering of conveyors to minimize fugitive dust during crushing and batching plant activities are mandatory. Non-petroleum based dust suppressants should be used. Blasting activities should be carried out by a certified and approved contractor and standard mitigation measures should be employed including the use of blasting mats, to prevent airborne rock fragments. No mitigation measures are available to minimize the effects of vibration during blasting.

7.2.2 OPERATION PHASE

During the operation phase no negative impacts are anticipated on the topography, terrain, noise or air quality.
7.3 Hydrological Impacts

7.3.1 SITE PREPARATION AND CONSTRUCTION PHASE

Hydrological impacts of the Vaca project relate specifically to changes upstream and downstream of the dam during construction and operation.

Upstream the impacts are related to the nature and extent of inundation. The inundation length of a Site B dam would be approximately 6.5 km in total (5.8 km on the Macal River plus 0.7 km on the Rio On) while the inundation length of a Site A dam would be 4.2 km (3.5 km on the Macal River and 0.7 km on the Rio On). Downstream the impacts would relate primarily to changes in flow rates and flood intensities.

Upstream Changes:

Impacts: During construction upstream impacts would be negligible since a diversion channel would be constructed to carry all flows past the dam structure, resulting in no upstream accumulation of water (therefore no inundation). Similarly, downstream flows would not be interrupted although water quality could be impaired by sediment outflows and other releases such as petroleum and other chemical wastes generated by construction activities.

Mitigation Measures: By utilizing sound construction practices, these negative impacts could be appropriately mitigated. The application of sound construction practices for the diversion channel should serve to prevent upstream inundation during construction. The use of silt screens and/or silt curtains at the diversion channel would be necessary to trap sediments upstream.
### 7.3.2 OPERATION PHASE

#### Upstream Changes

**Impacts:**

During operation the upstream impacts would result directly from the extent of inundation. With a dam at Site B, about 10km of river flow on the Macal River and Rio On would be converted to a standing reservoir (the inundation length of a Site B dam would be approximately 6.5 km in total – 5.8 km on the Macal River plus 0.7 km on the Rio On). This would result in the following hydrological impacts:

1) Loss of falls, rapids and whitewater runs in the river basin between Mollejon and Vaca
2) Increase in ground water levels
3) Increase in sediment load on the river bed
4) Changes in water quality, with conversion from riparian flow to standing reservoir (see discussion on water quality impacts below)

Similar impacts to 2) and 3) above were evaluated for the Chalillo dam project and considered to be negligible (AMEC E&C Services Ltd., 2001), and the Mollejon experience has demonstrated this. In the case of the Vaca dam, the impacts would be less, given the smaller size of the reservoir and the absence of critical hydrological features. However, loss of the rapids and whitewater conditions between Mollejon and Vaca would negatively impact the whitewater recreational activities, which occasionally occur on that stretch of river. (See Socio–economic impacts below).

Regarding sediment deposition in the reservoir, it has been shown that, at current rates of sedimentation in the Macal basin, it is highly unlikely that a build up of sediments would create a problem either for effective dam life or for water quality. However, during field investigation for this study, it was
observed that the clearing of forested areas for agriculture in the watershed appears to be taking place in an increasing and seemingly uncontrolled manner. If this is allowed to go unchecked, it is possible that the rate of erosive run off and sediment deposition in the reservoir could be increased significantly thus creating a problem. Similarly, agricultural chemicals could be added to the run off, thus impacting water quality. For these reasons, watershed management in the Macal basin needs to be improved to avoid future negative impacts in the reservoir.

Mitigation Measures: The inundation impacts on the riverbed are inevitable and cannot be mitigated. Improved watershed management is necessary to minimize potential sediment deposition in the reservoir. Even without the establishment of the Vaca Hydroelectric Project, improved watershed management is necessary to minimize sediment loading in the Macal River. The Government of Belize in collaboration with all watershed stakeholders, including BECOL, should address this concern as a matter of urgency.

Downstream Changes

Impacts: Potential downstream hydrological impacts arising from operation of the Vaca dam include.

1) Changes in the flows and river bed configuration immediately below the dam structures
2) Changes in normal flows and flood plain configuration at critical locations further downstream, including:
   a) Vaca Falls
   b) Domestic and recreational sites between Vaca and San Ignacio
3) Changes in flood intensities with extreme rainfall conditions
4) Extreme flooding due to dam failure
5) Changes in sedimentation immediately below the dam
Changes Immediately Below the Dam

**Impacts:** A Vaca Site B dam would have a powerhouse at the toe of the dam and a tailrace where the discharge immediately re-enters the river after exiting the turbines. However, because the river channel will be deepened to ensure continuous flow, there will be a downstream impact of about 1 km (Figure 5.5.4 b). In addition, flows over the spillway would be discharged directly to the river.

**Mitigation Measures:** These impacts are inevitable given the alternate dam designs and, will have hydrological and ecological significance. This is discussed separately under ecological impacts.

Changes in Macal River Downstream Flows

**Impacts:** Data presented in the hydrology section (Figures 5.5.5 b,c,d) show that with construction of the Chalillo dam, downstream flows at Cristo Rey will be dampened so that wet weather floods will be reduced and dry weather base flows will be increased. The Vaca scheme being a run of the river operation would not significantly change this pattern of flows so that during an average hydrological year, Macal River flows would normally vary between 10 m³/s and 20 m³/s. During a dry year, flows at Cristo Rey would normally be between 5 m³/s and 15 m³/s while during a wet year, the flows would be about 20 m³/s and above. In each of these conditions extreme rainfall conditions would nevertheless increase the flows and create floods (see Figures 5.5.5 b and c).

As a result of the modulated flows the Vaca falls below dam site B would have flows for most of the time between 5 m³/s (dry years), and 20 m³/s (wet years), but these would increase during floods. Based on these flows, it is anticipated that the falls would retain their attractive feature throughout the
year and not be as seasonally variable as is now the case. This may be regarded as a positive impact.

If the dam is located at site A, the Vaca falls would not benefit from the modulated Macal River flows and, at times, would only receive 1 m$^3$/s as riparian release from the dam. This would have a negative impact on the falls as an attraction site.

Below the Vaca Falls and downstream to San Ignacio, the modulated flows would create more stable river conditions and a well defined flood plain. This should favour the downstream users and activities, including settlements at Negroman and Cristo Rey and tourist facilities at Black Rock River Lodge and Chaa Creek Resort. In addition, some water sport activities such as tubing, canoeing and kayaking would have more favorable year round river depths and flows, except during extreme flood periods.

**Mitigation Measures:** No mitigation measures are necessary as these impacts are deemed to be positive.

**Changes in Flood Intensities**

**Impact:** Wagenseil (1999) has described the characteristics of flooding on the Macal River and has emphasized that while upstream impoundment would attenuate flood surges, it would not eliminate them altogether, as Figures 5.5.5 b and 5.5.5 c clearly show. Similarly, we may conclude that with a Vaca dam in place, extreme flood events would still occur but on fewer occasions and at lower intensities. According to Wagenseil the design of any dam should take into consideration the need for adequate storage space to delay high flows surges and should possess sufficient reserve capacity to ensure public safety downstream. In the case of Vaca dam, this has been incorporated into the preliminary design utilizing the Probable Maximum Flood (PMF) as the Inflow Design Flood (IDF). Hence, flood surges with a
Vaca dam in place should not be greater than at present and could be significantly less, depending on the dam’s final design.

**Mitigation Measures:** The overall management of flows in the entire Macal River basin is not the responsibility of BECOL, but must be the responsibility of the National Pro-Tempore Water Commission which was established under Statutory Instrument No 62 of 2004. This will ensure that essential flows in critical areas are maintained at all times. These critical areas and flows should be determined by the Commission.

**Flooding due to Dam Failure**

**Impacts:** The possibility of dam failure has been considered both in the preliminary design of the dam and in the projections for downstream flows given dam failure under different flood regimes. Increase in flood heights and levels of inundation (flood plain) have been assessed at various points downstream of the proposed Vaca dam (see Appendix IV), and have been illustrated by flood plain contours shown in Figure 5.5.5 e (insert in back pocket). The figure shows that at Negroman, Cristo Rey, San Ignacio and locations further downstream the flood plain with dam failure at the Probable Maximum Flood (PMF) would not be significantly different than at PMF without dam failure. However, nearer to the dam the height of the floods would be 1-2 metres higher. In terms of the flood plain this would not be significant, as this increase would be contained within the walls of the steep river valley.

Under fair weather conditions (for example Macal River flows at Vaca at 23 m$^3$/s), dam failure would result in flooding at Negroman and, to a lesser extent, at Cristo Rey, San Ignacio and downstream locations on the Belize River (see Figure 5.5.5 e, insert in back pocket). However, the extent of this flooding would be well within the contours of the usual wet season floods and would persist for only a few hours (see Appendix IV).
Under both the PMF and fair weather conditions, the time of travel of the peak flood from Vaca to Negroman, Cristo Rey and San Ignacio would be rapid, varying at Negroman from approximately 20 minutes (PMF failure) to approximately 45 minutes (fair weather failure). Hence, beside the extent of the flooding the short warning time would be a critical element in hazard management. All the above considerations are based on an assumption of total and instantaneous dam failure. In reality, this is a most unlikely occurrence and must be regarded as an extreme worst case scenario.

**Mitigation Measures:** The Vaca dam operations should incorporate certain features that will create a link to the Flash Flood Early Warning System (FFEWS) that has been implemented at Chalillo (Chalillo ECP, April 5, 2002). BECOL should also revise the Emergency Preparedness Plan (EPP) in conjunction with the National Emergency Management Organization (NEMO) and its affiliates DEMO and CEMO to include the facilities at Vaca. This revised plan should be completed before the completion of the Vaca dam. BECOL should provide signals (digital or analogue) to the National Meteorological Service for at least three threshold reservoir levels (Alert, Warning and Emergency Phases). These signals should be relayed by National Oceanographic and Administrative Organization (NOAA) satellite for immediate transmission and dissemination. In addition to appropriate dam design the effective mitigation measure for flooding with or without dam failure would be a Flash Flood Early Warning System (FFEWS) and the implementation of an Emergency Preparedness Plan. The FFEWS should be linked to the procedure already developed by BECOL for Chalillo, which is in association with the National Meteorological Service. BECOL would inform the National Meteorological Service of any pending flood hazard, and they in turn notify the public and set in train the necessary emergency procedures. This requires a reliable and continuous communication system between BECOL, the National Meteorological Service and the downstream
communities. It is desirable that the plan be regularly reviewed and upgraded with full stakeholder participation, in order to ensure its acceptance and compliance by the general public. This EIA report includes a ‘Dam Break’ analysis produced by Gilbert-Green and Associates for BECOL and is presented in Appendix IV. In addition flood plain contours for dam failure under PMF and fair weather conditions from Vaca to Belmopan are shown in Figure 5.5.5 e (insert in back pocket).

Changes in Sedimentation

**Impacts:** The estimates of sedimentation in a Vaca reservoir indicate that there would not be significant deposits of sediment over time, which would impact either the reservoir’s life or water quality. Similarly there would not be a significant reduction or increase in downstream sediment load because of the dam. Hence, this does not constitute either a positive or a negative impact.

**Mitigation Measures:** Improved watershed management in the Vaca and Mountain Pine Ridge Forest Reserves is necessary to reduce the incidence of uncontrolled agricultural practices and to ensure that there is no increase in sediment and agricultural chemical run-off to the Macal River. It is recommended that inspection of the reservoir bed takes place as a regular maintenance operation and that flushing take place as required. Carefully controlled reservoir flushing is necessary to mitigate any downstream sedimentation impacts. As for the Chalillo dam, the Department of the Environment may require that approval be sought from them prior to flushing the dam.

Clearance of Vegetation Upstream

**Impacts:** Large tracts of vegetation would have to be cleared in the area of inundation in order to prevent decreased water quality resulting from decaying vegetation, and the subsequent uprooting and release of vegetation within the impoundment area.
Mitigation Measures: Clearing of vegetation should be conducted manually, with the Forest Department approved use of heavy equipment, and/or burning. Clearance of vegetation by burning should be conducted under the supervision of the Forest Department and with the immediate availability of fire fighting equipment. Construction of fire paths is recommended with a minimum width of ten (10) metres in order to prevent the escape of fires, which could have the potential to destroy forested areas and associated wildlife. A vegetation clearance plan should be submitted to the Forest Department for approval prior to the commencement of any clearing activities.

7.4 Water Quality Impacts

This discussion evaluates the likely impact(s) of the proposed Vaca dam and the cumulative effects of the existent dam at Mollejon and the soon to be commissioned dam at Chalillo on water quality in the Macal River and other tributaries and rivers.

Hydroelectric dams may influence surface waters in the immediate vicinity of the dam and as far downstream as the river estuary and in some cases the coastal plains (World Bank, 2003). The potential impacts associated with hydroelectric dams are dependent on many factors such as the design and location of the dam, the sensitivity of the local environment and the mitigation measures implemented to modify dam design and operation. The primary water quality impacts associated with dams are:

- Temperature changes
- Downstream nutrient depletion
- Colonization by aquatic plants
- Reduced dissolved oxygen
- Increased acidity of bottom waters
- Increased mercury levels in fish
- Increase in salinity levels
- Reduced downstream sedimentation
- Increased downstream erosion rate
Temperature Change

**Impacts:** Damming a river and creating a lake like environment can cause changes and variations in the temperature of the water and the concentration of dissolved gases. The changes in water quality would be related to the retention time in the reservoir. Surface temperatures may rise when the flow of water is slowed or stops. For ‘run of the river’ dams such as Mollejon and Vaca the retention time is short and therefore the likelihood of significant alterations in temperature is low. Current data show that the difference in temperature at Mollejon and further downstream is approximately 1 degree. The retention time at Chalillo should however be longer. Chalillo will effectively be the control for both Mollejon and Vaca. The releases from Chalillo should be warmer than that from Mollejon since the retention at Chalillo will be longer. During the dry season water will likely be retained at Chalillo longer to ensure that Mollejon has the necessary fuel to produce the maximum amount of electricity. The accumulated effect and lower seasonal flows during the dry season could result in slightly higher temperature waters downstream of the three dams. Warming or cooling of natural rivers may alter the dissolved oxygen and suspended solids concentration, as well as influence chemical reactions (McCully, 2001).

**Mitigation Measures:** *No practical mitigation measures exist for the regulation of water temperature from the dam outflows for this type of hydroelectric dam without affecting its generating potential.*

Nutrients, Dissolved Oxygen and Water Acidity

**Impacts:** Reservoirs act as a repository for nutrients. The decomposition of organic matter in the inundated area supplies additional nutrients to the reservoir. These nutrients along with nutrients transported in stream flow accumulate in the reservoir providing a nutrient rich environment. Further downstream
may suffer from low nutrient levels due to the absence of nutrients transported in normal stream flow.

The nutrient rich environment in the reservoir may support an increased fish population. Algae and other aquatic plants may also proliferate to nuisance levels. Mats of aquatic plants can clog dam outflows and irrigation canals; curtail recreation, increase water treatment costs and increase water loss via transpiration.

The algae, through photosynthesis, may contribute to increased dissolved oxygen levels in the surface waters. On the contrary water at depth may suffer from reduction of oxygen (anoxic) due to the removal of oxygen from the water to aid the decomposition of dead and decaying organic matter (algal mats). Hydrogen sulfide may be produced as a byproduct of decomposition, which in turn may cause bottom waters to become acidic. Another sequence of chemical reactions may then be initiated; the acidic bottom waters may cause the dissolution of minerals such as iron and manganese. If the water becomes sufficiently anoxic fisheries may be damaged.

Mitigation Measures: *These impacts are mitigated through the clearance of vegetation in the inundation area prior to flooding, as well as an effective reservoir management program.*

Increased Mercury Levels in Fish

Impacts: Recent research has shown that mercury bio-accumulates in fish in reservoirs. Naturally occurring mercury is transformed by bacteria into methyl mercury, a central nervous system toxin (McCully, 2001). Mercury levels in the Macal River and Rio On (data from present EIA study) are at, or below, detection levels.
Mitigation Measures: A recent study showing levels of mercury in predatory and non-predatory fish from the Macal River (Flores, 2005) stated that an assessment of mercury levels in fish from other water bodies countrywide should be conducted, and a plan of action including mitigation measures, public awareness, monitoring and enforcement should be developed and implemented involving the relevant stakeholders. BECOL, under the Environmental Compliance Plan for the Chalillo Dam, is responsible for developing and implementing a Mercury Risk Management Program. The Mercury Risk Management Programme for the Chalillo Dam should be extended to the new Vaca facility.

Reduced Downstream Sedimentation and Increased Erosion Rate

Impacts: Sediments that are typically suspended in water collect behind a dam and may deprive the downstream habitats of organic and inorganic nutrients. The loss of nutrients is often compensated for by use of fertilizers. Sediment build up over time may also reduce the capacity of the dam, lowering its efficacy. The release of sediment free waters may also effectively erode soil and vegetation in the river bed and along its banks. In the case of Vaca, the expected rate of sedimentation should not result in any of these impacts.

Mitigation Measures: Soil conservation activities and control of land use in the watershed can mitigate the sedimentation of the reservoir. Any sediment flushing, however minor, will supply downstream waters with sediment, and should be carefully regulated and monitored.

Increased Salinity

Impacts: Dams in hot climates may result in the evaporation of a considerable amount of water as a result of the surface area of water exposed to the sun. This is not expected to be a problem at Vaca.
Mitigation Measures:  Regulation of water flows and the retention time will reduce any potential salinisation effects of evaporation.

7.5 Biological Environmental Impacts

Impacts on the biological environment of the proposed Vaca Hydroelectric Project would include impacts on the flora and fauna of the terrestrial and riverine environments. These impacts would vary depending on the different phases of the proposed project as:

1. Site Preparation and Construction
2. Operation
3. Decommissioning

7.5.1 SITE PREPARATION AND CONSTRUCTION

The site preparation and construction phase of the proposed project would result in the majority of negative impacts that have been identified. These include the following:

Loss of vegetation

Impacts:  Direct impacts of the proposed development at Site B would result in the loss of the following:

- Approximately 5.6 km of riverine ecosystem
- Approximately 100-125 acres of ‘tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills’
- Up to 40 acres of ‘deciduous broadleaf lowland riparian shrubland in hills’

Direct impacts of the proposed development at Site A would result in the loss of the following:

- Approximately 3.0 km of riverine ecosystem
- Approximately 35-45 acres of ‘tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills’
- Up to 22 acres of ‘deciduous broadleaf lowland riparian shrubland in hills’
• Up to 10 acres of ‘tropical evergreen seasonal broadleaf lowland forest over calcareous soils: Tehuantepec-Peten Variant’ and/or agro-productive lands – depending upon route of access road and power-lines.

In the local and national context:

• 100-125 acres of ‘tropical evergreen seasonal broadleaf lowland forest over steep calcareous hills' represents approximately 0.06-0.07% of the total extent of this ecosystem in Belize (as mapped in the Belize Ecosystem Map, Meerman & Sabido (2004).
• 40 acres of ‘deciduous broadleaf lowland riparian shrubland in hills’ represents approximately 0.6% of the total extent of this ecosystem in Belize (as mapped in the Belize Ecosystem Map, Meerman & Sabido (2004).
• 10 acres of ‘tropical evergreen seasonal broadleaf lowland forest over calcareous soils: Tehuantepec-Peten Variant’ represents less than 0.003% of the total extent of this ecosystem in Belize (as mapped in the Belize Ecosystem Map, Meerman & Sabido (2004).
• The inundation of up to 165 acres of terrestrial habitat represents a little under 0.1% of the combined areas of the Vaca and Mountain Pine Ridge Forest Reserves.

There are no wetland habitats to be considered on this section of the Macal River.

**Mitigation Measure:** There is no mitigation measure for the loss of vegetation within the footprint of the area of inundation, quarry areas, access roads, transmission line right-of-way, power house or dam. However, it is recommended that as much as possible of the construction activities remain within the footprint of the development and that no side-tipping of material or storage of machinery occurs beyond the footprint. Wildlife rescue has been performed in other countries, but has not met with major success (World Bank, 2003). However, wildlife rescue is recommended here to mitigate the loss of specimens, particularly for any endangered species.

**Loss of Habitats (Riverine, Riparian and Forest Habitats)**

**Impacts:** Three main habitats would be impacted by the dam. The level of impact for each is described below:
• **Riverine**

At the reservoir the riverine habitat will effectively be removed, and replaced with a relatively deep lake habitat. For the majority of reptile species that may use the riverine habitat, it is used primarily as a water resource within the ecosystem rather than as a habitat. As such, the water resource will not be removed or negatively impacted by the proposed development.

The one reptile species, within the proposed development area for which the river is the principle habitat, is the Morelet’s Crocodile. As noted in the baseline data of this report, this section of the Macal River is somewhat marginal habitat for this species. It prefers still pools or freshwater lakes/swamps, or slow-flowing vegetated streams or rivers. Whilst the proposed development will remove the riverine habitat for the Morelet’s Crocodile, it will be replacing it with a lake habitat that is potentially better suited to this species, and which may support a rather higher density.

*Mitigation measures:* No mitigation measures are required.

• **Shrubland**

Various reptile and amphibian species use the riparian shrubland habitat for feeding, basking or breeding. For three species of reptile (*Iguana iguana, Basiliscus vittatus, Sceloporus variablis*), it is the primary habitat.

- Feeding: A few species, such as *Iguana iguana* occurs primarily within the riparian belt, feeding mostly upon the fruits and foliage of species including figs and bri-bri. Species such as *Basiliscus vittatus* and *Sceloporus variablis* hunt invertebrates in the open sunny areas.
- Basking: Relatively few tropical reptile species bask in the way that is common amongst reptiles of temperate regions. Species that do (or are likely to) bask within the riparian belt of this section of the Macal River include species also using the habitat for its food resources, namely *Iguana iguana, Basiliscus vittatus, Sceloporus variablis*, and to a lesser extent *Crocodylus moreletii*. 
o Breeding: *Iguana iguana* and *Basiliscus vittatus* lay their eggs in the exposed sand banks adjacent to the River, and rely upon the elevated temperature to incubate their eggs.

Within this section of the Macal River, another habitat component that is critical for most of the amphibian species recorded is that of the rain-filled pools on the riverbanks, which appear to be the only suitable breeding sites for these species in this locality. These pools will be lost completely by the proposed inundation. Whilst the impacted species are not of conservation concern, and occur throughout much of the coastal lowlands, they still represent an important component of the fauna of the project area.

**Mitigation Measures:** For reptiles that bask in the area, as with feeding resources, mitigation actions could be undertaken to help replace this component of the habitat that will be lost. Removal of the riparian shrubland would remove this important component of the habitat, though mitigation actions could be undertaken to re-create nesting areas for *Iguana iguana* and *Basiliscus vittatus* above the banks of the proposed dam inundation.

- **Forest**

If the proposed development were to take place at Site B, up to 100-125 acres of forest habitat for reptiles and amphibians will be lost (or approximately 35% of this for development at Site A), plus an additional smaller area for roadways, power-lines and support infrastructure. This represents a loss of less than 0.1% of the combined areas of the Vaca and Mountain Pine Ridge Forest Reserves. For this specific forest ecosystem, the area represents approximately 0.06-0.07% of the total national coverage (as mapped in the Belize Ecosystem Map, Meerman & Sabido (2004). In terms of absolute area, it cannot be considered a significant loss for the reptiles utilizing this ecosystem.
Mitigation Measures: Despite this, in the interests of maintaining as much ecological integrity as possible, the developers should take all steps possible to confine the footprint of impact to that of the actual developments: the dam, the inundation area, roadways and power-lines – and minimize all negative impacts outside that footprint.

Fragmentation of Terrestrial and Riverine Habitats through Clearing of Vegetation and Impoundment of Water

Impacts: Terrestrial habitats may become fragmented into smaller components when small parcels of vegetation are left standing. This may occur when access roads are created or the right-of-way for the transmission lines is cut. Vegetation will continue to survive but wildlife that select forested areas such as some species of birds, reptiles and mammals, will likely move away from isolated vegetative patches back into forested areas. This could result in niche pressure if these forested areas are already occupied by wildlife populations.

The riverine habitat would be fragmented at the point of installation of the dam. Species upstream would have opportunities to travel downstream, but downstream species would not be able to move upstream.

In rivers where migratory patterns are essential to species survival, fish tunnels have been created in dams. However, this has a limited success rate (World Bank, 2003) and is not being recommended for this project. Fish ladders were also requested in the Environmental Compliance Plan for Chalillo but are not being recommended here, as the Vaca dam is the third in a series of dams, and the Mollejon dam would create a physical barrier for fish that may successfully pass the Vaca dam.
Stranding of Wildlife

Impacts: Fragmentation of terrestrial habitat can also occur within the inundation area as inundation is likely to result in isolated tree tops along the reservoir’s edge or through the creation of small islands within the inundation area. Highly mobile species such as birds would relocate to adjacent habitats. Reptiles and amphibians isolated in this way would be stranded and eventually die.

Mitigation Measures: If endangered species are identified as nesting or breeding in isolated vegetative patches, efforts should be made to rescue and relocate them.

Impacts on Fish

Impacts: During the construction phase, there may be a number of short term impacts on the fish fauna. These are described below:

- **Soil erosion and silt run-off**
  During the removal of trees and other vegetation for construction of the dam, associated facilities, quarry and access roads, there may be problems of increased soil erosion and silt run-off into the water, especially during rains. This can cause increased turbidity in the water on-site and downstream which may affect fish respiratory functions.

- **Siltation of key fish breeding and nursery areas**
  For fish species that require non-silt conditions (e.g. rock or gravel), an increase in sediment, as a result of soil erosion and runoff, may prevent breeding activity as a result of alteration of the substrate.
Mitigation Measures: For both the above impacts, proper construction practices to reduce runoff of sediments should be applied, including the use of sediment curtains to reduce sediment load in the water; the diligent control of erosion; maintenance of a vegetation buffer between roads, camp construction site and the river; and careful siting of the quarry and good construction practices.

Impacts: Contamination by building materials and machinery: The construction materials and chemical have the potential to contaminate the water and alter the water chemistry, in the event of spills.

Mitigation Measures: Good line management and sound construction practices should minimize this risk. However, in the event of spills a spill response plan and clean up procedures should be implemented as indicated in the appropriate sections below.

Impacts: Use of explosives: Fish can be particularly susceptible to blast shocks and rock fragments in the water.

Mitigation Measures: The timing of blasting should coincide with low water levels in dry season and should limit the number of fish affected.

Impacts: Blocking of fish migration: The construction phase may disrupt fish migration altering upstream and downstream species composition. Whilst only one species of migratory fish was identified during the survey (Agonostomus monticola), there is a general movement of other fish species up and down the river, important in the maintenance of genetic diversity.

A second migratory species, Anguilla rostrata, was recorded upstream at the Chalillo site (though not recorded at the Vaca project site). This
species migrates downstream as an adult to spawn in the Caribbean, with the young elvers then migrating back upstream over a series of years.

The construction of the dam, being so close to the Mollejon, is therefore unlikely to impact either of these species any further than the Mollejon dam already does.

**Mitigation Measures:** The ideal would be to install some form of by-pass (either wet trough or fish ladder) to provide the A. monitcola with a means to migrate, this system is unlikely to be useful for other species (cichlids and smaller fish), and will only provide access to the area between the Vaca dam and Mollejon. However, the wet trough and fish ladder are not being recommended here as the other two dams do not have either of these and migratory movement would eventually be blocked. Anguilla rostrata is less affected by the presence of dams, as individuals are able to migrate overland around barriers such as dams reducing the need for fish passes, which have been shown to be of only limited use in mitigation elsewhere in the world (World Commission on Dams, 2000).

**Impacts: Interruption of stream flow:** During construction, the temporary diversion of the river course may provide interrupted stream flow, especially if coffer dams are used to facilitate engineering work.

**Mitigation Measures:** Streamflow should be maintained at all times, as far as possible, with the creation of diversionary channels. Any diversionary channel needs to be located so as to divert the flow sufficiently far from the construction site to be free of construction contamination (particularly sediment runoff, cement and oil residues). It should also be accessible to the fish fauna presently occupying the area, to minimize disruption to migratory and non-migratory movement up and down stream.
Impacts: First filling of reservoir: The most immediate impact of inundation is the loss of riverine habitat – the riffles, pools and falls that provide the lotic fish fauna of the area with their ecosystem requirements. These fish require fast running streams, and do poorly in the still waters of reservoirs, showing a tendency to stay close to the reservoir edges and mouths of tributaries flowing into the reservoir. The deeper waters tend to be under-utilized, as they do not fill the niche requirements for these species.

Mitigation Measures: There are no mitigation measures suitable for this change of habitat.

Impacts on Reptiles and Amphibians

As the dam and support facilities are constructed, some amphibians and reptiles may be lost through the use of heavy machinery in the earthworks operations. Such losses are insignificant in conservation terms, and it is likely that most specimens of the more mobile species will vacate the immediate area as such works are initiated.

Mitigation Measures: Modest habitat modification / management within the 10m belt of vegetation buffering the inundation area should be undertaken in order to replace as much of the lost functionality of the riparian shrubland as possible in terms of use by amphibians and reptiles. This should include:

- The creation of 25-50m² (i.e. 5m x 5m, or 5m x 10m) sand banks at the edge of the inundation area appropriately spaced depending on the topography of the inundation area and the location of suitable sites, on both banks. These should be approximately 0.5m high, and provide open nesting and basking sites for several species.
- The creation of numerous small shallow pools (from 10m² to 25m², and 0.15m to 0.3m deep) within the same reservoir bank area. These pools should be appropriately be spaced on both banks, and would re-create breeding sites for the majority of the amphibian fauna of the locality. Vegetation should not be cleared around or in these pools.
• Known food sources for green iguanas (and howler monkeys) could be inter-planted amongst existing vegetation along the newly formed reservoir banks. These should include the bri-bri and fig species currently found in or adjacent to the riparian shrubland.

Impacts on Mammals

The footprint of the proposed dam and associated activities is small in comparison to the total area of the three surrounding protected areas (Vaca Forest Reserve, Mountain Pine Ridge Forest Reserve, and Elijio Panti National Park). The focal area is characterized by steep terrain, with a lack of flood plain areas, making it less than ideal habitat for many of the mammal species (studies in Cockscomb Basin Wildlife Sanctuary, for example, show that the jaguar is thought to prefer lower, less steep terrain, as do the two species of peccary). Whilst mammals associated with riparian and broadleaf forests should be relatively abundant, the low perceived density when talking with residents of the area suggests that numbers are depressed through hunting pressure. Jaguar and puma can be expected to be present (and have been recorded both from vocalizations (Herrera, 2005), and from tracks (observed during this EIA study). However, they are in lower numbers than in less accessible parts of the protected areas, because of the decline in prey base through hunting pressure. The hunting, and the increasing land clearance in the area, is likely to have a far greater impact on the mammals, both in terms of severity and scale, than the dam has the potential to be.

Negative impacts:

- increased noise level during initial dam construction
- potential interruption of water flow downstream
- the clearing of roads and power lines, fragmenting forest ecosystems (a barrier particularly for movement in *Alouatta pigra* and *Poto flavus*)
- increased human access to the area if infrastructure is put in place, but there is no protection of the immediate watershed (especially land clearance and hunting)

**Positive impacts:**
- protection from hunting pressure within the general dam area, contiguous with that already protected by the Mollejon dam
- for the carnivores, protection of prey species from hunters
- prevention of further land clearance for agricultural land within the dam catchment area
- for some opportunistic species (for example, gray fox, northern raccoon, Virginia opossum, big-eared climbing rat), greater opportunity for scavenging, with the presence of humans (but this should be minimal if appropriate solid waste management practices are implemented)

**Mitigation Measures:** The following mitigation measures may be applied:

- Active patrolling of catchment area, reducing hunting pressure and land clearance (responsibility of the Department of Forestry)

- Compensation measures could be put into place through environmental offset for example, a trust fund for active protection of the watershed as an effective conservation area, or designation of the watershed for protection. This would have to be approved and implemented by the Forestry Department in association with other relevant government agencies. BECOL is not expected to capitalize a trust fund for watershed management. The fund would have to be managed by a professional financial institution that would seek donations to capitalize the fund, and a percentage of the funds would in turn be used for fund management.

- Liaison with Department of Lands and Survey to ensure land within water catchment area is not allocated as farmland
Birds

Impacts: The following impacts may occur to the avifauna:

- **Noise and Disturbance Levels**
  During construction of the dam, species in the immediate vicinity of the construction site will be displaced, both by the clearance of vegetation, and by the noise and disturbance levels. More sensitive species, such as keel-billed motmots, may move out of the valley system entirely, into areas that may already have reached carrying capacity, or areas of more marginal habitat.

- ** Interruption of Water Flow**
  Species such as kingfishers and herons rely on the health of the riverine ecosystem, which would be impacted by any changes in waterflow or water quality.

- **Fragmentation of habitat**
  The creation of roads and clearance for the powerline within the broadleaf forest area will impact forest species, as some would not cross open areas, causing fragmentation of the population.

Mitigation Measures: Unnecessary road creation should be avoided, and road and powerline width should be kept to the minimum requirement. The majority of the species present in the area would not, however, be significantly affected.

Habitat Disruption

Impacts: Habitat disruption is expected in the short term for those species adjacent to the footprint of the development areas. Habitat disruption would result from the noise of heavy machinery, noise and vibration from blasting activities, as well as noise and activity from the presence of humans. Species are likely
to move away from the highest levels of disturbance, adjacent to the footprint, but are likely to return after completion of construction.

**Mitigation Measures:** There are no mitigation measures suitable for this short-term impact.

### Increase in Turbidity Levels

**Impacts:** The removal of vegetation along the riverbanks and work within the riverbed are likely to disturb soils and riverine sediments resulting in increased levels of turbidity in the riverine environment, measured as total suspended solids (TSS). This impact can be exacerbated in the wet season when heavy showers result in terrestrial washdown of exposed soils. This is a short-term impact, and levels of TSS will return to normal after construction activities are completed and through flushing of the system through constant movement of water. Increased turbidity in the river can result in the reduction of respiratory and feeding activities of some fish species.

**Mitigation Measures:** Increased turbidity is a short-term impact but mitigation is recommended through the deployment of silt screens around areas where any riverbed work is in progress, and along the river banks where vegetation is being cleared and loose topsoil is exposed.

### Loss of Vegetation

**Impacts:** Large tracts of vegetation will have to be cleared to facilitate the construction activities and the area of inundation. This will result in the loss of vegetation including some riparian forest and broadleaf forest species.

**Mitigation Measures:** Any areas that have been cleared for medium term activities such as the establishment of the camp site, storage areas, office facilities and construction access roads should involve work only within the footprint of...
these facilities and site rehabilitation including replanting of trees and re-grassing of areas, must be undertaken.

Increased Hunting Pressure

Impacts: The establishment of a residential construction camp site and the creation of construction roads and transmission line alignment would result in increased access to previously inaccessible forested areas. The occurrence of a large workforce in the area coupled with increased access could result in increased hunting pressure on game birds and small mammals.

Mitigation Measures: All workers should be briefed on the hunting regulations and advised of a no hunting policy for the residential construction camp.

Increased Sedimentation

Impacts: Increased levels of sedimentation may occur in the Macal River in the vicinity of the construction zones as a result of clearing of vegetation and exposure of topsoil, the use of earth moving equipment, blasting activities and riverbed works.

Mitigation Measures: In order to minimize the impact of sedimentation on aquatic life in the river polyethylene liners or liners of similar suitable material should be used to line the cofferdam. Sediment curtains or silt screens supported on a boom should be deployed at the site of any riverbank or riverbed excavation to prevent disturbed sediments from entering the stream flow. Riverbank and riverbed excavation should be limited to the dry season as far as is possible. All stockpiles of earth materials, including fines and aggregate, should be located away from the edge of the river (up to the 100 year flood level). Servicing of crushers and excavation machinery should not be permitted within 30 m of the high water mark for the river. Washing of
aggregate should not be conducted in the river, and wash-water should be stored in sedimentation ponds to allow for settling and reuse. Rehabilitation of excavated riverbank areas should be conducted by replacing suitable riparian vegetation on completion of construction works.

7.5.2 OPERATION PHASE

Sedimentation

Impacts: The periodic flushing of the reservoir may result in the release of sediments at a level higher than carried in the regular seasonal flows.

Mitigation Measures: In order to reduce the impacts of sedimentation on aquatic life downstream, BECOL should notify the Department of the Environment when it intends to carry out flushing activities. Flushing should only be conducted after the Department of the Environment has given approval to do so. As for the Chalillo dam the DOE may request that notification be given them, in order to grant approval before flushing activities are carried out.

After construction is completed, the operation of the dam would present other impacts:

Alteration of Biodiversity

Impacts: During operation of the dam the main ecological impact would be the reduction of riverine/riparian/floodplain habitat diversity, resulting from the dampening effect of the installation of the dam and reduction in flood flows. The riparian and floodplain habitats thrive on the seasonal highs and lows of the river, which create seasonal droughts or pulses of water and nutrients, which are indicators for the onset of reproduction, hatching, migration and other life cycle stages (McCully, 2001). The dynamics of this system would be reduced between the site of the dam and as far upstream as the Mollejon Power Plant, as well as downstream of the dam, as there would be
more regular flows and reduction of the seasonal floods. This would result in a more stable riparian habitat but could result in reduced biodiversity.

**Mitigation Measures:** There is no mitigation measure suitable for preventing the alteration of biodiversity as a result of more stable flows.

**Alteration of Existing Temperature Regime**

**Impacts:** The accumulation of water behind the dam would result in alteration of temperatures particularly between the summer months and the cooler months. In the summer water on the bottom would be cooler than on the top, and in the cooler months the water would be warmer on the bottom than on the top. Although the temperature variation in the Macal River is not as extreme as would be experienced in temperate climates, the variation in temperature in the winter is reported as having a mean monthly minimum of 16-17°C and a mean monthly maximum of 29°C (CI Power, 1991). In the summer, the mean monthly minimum is reported as 24-25°C in the summer with the mean monthly maximum of 32-33°C. This range may be important to the biological life-cycles of aquatic species, and alterations could in the long-term result in changes in fish populations.

**Mitigation Measures:** No practical mitigation measures exist for the regulation of water temperature from the dam outflows for this type of hydroelectric dam without affecting the generating potential.

**Impacts on Fish**

The creation of the dam, the alteration of the riverine flow and dam operation may have several impacts on the fish species. These are given below:

**Impacts:** Discharge of cool and / or anoxic water from the hypolimnion

One effect of storing water behind a dam may be the creation of thermal stratification – a lack of mixing between the warm surface layer
(epilimnion) and cold water at lower levels (hypolimnion). The drawing of water from the bottom of the reservoir through low-level outlets may release water that can be up to 10°C below that of the stream conditions. This may cause a shift in fish distribution, driving fish into warmer waters downstream, and producing a cold water ‘desert’ below the dam, with declining productivity, and resultant decreased fish diversity. Sub-lethal impacts of cold water release, resulting in a lowering of the body temperature of fish can include a slowing of physiological processes such as reproduction and growth, and a decrease in the ability to fight infection.

**Mitigation Measures:** The water temperature difference at Mollejon was measured as 2° to 3°C cooler than the surface temperature of the reservoir (S. Usher, Pers. Com.), which is not a cause for concern. However, the Vaca dam may show greater temperature difference, depending on the structure of the dam chosen. Monitoring of the water temperature, can ensure that the temperature of the water released is not a cause of concern for the fish fauna.

**Impacts:** **Blocking fish migration:** On the positive side, construction of a dam would prevent the spread of tilapia upstream. Tilapia (*Oreochromis mossambicus*) was sampled in the Macal River between San Ignacio / Santa Elena and the Chalillo site (Flores et. al., 2005). It is strongly recommended that all efforts are made to keep invasive species such as tilapia out of the reservoir, as this will disrupt the native fish populations that do establish themselves in the inundation area, and will also release this species into the rivers downstream.

**Impacts:** **Release of contaminated sediments into the food chain:** The current primary concern in terms of contaminant release is the formation of methylmercury and its subsequent concentration in the food chain. Mercury
is present in localized mineral deposits worldwide, but the greatest source in the environment is in an inorganic form in the soil (primarily as a result of atmospheric deposition). Whilst concentrations in the atmosphere are very low, water catchments carry runoff containing soil particles into the water systems, to eventually be trapped behind the dam wall. Here, they settle into the hypolimnion – the poorly oxygenated region at the bottom of the reservoir. The sediments gathered here are anoxic, with sulfate reducing bacteria that combine the inorganic mercury with methane (from decomposing submerged vegetation), forming methylmercury, a form more easily absorbed by fish and other aquatic life. The rate of methylation of mercury is dependant on the degree of bacterial activity, and this in turn is dependent on the amount of carbon available (these microorganisms using sulfate and carbon in the methylation process) (SWQB, 2001).

It has been demonstrated in other countries that fish tissue mercury concentrations may rise significantly in the impoundments that form behind new dams, and then gradually decline to an equilibrium level as the carbon provided by the vegetation becomes depleted (SWQB, 2001). It may be possible to use this need for carbon in the management of mercury levels – the clearance of vegetation in Chalillo before inundation, for example, should remove much of the carbon potentially available to the bacteria (though there will still be an initial peak of methylmercury following flooding, with the organic content of the soil and roots). With seasonally changing water levels, the problem of methylmercury production will continue as low reservoir waters allow the growth of vegetation in the exposed substrate, this becoming a fresh source of carbon (and potentially methane) once the area is flooded again and the vegetation matter decomposes. Control of water levels, and the control of growth of vegetation in exposed areas when water levels are low, may therefore be one way of controlling the production of methylmercury.
The second point of control of methylmercury may be in the water that is released from the dam (US.EPA, 1997). The mercury conversion takes place in the hypolimnnetic waters towards the bottom of the reservoir – an area that is generally sufficiently anoxic to prevent much life other than anaerobic bacteria from existing there. It is thought that the concentration of methyl mercury would be higher than in the epilimnetic layer, and by drawing water from here, increased levels are released into the water system, where it would then be incorporated into the food chain down river. By drawing water from higher in the water column, it is possible that down-river contamination may be avoided to some extent.

Fish can generally excrete inorganic mercury, but methylmercury is retained in the fish following ingestion. Due to the concentration of mercury in the food chain, predatory fish at or near the top of aquatic food chains and larger, older fish tend to have the highest concentration of mercury and, therefore, pose the greatest risk to human consumption.

A second concern is the release of contaminants into the water from rotting vegetation following inundation. With the current concerns of mercury build-up through this process, there was a requirement at Chalillo for the clear felling and burning of vegetation within the inundation area before water catchment could began (the effects of mercury build-up itself will be dealt with later under Dam Operation Phase Impacts). This results in the removal of a carbon source otherwise available for the anaerobic bacteria responsible for the conversion of inorganic mercury into methylmercury, an organic chemical toxic to biodiversity, that builds up through the food chain, concentrating in the fish (particularly predatory species).

Whilst burning the vegetation gives an immediate increase in greenhouse gas emissions, over the long term there are greater benefits than non-clearance and burning. Removal of the carbon source (vegetation)
significantly reduces anaerobic decomposition within the reservoir, and the resultant production of methane – and thereby limits the scope for methylation of mercury deposits. Thus overall carbon dioxide and carbon monoxide output from the system is likely to be similar for clearance and non-clearance approaches over the long term, the very active greenhouse gas, methane, should not be produced in any quantity from burning.

It should be recognized that the net effects of pre-inundation removal of vegetation as an alternative are not yet well understood (World Commission on Dams, 2000).

**Mitigation Measures:** A recent report by the Ministry of Health in Belize investigated the mercury level in fish at a number of sites on the Macal, Mopan and Sibun rivers, in relation to the location of the Chalillo dam (Flores et. al., 2005). Whilst the number of fish sampled was low (seventeen), results did show increased levels of mercury in the Petenia splendida, the primary predatory fish in the lower reaches of the Macal, and in the Belize River (an average of 0.53µg/g – recommended maximum levels for human consumption are 1.0µg/g (UNEP 2002). However, without further studies, it is impossible to link this to a single source of mercury. It is also difficult to compare mercury levels between different ages and different species of fish.

**BECOL has been requested (by the ECP for Chalillo) to implement a Mercury Risk Management Programme. It is recommended that a similar programme be implemented for the Vaca dam.**
7.6 Archaeological Impacts

7.6.1 SITE PREPARATION AND CONSTRUCTION PHASE

It is understood that any recommendations regarding mitigation for archaeological or cultural resources be subject to the final approval and authority of the Institute of Archaeology, National Institute of Culture and History, Belmopan.

Damage or Loss of Archaeological Features

Impacts: The rapid archaeological survey of the Vaca to Mollejon area of the Macal River revealed no features of major archaeological significance. Therefore from an archaeological perspective BECOL could proceed with construction of the dam at any of the two proposed locations. However, during the site preparation and construction phase archaeological artifacts could be damaged or destroyed in the proposed area of inundation, access roads, dam abutment and the transmission line right-of-way, as a result of the use of heavy machinery, vegetation clearance and earth moving activities.

Mitigation Measures: In order to minimize the potential negative impacts on cultural resources and archaeological features within the footprint of the development, it is recommended that detailed archaeological surveys of the area of inundation and other areas within the footprint of the development particularly along the Cohune ridges and the travertine dams, be conducted by a professional archaeologist, under the supervision of, and in association with the Department of Archaeology. All investigations within the area of inundation must be completed before filling of the reservoir. If any prehistoric mounds are discovered these should be excavated from a lower to higher elevation sequence, with resources in the lower sequence being excavated first. During construction activities any archaeological resources unearthed or identified during earth movement activities should be
immediately reported to the Department of Archaeology and activities in that area suspended until the Department of Archaeology is able to investigate.

7.6.2 OPERATION PHASE

Inundation Impacts: During the operation phase any cultural resources or archaeological features not excavated and salvaged, or not identified, would be permanently inundated.

Mitigation Measures: No practical mitigation measures are suitable for the loss of cultural resources or archaeological features not identified, excavated or salvaged, once permanent inundation has taken place.

7.7 Construction of Dam and Auxiliary Infrastructure

Impacts related to construction of the dam and auxiliary infrastructure include short-term and long-term impacts as well as direct and indirect impacts. These are given below:

Site Clearance

Impacts: Site clearance will be required to facilitate the construction of the dam and associated structures and facilities.

Mitigation Measures: The impacts and mitigation measures for site clearance on the physical, hydrological, biological, archaeological, and socio-economic environments are given in Sections 7.2 to 7.6.

Road Construction

Impacts: Construction of roads would be a long-term irreversible impact. This would include the construction of access roads, quarry roads and operational roads.
**Mitigation Measures:** The impacts and mitigation measures for road construction on the physical, hydrological, biological, archaeological, and socio-economic environments are given in Sections 7.2 to 7.6.

**Materials Transport, Processing, Handling and Storage**

**Impacts:** Materials usage would include aggregate and other earth materials as well as chemicals and other hazardous materials.

**Mitigation Measures:** Worker training in the care, use, handling and storage of hazardous materials is required for appropriate categories of workers. Transportation of aggregate, fines and other earth materials should be in designated vehicles, properly covered and secured, and not exceeding axle limits.

**Hazardous Material Storage**

**Impacts:** Hazardous materials such as chemicals, petroleum products and explosives would be required during the construction phase. Spills and leaks from hazardous materials could result in contamination of soil and the terrestrial and aquatic environments, resulting in loss of vegetation or wildlife. Explosives could pose the risk of unscheduled detonation if exposed to fires or high temperatures.

**Mitigation Measures:** All hazardous material should be appropriately separated and stored in designated signed areas, with appropriate demarcation and entry restrictions. Where appropriate, petrochemicals and other hazardous liquids should be stored in contained areas, surrounded by berms or concrete containment, so as to restrict the movement of hazardous substance into the terrestrial or aquatic environments in the event of spills or leaks. A Spill Contingency Plan should be prepared for all hazardous materials and should be submitted to the Department of the Environment for approval. Explosives and other flammable materials should be stored in clearly
labeled designated areas, and explosives should be stored in a building made of reinforced concrete and surrounded by a berm.

All fuel tanks should be contained within a berm wall of reinforced concrete and properly sealed to prevent leaks in the event of an accidental spill. The containable spill volume should be at least 120% of the volume of the largest tank. An oil/water separator should be fitted to the outlet valve.

All spills of hazardous materials should be immediately reported to the Department of the Environment and measures taken to contain the spill and remediate the area.

Equipment Storage

**Impacts:** Adequate space would have to be provided for storage of equipment.

**Mitigation Measures:** The mitigation measures as presented in Sections 7.2 – 7.6 for the clearance and rehabilitation of vegetated areas should be implemented.

Equipment Maintenance

**Impacts:** Maintenance of equipment including heavy machinery and vehicles, would be required during the site preparation and construction phase. Equipment maintenance would require the use of lubricants, oils, hydraulic fluids and other petroleum products.

**Mitigation Measures:** Best practices should be employed in the siting of maintenance areas away from the riverbank. The proper collection of these lubricants, oils, hydraulic fluids and other petroleum products should be carried out and these materials stored in properly labeled containers. These containers should be stored in a designated signed area before removal for disposal at a designated and approved site. Any contaminated soils should be remediated.
Waste Disposal

**Impacts:** Solid waste would be generated from the residential construction camp, work sites and office facilities. Solid waste would also include construction rubble and cleared vegetation. Liquid waste, including gray water and sewage effluent would also be generated.

**Mitigation Measures:** A Waste Management and Pollution Control Plan should be prepared which includes all aspects of the proposed works and the physical areas of the proposed project. This plan should be prepared in association with and be approved by the Department of the Environment and the Public Health Bureau, and should include all aspects of solid waste and liquid waste including sewage.

All solid waste generated during the course of site preparation and construction should be properly collected and stored in a designated area to facilitate sorting, if required at that stage, before being disposed of at designated and approved disposal sites. Solid waste should be separated by category, and kitchen and domestic waste should be separated into non-biodegradable and biodegradable materials.

Liquid waste should not be allowed to flow into natural drainage channels or be disposed of in any waterway. All bathrooms should be outfitted with shower stalls connected to a common drainage system which leads to the outside of the building into temporary storage tanks. Laundry facilities should be incorporated into the bathroom areas and lead into the common drainage system. This gray water (showers and laundry) should be disposed of through a properly designed leach field or alternatively be used for irrigation on the residential campsite.

Composting toilet facilities or ‘low flush toilets’ should be provided at the residential campsite as well as current construction areas. These facilities should be fitted with properly designed sealed septic tanks. Chemical toilets may also be used and should be supplied, serviced and maintained by an approved contractor.
All liquid waste, including sewage, should be appropriately treated before disposal at sites approved by the Department of the Environment and the Public Health Bureau. The Department of the Environment and the Public Health Bureau should also approve the sewage treatment options.

Biodegradable waste should be composted at a designated area approved by the Department of the Environment, the Public Health Department and and placed in sturdy containers that can be sealed shut. This will prevent the proliferation of odour and discourage rats, raccoons and other pests and vectors from entering the area. Domestic and kitchen waste should be removed from the site daily, and solid waste receptacles should be removed from the designated storage areas at least three times per week. Vehicles used to transport waste should be covered during transport.

Solid waste should not be subjected to open burning. Vegetative matter may be burned in a designated area and as approved by the Department of the Environment and the Forest Department.

Equipment parts, derelict machinery and metal components should be transported to a designated recovery area where they may be sorted and separated. Material that may be reused should be kept and stored. Any material not to be reused should be disposed of at an approved and designated solid waste disposal site.

**Blasting Impacts:** Short-term impacts would occur in the creation of noise, dust and vibration during blasting activities. No major towns or villages have been identified.
in close proximity to the proposed dam site and these impacts should be contained within the construction zone.

**Mitigation Measures:** Blasting activities should be carried out by a certified and approved contractor and standard mitigation measures should be employed including the use of blasting mats, to prevent airborne rock fragments. No mitigation measures are suitable to minimize the effects of vibration during blasting.

**Scarring of the Landscape**

**Impacts:** Scarring of the landscape may occur during site preparation and construction activities if best practices are not employed.

**Mitigation Measures:** Mitigation measures to minimize scarring of the landscape are presented in Sections 7.2 to 7.6.

**Foundation Preparation**

**Impacts:** The preparation of the foundation for the dam and abutments would include vegetation clearance, blasting, boring and grouting activities.

**Mitigation Measures:** Mitigation measures presented for activities such as vegetation clearing, blasting and riverbed works (Sections 7.2–7.6) should be implemented. All preliminary engineering designs for the dam should be submitted to the Ministry of Works for review and approval.

**Transportation**

**Impacts:** Impacts related to transportation would include potential for spills of hazardous materials during transport, accidents and injury, generation of fugitive dust from uncovered vehicles and vehicles traveling on unpaved roads, overloading of vehicles and exceeding of axle limits.
Mitigation Measures: *A Spill Contingency Plan should be prepared for the response to and clean-up of accidental spills. All vehicles transporting earth materials on open roads should have their cargo covered. Vehicles should adhere to all prescribed legal limits, which would reduce the risk of accident and spillages. Any spills on open roads should be cleaned-up within 24 hours and disabled vehicles should be removed to the designated maintenance area.*

Vegetation Clearance for Inundation Area

Impacts: Large tracts of vegetation would have to be removed to facilitate the establishment of the inundation area.

Mitigation Measures: *Measures to be used during vegetation clearance to minimize potential negative impacts are presented in Sections 7.2 to 7.6.*

Hazard Management

Impacts: Management of hazards should include fires, floods, explosions, river diversion and noise and dust abatement. Fires used to clear and burn vegetation could get out of control and escape to forested areas or storage areas. The use of explosives could also result in fires. Floods could occur as a result of river diversion and the installation of coffer dams, particularly during the wet season. Noise and dust are short-term impacts that are anticipated during the site preparation and construction phase due to the clearing of vegetation, movement of vehicles, earth movement, blasting activities and general construction works.

Mitigation Measures: *A Hazard Management Plan should be prepared to include aspects related to fires, floods, explosions, river diversion, noise and dust. This plan should be submitted to the Department of the Environment and the Public Health Department for approval. Evacuation procedures should also be included in the plan. Explosives should be stored in a separate clearly*
designated building made of reinforced concrete and surrounded by a berm. Clearing of vegetation by burning should be carried out with the supervision of the Forest Department. Clearing of large tracts of vegetation should only be carried out with a fire break with a minimum width of 10 m. Blasting activities should be carried out by a certified and approved contractor and standard mitigation measures should be employed including the use of blasting mats, to prevent airborne rock fragments. No mitigation measures are suitable to minimize the effects of vibration during blasting. Periodic wetting should be carried out on all stripped, bare surfaces and stockpiles of fines.

A properly designed and engineered coffer dam should be installed to facilitate river diversion and prevent flooding.

Security

Impacts: The presence of BECOL professional staff, security personnel, contractors and subcontractors in the area demarcated by the footprint of the proposed project would be a positive impact for improved security measures within the Vaca Forest Reserve. Currently there are unsupervised activities taking place within the forest reserve, and the activities of the proposed project may prove a deterrent to any illegal activities.

Mitigation Measures: Prior to project implementation BECOL in association with the Forest Department should ensure that all contractors, subcontractors and labourers receive appropriate sensitization on the rules and regulations of the Vaca Forest Reserve. Any illegal activities observed within the boundaries of the Vaca Forest Reserve should be reported immediately to the appropriate authorities.
Spill Response

**Impacts:** The use of hazardous materials including petrochemicals would be required during the site construction and preparation phase.

**Mitigation Measures:** A Spill Contingency Plan should be prepared for all hazardous materials, and should be submitted to the Department of the Environment for approval. All fuel tanks should be contained within a berm wall of reinforced concrete and properly sealed to prevent leaks in the event of an accidental spill. The containable spill volume should be at least 120% of the volume of the largest tank. An oil/water separator should be fitted to the outlet valve. All spills of hazardous materials should be immediately reported to the Department of the Environment and measures taken to contain the spill and remediate the area.

Public Health and Safety

**Impacts:** Public health and safety would be important for all professional staff of BECOL, skilled and unskilled labourers, contractors and subcontractors, and would be relevant to the residential workers campsite, all work areas, all storage areas and transportation routes. Potential negative impacts on public health could include medium term impacts during the site preparation and construction phase. These are related to the generation of solid waste, generation of liquid waste, accident and/or injury, exposure to hazardous materials and activities, exposure to dangerous wildlife, increase in occurrence of pests and vectors, and increased levels of fugitive dust and noise.

**Mitigation Measures:** Mitigation Measures to ensure public health and safety should include best practices in terms of collection, storage, removal and disposal of solid and liquid waste should be employed at all work sites, storage sites and the residential camp. Solid and liquid waste should be separated as
appropriate and contained in a designated area or areas, in properly covered and sealed receptacles, and should be removed and disposed of by an approved contractor on a regular and timely basis.

Workers on site should be equipped with appropriate safety gear including hard hats, eye shields, dust masks, ear muffs, construction boots and safety vests.

All hazardous materials including chemicals, petroleum products, flammable material and explosives should be separated and stored in clearly signed and designated areas. Signage should include the type and / or nature of the material, relevant dates of delivery and expiration and handling rules. Worker training for the use and handling of hazardous materials should be conducted as required.

Pests and Vectors

Impacts: The potential exists for breeding of mosquitoes within the reservoir resulting in increased incidence of Malaria and Dengue. Potential problems exist with the Virginia opossums, raccoons, rats and vultures during the construction phase if garbage disposal is not adequately addressed. Cayo District has periodically had small outbreaks of rabies, which is carried by raccoons.

It should be noted that indications from the previous dam at Mollejon are that the likelihood of increase in pests and vectors is minimal. While the water is held in the reservoir it does circulate and receives daily inflows which would discourage the breeding of mosquitoes.

Mitigation Measures: Mitigation for minimizing the incidence of pests and vectors is through the implementation of proper solid waste storage and disposal.
mechanisms at the residential camp site and construction areas so as not to encourage raccoons, rats, cockroaches and other pests and vectors.

Risks to Personnel from Wildlife

Impacts: The direct risk of bites from poisonous snakes such as Bothrops asper and Atropoides nummifer is a concern, with far lower risk of incidents with Micrurus. Bothrops asper is known to occur at higher densities in rural areas - feeding on human commensals such as rats. The plant Black Poisonwood (Metopium brownei) could be the source of discomfort during land clearance. However it is likely that vegetation clearance work would be undertaken by a local workforce who would be aware of poisonwood, how to recognize it, cut it, and treat the rashes it can cause.

Mitigation Measures: The duration of construction should not be long enough to allow such an increase in numbers of pests and vectors to take place, and proper garbage disposal should go a long way to reduce the issues with rodents. Adequate briefings on operational protocols (regarding snakes and Black Poisonwood) are the best way of minimizing the risk to personnel.

Wildlife Protection

Impacts: The establishment of a residential construction camp site and the creation of construction roads and transmission line alignment would result in increased access to previously inaccessible forested areas. The occurrence of a large workforce in the area coupled with increased access could result in increased hunting pressure on game birds and small mammals.

The following specific impacts may affect birds:

- **Disturbance of nest sites**

  Two species of concern are highlighted as nesting on banks or cliffs – the orange-breasted falcon and the keel-billed motmot. If nest sites are identified for these species, disturbance should be minimized.
• **Positive Impacts – protection**
  The presence of the Mollejon dam area, with its restricted access / no-hunting regulations, is providing some protection for the listed species of concern, and other birds that are associated with the same ecosystems and impacted by the same threats. The extension of this active protection to include the Vaca area will increase the protection of these species.

**Mitigation Measures:** *All workers should be briefed on the rules and regulations for the Vaca Forest Reserve, including hunting regulations and should be advised of a No-hunting Policy for the residential construction camp.*

**Transmission Line - Alignment and Right-of Way:**

**Impacts:** The establishment of the transmission line would require clearing a right-of-way of 20m for the entire alignment. This would require clearance of vegetation, limited earth movement and boring.

**Mitigation Measures:** *The alignment of the transmission line should be determined and approved by the Department of the Environment and the Forest Department. Before clearing, the entire alignment should be staked out with highly visible markers. As far as possible slopes greater than 30 degrees should be avoided unless the lines can be attached to poles which are sited on the summit of a hill. Topsoil removed during construction of the transmission line should be stockpiled for use during site rehabilitation activities. The alignment for the transmission line should be hand-cleared as far as is possible. The burning of any cleared vegetation should not be conducted without the approval of the Forest Department, and with fire fighting equipment in close proximity. All activities should be contained within the right-of-way.*
Residential Worker Camp Site

**Impacts:** The residential worker camp site should provide an environment that is safe, clean, comfortable, functional, aesthetically appealing and with minimal negative impacts on the immediate environment.

**Mitigation Measures:** *A plan for the residential camp should be prepared by BECOL and submitted to the Department of the Environment and the Forest Department for approval. During construction of the camp site all the mitigation measures presented for clearance of vegetation, earthworks (including trenching), solid and liquid waste management, drainage control and site rehabilitation, should be employed. Building design should be aesthetically appealing and designed for good ventilation, effective lighting and provide easy access to facilities such as bathrooms, kitchens and recreational areas. Buildings should be designed to withstand storm force winds and rains that could be generated by a Category Three Hurricane. After closure, the camp site should undergo a comprehensive cleanup and site rehabilitation. The camp site should be equipped with an adequate number of fire extinguishers. Adequate supply of potable water and electricity should be available on a continuous and uninterrupted basis.*

### 7.8 Extraction of Materials

**Impacts:** Material downstream at Site B as well as upstream at Site B may be suitable for aggregate. If the rock-fill option is chosen at Site B aggregate could be generated from excavated material for the spillway. The amount of material required is anticipated as 700,000 m³.

**Mitigation Measures:** In order to minimize the negative impacts associated with quarrying activities material upstream of Site B, and within the footprint of...
the area of inundation, could possibly be used. BECOL should investigate this option. Excavation of material from within the reservoir area would significantly minimize the extent of environmental impact and scarring of the landscape.

**Mitigation Measures:** BECOL should investigate the availability of using material from any existing burrow pits and quarry areas. Where availability and transportation requirements make the use of materials from these existing areas feasible, BECOL should use these. If additional material is required from new areas, these new areas may only be utilized on approval of the Department of the Environment, the Forest Department and the Geology and Petroleum Department. The boundaries of all extraction sites should be clearly marked by pegs or tape before work begins, and should remain visible while the site is in use. All mitigation measures presented for the clearing of vegetation, creation of access roads, removal of topsoil, transportation of earth materials, worker health and safety, dust and noise abatement, stockpiling of earth material, washing of aggregate, equipment maintenance and storage and site rehabilitation, should be instituted here. No riverbed extraction should be conducted other than for the site of the dam, powerhouse and tailrace.

### 7.9 Dam Failure

#### 7.9.1 OPERATION PHASE

**Impacts:** Dam failure is a relatively rare occurrence but has been known to occur as a result of extreme seismic activity and other catastrophic events. On occasion dam failure may also be caused by inadequate maintenance over several years. In all cases adequate design taking into consideration all the probable catastrophic events, appropriate inspection and maintenance, and early warning of potentially damaging events can considerably reduce the likelihood of dam failure. Factors that can undermine the integrity of the
Total dam failure would result in the sudden and immediate release of the entire reservoir of water along with the broken dam structure and any rocks and debris held within the reservoir. The main impact of dam failure is downstream flooding.

**Mitigation Measures:** Dams will naturally deteriorate over time, but the rate and extent of deterioration is unique to each dam. However, routine preventative maintenance is essential to ensure that deterioration is immediately observed and where possible repaired. BECOL should prepare a Dam Inspection and Maintenance Plan for review by the Department of the Environment. Performance monitoring instrumentation should be installed in the dam and should include vibrating piezometers for measuring water pressure and survey instruments for measuring movements. A draining and inspection gallery should be constructed in the body of the dam if a Reinforced Concrete Dam is built, and should include seepage measuring weirs. The spillway of the dam should be designed to accommodate the Probable Maximum Flood (PMF) and provide controlled routing for a flood with a 100-year return period. BECOL should prepare an Emergency Preparedness Plan (EPP) in conjunction with the National Emergency Management Organization (NEMO) and its affiliates DEMO and CEMO. This plan should be completed before the completion of the Vaca dam. BECOL should provide signals (digital or analogue) to the National Meteorological Service for at least three threshold reservoir levels (Alert, Warning and Emergency Phases). These signals should be relayed by National Oceanographic and Atmospheric Administration (NOAA) satellite
for immediate transmission and dissemination. The establishment of a Flash Flood Early Warning System (FFEWS) is necessary, and dam operations should include a link to the FFEWS established at Chalillo (Chalillo ECP, April 5, 2002). This FFEWS must be developed in conjunction with relevant government agencies and all the stakeholders downstream of the proposed Vaca Dam, so that in the event of dam failure or PMF, downstream communities such as Negroman, Cristo Rey and San Ignacio can take rapid and effective, evasive action. The FFEWS should follow the procedure already developed by BECOL, in association with the National Meteorological Service, whereby BECOL informs them of any pending flood hazard, and they in turn notify the public and set in train the necessary emergency procedures. This requires a reliable and continuous communication system between BECOL, the National Meteorological Service and the downstream communities.

7.10 Decommissioning

Dam decommissioning can be defined as any cessation of operation of the dam and its facilities. This may be merely stopping the generation of electricity, removal of any components of the operation or demolition and total removal of the dam with restoration of the river bed to its original state.

After a dam has been decommissioned, ecosystem restoration may be undertaken. The impacts on ecosystem restoration from the process of decommissioning are usually complex and always site specific. However, there are some issues that are usually relevant to decommissioning, and these include the following:

- Release of potentially contaminated accumulated sediment behind the dam
- Disposal of the potentially contaminated sediment
- Removal of existing lake or reservoir habitat and reforming a riverine habitat
- Regenerate of riparian vegetation and habitats and possible loss of stable lakeside vegetation
- Alteration of land use patterns upstream or downstream
Decommissioning of a dam may be required for safety reasons if the dam has outlived its projected existence, if lower profit margins in the generation of power are being realized, or because of concerns for environmental impacts or social impacts.

Decommissioning may be capital intensive and involve demolition works, riverbed restoration, habitat restoration and the transport and disposal of rubble, waste and contaminated sediments. The actual cost of decommissioning is difficult to predict as many variables are involved. In some countries decommissioning funds are put aside during the commissioning of the dam, or during the period of operation (World Commission on Dams, 2000).

Although the effects of decommissioning of dams are not well studied, the World Commission on Dams (2000) states that decommissioning should be subjected to environmental, social, technical and economic assessment in the same way as is done for the establishment of a new dam. A feasible study could also be done which would seek to advise on the best option for decommissioning.

If required by the relevant Government of Belize agencies, decommissioning and abandonment plans will be developed by BECOL, in the future, and after consultation with the relevant agencies and regulatory authorities. Physical, biological and socio-economic issues associated with decommissioning and abandonment will be taken into consideration in the development of these plans. The decommissioning plan should indicate plans for various levels of decommissioning, including partial decommissioning (from cessation of operations and removal of any components), to total decommissioning (including removal of the major structures and restoration of the riverbed to its former state). In some cases testing or monitoring will be undertaken to ensure that the sites are free of contamination. If contamination is discovered, the sites should be restored by BECOL, to approved standards. As recommended by the World Commission on Dams (2000), and if required by the Department of the Environment, the decommissioning plan should be subjected to
its own environmental assessment with the Terms of Reference being approved by the DoE, as was done for the dam construction.

### 7.11 Socio-Economic Factors

Impacts for the proposed dam project have been categorized based on project development phases or impact spectrum, namely, planning, construction, operation and decommissioning. Several stakeholders were consulted during the process and included communities within the area, users of the Macal River and BECOL itself being identified as a stakeholder.

#### 7.11.1 PLANNING

Overall, since this proposed project is the final stage within the Macal Hydroelectric Development Project as per the Canadian International Power Services Inc., Power Study of 1990, some stakeholders and various public entities consulted have preconceived perceptions based on their involvement and experiences with the public consultation processes, or lack thereof, employed in the development of the previous two dams. This reality is influencing the views of stakeholders in the planning phase of the proposed Vaca project. With regard to the Phase 1-Mollejon Project, the consensual view is that the development of the project was largely shrouded in secrecy with a resultant lack of information dissemination that led to speculation about undue political control and the lack of transparency. The prevailing perception belief held by some stakeholders is that the Phase 1 Mollejon Project was not a good investment based on its relatively low electricity generation output compared to its development costs. This has been somewhat countered by the argument that each dam phase has to be evaluated as part of the whole scheme rather than simply as a “stand-alone” project.

The intense lobbying efforts of the environmental conservation activists against the Phase 2 Chalillo Dam led to the scrutiny of various aspects of the project’s development including safety issues surrounding the possibility of dam failure due to conflicting technical interpretations of the geologic foundations of the dam site, its economic viability from a
cost-benefit analytical perspective\textsuperscript{15}, the possible loss of certain threatened species\textsuperscript{16} and the ongoing debate of how present dam construction is following the Environmental Compliance Plan incorporated within the project’s approval process. The feelings of “bad faith” from some stakeholders’ perspective stem from allegations of the withholding of critical data and information from stakeholders opposed to the dam and the misleading technical interpretations of critical data related to geology and biodiversity in the dam area. A positive outcome of the development debate about the Chalillo project is that there has been widespread cross-fertilization of ideas and comprehensive discussions of the pros and cons of the development of dams on a whole and in particular dams with reservoir capacity that would have inevitable environmental impacts at a wider scale than regular “run of river” dam projects. This bodes well for the proposed Phase 3 Vaca Hydroelectric Project as many of the fundamental issues have been dealt with in the previous phases.

There are also several process-related and macro environment issues that are evident in the planning phase. These include:

\textit{General Process Issues:}

\begin{itemize}
  \item Skepticism about the integrity and veracity of the EIA exercise since BECOL is the client and it is believed they may have undue influence over what is included in the final EIA report
  \item Concern about the effectiveness and efficiency of information flow to local citizens regarding key environmental data and information that are ultimately related to public health and safety\textsuperscript{17}. This information is deemed to be public knowledge and should therefore be easily accessible
  \item Concern about whether the dam will be built even if the majority of public opinion is against it and a belief that the “no-action” alternative is not as prominent an option as it could be in the EIA process
\end{itemize}

\textsuperscript{15} Discussions centred around whether or not the dam would eventually lower electricity costs
\textsuperscript{16} It was asserted by environmental activists that significant populations of scarlet macaws would have been impacted
\textsuperscript{17} E.g. water quality data, flood hazard prediction data etc.
There is an overall belief that the approval of this dam will be easier since it is the last of the three-phased process and is essentially a “done deal”

There is a public perception that BECOL may not be a long-term stakeholder in the electricity generation business in Belize and so there is suspicion about loyalty to the community and a reluctance on behalf of certain stakeholders to engage in consultation

There is a general lack of awareness and understanding of the Environmental Impact Assessment (EIA) process\(^\text{18}\);

Overall perceptions of political control and official corruption associated with the Macal River Hydroelectric Projects.

**Macro Issues:**

- There is an overwhelming concern that electricity rates will continue to rise despite the building of the proposed Vaca Hydroelectric Project and the overall Macal River Hydroelectric Scheme
- Inadequate awareness of national energy situation and interest in learning more about overall energy demand and related issues\(^\text{19}\) in country
- Identification of illegal land leases\(^\text{20}\), access roads, human settlements, illicit xate palm harvesting within the Vaca Forest Reserve adjacent to the proposed Vaca Hydroelectric Project and their potentially substantial and cumulative negative ecological impacts on surrounding ecosystems
- Concern about climate change and the changing hydrological patterns that have resulted in drier conditions, and consequently concerns about enough water flow to sustain hydroelectricity on the Macal River, as the anecdotal evidence\(^\text{21}\) suggests less rainfall occurring in the region

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\(^{18}\) Stakeholders are particularly uncertain as to what considered impacts within an EIA would cause a development project to be delayed or rejected. The roles of the National Environmental Appraisal Committee (NEAC) and the Public Utilities Commission (PUC) are sometimes unclear to stakeholders.

\(^{19}\) Key issues that generated interest were energy efficiency and use of wind power as commercial energy source.

\(^{20}\) Since leases are being granted although the area is under protected area status, it could be considered unofficial dereservation.

\(^{21}\) Several stakeholders that have lived in the district for many years believe that there is less rainfall now than there was decades ago. Although this indigenous knowledge is valuable, rainfall monitoring data show that
• A lack of understanding of why three dams are needed for the Macal River Hydroelectric Scheme opposed to one or two dams

• Inadequate understanding of the national potential of hydroelectricity and why the Macal River was chosen for hydroelectric development

• Perception that the Cayo District is bearing the disproportionate burden of developing national electricity generation, basically the country is benefiting from the usage of a local district resource

• Concern regarding waste management particularly from urban landfills and local businesses and resultant implications for effluence drainage into the Macal River

• Concern about the perception of “foreigners” giving misinformation to locals regarding dam development and other development projects

• The perception of complete loss of control of the Macal River to BECOL

7.11.2 SITE PREPARATION AND CONSTRUCTION

In terms of geographic impact of the proposed project, it is most likely that the initial positive social impacts which are employment related will be derived by communities closest to the physical dam site, namely the towns of Benque Viejo del Carmen and San Ignacio/Santa Elena and the village of San Jose Succotz. Table 7.11.2 indicates the possible construction employment potential for the two major municipalities in the Cayo District. There is also a temporal characteristic to the impacts as well as these impacts will be realized overwhelmingly in the planning and construction phase. Social impacts during the construction phase would most likely be due to the sharp increase and influx of outside workers that will be generally concentrated in a small geographic area. Social interaction between workers and nearby communities will most likely also have both positive and negative elements and will require some absorption strategies and mitigation measures to ensure that opportunities are capitalized on and threats planned for so that impacts can be lessened.

while there have been cyclical drought conditions over the last few years, normal rainfall measurements are beginning to be recorded indicating a return to normalcy.

22 This is a variation of the often encountered NIMBY (Not In My Back Yard) syndrome.
Table 7.11.2: Construction Employment Potential for Major Cayo Municipalities

<table>
<thead>
<tr>
<th>Town</th>
<th>Occupation Type</th>
<th>Total Male Labourers</th>
<th>% Of Total Male Labour Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benque Viejo del Carmen</td>
<td>Bricklayers*</td>
<td>114</td>
<td>18.2%</td>
</tr>
<tr>
<td></td>
<td>Building/Construction</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>San Ignacio</td>
<td>Bricklayers*</td>
<td>325</td>
<td>16.5%</td>
</tr>
<tr>
<td></td>
<td>Building/Construction</td>
<td>92</td>
<td></td>
</tr>
</tbody>
</table>

Source: Derived and adapted from Census 2000 raw data-Central Statistical Office. *Bricklayers selected as an indicator skill, which is a recognized socio-economic indicator. This is not an indication of the skills required for the construction of any dam constructed at Vaca.

Other Specific Impacts

- concerns about worker safety and employment-related matters such as labour law abidance
- the extent of the ecological impact of the construction site particularly regarding deforestation as well as the sheer number of temporary workers (app. 300-400) that would be using the area
- possible increase in crime and security-related incidents in area based on increased access and presence of individuals because of dam construction

7.11.3 OPERATION/MAINTENANCE AND SPECIFIC IMPACT ISSUES

Specific issues and concerns identified regarding the operation of the proposed Phase 3 Vaca Hydroelectric Project include *inter alia*:

- The impact on the water level of the river and possible flooding resulting from dam failure

23 It has been initially ascertained that the Macal River has a highly fluctuating flow pattern as while water levels can go quite low during the dry season, there is anecdotal evidence of flooding reaching up to 100-150 feet above the river bank within the past 10-15 years.
24 Other mitigation mechanisms such as liability insurance to cover community losses based on dam failure was also mentioned.
• Water quality\textsuperscript{25} both in terms of the river being a potable source of water and a safe recreational waterway

• Potential of disease burden based on water borne chemicals particularly mercury poisoning and bioaccumulation in fish\textsuperscript{26}

• Concern and perceptions that dam development and controlled water flows will lead to rising water temperatures in the river which could impact aquatic life

• Competing uses of the river from agri-businesses\textsuperscript{27} and loss of traditional uses\textsuperscript{28}

• Loss of tourism-based revenues\textsuperscript{29} from recreational activities due to changes in river environment particularly water flow\textsuperscript{30} or possibly water quality

• Concern about what potential exists for increased electricity generation to remedy periodically low and inconsistent voltage flow

• Concern about ecological impact of the dam on key ecosystem health indicator species such as snails and insects

• Interest in ascertaining whether or not the reservoir areas of the macal river hydroelectric Scheme would be utilized for recreational purposes

The last stage of the social impact assessment process was further and more in-depth public consultations with communities within the dam’s “sphere of influence” and bilateral discussions with specific groups (e.g. NGOs, community-based organizations, private sector networks).

\textsuperscript{25} Concerns are related to the impacts of the water being stagnated while in the reservoirs.
\textsuperscript{26} There have been reports of fish extracted from the Macal River that have high levels of mercury bioaccumulation. However, more investigative research is needed to ascertain the source and cause of the levels of toxicity in the river’s fish population
\textsuperscript{27} Stakeholders noted an increase in pig farms in the immediate vicinity of the Macal River and the apparent lack of environmental management of animal fecal matter entering the river. It should be noted that the Department of the Environment has reported that recent water quality testing in the river is showing high levels of fecal coliform counts. It is not definitive however that any one source is causing this to happen.
\textsuperscript{28} Key river uses include potable water source, irrigation for agriculture, laundry washing, fishing, swimming, bathing, vehicle washing and tourism-related recreational activities such as kayaking, canoeing, tubing and whitewater rafting.
\textsuperscript{29} Since tourism in the Cayo District has a high level of socioeconomic importance both at the local and national level, possible tourism revenue losses would have to be calculated through econometric and scenario-based models to ascertain reasonable estimates of product impact and revenue loss. This is deemed to be outside of the scope of the EIA process but could be a follow-up activity to the EIA exercise.
\textsuperscript{30} The most noted impacts would be on ecoresort properties the furthest upstream and one international tour operator that specializes in whitewater rafting on a seasonal basis
7.11.4 MOST FREQUENTLY MENTIONED ISSUES AND CONCERNS

The most frequently raised social impact issues and concerns related primarily to the following:

1. Overall national energy needs (San Ignacio, Cristo Rey, San Jose Succotz, Cayo Tour Guides Association, Belize Tourism Industry Association, Belize Ecotourism Association);
2. Electricity rates (San Ignacio, Cristo Rey, San Jose Succotz, Cayo Tour Guides Association, San Ignacio Town Board);
3. River hydrology (water flow, quality and temperature) (San Ignacio, Cristo Rey, Cayo Tour Guides Association, San Ignacio Town Board, Belize Tourism Industry Association);
4. Possible catastrophic dam failure (San Ignacio, Cristo Rey, Cayo Tour Guides Association, Belize Tourism Industry Association) and
5. Differing levels of dissatisfaction with the overall Macal River Hydroelectric Scheme development and the public involvement process throughout its development (San Ignacio, Cristo Rey, Cayo Tour Guides Association, Belize Tourism Industry Association and Belize Ecotourism Association).

7.11.5 CONSTRUCTION PHASE

Employment

Impacts: The generation of employment for skilled and unskilled labourers, suppliers, cooks and various levels of staff requirements would be a major positive impact during site preparation and construction activities. Employment will vary between normal and peak activities with an average of about 300-350 persons required. Workers would be hired from local areas as well as from overseas. The skill set requirements will vary from management level staff to cook and should include engineers, technicians, drivers, concrete specialists, steel benders, welders, electricians, etc.

Mitigation Measures: No mitigation is required for this positive impact.
Public Health

Impacts: Potential negative impacts on public health include medium term impacts during the site preparation and construction phase. These include generation of solid waste, generation of liquid waste, accident and/or injury, exposure to hazardous materials and activities, exposure to dangerous wildlife, increase in occurrence of pests and vectors, and increased levels of fugitive dust and noise levels.

Mitigation Measures: Best practices in terms of collection, storage, removal and disposal of solid and liquid waste should be employed at all work sites, storage sites and the residential camp. Solid and liquid waste should be separated as appropriate and contained in a designated area or areas, in properly covered and sealed receptacles, and should be removed and disposed of by an approved contractor on a regular and timely basis.

Workers on site should be equipped with appropriate safety gear including hard hats, eye shields, dust masks, ear muffs, construction boots and safety vests.

All hazardous materials including chemicals, petroleum products, flammable material and explosives should be separated and stored in clearly signed and designated areas. Signage should include the type and/or nature of the material, relevant dates of delivery and expiration and handling rules. Worker training for the use and handling of hazardous materials should be conducted as required.

Pests and Vectors

Impacts: The potential exists for breeding of mosquitoes within the reservoir resulting in increased incidence of Malaria and Dengue. Potential problems exist with the Virginia opossums, raccoons, rats and vultures during the
construction phase if garbage disposal is not adequately addressed. Cayo District has periodically had small outbreaks of rabies, which is carried by raccoons.

It should be noted that indications from the previous dam at Mollejon are that the likelihood of increase in pests and vectors is minimal. While the water is held in reservoir it does circulate with release from the base discouraging the increase of vectors.

Mitigation Measures: Mitigation for minimizing the incidence of pests and vectors is through the implementation of proper solid waste storage and disposal mechanisms at the residential worker site and construction areas is essential so as not to encourage raccoons, rats, cockroaches and other pests and vectors.

Risks to Personnel from Wildlife

Impacts: The direct risk of bites from poisonous snakes such as Bothrops asper and Atropoides nummifer is a concern, with far lower risk of incidents with Micrurus. Bothrops asper is known to occur at higher densities in rural areas - feeding on human commensals such as rats. The plant Black Poisonwood (Metopium brownei) could be the source of discomfort during land clearance. However, it is likely that vegetation clearance work would be undertaken by a local workforce who would be aware of poisonwood, how to recognize it, cut it, and treat the rashes it can cause.

Mitigation Measures: The duration of construction should not be long enough to allow such an increase in population density to take place, and proper garbage disposal should go a long way to reduce the issues with rodents anyway. Adequate briefings on operational protocols (regarding snakes and Black Poisonwood) are the best way of minimizing the risk to personnel.
7.11.6 OPERATION PHASE

Employment: Generation of employment during the operation phase will be minimal and likely to include existing professional staff of BECOL.

Flood Control: During the operation phase flow modulation of the Macal River will occur with year round use of the river for domestic activities (bathing and washing) and recreational activities (river tubing, kayaking and canoeing). There should be a reduction in the number of annual floods as well as a reduction in intensity of the flood events. There should be increased and more sustained flow during the normal dry periods.

Mitigation Measures: BECOL should prepare an Emergency Preparedness Plan (EPP) in conjunction with the National Emergency Management Organization (NEMO) and its affiliates DEMO and CEMO. This plan should be completed before the completion of the Vaca dam. BECOL should provide signals (digital or analogue) to the National Meteorological Service for at least three threshold reservoir levels (Alert, Warning and Emergency Phases). These signals should be relayed by National Oceanographic and Atmospheric Administration (NOAA) satellite for immediate transmission and dissemination. A Flash Flood Early Warning System (FFEWS) should be incorporated in dam operations, and linked to the FFEWS at Chalillo (Chalillo ECP, April 5, 202), to be managed by BECOL professional staff in association with the National Meteorological Service. This EWS would require BECOL staff to monitor the indicators of increased flow (rainfall, river flow, water colour) at the dam and advise the National Meteorological Service, accordingly. Flood control should be a positive cumulative impact with the three dams in place as all three should be linked in a Flash Flood Early Warning System.

7.12 Potential Cumulative Impacts
The proposed Vaca Hydroelectric Project does not stand in isolation as a project on the Macal River but is one of three, two of which have previously been approved by the Department of the Environment and are either in operation (Mollejon) or under construction and soon to be commissioned (Chalillo). While the environmental impacts of the Vaca scheme considered in this EIA have largely been concerned with the scheme itself, its total impact must also be considered cumulatively with those of the other two schemes. These cumulative impacts relate both to construction and operation.

7.12.1 CUMULATIVE CONSTRUCTION IMPACTS
Until about twelve years ago, the Macal River Basin was relatively undisturbed as far as major structural developments were concerned. Since then, with the construction of the Mollejon and Chalillo Hydroelectric Projects significant changes have occurred:

1) Roads have been constructed for access to each of the schemes and human intrusion and activity in the Mountain Pine Ridge and Vaca Reserves has increased considerably
2) Temporary work camps have been established to accommodate more than 300 workers at a time. These camps have been outfitted with amenities for a range of human activities including sleeping, eating, recreation, the disposal of liquid and solid wastes, and basic maintenance
3) Vehicular transportation has increased with attendant impacts of dust generation, spillages and accidents
4) Human interactions with neighbouring communities have increased
5) Illicit activities like hunting have increased
6) Quarries have been opened up resulting in destruction of vegetation and scarring of the landscape
7) Hazardous materials including explosives have been imported into the area with the need for increased security and vigilance
8) Noise and dust levels have increased

All the above impacts are likely to occur with construction of the Vaca scheme and most are inevitable although of only short to medium-term duration. Nevertheless, they will add
significantly to the increase in human activity in the area. Fortunately, the three hydroelectric schemes are located in three discrete sections of the Macal River Basin and are sufficiently separated so that the cumulative impacts would not be as great as if they were in close proximity to each other. Furthermore, their separation in time would also reduce their cumulative impacts. For example, the Mollejon construction impacts have all but disappeared and rehabilitation of the terrain is virtually complete. The same is expected to occur at Chalillo after about five years and, in turn, also at Vaca. The assessment therefore is that given these conditions, the cumulative construction impacts would be minimal and mostly reversible.

7.12.2 CUMULATIVE OPERATION IMPACTS

7.12.2.1 Hydrology

The proposal to construct three hydroelectric schemes on the Macal River had to be originally assessed not only for the potential for power generation but also for the control of flows in the Macal River. Hence, the hydrology of the entire river system was investigated and the rationale for three dams in series on the river established. More recently, the addition of the Vaca dam as the most downstream of the three dams has been assessed, particularly in regard to its potential impact on downstream flows under fair weather conditions and at probable maximum floods (PMF). According to Gilbert-Green and Associates (2005 c, Table 2), the PMF at Vaca (downstream) is projected as 14,668 cms, which would be at least five times higher than the 1:100 year flood, with Chalillo in place (2318 cms) as shown in Table 7.12.2.1, below).
Table 7.12.2.1: Comparison of flows with and without Chalillo Dam

<table>
<thead>
<tr>
<th>Return Period (Years)</th>
<th>No Chalillo Dam (cms) (Harza, 1995)</th>
<th>With Chalillo Dam (cms) (AMEC, 2001)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chalillo</td>
<td>Cristo Rey</td>
</tr>
<tr>
<td>2</td>
<td>530</td>
<td>754</td>
</tr>
<tr>
<td>5</td>
<td>1130</td>
<td>1609</td>
</tr>
<tr>
<td>10</td>
<td>1710</td>
<td>2430</td>
</tr>
<tr>
<td>20</td>
<td>2410</td>
<td>3438</td>
</tr>
<tr>
<td>50</td>
<td>3590</td>
<td>5112</td>
</tr>
<tr>
<td>100</td>
<td>4690</td>
<td>6678</td>
</tr>
</tbody>
</table>

Hence, the effect of the Chalillo dam (and the Mollejon and Vaca dams downstream) would be to reduce (but not eliminate) flood flows considerably.

The impact of dam failure at Vaca under PMF and fair weather conditions has been discussed in Sections 5.5 and 7.5). A similar assessment was previously made for dam failure at Chalillo. All the evaluations show that dam failure at any of these plants under PMF would not materially increase the flood plain beyond the natural PMF contours.

The conclusion then is that with three hydroelectric dams in place, flows in the Macal River would be modulated year round (fewer instances of flooding in wet months and fewer instances of drying in dry months) and that the potential for catastrophic flooding with dam failure would be not greater than with PMF and no dam failure.

7.12.2.2 Water Quality

Water quality in the upper Macal River basin has been shown to be good and suitable as a source of potable water, given basic treatment of settling, filtering and chlorination. The cumulative effect of the three dams is not likely to change this. However, as has been discussed, impoundment may affect temperature and dissolved oxygen levels to slight degrees and could possibly, though unlikely, affect fish breeding. To date, this has not been observed at Mollejon but may require further investigation. However, the one issue
of major concern is the possible increase of mercury levels in reservoir water and in fish. This EIA study supports the recommendation of a recent PAHO report (Flores, et al 2005) that BECOL undertake a sampling programme to assess the nature and extent of this potential problem.

Except for the uncertain issue of mercury levels, it is believed that water quality in the Macal River is not likely to deteriorate when the three hydroelectric schemes are in operation.

7.12.2.3 Ecology
Every hydroelectric scheme has a direct impact on ecology, primarily due to permanent inundation of the river bed and the reservoir area. The impacts that would be caused by the Vaca scheme have been discussed in detail in Section 7.0. These impacts add to the cumulative impacts of the Mollejon and Chalillo schemes which are largely irreversible and permanent. In the case of Vaca the ecosystems losses are not considered to be great at the national scale, and the flora and fauna that would be lost, displaced or threatened, with the exception of those listed (Appendix V), are not on any critical list. Hence, these impacts, while inevitable, should not significantly alter the ecology of the area nor contribute cumulatively to ecological decline in the Macal River Basin.

7.12.2.4 Archaeology
The Rapid Archaeological Assessment done for this EIA has not identified any significant archaeological features in the area of the proposed Vaca Project (Appendix VI). This is unlike the Chalillo area where extensive work has identified several features of significance. However, the present EIA study has recommended that before any construction begins at Vaca, a more thorough investigation be made especially of the travertine dams and Cohune ridges, to determine conclusively whether or not significant features exist and if they do to conduct mapping, excavation and/or salvage exercises as appropriate.
In addition, the archaeologist’s report has summarized knowledge of the Mayan presence in the Macal River Basin and placed the Vaca area in perspective with regards to the location and density of settlements in the area. While the analysis indicates that inundation of the basin for the Vaca Project would not create any serious archaeological loss, the results of the RAA have served to throw further light on the Mayan presence in the area.

Perhaps the greatest significance, therefore, of the archaeological investigations for the Vaca and Chalillo Projects, has been to concentrate more attention to these areas and to better place them within the context of Mayan history. As a result, it is likely that they may serve to encourage further archaeological investigations in this general area.

In summary, whereas the Vaca Project is unlikely to result in significant or additional archaeological loss in the Macal River Basin, the attention it has drawn to the archaeology of the area, together with Chalillo investigations has served to forward overall knowledge of Mayan occupation in the Cayo district.

7.12.2.5 Socio-economics

The proposed Vaca project being the third hydroelectric scheme on the Macal River has benefited from the increase in public information and awareness as a result of consultations and public hearings conducted over the past five years. In the present case consultations have been on-going since June 2005 so that there is a fair level of awareness especially in the Cayo District. These consultations have served to disseminate information on the nature of the Vaca project as well as to air the concerns of the public concerning the project. In general, these concerns have centred on both technical and non-technical issues and have revealed both the level of understanding of the project as well as the sensitivities surrounding it. In particular, the consultations have revealed many of the perceptions about the nature of hydroelectric schemes as well as the precise nature of those on the Macal River. As a result of these perceptions, many of which have been negative, sensitivities are heightened and some believe that the Vaca project now adds “insult to injury” as far as the perceived impacts are concerned. Regrettably, many of the perceptions are founded on
false information or on limited understanding and it is necessary that these be clarified through further information sharing and dialogue. BECOL’s current owner, Fortis, which is the proponent for the Vaca scheme was not responsible for the development of the Mollejon project and became involved in the Chalillo project after its conception. However, many in the public have made false allegations about the company in respect of all three projects as an integrated scheme. This is one of the major misunderstandings which need to be cleared up if the public is to assess the Vaca project in its own light. At the same time, how the Vaca project fits into the entire hydroelectric development on the Macal River needs to be better understood. Without this understanding the ability of the public to respond to and address all legitimate concerns will be compromised.

Another of the issues that needs to be better understood is the impact of the hydroelectric schemes on the security and costs of electricity generation in Belize. While the overall economics of these schemes are complex and difficult to address in public fora, the perception that hydroelectric schemes should lower the cost of electricity to the consumer must be dealt with. While economic evaluation may show that as a result of the three hydroelectric schemes the cost of electricity to the consumer will not be as high as if electricity were generated otherwise or imported from Mexico, the average consumer does not understand this and only relates the cost of electricity in the present to what he actually paid in the past. Hence, although factors such as the relative cost of electricity generation by using other technologies, as well as inflation costs are not taken into consideration by the general public when making comparisons, they do impact on the cost to the consumer. While BECOL has made the case that hydroelectricity generation is a least cost option for Belize this needs to be explained to the public if BECOL wishes to have full public support for the hydroelectric schemes.

Another public perception which should be dealt with is the impact on the Cayo District in terms of employment. While the projects will hardly affect employment in the operation phase, during construction there will be ample opportunity for employment for skilled and unskilled labour over approximately two years. As far as possible, this labour should be supplied from communities in the Cayo District. However, some importation of skills from
outside is inevitable. The Cayo population needs to understand this and should not feel threatened by the use of outside workers. In addition, the interaction between local and outside workers should be appropriately managed by contractors so as not to cause undue friction or conflict. In the short to medium term the increased employment should constitute a very positive impact.

The main technical issue of concern, regarding all the hydroelectric schemes, is the future of the Macal River and its potential for catastrophic flooding. As pointed out before the three schemes in series should serve to modulate flows of the river where there are human settlements and recreational activities. However, the public is always concerned about what would happen with failure of any of the dams. This issue has been fully explored by hydrologists connected with the projects and it has been shown that dam failure would not create a flood hazard any greater than that of a Probable Maximum Flood (PMF). In fact dam failure other than during a PMF would only create flooding within the usual flood plain. This should be carefully explained to the general public so that the perceptions of catastrophe in the event of dam failure are put in their proper perspective.

With regard to overall management of the Macal River flows, the public should be made aware of the fact that the National Pro-Tempore Water Commission and not BECOL is the responsible entity. Similarly, with regards to the management of flood hazards in the Macal River Basin the National Emergency Management Organization (NEMO) and its affiliates are the responsible government agencies. The fact that BECOL is represented on both of these entities is critical to an understanding of their role in the development and management of a Flash Flood Early Warning System (FFEWS) and an Emergency Preparedness Plan (EPP). BECOL’s participation as well as the participation of other stakeholders, should contribute to the effective management of hazardous floods.

The need for good watershed management in the Vaca and Mountain Pine Ridge Forest Reserves has been emphasized in the body of this EIA. Implementation of the Vaca project should create a further opportunity for putting in place an effective watershed management programme involving public and private sector stakeholders. As all three hydroelectric
schemes could be negatively impacted by poor watershed management resulting in increased sediment and agricultural chemical run-off, the involvement of BECOL is critical. The benefit of good watershed management in the Macal River Basin should be obvious to all responsible stakeholders.

There is growing concern about the increase in illegal activities in the Forest Reserves. For example, the illicit harvesting of the leaves of the Xate Palms for export to the ornamental market, is having a deleterious effect not only on the palms themselves but also on the forest reserves. The operation of the three hydroelectric plants may serve to discourage this activity and thus contribute to the conservation of the forest reserves. Similarly, illicit hunting in the reserves (particularly of small mammals and game birds) should be prevented, and the presence of the hydroelectric schemes in the area may serve to discourage this activity.

In conclusion, public information dissemination is vital to allay the fears of the public regarding flooding, the potential for dam failure and all other concerns of a technical nature. BECOL chairs a Public Information Committee and this committee should be fully utilized to ensure that accurate information is given on a timely basis. Additionally, the expectation that the hydroelectric schemes should result in cost benefits to the consumer should be explained in terms of overall savings on the cost of electricity generation for the country of Belize and the direct benefits to the consumer. BECOL, as a key stakeholder in the Macal River Basin and Watershed should participate fully, along with relevant private and public sector stakeholders, in the collaborative management of the watershed and river flows. Illegal activities within the forest reserves such as harvesting of the Xate palm and hunting of small mammals and game birds should be eliminated altogether, and the presence of the hydroelectric schemes along the Macal River should contribute to the reduction of these activities through an increased presence in the area and additional security measures.

Plate 7.12.2.5 illustrates some of the socio-economic impact concerns expressed by stakeholders in the Macal River Basin.
Plate 7.12.2.5 A, B, C, D E

7.12.2.5 A: The flood plain during peak floods at Chaa Creek

Plate 7.12.2.5 B: The Macal River at Cristo Rey showing domestic and recreational activities on the river
Plate 7.12.2.5 C: One of the two bridges crossing the Macal River at San Ignacio. This bridge is inundated under existing wet season floods.
Plate 7.12.2.5 D & E: Degradation of the Vaca Forest Reserve

Plate 7.12.2.5 D

Plate 7.12.2.5 E
8.0 Analysis of Alternatives

8.1 Alternative Design

Alternative designs have been considered in the preliminary engineering of a Reinforced Concrete Dam and a Concrete Face Rockfill Dam. The environmental aspects of these two designs have been evaluated in Section 6.0. The designs are shown in Appendix I.

8.2 Alternative Sites

Initial geotechnical investigations were conducted at four different sites (AGRA CI Power/BEL, 1999). A review of these investigations and verification of the suitability of these sites for dam construction was done by Cho and Moore (2004). Dam Site 1 (now Vaca Site A) (UTM Coordinates N1881193, E 0282700) is located downstream of the confluence of the Rio On with the Macal River. No faults were observed and the rock appeared to have good mechanical properties and would make a suitable foundation for the construction of a dam. The second site, dam Site 2, was located approximately 850 m downstream of the confluence (UTM Coordinates N1881835, E0282159). This site was located within a fault/shear zone which trended in a SW-NE direction. This site has been excluded from further consideration. The third site was located at UTM Coordinates N1882399, E0281440 and the 4th site (now Vaca Site B) was located at UTM Coordinates N1882593, E0281008. Site 4 and Site 3 both had rock that was massive, very hard and showed little jointing. No faults were observed and the rock appeared to have good mechanical properties and would be a suitable foundation for dam construction (Cho and Moore, 2004). No further downstream sites were considered feasible and therefore not evaluated.

Subsequently, Sites 1 and 4 (now Site A and Site B) were chosen for more detailed geotechnical and environmental evaluation. The results of the environmental evaluation indicate that Site B would create fewer environmental impacts than Site A (Section 6).
Based on a general knowledge of the Macal River Basin no other sites were considered suitable for placement of the dam.

**8.3 Quarry Site Alternatives**

The environmental evaluation has considered various options for the excavation of suitable construction material.

- The 2.96 km tunnel for a Site A dam
- The spillway channel excavation at Site B for a Concrete Face Rockfill Dam
- A discrete quarry site on the western ridge of the Site B gorge, and
- A quarry site immediately upstream of the Site B dam within the inundation area

Given the preference for Site B as the dam site, options c) and d) above are the feasible options to be considered for the concrete dam, while b) is the preferred option for the Concrete Face Rockfill Dam construction. This EIA has recommended that further consideration should be given to siting the quarry within the footprint of the inundation area. However, if this does not prove feasible then option c), a quarry site on the western ridge of the gorge, would be acceptable.

The spillway channel construction at Site B will require the excavation of material if the Concrete Face Rockfill Dam (CFRD) is chosen. The excavation of the spillway channel would be essential to the design of the CFRD and would generate a substantial amount of quarry material (600,000 m³ of aggregate) that would then necessitate only a small additional quarry site, if any.

This EIA has also recommended that consideration be given to utilizing material from existing burrow pits and / or quarry sites, but this requires further investigation and the developers do not believe that this will be required for the Concrete Face Rockfill Dam option. Any selected site for quarrying must be approved by the Department of the Environment and the Geology and Petroleum Department.
Whichever of the above options is chosen, necessary quarrying activities can be conducted in an environmentally acceptable manner as long as best practices are observed with strict monitoring and controls.

### 8.4 The No Action Alternative

The development of any hydroelectric scheme involves inevitable environmental impacts. Some of these are negative and some positive. However, the deciding factor for any scheme is usually the cost benefits derived from securing a steady and predictable source of electricity. In the case of the Vaca project BECOL has set out its case for its implementation as part of a three part series of hydroelectric developments on the Macal River. From all accounts their projections have received support within Belize although there has also been noted opposition. Nevertheless in both previous schemes at Mollejon and Chalillo the benefits to Belize have been regarded as outweighing any negative environmental impacts created by their implementation. In the case of the Vaca project the negative environmental impacts appear to be no greater than for the other two and indeed seem to be less. At the same time there are definite positive impacts associated with the scheme particularly as regards to management of the Macal River flows, flood control, and recreation and domestic uses of the river.

From consultations with downstream stakeholders a number of concerns both of a technical and non-technical nature have been raised with regard to the Vaca project. However, many of these arise from misunderstanding and misperception of what the scheme entails. In addition, negative attitudes toward the scheme seem to have arisen as a result of how the previous schemes at Mollejon and Chalillo were presented to the public. In the present case the approach to public information dissemination has been open and transparent and has been ongoing in the Cayo District since June 2005. While these consultations do not guarantee acceptance of the project they nevertheless allow for more rational consideration of its benefits and dis-benefits.
The issues raised by the public centre primarily around the following:

1) The management of flows on the Macal River
2) Hazard vulnerability because of possible dam failure
3) Ecological losses as a result of inundation by the reservoir
4) Archaeological losses as a result of inundation by the reservoir
5) The cost of electricity

In the final analysis it is up to the Government and people of Belize to decide whether the perceived impacts are enough to outweigh the benefits to be derived from the generation of approximately 17.8 MW of electricity by a Vaca plant. The No Action Alternative would therefore be based on economic cost benefit considerations, a part of which involves the off-setting of environmental impacts (real and/or perceived) against economic gains. That assessment must eventually be made by the Public Utilities Commission who could decide that an alternate form of electricity generation would be in the best interest of the entire nation.

This EIA report has attempted to set out all the potential environmental impacts both negative and positive that may be associated with the Vaca project. It does not recommend a decision one way or another. Hopefully, however, it has faithfully presented the facts on which the best decisions can be made.

The decision whether or not to implement the Vaca project rests eventually with the Public Utilities Commission (PUC) who will consider all the alternatives for power generation presented to them by various entities through a bidding process. Hence, even if the Vaca project is considered to be economically and environmentally feasible it must still compete with other electricity generation options for acceptance. Therefore, a No Action Alternative can only be fully assessed when the competing projects are presented.
9.0 Mitigation Plan

This section presents the mitigation measures to be utilized during the site preparation, construction and operation phases for the Vaca Project. Specific mitigation measures related to disaster management are given in Section 9.4.

9.1 Physical Aspects

Topography and Terrain Mitigation Measures (Responsibility of BECOL in association with relevant government agencies as indicated):

- All construction related activities remain within the footprint of the development so as to minimize the potential negative impacts on the environment. This includes storage of equipment and machinery and no side-tipping of excavated spoil, and land clearing only within the right-of-way for the transmission line (30m) and access roads (20m).

- Plant debris should be piled along the edge of the right-of-way pending removal to a suitable disposal site. Any required burning should be carried out under the supervision of the Forest Department. Fire extinguishers should be on site at all times.

- Regarding the quarry site, if material were excavated from upstream of the abutment site, within the footprint of the inundation area this would reduce the impact of long-term irreversible changes on the topography. If the quarry site is outside the footprint of the inundation area, best quarrying practices would be required to ensure successful post construction rehabilitation.

- All access roads should be built in conjunction with the Ministry of Works and the Forest Department.

- Best practices for construction should be employed and site-rehabilitation should be performed at the end of the construction phase.

- Site rehabilitation should include removal of decommissioned buildings and structures that have not been identified as having future beneficial use, removal
of equipment, vehicles and machinery, remediation of soils in the event of petroleum spills, removal of solid and liquid waste for disposal at an approved designated facility, and replanting/re-grassing of areas as appropriate to minimize the impact of scarring of the landscape. Site rehabilitation should also include the realignment of any altered drainage channels, to pre-construction natural flows.

- Long-term maintenance of the operational roads and transmission line right-of-way are recommended to maintain service quality as well as aesthetic appeal.

**Air Quality and Noise (Responsibility of BECOL):**

- In order to minimize short-term impacts on air quality and noise proper maintenance of machinery and equipment is necessary to limit poor vehicular emissions and noise.
- Periodic wetting of stripped dry areas, periodic wetting of stockpiles of fines, and covering of conveyors to minimize fugitive dust during crushing and batching plant activities are mandatory.
- Non-petroleum based dust suppressants should be used.
- Blasting activities should be carried out by a certified and approved contractor and standard mitigation measures should be employed including the use of blasting mats, to prevent airborne rock fragments.

### 9.2 Hydrology Aspects

**Flooding (Responsibility of BECOL):**

- By utilizing best construction practices, upstream hydrology impacts could be appropriately mitigated. A well constructed and managed diversion channel would serve to prevent upstream inundation during construction.

**Sedimentation (Responsibility of BECOL):**

- The use of silt screens and/or silt curtains at the diversion channel would be necessary to trap sediments upstream.
The overall management of flows in the entire Macal River Basin is not the responsibility of BECOL, but must be the responsibility of the National Pro-Tempore Water Commission which was established under Statutory Instrument No 62 of 2004. This will ensure that essential flows in critical areas are maintained at all times. These critical areas and flows should be determined by the Commission. Improved watershed management in the Vaca and Mountain Pine Ridge Forest Reserves is necessary to reduce the incidence of uncontrolled agricultural practices and to ensure that there is no increase in sediment and agricultural chemical run-off to the Macal River.

Inspection of the reservoir bed should take place as a regular maintenance operation and flushing should take place as required. Carefully controlled reservoir flushing is necessary to mitigate any downstream sedimentation impacts. As for the Chalillo dam, the Department of the Environment may require that approval be sought from them prior to flushing the dam.

Flooding due to Dam Failure (Responsibility of BECOL in association with relevant government agencies as indicated):

The Vaca dam design must incorporate all necessary features to ensure that flood intensities are not increased but are reduced as much as possible.

BECOL should prepare an Emergency Preparedness Plan (EPP), which links to the one established for Chalillo, in conjunction with the National Emergency Management Organization (NEMO) and its affiliates DEMO and CEMO. This plan should be completed before the completion of the Vaca dam. BECOL should provide signals (digital or analogue) to the National Meteorological Service for at least three threshold reservoir levels (Alert, Warning and Emergency Phases). These signals should be relayed by National Oceanographic and Administrative Organization (NOAA) satellite for immediate transmission and dissemination.

A Flash Flood Early Warning System (FFEWS) should be implemented, which links to the one established for Chalillo, and an Emergency Preparedness Plan (EPP) should be prepared. The FFEWS should follow the procedure already
developed by BECOL, in association with the National Meteorological Service, whereby BECOL informs them of any pending flood hazard, and they in turn notify the public and set in train the necessary emergency procedures. This requires a reliable and continuous communication system between BECOL, the National Metrological Service and the downstream communities. It is desirable that the plan be regularly reviewed and upgraded with full stakeholder participation, in order to ensure its acceptance and compliance by the general public. Information on the extent of the flood plain under PMF and fair weather conditions, as generated in the ‘Dam Break’ analysis produced by Gilbert-Green and Associates for BECOL (Appendix IV and Figure 5.5.5. e insert in back pocket), should be incorporated into the FFEWS and EPP.

9.3 Water Quality

Mercury Risk (Responsibility of BECOL in association with relevant partners as indicated)

- Clearance of vegetation in the inundation area prior to flooding, should be done to reduce the risk of methylation of mercury and the subsequent accumulation of this toxin in fish. A recent study showing levels of mercury in predatory and non-predatory fish from the Macal River (Flores, 2005) stated that an assessment of mercury levels in fish from other water bodies countrywide should be conducted, and a plan of action including mitigation measures, public awareness, monitoring and enforcement should be developed and implemented involving the relevant stakeholders. BECOL, under the Environmental Compliance Plan for the Chalillo Project, is responsible for developing and implementing a Mercury Risk Management Program. The Mercury Risk Management Programme for the Chalillo Project should be extended to the new Vaca facility.
Sedimentation (Responsibility of BECOL)

- Soil conservation activities and control of land use in the watershed should mitigate the sedimentation of the reservoir. Any sediment flushing, however minor, will supply downstream waters with sediment, and should be carefully regulated and monitored. Sediment flushing should only be conducted on approval by the DOE.

9.4 Ecological Aspects

Vegetation Clearance and Terrestrial Habitat (Responsibility of BECOL in association with relevant government agencies as indicated):

- Clearing of vegetation should be conducted manually, with the Forest Department approved use of heavy equipment, and/or burning.

- Clearance of vegetation by burning should be conducted under the supervision of the Forest Department and with the immediate availability of fire fighting equipment. Construction of fire paths is recommended with a minimum width of ten (10) metres in order to prevent the escape of fires, which could have the potential to destroy forested areas and associated wildlife.

- A vegetation clearance plan should be submitted to the Forest Department for approval prior to the commencement of any clearing activities.

- As much as possible of the construction activities should remain within the footprint of the development and no side-tipping of material or storage of machinery should occur beyond the footprint.

- Any areas that have been cleared for medium term activities such as the establishment of the camp site, storage areas, office facilities and construction access roads should involve work only within the footprint of these facilities and site rehabilitation including replanting of trees and re-grassing of areas, must be undertaken.
Wildlife Protection (Responsibility of BECOL):

- Wildlife rescue may be performed, as appropriate, to mitigate the loss of specimens, particularly for any endangered species.
- If endangered species are identified as nesting or breeding in isolated vegetative patches, efforts should be made to rescue and relocate them.
- All workers should be briefed on the hunting regulations and advised of a no hunting policy for the residential construction camp.
- The creation of 25-50m³ (i.e. 5m x 5m, or 5m x 10m) sand banks at the edge of the inundation area, appropriately spaced and dependent on the topography of the inundation area, on both banks. These should be approximately 0.5m high, and provide open nesting and basking sites for several species.
- The creation of numerous small shallow pools within the reservoir bank area (from 10m² – 25m² and 0.15m to 0.3m deep).
- Known food sources for green iguanas (and howler monkeys) could be interplanted amongst existing vegetation along the newly formed reservoir banks. These should include the bri-bri and fig species currently found in or adjacent to the riparian shrubland.

Aquatic Habitat (Responsibility of BECOL)

- In order to minimize the impact of sedimentation on aquatic life in the river polyethylene liners or liners of similar suitable material should be used to line the cofferdam.
- Sediment curtains or silt screens supported on a boom should be deployed at the site of any riverbank or riverbed excavation to prevent disturbed sediments from entering the stream flow.
- Riverbank and riverbed excavation should be limited to the dry season as far as is possible. All stockpiles of earth materials, including fines and aggregate, should be located away from the edge of the river (above the annual flood level).
- Servicing of crushers and excavation machinery should not be permitted within 30 m of the high water mark for the river.
• Washing of aggregate should not be conducted in the river, and wash-water should be stored in sedimentation ponds to allow for settling and reuse.

• Rehabilitation of excavated riverbank areas should be conducted by replacing suitable riparian vegetation on completion of construction works.

• In order to reduce the impacts of sedimentation on aquatic life downstream, BECOL should notify the Department of the Environment when it intends to carry out flushing activities. Flushing should only be conducted after the Department of the Environment has given approval to do so. As for the Chalillo dam the DOE may request that notification be given them, in order to request approval before flushing activities are carried out.

• The creation of numerous small shallow pools (from 10m² to 25m², and 0.15m to 0.3m deep) within the same reservoir bank area. These pools should be appropriately spaced on both banks, and would re-create breeding sites for the majority of the amphibian fauna of the locality. Vegetation should not be cleared around or in these pools.

9.5 Archaeological Features

Damage or Loss (Responsibility of BECOL in association with the Institute of Archaeology):

• In order to minimize the potential negative impacts on cultural resources and archaeological features within the footprint of the development, it is essential that detailed archaeological surveys of the area of inundation and other areas within the footprint of the development particularly along the strips of land containing Cohune palms be conducted by a professional archaeologist, under the supervision of, and in association with the Department of Archaeology.

• These detailed surveys should be conducted and completed within the time frame of the construction period for the dam.

• All investigations within the area of inundation must be completed before filling of the reservoir area.
• Any prehistoric mounds that are located by a more detailed survey, should be excavated by professional archaeologists and under the supervision of the Department of Archaeology, from a lower to higher elevation sequence, with resources in the lower sequence being excavated first.

• A sample of the possible terraces or travertine dams should be excavated in order to determine their actual identity.

• Any incomplete investigations should be conducted at the higher elevations during the dry season.

• During construction activities any archaeological resources unearthed or identified during earth movement activities should be immediately reported to the Department of Archaeology and activities in that area suspended until the Department of Archaeology is able to investigate.

9.6 Construction Of Dam And Auxiliary Infrastructure

(Responsibility of BECOL in association with relevant government agencies as indicated):

Site Clearance:

• The measures to be implemented during site clearance on the physical, hydrological, biological, archaeological, and socio-economic environments are given in Sections 9.1 to 9.4.

Road Construction

• The measures to be implemented during site clearance on the physical, hydrological, biological, archaeological, and socio-economic environments are given in Sections 9.1 to 9.4.

• As far as is feasible activities should remain within the designated 20 m right-of-way.
Materials Transport, Processing, Handling and Storage

- Worker training in the care, use, handling and storage of hazardous materials is required for appropriate categories of workers.

- Transportation of aggregate, fines and other earth materials should be in designated vehicles, properly covered and secured, and not exceeding axle limits.

Hazardous Material Storage

- All hazardous materials should be appropriately separated and stored in designated signed areas, with appropriate demarcation and entry restrictions.

- Petrochemicals and other hazardous liquids should be stored in contained areas, surrounded by berms or concrete containment, so as to restrict the movement of hazardous substance into the terrestrial or aquatic environments in the event of spills or leaks.

- A Spill Contingency Plan should be prepared for all hazardous material and should be submitted to the Department of the Environment for approval.

- Explosives and other flammable materials should be stored in clearly labeled designated areas, and explosives should be stored in a building made of reinforced concrete and surrounded by a berm.

- All fuel tanks should be contained within a berm wall of reinforced concrete and properly sealed to prevent leaks in the event of an accidental spill. The containable spill volume should be at least 120% of the volume of the largest tank. An oil/water separator should be fitted to the outlet valve.

- All spills of hazardous materials should be immediately reported to the Department of the Environment and measures taken to contain the spill and remediate the area.

Equipment Storage

- The mitigation measures as presented in Sections 9.1 to 9.4 should be implemented.
Environmental Impact Assessment

- Rehabilitation of cleared areas should be done on completion

Equipment Maintenance

- Best practices should be employed in the siting of maintenance areas away from the riverbank.
- The proper collection of lubricants, oils, hydraulic fluids and other petroleum products should be carried out and these materials stored in properly labeled containers.
- These containers should be stored in a designated signed area before removal for disposal at a designated and approved site.
- Any contaminated soils should be remediated.

Waste Disposal

- A Waste Management and Pollution Control Plan should be prepared which includes all aspects of the proposed works and the physical areas of the proposed project. This plan should be prepared in association with and be approved by the Department of the Environment and the Public Health Bureau, and should include all aspects of solid waste and liquid waste including sewage.
- All solid waste generated during the course of site preparation and construction should be properly collected and stored in a designated area to facilitate sorting, if required at that stage, before being disposed of at designated and approved disposal sites. Solid waste should be separated by category, and kitchen and domestic waste should be separated into non-biodegradable and biodegradable materials.
- Liquid waste should not be allowed to flow into natural drainage channels or be disposed of in any waterway.
• All bathrooms should be outfitted with shower stalls connected to a common drainage system which leads to the outside of the building into temporary storage tanks. Laundry facilities should be incorporated into the bathroom areas and lead into the common drainage system. This gray water (showers and laundry) should be disposed of through a properly designed leach field or alternatively be used for irrigation on the residential campsite.

• Composting toilet facilities or ‘low flush toilets’ should be provided at the residential campsite as well as current construction areas. These facilities should be fitted with properly designed sealed septic tanks. Chemical toilets may also be used and should be supplied, serviced and maintained by an approved contractor.

• All liquid waste, including sewage, should be appropriately treated before disposal at sites approved by the Department of the Environment and the Public Health Bureau. The Department of the Environment and the Public Health Bureau should also approve the sewage treatment options.

• Biodegradable waste should be composted at a designated area approved by the Department of the Environment, the Public Health Department and the Forest Department. The compost generated should be used for landscaping and rehabilitation after the construction phase has been completed.

• Kitchen and domestic waste should be stored in sturdy polyethylene bags, and placed in sturdy containers that can be sealed shut. This will prevent the proliferation of odour and discourage rats, raccoons and other pests and vectors from entering the area. Domestic and kitchen waste should be removed from the site daily, and solid waste receptacles should be removed from the designated storage areas at least three times per week. Vehicles used to transport waste should be covered during transport.

• Solid waste should not be subjected to open burning. Vegetative matter may be burned in a designated area and as approved by the Department of the Environment and the Forest Department.
• Equipment parts, derelict machinery and metal components should be transported to a designated recovery area where they may be sorted and separated. Material that may be reused should be kept and stored. Any material not to be reused should be disposed of at an approved and designated solid waste disposal site.

Blasting

• Blasting activities should be carried out by a certified and approved contractor and standard mitigation measures should be employed including the use of blasting mats, to prevent airborne rock fragments.

• Forty-eight (48) hours public notification should be given prior to blasting activities.

Scarring of the Landscape

• Mitigation measures to minimize scarring of the landscape are presented in Sections 9.1 to 9.4.

Foundation Preparation

• Mitigation measures presented for activities such as vegetation clearing, blasting and riverbed works (Sections 9.1 to 9.4) should be implemented.

• All preliminary designs and layouts should be submitted to the Ministry of Works for review and approval, and all additional geotechnical assessments should be completed and submitted to the Inspector of Mines of the Geology and Petroleum Department for review.

Transportation

• A Spill Contingency Plan should be prepared for the response to and clean-up of accidental spills.

• All vehicles transporting earth materials on open roads should have their cargo covered. Vehicles should adhere to all prescribed legal limits, which would reduce the risk of accident and spillages.
• Any spills on open roads should be cleaned-up within 24 hours and disabled vehicles should be removed to the designated maintenance area.

Vegetation Clearance for Inundation Area

• Measures to be used during vegetation clearance to minimize potential negative impacts are presented in Sections 9.1 to 9.4.

9.7 Security
(Responsibility of BECOL):

• Prior to project implementation BECOL in association with the Forest Department should ensure that all contractors, subcontractors and labourers receive appropriate sensitization on the rules and regulations of the Vaca Forest Reserve.

• Any illegal activities observed within the boundaries of the Vaca Forest Reserve should be reported immediately to the appropriate authorities.

9.8 Public Health and Safety

Solid and Liquid Waste (Responsibility of BECOL)

• Mitigation Measures to ensure public health and safety should include best practices in terms of collection, storage, removal and disposal of solid and liquid waste should be employed at all work sites, storage sites and the residential camp.

• Solid and liquid waste should be separated as appropriate and contained in a designated area or areas, in properly covered and sealed receptacles, and should be removed and disposed of by an approved contractor on a regular and timely basis.

• Workers on site should be equipped with appropriate safety gear including hard hats, eye shields, dust masks, ear muffs, construction boots and safety vests.
Hazardous Materials (Responsibility of BECOL)

- All hazardous materials including chemicals, petroleum products, flammable material and explosives should be separated and stored in clearly signed and designated areas. Signage should include the type and/or nature of the material, relevant dates of delivery and expiration and handling rules.

- Worker training for the use and handling of hazardous materials should be conducted as required.

Pests and Vectors (Responsibility of BECOL)

- Proper solid waste storage and disposal mechanisms should be instituted at the residential camp site and construction areas so as not to encourage raccoons, rats, cockroaches and other pests and vectors.

- Solid and liquid waste should be separated as appropriate.

- Solid waste should be stored in sturdy polyethylene bags, in properly covered and sealed receptacles, and kept in a designated area until removal by an approved contractor on a regular and timely basis.

Risks To Personnel From Wildlife (Responsibility of BECOL)

- The duration of construction should not be long enough to allow such an increase in numbers of pests and vectors to take place, and proper garbage disposal should go a long way to reduce the issues with rodents.

- Adequate briefings on operational protocols (regarding snakes and Black Poisonwood) are the best way of minimizing the risk to personnel.

9.9 Transmission Line - Alignment and Right-Of Way
(Responsibility of BECOL in association with relevant government agencies as indicated)

- The alignment of the transmission line should be determined and approved by the Department of the Environment and the Forest Department.
• Before clearing, the entire alignment should be staked out with highly visible markers. As far as possible slopes greater than 30 degrees should be avoided unless the lines can be attached to poles which are sited on the summit of a hill.

• Topsoil removed during construction of the transmission line should be stockpiled for use during site rehabilitation activities.

• The alignment for the transmission line should be hand-cleared as far as is possible. The burning of any cleared vegetation should not be conducted without the approval of the Forest Department, and with fire fighting equipment in close proximity.

• All activities should be contained within the right-of-way.

9.10 Residential Worker Camp Site
(Responsibility of BECOL in association with relevant government agencies):

• A plan for the residential camp should be prepared by BECOL and submitted to the Department of the Environment and the Forest Department for approval.

• During construction of the camp site all the mitigation measures presented for clearance of vegetation, earthworks (including trenching), solid and liquid waste management, drainage control and site rehabilitation, should be employed.

• Building design should be aesthetically appealing and designed for good ventilation, effective lighting and provide easy access to facilities such as bathrooms, kitchens and recreational areas.

• Buildings should be designed to withstand storm force winds and rains that could be generated by a Category Three Hurricane. After closure, the camp should undergo a comprehensive cleanup and site rehabilitation.

• The camp site should be equipped with an adequate number of fire extinguishers.
• Adequate supply of potable water and electricity should be available on a continuous and uninterrupted basis.

9.11 Extraction of Materials
(Responsibility of BECOL in association with relevant government agencies):

• In order to minimize the negative impacts associated with quarrying activities, material upstream of Site B, and within the footprint of the area of inundation, could possibly be used. BECOL should investigate this option. Excavation of material from within the reservoir area would significantly minimize the extent of environmental impact and scarring of the landscape.

• BECOL should investigate the availability of using material from any existing burrow pits and quarry areas. Where availability and transportation requirements make the use of materials from these existing areas feasible, BECOL should use these.

• If additional material is required from new areas, these new areas may only be utilized on approval of the Department of the Environment, the Forest Department and the Geology and Petroleum Department.

• The boundaries of all extraction sites should be clearly marked by pegs or tape before work begins, and should remain visible while the site is in use.

• All mitigation measures presented for the clearing of vegetation, creation of access roads, removal of topsoil, transportation of earth materials, worker health and safety, dust and noise abatement, stockpiling of earth material, washing of aggregate, equipment maintenance and storage and site rehabilitation, should be instituted here.

• No riverbed extraction should be conducted other than for the site of the dam, powerhouse and tailrace.
### 9.12 Mitigation Matrix

A matrix has been prepared which summarises the mitigation measures to be implemented against the related impacts (Table 9.2).

<table>
<thead>
<tr>
<th>Mitigation Measures</th>
<th>General Environmental Impacts</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Topography</td>
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<tr>
<td>Engineering Design</td>
<td></td>
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<tr>
<td>Geological Investigations</td>
<td>X</td>
</tr>
<tr>
<td>Vegetation Clearance Plan</td>
<td></td>
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<tr>
<td>Fire Break</td>
<td>X</td>
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<tr>
<td>FF Early Warning System</td>
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<tr>
<td>Emergency Preparedness Plan</td>
<td>X</td>
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<tr>
<td>Spill Contingency Plan</td>
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<tr>
<td>Solid Waste Management Plan</td>
<td>X</td>
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<tr>
<td>Sewage Treatment Plan</td>
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<tr>
<td>Liaison with GoB Agencies</td>
<td>X</td>
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<td>Liaison with Stakeholders</td>
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<tr>
<td>Salvage and Excavation</td>
<td>X</td>
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<td>Employment</td>
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<td>Training</td>
<td>X</td>
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<td>Public Awareness Programme</td>
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<tr>
<td>Construction Monitoring</td>
<td>X</td>
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<tr>
<td>Operation Phase Monitoring</td>
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</tr>
</tbody>
</table>
9.13 Mitigation Costs

Mitigation measures to be implemented in order to minimize negative environmental impacts can be grouped into five main categories as discussed below:

9.13.1 DESIGN PHASE

These mitigation measures should be included in the design phase of the project and include aspects related to engineering design of the dam and appurtenant structures, the dam break analysis and environmental investigations and recommendations. Some of these initial costs have already been borne by BECOL. Detailed engineering designs, if the project is approved, as well as further geotechnical investigations would be required and the costs of these would also be borne by BECOL and would have to be determined when these aspects have been commissioned.

9.13.2 PUBLIC PARTICIPATION AND AWARENESS

Public participation through the staging of public hearing(s) is usually required by the Department of the Environment (DOE) as part of the EIA process, and to inform the DOE in their decision–making. The number of DOE requested public hearings to be staged would be determined by the DOE, after submission of the Final EIA Report for their review and in association with the National Environmental Advisory Council (NEAC). The cost of these public hearings would be borne by BECOL as per regulations and may include the following:

- Logistical arrangements for securing a suitable venue, refreshments, public address system, etc.
- The preparation of materials such as project information handouts, maps and charts for display, including english/spanish translation as and if required
- All costs related to ensuring the participation of relevant becol personnel, project engineers, and the EIA team
✓ Preparation and submission of a report of the public hearing (s) to include the level and nature of participation, main issues raised and covered and any recommendations forthcoming from the session.

Additionally, if approval is given to the project BECOL, should engage in a public awareness campaign which should keep the public informed of the progress of project development, any issues that may directly affect the public (such as use of transportation routes, spills of hazardous materials, flows in the Macal River, etc.) and on-going communication with the public to ensure the maximum level of information exchange. This public awareness campaign for the Vaca dam could be incorporated into existing public awareness programmes currently being run by BECOL.

9.13.3 POST ENVIRONMENTAL COMPLIANCE PLAN

If the project is approved and an Environmental Compliance Plan (ECP) is issued, the ECP may request the preparation of several documents to be submitted to the DOE and other relevant government agencies, such as the Forest Department and Public Health Bureau, for their review and approval prior to project implementation, or at various stages of project implementation. These may include the following:

✓ Detailed Monitoring Plan
✓ Waste Management and Pollution Control Plan
✓ Vegetation Clearance Plan
✓ Hazardous Spills Contingency Plan
✓ Mercury Risk Management Programme (This may be incorporated into the one Prepared for Chalillo and would bear only a portion of the estimated cost of $ 75,000)
✓ Flash Flood Early Warning System
✓ Emergency Preparedness Plan
9.13.4 SITE PREPARATION AND CONSTRUCTION PHASE

Prior to and during the site preparation and construction phase additional studies would be required. These include an archaeological survey and ecological monitoring as determined by the DOE. These costs may be approximately $60,000.

9.13.5 OPERATION PHASE

During the operation phase, the implementation of monitoring and maintenance would be required. These costs would be determined at a later date and in consultation with design engineers. The establishment and implementation of plans prepared as described in Section 9.2.3 would be the responsibility of BECOL as dictated by pertinent laws.

Additionally, any other aspects related to the implementation of the Environmental Compliance Plan would be the responsibility of BECOL as spelt out in the law. These aspects would include facilitating monitoring and compliance by the relevant authorities as required by law, and would also include any incremental increases over time. The cost of compliance is broadly estimated to be in the range $1 million. The cost of monitoring during the operation phase is expected to be approximately $28,000 annually and includes the costs for labor, transportation, laboratory analysis and sampling containers. Annual incremental increases should be anticipated.

9.14 Disaster Management

Disaster management must be considered as a high priority for BECOL and should cover all aspects of the site preparation and construction phase as well as the operation phase. Disaster management should address the potential for fires, explosions, floods and spills, as well as storage of hazardous materials, care and handling of hazardous materials and worker health and safety.
Hazard Management

- A Hazard Management Plan should be prepared to include aspects related to fires, floods, explosions, river diversion, noise and dust. This plan should be submitted to the Department of the Environment and the Public Health Department for approval. Evacuation procedures should also be included in the plan.

- Explosives should be stored in a separate clearly designated building made of reinforced concrete and surrounded by a berm.

- Clearing of vegetation by burning should be carried out with the supervision of the Forest Department. Clearing of large tracts of vegetation should only be carried out with a fire break with a minimum width of 10 m.

- Blasting activities should be carried out by a certified and approved contractor and standard mitigation measures should be employed including the use of blasting mats, to prevent airborne rock fragments.

- Periodic wetting should be carried out on all stripped, bare surfaces and stockpiles of fines.

- A properly designed and engineered coffer dam should be installed to facilitate river diversion and prevent flooding.

- Appropriate training in the care and handling of hazardous materials should be carried out for designated contractors, subcontractors and labourers.

Hazardous Material Storage

- All hazardous material should be appropriately separated and stored in designated signed areas, with appropriate demarcation and entry restrictions.

- Petrochemicals and other hazardous liquids should be stored in contained areas, surrounded by berms or concrete containment, so as to restrict the movement of hazardous substance into the terrestrial or aquatic environments in the event of spills or leaks.
• A Spill Contingency Plan should be prepared for all hazardous material and should be submitted to the Department of the Environment for approval.

• Explosives and other flammable materials should be stored in clearly labeled designated areas, and explosives should be stored in a building made of reinforced concrete and surrounded by a berm.

• All fuel tanks should be contained within a berm wall of reinforced concrete and properly sealed to prevent leaks in the event of an accidental spill. The containable spill volume should be at least 120% of the volume of the largest tank. An oil/water separator should be fitted to the outlet valve.

• All spills of hazardous materials should be immediately reported to the Department of the Environment and measures taken to contain the spill and remediate the area.

**Flooding due to Dam Failure**

• The Vaca dam design must incorporate all necessary features to ensure that flood intensities are not increased but are reduced as much as possible.

• Dams will naturally deteriorate over time, but the rate and extent of deterioration is unique to each dam. However, routine preventative maintenance is essential to ensure that deterioration is immediately observed and where possible repaired. BECOL should prepare a Dam Inspection and Maintenance Plan for approval.

• Performance monitoring instrumentation should be installed in the dam and should include vibrating piezometers for measuring water pressure and survey instruments for measuring movements.

• A draining and inspection gallery should be constructed in the body of the dam, if the Reinforced Concrete Dam is implemented, and should include seepage measuring weirs.

• The spillway of the dam should be designed to accommodate the Probable Maximum Flood (PMF) and provide controlled routing for a flood with a 100-year return period.

• The establishment of a Flash Flood Early Warning System (FFEWS) which is linked to the FFEWS established for Chalillo (Chalillo ECP, April 5, 2002) is necessary. This FFEWS must be developed in conjunction with relevant government agencies and all the stakeholders downstream of the proposed Vaca Dam, so that in the event
of dam failure downstream communities such as Negroman, Cristo Rey and San Ignacio can take rapid and effective, evasive action.

- The FFEWS should follow the procedure already developed by BECOL, in association with the National Meteorological Service, whereby BECOL informs them of any pending flood hazard, and they in turn notify the public and set in train the necessary emergency procedures. This requires a reliable and continuous communication system between BECOL, the National Metrological Service and the downstream communities. It is desirable that the plan be regularly reviewed and upgraded with full stakeholder participation, in order to ensure its acceptance and compliance by the general public.

- BECOL should prepare an Emergency Preparedness Plan (EPP) in conjunction with the National Emergency Management Organization (NEMO) and its affiliates DEMO and CEMO. This plan should be completed before the completion of the Vaca dam. BECOL should provide signals (digital or analogue) to the National Meteorological Service for at least three threshold reservoir levels (Alert, Warning and Emergency Phases). These signals should be relayed by National Oceanographic and Atmospheric Administration (NOAA) satellite for immediate transmission and dissemination.

- Information on the extent of the flood plain under PMF and fair weather conditions, as generated in the ‘Dam Break’ analysis produced by Gilbert-Green and Associates for BECOL (Appendix IV and Figure 5.5.5. e insert in back pocket), should be incorporated into the FFEWS and EPP.

9.15 Climate Change

No country should be unaware at this time of the onset of global warming as a world-wide phenomenon which will impact the way it does development and fashions its lifestyle. With global warming will come in one way or another, climate changes that involve increase in ambient temperatures, changes in rainfall patterns and likely increases in the frequency and intensity of tropical storms (hurricanes), among others. Nor should any country be unprepared to
adapt to these climate changes by either denying their reality or by believing that there is nothing it can do too mitigate their effects.

In the case of Belize, some of these effects may already be occurring if the increasing hurricane events in recent years are linked in any way to climate change, as many scientists believe. Similarly, recent variations in rainfall patterns could either be the result of normal wet/dry year cycles or the beginning of more long term changes. Scientists have still not reached a consensus on this issue. In the meantime, however, the Government and people of Belize must seriously consider how these changes could affect their daily living and development and begin to make the necessary adjustments. Fortunately, there is good evidence to suggest that this is occurring.

With regards to the proposed Vaca Hydroelectric Project (as well as the Mollejon and Chalillo Projects) the following climate change impacts must be considered:

1) Changes in rainfall pattern, affecting hydrological projections and therefore power generation expectations
2) Increased hurricane events also affecting hydrological projections and, in addition, the potential for catastrophic dam failures and the need for effective hazard management
3) Increase in ambient temperatures, affecting temperature and other water quality parameters in the reservoir such as dissolved oxygen levels. These changes in time could affect aquatic life as upper threshold limits are approached or exceeded.

In order to address these issues, BECOL needs to take the following precautionary mitigative measures:

1) Be thoroughly informed about the nature and implications of climate change through training and information dissemination within the company
2) Establish capabilities for and participate in climate monitoring networks to contribute to and keep abreast of relevant meteorological data and other information, especially in the Macal River Basin.
3) Design all engineering structures in the Vaca scheme to ensure adequate allowance for climate change possibilities over the next 100 years or more (i.e. the effective life of the scheme)

4) Train for and participate in hazards management networks (with NEMO) for the Macal River Basin

5) Develop and maintain its own Early Warning System to enable adequate response within and outside the company in case of pending hazards

One of the main contributors to global warming is the burning of fossil fuels to generate electricity and, in order to mitigate this challenge, more and more countries are turning to the use of renewable energy resources, including hydroelectric generation. Currently, more than 60% of Belize’s electricity, whether self generated or imported from Mexico, derives from fossil fuels. With the Mollejon, Chalillo and Vaca Projects in place (and also smaller hydroelectric schemes) Belize would generate more than 50 MW of electricity from this non-fossil fuel source. For Belize, this would be a significant contribution to the reduction in fossil fuel burning, and therefore to global warming and climate change.
10.0 Monitoring Plan

Monitoring will be required for the life of the Vaca Dam project and should include the Site Preparation and Construction Phases as well as the Operation Phase, as outlined below:

10.1 Site Preparation and Construction Phase

If the Vaca dam project is approved, during site preparation and construction BECOL should implement a monitoring programme that should include, but not necessarily be limited to, the following parameters:

**Riverine Water Quality**
- Dissolved Oxygen
- Total Suspended Solids
- Oil and Grease
- Total and Faecal Coliforms
- Water Temperature
- Alkalinity
- Hardness
- PH
- Conductivity
- Chlorides
- Salinity
- Ammonia

**Ecology**
- Vegetation Clearance
- Status of Endangered Species
- Hunting Pressure

**Construction Camp**
- Potable Water Quality
- Solid Waste Disposal
- Sewage Treatment and Disposal
- Public Health and Safety
- Hunting Pressure
Monitoring during this phase should be fortnightly or monthly as recommended by the Department of the Environment (DOE). Additionally, the DOE should monitor BECOL’s activities during this phase to ensure adherence to the Environmental Compliance Plan.

### 10.2 Operation Phase

During the operation phase, the following parameters should be monitored:

**Water Quality**
- Dissolved Oxygen
- Total Suspended Solids
- Oil and Grease
- Total and Faecal Coliforms
- Water Temperature
- Alkalinity
- Hardness
- PH
- Conductivity
- Chlorides
- Salinity
- Ammonia

**Ecology**
- Status of Endangered Species

**Hydrological and Meteorological Monitoring**
- River Stage
- Flow and Discharge
- Turbidity
- Rainfall
- Humidity
- Radiation
- Wind Direction and Wind Speed
- Evaporation and Evapo-transpiration
- Rainfall distribution within sub-basins

A minimum requirement of monthly monitoring is recommended. However the frequency may be increased as recommended by the DOE, and in association with relevant government agencies and stakeholders, as required. Monitoring should be incorporated into the BECOL EMS as appropriate (Appendix VIII).