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**PRE-FEASIBILITY STUDY
FOR THE POPA FALLS HYDRO POWER PROJECT
PRELIMINARY ENVIRONMENTAL ASSESSMENT
EXECUTIVE SUMMARY**



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1 INTRODUCTION

To meet the growing demand for power in Namibia and ensure reliability of supply to the northern regions, NamPower proposes to develop a 20 MW hydro power station on the Okavango River near Divundu. Eco.plan (Pty) Ltd was appointed to undertake a Preliminary Environmental Assessment (PEA) as part of a pre-feasibility study by Water Transfer Consultants. The engineering proposal evolved in response to technical, economic and environmental considerations during the pre-feasibility study. A full Environmental Impact Assessment will be required if the project proceeds to the next phase.

2 THE PROPOSED HYDRO POWER PROJECT

The proposed project is situated near Divundu, and includes the following components.

A **gated weir** would provide the pressure head needed to generate power. The proposal is a run-of-the-river scheme and does not require storage of water. Three sites were shortlisted, the details of which are provided in the table below.

Weir Site	Location of Weir	Upstream Extent of impoundment	Full Supply Level	Proposed Weir Height	Weir Basin Capacity	% of Mean Annual Discharge
Site 2	2km upstream of Popa Falls, and downstream of the Divundu bridge	1,6km upstream from F.Dimbare Youth Centre	1007.5 m.a.m.s.l.	7,5 m	22,5 million m ³	0.065 %
Site 4	4,3 km upstream of the Divundu bridge.	Just below Andara Mission	1010.0 m.a.m.s.l.	9,0 m	16,6 million m ³	0.050 %
Site 5	1km downstream of site 4 but upstream of the bridge at Divundu.	Just below Andara Mission	1010.0 m.a.m.s.l.	9,75 m	24,4 million m ³	0.066 %

Diversion canals were considered but found to be uneconomic. It is therefore proposed to use **Hydromatrix turbines** in the weir itself. These would be spaced across the weir, alternating with sluice gates. **Bulb turbines** may also be used - also placed in the weir. Placing turbines in the weir has the advantage of minimising impacts on the flow regime, as there is no diversion of the river. A **switchyard** will be constructed near the turbine generators. Power lines (132 kV) will be linked via Mukwe to Rundu, with a possible extension to Katima Mulilo later. Certain businesses, homesteads, and infrastructure will have to be relocated. Sources of materials are still to be determined.

The weir would be operated at "full supply level" (FSL) most of the time – i.e. with the water flowing 300mm deep over the top of the weir, and the rest passing through the turbines and sluice gates. "**TOPS gates**" are proposed to regulate the water level. As the inflow drops, gates will be closed one by one to maintain the water level at FSL. This will result in a slight lag in the hydrograph, but essentially the inflow to the impoundment will equal the outflow through the weir. At no stage will the river flow be blocked.

The need to ensure that sediment is passed through the weir is a key environmental issue. Two options are under consideration – sluicing or pumping. In the case of **sluicing**, all sluice gates would be opened for 4 to 6 weeks during the peak flow period to draw down the water level, thus increasing velocities to the "natural" state. No power can be generated during sluicing. In the case of **pumping**, a sediment trap would be constructed close to the inflow of the impoundment. Sediment would be pumped continuously from there to a discharge point immediately downstream of the weir.

The project will **not** be operated to meet daily peak power demand. Therefore, there will be no unnatural fluctuations in water level on a daily basis.

3 ALTERNATIVES TO THE PROPOSED HYDRO POWER PROJECT

NamPower has been investigating various options for power generation. Options have included hydro power (Epupa Falls and Baynes on the Cunene River), wind power (Lüderitz), and gas power (Kudu Gas at Oranjemund). Hydro power from a series of small stations on the Orange River has also been considered. Existing coal and diesel power stations are only used as backup as the cost of importing fuel is greater than the cost of importing power.

About half of Namibia's electricity is imported from South Africa and there is concern that prices will rise when South Africa's demand exceeds the production capacity. Power is also imported from Zambia via a 66kV line to Katima Mulilo, which is not connected to the Namibian national grid. There are however, plans to build a higher voltage line from the Livingstone Power Station at Victoria Falls to Katima Mulilo, which could be connected to the Namibian grid in future.

The PEA report also provides a discussion on the potential of alternative energy sources to meet the local and national demand for power in Namibia.

4 LEGAL AND POLICY REQUIREMENTS

While the Environmental Management Bill is still in draft form, the EA process in Namibia is driven by the Environmental Assessment Policy (1994). This PEA fulfils the requirements of the Policy and the provisions contained in the draft Act.

The PEA report contains an extensive review of the legal and policy framework in Namibia which governs this hydropower project. In terms of the existing legislation, the Constitution of Namibia, the Water Act (54 of 1956), the Forestry Act (12 of 2002), the Nature Conservation Ordinance (4 of 1975) and the Inland Fisheries Act (1 of 2003) all have relevance in terms of the proposed project.

It is also prudent, when considering a long-term project such as this, to consider the legal implications of future legislative requirements. Of relevance here are the: Environmental Management Bill, the Pollution and Waste Management Bill, the White Paper on National Water Policy for Namibia (2000), the draft Wetlands Policy (2003) and the Water Resources Management Bill (2001). The final designs and management plans for this project should conform with these proposed requirements, which may include *inter alia*, the need for permits, licences or authorisations. It should also be noted that the Okavango River from Mukwe to Popa Falls is recognised in the Draft Wetlands Policy (2003) as an area of high conservation importance. This area satisfies several of the criteria for Ramsar status.

Of equal importance for this project which may have far-reaching consequences across the national borders into Angola and more importantly, Botswana, are the obligations of the Namibian government to uphold the provisions of the various protocols and conventions to which it is a signatory. These include:

- The SADC Protocol on Shared Watercourse Systems. Under this protocol an inter-basin management committee, known as OKACOM was set up between Angola, Namibia and Botswana. The primary aim of OKACOM is for the respective governments to collaborate on international matters pertaining to the Okavango River and Swamps;

- The UN Convention on the Non-navigable Use of International Watercourses;
- The International Convention on Biological Diversity;
- The Convention on Wetlands of International Importance Especially as Waterfowl Habitat (known as the Ramsar Convention). The Okavango Swamps have been proclaimed as a Ramsar Site under this convention.

5 THE PUBLIC PARTICIPATION PROGRAMME

Eco.plan undertook a Public Participation Programme (PPP) in Namibia, while Ecosurv undertook a parallel programme in Botswana. Public meetings were held in Maun, Xaxanaka, Windhoek, Divundu and Rundu, and consultations were held with the authorities. A summary of issues and concerns was circulated to all interested and affected parties. These concerns have been addressed at a level appropriate to a Preliminary Environmental Assessment. They included bio-physical and socio-economic impacts, the planning process, and alternatives to the project.

The project faces considerable opposition, particularly from the public in Botswana. Concern about the Okavango Swamps has also been expressed in Namibia, South Africa and overseas. In Namibia concern also focused on the impacts on unique habitats affected by the weir impoundment, community based tourism projects, resettlement and its effect on subsistence livelihoods, and the effects on the project of changes in the catchment in Angola and Namibia.

6 THE PROJECT ENVIRONMENT

6.1 Climate

The Popa Falls area has a warm sub-tropical climate with summer rainfall. The rainfall averages 550 to 600 mm/year but is highly variable and unreliable. Evaporation is high, ranging from 1,820 to 1,960 mm/year. Climatic variation tends to be cyclical, with an 18 year oscillation in rainfall. This must be considered in the assessment of environmental impacts and project design. Measurements and predictions based on short term studies must be interpreted with caution.

6.2 Geology, Soils & Topography

The catchment of the Okavango River is composed mainly of deep Kalahari sands, extending far into Angola. Soils along the river are derived from these sands. The most fertile soils are close to the river, where the increased clay content improves water retention and fertility.

The topography of the Popa Falls area comprises dunes that have been stabilised by vegetation. Extensive floodplains are common on the Okavango and Cuito Rivers but the section from the Angolan border to Popa Falls is an exception. Here the river has incised into the dunes, and ridges of quartzite have been exposed forming many rapids, pools, and braided channels.

Below Popa Falls the valley flattens out and extensive floodplains occur, marking the transition to the "Panhandle" of the Okavango Delta. Here the channels become lined with

vegetation such as Papyrus and these channels leak water continually into the back swamps, so that the channels become more numerous but narrower downstream.

6.3 Tectonic Activity and Seismicity

The Okavango Delta and Panhandle have been formed by faulting and tectonic activity. Seismic data in the Delta for the period 1951 to 1992 shows that a total of 109 seismic events exceeding a magnitude of 2.7 were recorded. The highest magnitude was 6.7 on the Richter Scale. Popa Falls is approximately 50km from this zone. A seismic risk assessment is recommended to confirm that the proposed weir would not be affected.

6.4 Flora (Terrestrial)

In the **impoundment area**, while many of the species are common to southern Africa, the particular plant communities in the riverine habitats are unique within a Namibian context. The islands in the Mukwe - Divundu area are particularly important for conservation. The three habitats that are particularly important for biodiversity are: -

- **Terminalia sandy islands:** unique assemblages of large trees on residual dunes,
- **Depositional islands:** alluvial deposits, often on quartzite bases. These support very different vegetation types on more clayey soils, with species often found in the riparian fringe forests. A number of restricted range species occur, including several orchids.
- **Riparian fringing forests** are scarce and threatened. Much of it is already degraded through clearing for subsistence agriculture, but there are still mature tracts of woodland left near Andara, and on the east bank.

At least 5 Red Data Species of plants have been recorded within the Mukwe – Divundu area on islands and riverine fringes, in particular several species of ground orchids. Namibia's only species of Protea may still exist here but has not been recorded since 1986.

In the **areas downstream from Popa Falls to Mohembo** two other vegetation types occur: -

- **Sandbars and Islands** support reeds and patches of woody vegetation. There are no plant species of any conservation concern, but the habitat is important for breeding birds and reptiles.
- **Seasonally inundated grasslands/wetlands** are common in the Mahango Game Park area. There are many types of moist grasslands and wetlands here. There are few plant species of conservation concern, but the seasonal floodplains are extremely important habitats for numerous species of mammals and birds.

6.5 Fauna (Mammals, Reptiles & Amphibians)

The area is rich in mammals, reptiles and amphibians: 38 species of frogs, 75 reptiles and 124 mammals, are known or expected to occur within the project area. Of these fauna, 10 species of frogs, 8 reptiles and 18 mammals are dependent on the current array of wetland habitats. Over 90% of these species are of national conservation concern. This figure reflects the high vulnerability of wetlands, as well as the rarity of this habitat in Namibia.

The rock outcrops, both terrestrial and aquatic, are especially important due to their scarcity in this region, and because they produce the rapids in the area. Rupicolous substrates, in general, are habitats of high endemism in Namibia.

6.6 Avifauna

The Mukwe - Mahango area supports the highest diversity of birds in Namibia with over 450 species. It is recognised as one of Namibia's most important biodiversity hotspots for birds.

At least 5 Red Data species are known to occur in the **riverine forests and rocky rapids** along the stretch of river that might be affected by an impoundment.

A further 12 Red Data species occur in the **floodplains, moist grasslands and sandbanks downstream**. The listed species include two that are globally threatened, and two that are threatened in Africa.

6.7 Aquatic Ecosystems

Fish species in the Okavango River are diverse and abundant as the river provides a wide habitat diversity. Some 71 species have been recorded in Namibia. Some of these are sufficiently generalised to survive impoundment, whilst others with more specific habitat requirements such as vegetation, rocks, and pools would die out. The seasonal floods are known to directly stimulate spawning, where wetlands provide safe nursery areas. Of particular importance are the rocky habitat specialists living in the reach from Mukwe to Popa Falls - mainly small clarids or catfish. Ten such species occur in this area, including two Red Data species, while a third species is considered vulnerable because of the scarcity of such habitat.

The local **aquatic invertebrates** and their ecological requirements are not well known and require further study. Forty of the insect species listed occur only on the Okavango River. More research has been done on the **snails** of the Okavango River, particularly those of medical or veterinary importance. One species of snail is thought to be endemic to this river, being found only at Andara and Popa Falls.

6.8 The Okavango River

The Okavango and Cuito Rivers both rise in the Angolan highlands and join about 80km upstream from Mukwe. Rainfall in Angola occurs between December and March, but peak discharge only occurs at Mukwe around April. Namibia, with much lower rainfall, contributes almost no runoff to the Okavango River. The mean annual discharge at Mukwe is about 9,585 Mm³/year. Overbank flooding into adjacent wetlands, is more or less an annual event. Annual hydrographs for Mukwe are highly variable, particularly for the annual flood period. From 1968 to 1998 the range in mean monthly flow velocity was 0.23 m/s (November) to 1.41 m/s (April). The rate of change of water level in the Mukwe – Divundu section is very gradual, typically 1 – 2 cm/day up to about 7cm/day. It is ecologically important that the project should not cause fluctuations in water level that exceed the natural rate of change.

Up until now, the catchment of the Okavango River in Angola has been altered very little by human activities, but in Namibia, much of the riverine forest has been destroyed for slash and burn agriculture or commercial irrigation projects, leading to some increase in turbidity in recent years. Nevertheless, the waters of the Okavango River are good quality, clear, well-mixed, well-oxygenated, typically soft with very low conductivity and low total dissolved salts. Recorded chemical and nutrient concentrations are low.

6.9 Sediment Transport Investigations

Many years of research by the Okavango Research Group, WITS University, (1986–1998) have shown that sediment is an important driver in the geomorphological and ecological functioning of the Okavango Swamps (Ellery *et al* 1993). For this pre-feasibility study, the estimates of sediment transport obtained from the literature were not sufficiently site-specific and therefore additional on-site measurements were taken at a DWA monitoring site just downstream from the Divundu bridge. From observations of the river it had been observed that under normal flow conditions, sediment is primarily transported as bedload, moving in a series of dune forms. Under these conditions, and given the extremely low clay and colloidal matter in the water column, suspended sediment appears to be very low. It is not yet known what the critical limits for suspension of the bedload are.

Suspended sediment was measured in June 2003. It ranged from 0.0002 g/litre at 2m above the riverbed to 0.0095 g/litre at 0.2m above the riverbed. Total suspended sediment load (fine sand, excluding organic matter) was calculated at approximately **24 m³/day**.

Bedload sediment transport using the Helley-Smith sampler has been undertaken by McCarthy *et al* (1991, 1992) in several studies in the Okavango Delta and Panhandle. They established a relationship between flow velocity and bedload discharge: $Q = 0.154 U^{3.4}$ (where Q is bedload discharge in kg/m/s and U is average flow velocity in m/s.) The same method was used at Divundu. Bedload transport was measured at **197 m³/day** at the time (McCarthy, April 2003). Based on the 30-year records of monthly flow velocities at Divundu, it was estimated that the average bedload discharge was approximately **70,000 m³/year**.

The Council for Geoscience also measured bedload sediment transport at Divundu using **side-scan sonar, high-resolution bathymetry** and a highly accurate positioning system (Coles, April 2003). Bedform dunes reached a maximum height of 1.07m, and wavelengths of 10 to 17 metres. Accurate measurement of transport could only be made over a 22m width of channel with prominent dunes. Transport here averaged 0.6869 m³ per metre of dune front in 24 hours. Extrapolating to the full width of the channel (where conspicuous dunes could not be imaged) introduced some inaccuracies. The total transport was estimated at **113 m³ /day** at the time of the study (April 2003). Annual estimates could not be made as no relationship has yet been established between sediment movement measured by sonar and flow velocity.

A number of general conclusions were made about sediment transport.

- Accurate measurement of bedload transport is notoriously difficult. This means that the figures provided should be used or interpreted with great caution.
- The sediment load of the river consists mostly of fine sand, ranging in size from 0.25mm to 0.43mm. The sand is transported primarily as bedload in the form of dunes.
- Concentrations of clay and organic matter are very low, so the water is clear. However this material accumulates in pools and reedbeds and is probably important for nutrient supply.
- The Helley-Smith sampler has produced reliable results in the past but is difficult to calibrate. The sonar side-scan and bathymetry is accurate where substantial dunes are evident, however, interpolation across parts of the channel that have no prominent dunes is difficult. It is therefore recommended that both Sonar and Helley-Smith methods should be used in any future studies in order to cross-correlate results.
- A considerable amount of further work is required to obtain reliable estimates of sediment volumes and transport mechanisms under various flow conditions.

6.10 The Ecological Importance of Sediment Accumulation in the Okavango Delta.

The Okavango River and Swamp system is extremely unusual in global terms. Virtually the entire catchment and Okavango Delta is underlain by quartzitic Kalahari sands. This results in the river's load being primarily fine sand, with little clay or silt in suspension, and low nutrient concentrations. The Okavango Delta is essentially a closed hydrological system, with most (98%) of the water being lost to the atmosphere by evapotranspiration. The Delta wetland has evolved around these unusual conditions. Notwithstanding the high evaporation loss, saline surface water is rare. The Delta exhibits immense habitat and biological diversity. Sediment transported to the Delta plays a pivotal role in maintaining this diversity and reducing the impact of the high evaporative loss. The role of sediment is explained as follows.

In the Panhandle of the Okavango Delta, the river divides into a number of distributaries, which spread water across the fan. Channel banks are formed by aquatic plants growing on a substrate of peat. The channel margins therefore leak water continually into the surrounding wetlands. As the annual flood rises the seasonal wetlands also become inundated. Virtually all of the river's load is deposited in the Delta, as detailed below.

Suspended silt, mud and organic material, available at low concentrations, accumulates in the wetlands, forming a component of the peat that underlies the aquatic vegetation.

Dissolved salts are accumulated in the permanent and especially the seasonal wetlands, yet saline pans are rare. There is a complex and intricate relationship between salt build up on the islands and the regular failure of channels.

Fine sand is transported as bedload in channels. The channels leak water, and become progressively narrower downstream. Bedload accumulates on the channel beds, while the flanking vegetation accumulates upward so that channel depth remains unchanged. Thus, the entire channel and its flanking wetland is slowly elevated above the surrounding wetlands. In time, the channel fails, water diverts to form new channels and former wetlands become dry. The peat catches fire and slowly burns down, releasing nutrients, organics and clays. Nutritious grasslands result, which support high game populations. Over time, the nutrients are dissipated and the nutritional quality of the grasslands declines. Thus, through the process of channel aggradation and failure, ecosystems are continually renewed. It is this constant change which is responsible for the immense biological diversity of the Okavango Delta.

Thus the sediment load, and particularly sand, is absolutely vital to the ecological functioning of the Okavango Delta.

6.11 Socio-economic and Political Environment

About half of the 201,000 people in the Kavango Region are rural dwellers. Most live along the Okavango River. Over 50% of households have no cash or wage incomes, but for some households government pensions make a small contribution. The dependency ratio is high (52%) due to a high proportion of young people. Electricity is likely to remain unaffordable for most people. There is a high incidence of disease in the Kavango Region with AIDS and malaria being responsible for most deaths.

There are two main ethnic groups in the project area. The majority language group is the Kavango – Mbukushu people, and the minority San – Khwedam group. There are various traditional leadership systems and land tenure systems. The local leaders play an important role in the allocation of land and grazing rights, and settling disputes. Much of the land is communal, but some is exclusive. Since authority structures and land tenure systems are complex, issues such as resettlement and compensation may be complicated.

The economy of the Mukwe - Bagani area is based mainly on subsistence agriculture, grazing (especially cattle), and fishing. Subsistence fishing is important in the diet in Namibia and Botswana. Along the Namibian reaches, some 35 – 55% of households catch fish. Wood is extremely important for building, heating and cooking. Reeds, thatching grass, roots, palm leaves, and grasses are also used for household items and souvenirs. Wild fruits, berries and mushrooms are also used. Thus the local people are highly dependent on natural resources.

Alternative incomes such as employment through tourism are potentially important in this area. Tourism is the fastest growing economic sector in the world and in Namibia, where its value increases by 8-10% per year. Tourism is Namibia's third largest industry and second largest earner of foreign exchange. Namibia's tourism sector is based on its unique natural environments, large unspoiled areas, the diversity of interesting wildlife, and majestic scenery. Tourism in the Kavango and Caprivi regions has recently increased markedly and has great potential, including community-based tourist ventures. There are currently six lodges between Divundu and Mohembo, and two campsites. The area near Andara is still largely unspoiled, particularly the islands, and has considerable potential for tourism. There are four protected areas located near Popa Falls, which are proposed to be merged to form the Bwabwata National Park. There will be scope for community based tourism here.

The Ministry of Agriculture plans to develop a number of irrigation projects along the river between Rundu and Divundu – ultimately totalling 8,563 ha. When fully developed, the combined water demand will be 128,445,000 m³/annum (1.34% of the average annual discharge to Botswana). One of these projects is proposed east of the river near Mukwe.

There is limited potential for forestry in the Kavango Region. Of the 57 potential timber species, two can be utilised sustainably (on a 100 year rotation). The use of timber is currently not organised, and there is no active protection of this resource.

With a few exceptions, the Kavango and Caprivi Regions are almost devoid of manufacturing. A few exceptions include woodwork/furniture products, maize mills and bakeries. Carving and home crafts have a potentially good market with tourism. The development of industry is hampered by distance from markets and sources of raw materials. Agricultural potential is limited, but forestry products could be worked in this area. Tourism probably offers the greatest potential for sustainable development in this area.

7 PRELIMINARY ASSESSMENT OF ENVIRONMENTAL IMPACTS

7.1 Introduction and Assessment Criteria

The key environmental issues were assessed, based on the nature, extent, duration, intensity, and probability of occurrence. The significance of each impact was determined as a synthesis of the above criteria. A **low** significance means that the impact would not affect a decision to approve the project, or the particular project alternative. **Medium** significance means that the assessed impact should have an effect on the decision unless it is effectively mitigated. A **high** significance means that an impact should affect the decision regardless of any mitigation, or where a serious impact cannot be mitigated.

For many environmental aspects, the nature of impacts has been identified, but further investigation has been recommended to determine their magnitude.

7.2 Assessment of Bio-Physical Impacts

Zero Water Abstraction

The project would not involve any abstraction of water.

Evaporation and Seepage

It was estimated that the impoundment would lose 4,8 million – 6,3 million m³/year through additional evaporation as a result of the increased surface area. This amounts to 0.050% to 0.066% of the mean annual discharge of the river at Mukwe. This impact is considered to have a **low** significance. It is possible that seepage into the Kalahari sands may be increased and this needs to be quantified. The volume of increased seepage is unlikely to be significant on its own. However, the cumulative impacts of water loss and abstraction in the long term need further investigation.

Impacts on the Hydrograph: Operation at Full Supply Level After One-off Filling

At no stage will the flow of the river be completely interrupted. Since there is no diversion of water from the river and no significant storage, impacts on the hydrograph will be minimised. The volume of the impoundment represents only 0.17% - 0.25% of the mean annual discharge. After construction, it will take 5 – 15 days to fill the impoundment at flow rates of 200 to 400 m³/s if only 10% of the flow is held back. In terms of the hydrograph, it is recommended to fill the impoundment during the high flow season.

The weir will be operated at full supply level most of the time. As the flood declines, gates will be closed one by one to maintain the full supply level (FSL). This will result in a slight lag in the hydrograph. However, because the volume of the impoundment is small in relation to the total flow, the impact on the flood hydrograph would be small. Even when all the gates are closed, the full flow of the river will still be going through the turbines in the weir.

The effect on the hydrograph of a one-off filling and operation at full supply level is considered to be of **low** significance, if it takes place during the high flow season. The rate of change in the water level should not be allowed to exceed the natural rate of change in water level.

Impacts on the Hydrograph: Annual Sluicing of the Impoundment to Remove Sediment

In view of the importance of sediment for the functioning of the Okavango Swamps, two methods of sediment transfer from the proposed impoundment have been identified in the technical study: annual sluicing and bypass pumping.

If the impoundment is sluiced annually to remove sediments, then the rate of draw down and refilling would lead to greater impacts on the hydrograph than those discussed above. Sluicing involves lowering the water level by opening the gates fully for 4-6 weeks during the peak flow. During sluicing no power can be generated, therefore, it would be necessary to lower the water level as fast as possible and refill quickly after sluicing to minimise power generation losses. It was estimated that the water level would change as much as 10 times faster than the natural rate of 1-7cm/day. This is considered to be a **highly** significant impact. Further investigation of the impacts on the hydrograph is recommended.

Impacts on the Hydrograph: Pumping of Sediment

Continuous pumping of sediment past the weir would have no significant impact on the hydrograph.

Impacts on the hydrograph: Possible Daily Variation in Water Levels

On the Cunene River the Ruacana Hydro Power station, causes two daily peaks in water level, resulting in serious impacts on invertebrates along river margins. However, the Popa Falls Hydro Power Project is a run-of-the-river scheme and operation to meet daily peak demand is **not possible**. Therefore unnatural daily fluctuations in water level **will not arise**.

Impacts on Sediment Transport: Deposition in the Weir Impoundment

When the river flow velocities drop on entering the still waters of the impoundment, it is expected that the suspended load will settle out and that the bedload movement will stall, thus resulting in deposition of sediment at the head of the impoundment. In the absence of active intervention to get sediment through the weir, bedload sediment will accumulate until an equilibrium state is reached. Thereafter, sand will again pass through the weir at its natural rate. Estimates of the time taken for this equilibrium state to be restored range from 110 to 230 years. Unless steps are taken to mitigate this, it will have several negative consequences downstream.

Impacts of Sediment Impoundment: Erosion of the River Bed Downstream

While the sediment is held up in the impoundment, the water flowing over the weir will contain very little sediment. This "sediment hungry" water will be highly erosive for some distance downstream until a new dynamic equilibrium in terms of sediment load has been reached. This could have an impact on the depth of the river, the banks and the sandbars in the river reaches downstream of the weir. The time and distance required to reach a new state of equilibrium needs further investigation and modelling.

To the extent that channel deepening occurs, overbank flooding through the **Mahango area** would be reduced, both in extent and frequency. This could result in the drying out of the floodplains, with severe negative impacts on certain species of mammals, fish, birds, and amphibians.

The **Panhandle and Okavango Delta** may become deprived of bedload sediment. This would result in channel deepening and the duration of the life of channels could be extended, with the result that permanent wetland in the upper Delta could be lost. The essential natural process of channel failure could be prevented for many years. Reduction in the rate of channel switching could result in stabilisation of plant communities, preventing ecosystem renewal, and habitat diversity would be reduced. It will probably be several decades before numerical models of the Okavango Delta become possible, enabling these impacts to be quantified. In the interim, only qualitative assessments of impacts can be made.

The impact of sediment accumulation in the weir impoundment must therefore be considered as a **potential fatal flaw**. However two possible mitigation measures have been proposed. The effectiveness of the proposed measures to get sediment through the weir still needs to be determined. WTC has proposed to undertake computer and kinetic modelling in the full Feasibility Study. However, the proposed mitigation measures themselves will cause certain adverse impacts, which are explained below.

Bio-physical Impacts of Sluicing

Sluicing involves opening all the weir gates during the high flow period each year. Assuming that sluicing can be made highly efficient, certain negative environmental impacts will result: -

- Firstly sand would be eroded from the channel downstream for 10½ to 11 months of the year. This could potentially cause the loss of sandbanks used by breeding birds.
- The release of 10½ to 11 months of accumulated sediment in 4 – 6 weeks, would probably result in deposition of the sediment downstream. How this sand would subsequently be redistributed would require modelling. It is likely that the channel below Popa Falls would become choked for a time, while sandbanks further downstream would be eroded away.
- Benthic fauna in the sand would be smothered by the release of sediment from the impoundment. The ecological impacts up the food chain are uncertain.
- Decay of organic material in the accumulated sediments in the impoundment may lead to depletion of oxygen in sediments, and the production of various gases. The release of the products of decomposition in concentrated form may have adverse ecological impacts, possibly even causing fish kills.
- Although in low concentrations, some of the clay-sized particles will settle in the impoundment. During sluicing this material will be released in abnormal concentrations—with further negative impacts on water chemistry, and turbidity.
- To the extent that sluicing affects the hydrograph there may be negative ecological impacts—e.g. on fish breeding, which is triggered by hydrological factors, changes in water temperature, or chemistry. Therefore, sluicing would involve significant ecological risks.
- Unnaturally rapid draw down of water level is expected to cause erosion around the perimeter of the impoundment and sandy islands. This risk needs to be further assessed.
- Sluicing would have to be continued indefinitely after decommissioning of the power plant, unless the weir was removed.

Although the magnitude and extent of these impacts needs to be determined, it is clear that sluicing will carry ecological risks that are considered to be **highly** significant. Moreover, there are likely to be additional ecological impacts that cannot be predicted. **Sluicing is therefore not recommended.**

Impacts of Pumping Sediment

Sediment would be captured as it enters the weir impoundment and pumped continuously to the downstream side of the weir, where it will be released. Assuming an efficiency close to 100%, pumping would have a number of advantages over sluicing:

- It would reduce or eliminate most or all of the negative impacts of sluicing listed above,
- Less organic matter and clay particles would be deposited in the impoundment, which may be important for the Okavango Swamps,
- Power could be generated throughout the year with no "down time" - so the economics and continuity of supply would improve,
- Less wear and tear on turbines due to less sand passing through them,
- Opportunity to determine the volumes of transport with greater accuracy on an ongoing basis. This would make a contribution to science and future studies on this river.

The negative impacts of pumping are considered to be of **low** significance. However, the effectiveness of this method still needs to be determined.

The disadvantages of the pumping option are: -

- The onus will be on the power station operator to avoid any interruption in sediment pumping. A back-up system for pumping would be essential.

- Sediment pumping would need to continue indefinitely after decommissioning, unless the weir was removed.

Impacts of Inundation of Islands and Riverine Forests

Some 4.0 km² to 5.3 km² of terrestrial habitat will become permanently inundated, depending on the weir site chosen. The areas inundated comprise extremely important habitat: riverine forests, island forest, and rocky riverbeds. Approximately 29% to 30% of the forested islands will be inundated at full supply level at weir sites 4 and 5. Die off of trees along the margins of the impoundment would also contribute to erosion as the roots stabilise the banks.

Impacts on Vegetation: Impoundment and Upstream Areas

There are five categories of vegetation that would be affected by the weir impoundment. The most negatively affected will be the *Terminalia* sandy islands, depositional islands, and riparian fringing forests. These habitats are unique in the Namibian context and on the Okavango River. Large portions of these habitats will be destroyed. The dry quartzite ridges, and upslope Kalahari sands will be less affected.

While the island- and riverine- plant communities are considered to be more important than individual species, several Red Data species that do occur in the affected area, are also of concern. The exact distribution of these species will require further investigation in order to quantify the impact on these species. However, it must be emphasised that the local loss of a rare species is not the only issue as rare species may contribute little to ecosystem functioning. It is the loss of habitats that is of greatest significance in this case.

The loss of island habitats and riverine forest is regarded as **highly** significant due to the substantial loss of unique habitat, and probably some Red Data species of plants as well.

Potential Introduction and Spread of Alien Aquatic Weeds, or Reeds and Papyrus

Alien aquatic weeds have been a major problem in dams in southern Africa, and there is the risk of introduction of these aliens on boats trailers, vehicles etc during construction or operation. If introduced, alien plants could spread to the Delta where they present a significant ecological threat and would be very expensive to eradicate. This impact has a low likelihood of occurrence, but the consequences are potentially serious. This impact is considered to be of **medium** significance as ongoing management is possible to prevent infestation.

In the case of pumping sediment, a sediment trap would be built near the inflow to the impoundment. If sediment were allowed to accumulate, over time this area would get shallower. This creates the potential for Papyrus and Phragmites to become established, which may encroach on the sediment trap. This is considered to be of **low** significance, but dredging and maintenance of this small part of the impoundment may be required.

Impacts of Flooding / Probable Maximum Flood (over and above the FSL)

The weir will influence the extent of the Probable Maximum Flood (PMF). WTC calculated the PMF as slightly less than 3000 m³/s with a return period of 1000 years. The water level during the PMF would be 0.75m above the top of the weir gates if the gates were fully closed. By comparison, the normal water level during operation will be 0.30m above the top of the weir.

The upstream extent of the weir's influence on the PMF is only slightly upstream of the full supply level. In the case of Weir Site 2 the PMF extends to about 2km above Frans Dimbare Youth Centre. For Weir Sites 4 & 5 the PMF would extend to a point just downstream from

Andara. The significance of the PMF, relative to the FSL requires further investigation. The only mitigation possible is to reduce the weir height.

Impacts of Possible Permanent Diversion for Operation of the Project

The WTC Technical study, (November 2003) found that the cost of diversion canals was not justified by the additional power generation. The diversion option is therefore **not proposed** and has not been assessed in the PEA report.

Possible River Diversion During Construction

Weir site 4 lends itself to a temporary diversion, to facilitate construction, due to the existence of a normally dry channel. Further assessment of this option is recommended in the full EA.

Impacts on Vegetation Downstream of the Weir and Popa Falls

Certain habitats along the river downstream of Popa Falls could be impacted by some of the project alternatives. The **sandbars** and **islands** have no plant species of any conservation concern, but they represent important breeding habitat for birds and reptiles. The **seasonally inundated grasslands/wetlands** support few plant species of conservation concern, but they represent some of the most important habitats for numerous species of mammals and birds. Any loss of these habitats as a result of scour and reduced flooding would result in major changes in the ecological functioning in the Mahango Game Park and the areas on the opposite bank. This would also have a significant impact on numerous reptiles, birds and mammals, many of which are Red Data Species.

The significance of the potential impact on wetlands in Namibia is rated as **medium**, because there is a possibility that the sediment problem can be solved by bypass pumping. In that case, the risk to wetlands would be decreased substantially. Should mitigation of sediment transport be less than optimal, the impact would have a high significance.

Okavango Swamps

McCarthy (2003) has provided a concise account of the potential impacts of the project on the Okavango Swamps. The role of sediment transport is critical to the geomorphological and ecological functioning of the Swamps. If sediment was trapped behind the weir, or mitigation measures failed or were inefficient, the following impacts could be expected in the Okavango Swamps:

- Channels would become deeper instead of aggrading as a result of the accumulation of fine sand on the channel beds,
- Channels would therefore remain for longer and channel failure would decrease,
- Since channel failure leads to redistribution of water across the swamps, this redistribution would be arrested,
- Terrestrial ecosystems would approach a climax status and ecosystem renewal would be prevented,
- Areas of the swamps would become salinised to toxic levels and die off.

In summary, constant change is the key to the bio-diversity and ecosystem renewal in the Swamps. The changes are driven by the supply of sediment. It is therefore essential that the sediment supply should not be interrupted. Thus a solution to the efficient and continuous transport of sediment past the weir is central to an assessment of the impacts on the Swamps.

Two other issues also need to be better understood: -

- Fish migrations: to the extent that the weir and its impoundment are an obstacle to fish migration, the Swamps could be adversely affected.
- Deposition of some of the clay and organic matter in the impoundment may be important in this nutrient-poor river system.

A full assessment of impacts on the Okavango Swamps can only be undertaken once the above-mentioned issues have been further investigated. The potential impacts in Botswana should be regarded as **highly** significant until it can be shown with a high degree of confidence, that the impacts on sediment transport, water quality, nutrients, and fish migrations can be mitigated effectively.

Impacts on Fauna (Mammals, Reptiles and Amphibians)

There are four types of habitat that will be affected by the project: -

- Rocky rapids reaches of the river will be inundated,
- Rocky koppies may be affected by quarrying for stone,
- Downstream of the weir the river course may become deepened and rocky sections more exposed (depending on sediment transport issues),
- Through the Mahango Game Park, channel deepening, if it occurs, would lead to drying out of the floodplains.

At this stage it is not possible to make a comprehensive assessment of all the fauna that will be affected by the project, but an inventory of the species known or expected in the area has been established. Species such as crocodiles, terrapins and otters may be affected, as well as others that are dependent on the aquatic/terrestrial interface. The impoundment may benefit Hippo, Cape Clawless Otter and Terrapins. However, the vulnerable Spottednecked Otter, which requires near-pristine habitat, may be adversely affected. The Three-toed Sengi is a species of national and global conservation concern, which may occur on the east side of the river in riverine vegetation/forests. The presence of this species within areas to be flooded could be considered to be a fatal flaw in some options of this development.

If erosion and channel deepening occurred downstream of the weir, then there may be significant negative impacts on all wetland species to a greater or lesser extent. Therefore, the natural seasonal flood regime of the river must be maintained at all times.

The river is a “linear oasis” that enables migrations of fauna between Angola and Botswana. In particular, aquatic fauna and species dependent on riverine vegetation must be able to pass through the weir area, and vegetated riverine corridor.

Detailed assessment of the impacts on fauna will be required during the full EA.

Impacts on Avifauna (Birds)

Of the 450 species in the area, only the impacts on Namibian Red Data species were assessed.

In the impoundment area, three species may benefit (two pelicans, and fish eagles). However, at least five Red Data species would be negatively affected by the loss of woodlands, islands, river margins, and the rocky rapids. These include the Rock Pratincole and Pel’s Fishing Owl.

If the wetlands/floodplains/moist grasslands, islands or sandbanks downstream are affected, then a further 12 Red Data species would be adversely affected. At least two of these are

globally threatened - the Slaty Egret and Wattled Crane. Two others are threatened in Africa – the White-backed Night Heron and Saddle-billed Stork.

The significance of this impact on birds is rated **high** for the impoundment area as a substantial portion of available habitat will be lost, and there is no mitigation possible – except to reduce the height of the weir.

In the downstream areas the impacts will depend on the solution to the sediment transport issue. Since a solution seems likely at this stage, the significance is rated as **medium**. If the sediment transport issue can be solved at a high level of efficiency and reliability, then there may be no significant impact on the floodplain species.

Impacts on Water Quality

During **construction**, there is the potential for pollution from fuels, oils, hydraulic fluids and possibly products used for sealing, but these impacts can be prevented. Disturbance of the riverbanks, reedbeds and forests will increase turbidity and may have certain short term impacts on water chemistry. The area to be inundated will have to be cleared of vegetation, otherwise eutrophication could occur in the impoundment.

During **operation**, various impacts on water quality are normally associated with impoundments. Decomposition of organic matter leads to high oxygen demand in sediments. Nutrient balances are altered and water temperature may be affected. The accumulation of clay and organic material in the impoundment may affect water quality and nutrient levels. This may be aggravated by the proposed agricultural projects along the river. To the extent that clays and organics are deposited in the impoundment, this would reduce the nutrient levels available to the floodplains downstream. Changes in water chemistry, dissolved gases, or temperature may affect biological processes in the river. Sluicing would aggravate the impacts on water quality and is not recommended. A more detailed assessment of water quality issues will be needed in response to further details on the operation of the weir.

There is little chance of pollution from the hydro power turbines or other installations during operation. However any potential for pollution by fuel and oils from vehicles, boats or storage facilities must be controlled through an Environmental Management Plan.

Ongoing monitoring of water quality changes associated with the project is recommended.

Impacts on Aquatic Ecosystems

The potential for impacts on the aquatic ecosystems arises from:

- Any significant perturbations to the flow hydrograph,
- The change from fast flowing shallow water to a slow flowing deep water environment,
- Loss of particular riverine habitats, erosion of sandbanks, loss of overhanging vegetation etc in the impoundment zone,
- Disruption of fish migrations due to the weir and the habitat barrier created by the impoundment itself,
- Changes in water chemistry, or possibly temperature.

In the impoundment area, the variety of riverine habitats, which allow for great diversity of plants, animals and fish, will be reduced. Many habitats associated with rocky rapids, island fringes, riverbank reed-beds, papyrus fringes, riparian woodlands, riffles and a variety of river microhabitats will be lost. The reduction in habitat diversity will cause a reduction in biodiversity over a linear distance of some 12 km. The species most vulnerable are the habitat specialists, and those that are dependent on the annual flood for successful reproduction,

whilst the more tolerant species with a wider range of habitats and feeding requirements would adapt. Not only will fish species diversity be reduced, but also the diversity of aquatic invertebrates. Of particular concern are the swift-flowing **rocky rapid** habitats. Two rare species are found only in rocky rapids, and these will probably not survive in the impoundment.

If sluicing is practised, there is an added risk that benthic macro-invertebrates on the downstream river bed could be smothered by the silt released from the weir.

In the Botswana section of the river, the most important factor determining fish productivity is thought to be the nutrient pulse that results from the seasonal floods. This nutrient pulse would be substantially disrupted by sluicing. If sediment pumping is practised instead, this impact will be reduced, but the impoundment will still retain some clay and organic matter.

Any significant perturbations in the hydrograph may trigger unseasonal fish migration or lead to impaired breeding.

The weir will be a barrier to fish migration and, as migration is often a response to breeding requirements, this could lead to reduced reproduction in the floodplains. The provision of a fish by-pass could mitigate this impact, but this would need to be designed to simulate the natural conditions of pools and riffles. Further investigation will be required to design a fish by-pass, based on knowledge of each migratory species.

During the construction phase, certain additional impacts could arise. These would include diversion of water around the construction site, increased silt load and turbidity, smothering of benthic organisms, and possibly blasting – which can lead to fish kills.

In summary, the potential impacts of the proposed hydro power project and weir will be most severe in the impoundment area as a result of the loss of habitat diversity. Depending on the operation of the scheme, there may also be downstream impacts. Should fish migration be affected, these impacts will extend upstream as well. Any changes to the magnitude, timing and duration of seasonal floods, or significant changes in water quality parameters will have an impact on river ecosystems, productivity and biodiversity.

The impacts on aquatic ecosystems have the potential to be significant and far-reaching. Although many of the impacts can be mitigated through careful design and operation of the scheme, the project will always carry significant risks in terms of ecological impacts as the available knowledge of these systems is not comprehensive.

Quarrying of Construction Material

Quarrying from the quartzites has the potential for impacts on plants, small animals and possibly fish, and will need to be assessed once sources of material are identified.

7.3 Assessment of Socio-Economic Impacts

Impacts on Subsistence Livelihoods

The local people rely heavily on natural resources. Although the people are poor, they enjoy a certain quality of life that could be threatened by relocation. Between 80 and 260 households will have to be relocated, depending on the choice of weir site. The World Commission on Dams has shown that displaced people have often suffered a number of negative impacts, but seldom share in the benefits of dams. The negative impacts would include loss of fertile plots, reduced grazing land, reduced forest resources, and potential for reduced fish resources.

It is normal practice in Namibia to compensate people by means of a cash payment. However, the impact of relocation of communities is far greater than a one-off financial consideration. Livelihoods may be seriously disrupted. It may therefore be necessary to engage with the community to develop economic alternatives. A full socio-economic assessment is necessary as part of the full Environmental Assessment in due course. The impact of relocation on subsistence livelihoods is considered to be of **medium** significance as it should be possible to mitigate the impacts to some degree.

Potential Diseases

The construction of dams elsewhere has often resulted in an increase in the incidence of certain diseases, due to ecological imbalances. Mosquitos may increase, resulting in increased incidence of malaria. The change from fast flowing water to a still water habitat has the potential to increase the incidence of bilharzia. This is a major problem, on parts of the Rundu floodplain upstream. The incidence of HIV/AIDS is already high in Namibia and the Divundu area. The introduction of a large workforce from outside of the area, creates an opportunity for the further spread of HIV/AIDS to and from this area. In the case of HIV/AIDS and bilharzia education can help to prevent disease, but malaria would be difficult to combat. This issue is considered to be of **medium** significance.

Impacts on Tourism in Namibia

The main negative impacts on tourism near the weir site could be visual impacts, noise, habitat destruction, and reduced biodiversity. If sluicing is practiced, sediment accumulation below the weir could obstruct boating. Noise may be an issue during construction for the N//goabaca campsite and Popa Falls Resort. The beautiful areas near Andara have considerable potential for tourist development, especially community-based ventures. It is difficult to predict how the presence of a hydro power station would affect the perceptions of tourists, but many eco-tourists are looking for “wild” natural areas. On the other hand the impoundment could be used as a tourist attraction with boat cruises and viewing hides.

Impacts on Local Commerce, Industry and Employment

The project can be expected to have a short term positive impact on trade and commerce in the Divundu area during construction. However, once construction is complete, only a handful of people will be required to stay and operate the project. Thus there will be little direct sustainable benefit for employment opportunities. The availability of power may create opportunities for tourism, small industries and irrigation in the area. However, the area suffers from other obstacles to industrial development, and probably the greatest economic potential for the area lies in tourism.

Aesthetic Impacts / Sense of Place

The visual impacts of the weir may be both positive and negative. Depending on the choice of site, the wall itself may have a negative visual impact, but the expanse of water should be visually attractive. The switchyard and powerlines are potentially the most unsightly components. It is difficult to mitigate this impact, except through site/route selection.

Noise from the turbines during operation is unlikely to be heard at a distance above the sound of the water passing through the weir.

Popa Falls and its surroundings is not a pristine area, but it has a special character which attracts tourists. “Sense of Place” is a subjective matter, but the destruction of significant

areas of riverine and island woodlands may have a negative impact on the “sense of place” that Namibians and foreign visitors attach to this area.

Impacts on Future Conservation Potential of the Area

A number of authors and policy documents have emphasised the uniqueness of the Mukwe – Popa Falls area in the Namibian context. This area has long been identified as in need of conservation. The Okavango valley woodlands are one of the most threatened habitats in the region and are largely unprotected. It is an area of high habitat diversity, high species richness, and supports a number Red Data species of birds, fish, plants and possibly animals.

The hydro power project could have a significant negative impact on the conservation potential of the area in two ways. Firstly, the destruction of a large portion of the forest remnants would result in fragmentation, which will reduce ecological viability and biodiversity. Secondly, the hydro power project would tend to encourage the perception that the area has been degraded – which may reduce the likelihood of any further conservation initiatives being successful in this area in the future. For these reasons, the impact of the project on the conservation potential of the area is considered to be **highly** significant. However, if the Ministry of Environment and Tourism committed itself to conserving the remaining area for eco-tourism, then the significance of this impact on future conservation initiatives may be reduced.

Impacts on Archaeological and Cultural Sites

There are many undisturbed archaeological sites within 500m of the river on the east bank. These have not been surveyed due to the presence of land mines and would be disturbed by bush clearing for the impoundment, and by erosion around the margins. These sites are considered to have a **medium** significance.

The islands of Dikuyu, Thipanana and Gororo upstream of Andara have been used by the Mbukushu as burial grounds. However sites upstream of Andara will not be affected. At the northern end of Popa Falls, an archaeological site exists with Middle Stone Age and Later Stone Age deposits, but it will not be affected if there is no diversion canal.

Clearing of landmines

In the area north of the Trans Caprivi Trunk Road and east of the River, there are still unexploded landmines, which have caused fatalities in the past two years. Anti-personnel mines would float if eroded from riverbanks, and may pose a threat. The impoundment area would have to be cleared of landmines first.

Socio-economic Impacts in Botswana

Tourism in Botswana is one of the mainstays of the country’s economy and a major source of foreign exchange earnings. A large population in Botswana also practises a subsistence livelihood based on the river. Moreover, the Okavango Swamps is a Ramsar wetland of international importance. Subsistence fishing and sports fishing are both important. Therefore any negative impacts on the Okavango Swamps would not be acceptable in Botswana.

This preliminary assessment has not been able to assess the potential impacts on the swamps in detail because further investigations on key issues such as sediment transport are required first. However, the most important issues that need to be addressed in the next study phase are: -

- to ensure that sediment supply is not interrupted,
- that there is no perturbation in the hydrograph compared with the natural regime,
- to design a fish by-pass to ensure that the free passage of all migratory fish,
- to ensure that water quality is not adversely affected,
- cumulative impacts on water quality due to land use changes, agriculture and climate change,
- quantification of the cumulative impacts of water loss and abstraction from the river.

The socio-economic impacts in Botswana will depend on the degree to which the above issues can be mitigated. At this stage it is likely that the sediment transport issue can be solved, and impacts on the hydrograph would be negligible if there is no sluicing. However, issues of water quality, fish migrations, and the cumulative impacts of irrigation agriculture and water abstraction, cannot be assessed in this PEA with any certainty. The impacts on aquatic ecosystems will be the most difficult to assess with full confidence. At this stage, the significance of adverse impacts in Botswana should be regarded as **potentially high**, until it can be shown with a high level of confidence, that the above-mentioned impacts can be effectively mitigated.

Need for Socio-economic Assessment within a Cost-benefit Framework

Given the fact that there are significant ecological, and economic risks associated with the hydro power project, it is recommended that a full socio-economic assessment be undertaken in order to weigh up the benefits against the economic, social and environmental costs of the project. This study should be carried out for the affected areas in Namibia, and Botswana. Two particular aspects need to be evaluated: the economic costs to subsistence communities, and the opportunity costs to potential tourism. These environmental and social costs need to be weighed up against the economic benefits of the project.

7.4 Cumulative and Synergistic Impacts, and Issues Related to the Planning Process

It is expected that many demands will be made on the water resources of the river from Angola, Namibia and Botswana. The major demands will be for irrigation and domestic supply. Furthermore, these demands need to be evaluated against the real threat of climate change. Various scenarios should be evaluated to ensure that the hydropower project remains viable under changing circumstances.

Evaporation and seepage from the proposed impoundment will be very small by comparison, but still part of the cumulative water loss from the system. These cumulative losses could become highly significant for the Okavango Swamps, and need to be assessed, though not necessarily as a pre-requisite for this project.

The public in Botswana, through the public participation process for this PEA, called for a strategic assessment of the resources of the river. The need for such a study is justified in terms of the expected water demand alone.

8 SUMMARY OF KEY IMPACTS

In the following table, the more significant environmental impacts are summarised, and their **significance** for decisions about the project is given. Potential mitigation options and recommendations for further work are also provided.

Potential Impact	Preliminary Assessment of Significance*	Potential Mitigation Options and/or Further Studies
Interruption in the free flow of sediment downstream	Potential fatal flaw	Bypass pumping or Annual sluicing Removal of weir on decommissioning Modelling
Inundation of forested islands and riverine forest	High	Select Site 2 to minimise impact Minimise height of the weir
Inundation of rocky riverine habitats	High	Select Site 2 to minimise impact Minimise height of the weir
Loss of unique habitats and biodiversity, including Red Data species in the impoundment area (plants, birds, fish and possibly faunal species)	High	Select Site 2 to minimise impact Minimise height of the weir Detailed ecological studies in EIA Determine distribution of Red Data species
Impacts of sluicing on the hydrograph / water levels	High - Sluicing not recommended	Investigate optimum time for sluicing and ecological impacts
Impacts of sluicing on downstream ecology and geomorphology	High Sluicing not recommended	Bypass pumping
Impacts on future conservation initiatives	High	MET could proclaim / increase the conservation status of the remaining high-value area Mukwe-Popa Falls
Scour of riverbed downstream of weir, erosion of important habitat, and/or reduced overbank flooding of wetlands. Consequent impacts on, birds, mammals, reptiles & amphibians downstream	High - Low	Bypass pumping of sediment Ensure continuous supply of sediment
Bio-physical & socio-economic impacts in the Okavango Swamps, Botswana (eg subsistence fishing and tourism)	High – Low	Physical modelling of sediment impacts and mitigation. Further assessment regarding fish migrations, water quality, turbidity, and changes in hydrograph/water levels. Detailed socio-economic survey including a cost-benefit analysis
Impact of erosion of islands and banks in weir basin during operations - as a result of sluicing	High - Low	Implement bypass pumping instead of sluicing
Impact on hydrograph: one-off filling and operation at full supply level	Medium – Low if filled during the high flow period)	Set strict operational guidelines to ensure that flow over the weir is within the natural variation in the hydrograph Fluctuations in water level must not exceed the natural rate of change
Interruption in fish migrations	Medium	Fish bypass channel Research regarding migrations
Impact of eutrophication during and after filling	Medium	Clear all vegetation in the basin prior to filling Make cleared timber available to local community Use local labour to clear vegetation
Impact of introduced alien plants (aquatic and terrestrial) and animals	Medium	Develop detailed Environmental Management Plan (EMP) for construction and operation, monitor and enforce

Impacts on subsistence livelihoods of relocation and affected natural resources	Medium	Calculate compensation costs on loss of livelihood as well as on loss of property and land Develop a Resettlement Plan to World Bank standards Include resettlement areas in EIA
Impact of work force on spread of sexually transmitted diseases	Medium	Employ construction labour locally Develop a community liaison and consultation plan Education and awareness training
Potential increase in disease e.g. malaria, biharzia	Medium	Education and awareness training
Impacts on tourism in the project area	Medium	Allow use of impoundment for boating Ensure that sediment does not choke channels downstream from the weir Erect bird and animal viewing hides Make power available locally
Impacts on archaeological sites	Medium	Detailed archaeological assessment is required
Impact of power lines on birds	Medium	Careful route alignment planning during EIA
Inundation of huts, businesses	Medium	Select Sites 4 or 5 to minimise impact or reduce weir height at Site 2 Conduct detailed socio-economic assessment
Inundation of infrastructure	Medium	Re-route road Reduce weir height
Impacts of pollution from oils, diesel, paint, concrete, sediment etc during construction	Medium	Develop detailed Environmental Management Plan (EMP), monitor and enforce
Inundation and erosion of islands and banks during Probable Maximum Floods	Low for the PMF; Unknown for intermediate floods	Minimise weir height
Water loss due to evaporation and seepage	Low	Minimise water surface area
Impact on hydrograph / water levels of pumping sediment	Low	Establish effectiveness of sediment pumping. Assess ecological impacts on benthic fauna
Impacts of bypass pumping on downstream ecology and geomorphology	Low	Assess impacts on benthic fauna Distribute sediment across the river width Pumping must be continuous
Impact of developing quarries and borrow pits during construction	Low	Conduct detailed surveys during EIA
Impact of construction of substation on vegetation	Low	Select site to minimise impact on flora and fauna Conduct detailed surveys during EIA
Visual impact of the substation	Low	Careful positioning Use existing trees as a screen or plant indigenous vegetation
Visual impacts on existing tourist facilities	Low	Design to minimise visual impacts Select site 4 or 5
Inundation of graves and burial sites	Low	Further survey and identification of sites in the inundation area is recommended
Land mines in zone of inundation	Low	Clear land mines prior to bush clearing
Potential for seismic activity	Low	Conduct seismic risk assessment in Feasibility Study

Potential risk of reed encroachment at sediment trap	Low	Dredging and maintenance
Impact of noise during construction and operation	Low	Develop detailed Environmental Management Plan (EMP) for construction and monitor
Water quality during operation	Not determined	Bypass pumping instead of sluicing Monitoring against baseline data
Impacts on aquatic ecosystems	Not determined	Minimise loss of rocky rapids by choosing weir site 2 or reducing weir height Assess impacts on benthic fauna
The impacts of cumulative effects	Not determined	Incorporate a cumulative effects study in the EIA
Impact of climate change on long-term viability of the project	Not determined	Use latest climate and runoff models to predict climate change and viability of project
Impact of catchment land use changes on water flow, quality and sediment production	Not determined	Model land use change for a variety of scenarios under changing climatic conditions

9 CONCLUSIONS & RECOMMENDATIONS

9.1 Comparison of Weir Sites

Weir site 2 (FSL at 1007.5 m.a.m.s.l) would have the least impact on the islands and riverine forest, except for one large forest on the east bank. Site 2 would have a greater impact on settlements and infrastructure than sites 4 and 5. The socio-economic impacts can be mitigated to a large degree, but the loss of unique habitats or species cannot be mitigated.

Weir sites 4 & 5 (FSL at 1010.0 m.a.m.s.l) would both have a greater impact on natural habitats than weir site 2. These two sites would have less impact on settlements, but they would nevertheless impact on the resource base on which people depend (subsistence agriculture, grazing land (reed beds in the river), sources of wood (from the riverine forest) and natural products, and possibly fishing grounds).

For any weir site, a fish-bypass will be essential. This will have to be designed for the local migratory species, with low gradients, riffles and pools that resemble existing conditions.

In view of the impacts in the impoundment area, it is recommended that serious consideration should be given to reducing the height of the weir, and/or selecting weir site 2.

9.2 Comparison of Alternatives for Sediment Transport

Sluicing of sediment has been proposed as one alternative to move sediment from the weir basin to the downstream river, but its effectiveness still needs to be modelled. The negative ecological and physical impacts are expected to be high. While it may be possible to quantify the physical impacts, it will not be possible to predict or quantify all the ecological impacts with any certainty. Therefore, sluicing of sediment is **not recommended**.

Pumping of sediment: If sediment can be pumped at a high level of efficiency then this would be a far better solution than sluicing. The efficiency of pumping needs to be determined, based on tried and proven technology.

Any sediment management measures would place the onus on the power station operator to ensure that the systems were operated efficiently according to an Environmental Management System.

After decommissioning of the hydro power plant, it would be necessary to continue pumping (or sluicing) indefinitely or, preferably, to remove the weir from the river.

9.3 Consideration of Alternatives

A decision about the feasibility of the Popa Falls Hydro Power Project will need to weigh up the benefits of the project against the costs, both in economic, social and environmental terms. It is recommended that a comprehensive socio-economic study should be undertaken that will enable the costs to society (in Namibia and Botswana) to be weighed up against the benefits of the project.

Certain environmental costs can be translated into economic terms e.g. resources of fish, grazing, and agricultural land. Other environmental costs, however, cannot be expressed in economic terms e.g. wellbeing derived from lifestyle occupations, aesthetic impacts, sense of place, or loss habitat and creatures that have no utility to people. In such matters it is necessary to make value judgements in order to include consideration of non-economic costs in the decision-making process. The public participation process (in Namibia and Botswana) should be involved to assist in making such judgements.

The maximum expected electricity output (20 MW) of the proposed project should be weighed up against these environmental “costs” to society. They should also be weighed up against the many alternative options for energy provision that are available. Namibia’s current policy of achieving self sufficiency in power generation also needs to be considered in light of abundant sources of power from hydro power schemes on the Zambezi River, in Angola and/or from the Kudu Gas Plant.

9.4 Recommendations for Further Investigations

This study has identified a number of key issues and impacts that require further investigation. Recommendations in this regard have been made throughout Chapters 7 – 9 in the report. While many significant impacts are already known to be unavoidable, the magnitude of these impacts needs to be quantified. For other issues, such as sediment transport, further investigation is required to determine the effectiveness of mitigation measures. Some impacts are likely to be difficult to quantify, particularly those in the aquatic environment. Where there is uncertainty, the *precautionary principle* should be applied.