A Critical Analysis of the Dunvegan Hydroelectric Project Environmental Impact Assessment

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ABSTRACT

This paper presents a critical analysis of an environmental impact assessment (EIA) for a proposed hydroelectric project on the Peace River at Dunvegan, Alberta, Canada. The EIA was submitted as part of the project proposal to the Natural Resources Conservation Board (NRCB) on June 19, 2000 as required by the Canadian Environmental Assessment Act, the Navigable Waters Protection Act, and the Fisheries Act. On June 7, 2001 the EIA was deemed complete pursuant to section 51 of the Environmental Protection and Enhancement Act.

A number of disagreements within the literature regarding the conceptual design of the project were found. Given that the site is located in an area with extremely variable geology and climate, the implications of geomorphic and hydroclimatic processes on the river, and proposed dam structure, do not appear to be adequately addressed within the EIA. Secondly, the area is known to have unstable geology and be prone to active erosion and slumping. The proposed project may impact, and possibly accelerate erosive processes within the Peace River and adjoining tributaries.

Ice effects are considered in the EIA, but no mitigation measures are outlined. The EIA provided insufficient sedimentation studies related to contaminant transport/deposition and no geo-chemical assessment for natural Hg. Water quality was assessed on the basis of hypersaturation of atmospheric gasses only, for which adequate mitigation measures were provided. Further, water quality variables should have been assessed in the EIA.

The EIA also contained very limited floral and non-native species studies. The continuous two-year construction activity is likely to represent a significant barrier to migration and reproduction of wildlife in the Dunvegan area. The project will also result in the permanent and seasonal flooding of a number of near shore ecosection subunits, primarily associated with islands and shorelines, resulting in local habitat fragmentation. The creation of a reservoir may also make new habitats available that are favorable for maintaining some animal populations.

The EIA identified technical limitations such as a lack of quantitative site-specific data that made sediment quality, benthic algae, and invertebrates unsuitable for use as valued environmental components, but this statement was not supported by the literature. Additionally, the EIA did not directly address the issues of phytoplankton or planktonic/benthic chlorophyll levels.

Methylmercury, ammonia, and green house gas production was accurately assessed based on the current body of literature. Most of the cumulative effects sections site technical boundaries or a lack of data as reasons for incomprehensive or absent effect assessments. As a result, the cumulative effects sections were inadequate, and not supported by the literature. Because biotic communities are structured along resource gradients and downstream communities are at least partly dependant on upstream processes, the cumulative environmental effects could be very significant to the Dunvegan ecosystem and the Peace/Athabasca Delta. Impoundments along river courses can interrupt natural longitudinal energy transport gradients, causing longitudinal shifts in physical and chemical variables, which in turn cause biotic shifts. It is believed that these mechanisms will ultimately affect biodiversity and environmental health at Dunvegan long-term.

(Key words: EIA, environmental protection, Canadian Environmental Assessment Act, CEAA, NEPA, Navigable Waters Protection Act, Canada, Alberta, fisheries, Peace River)

INTRODUCTION

In 1998, Glacier Power Limited initiated the review process for the Dunvegan hydroelectric project, a low-head, modular, run of river hydroelectric development, designed to minimize flooding and resultant environmental effects. On June 19, 2000, Glacier Power submitted an application to the Alberta Energy and Utilities Board (EUB), and the Natural Resources Conservation Board (NRCB) for approval to construct and operate a hydroelectric facility on the Peace River 2 kilometers upstream of the Dunvegan Bridge. The Dunvegan project is subject to the requirements of the Canadian Environmental Assessment Act (CEAA), since the project will require a permit under the Navigable Waters Protection Act and an authorization under the Fisheries Act. Fisheries and Oceans Canada is the responsible authority for the project. An environmental impact assessment was submitted as part of the application (Natural Resources Conservation Board 2001).

The proposed Dunvegan project meets one of the Alberta Environmental Protection and Enhancement Act (AEPEA) thresholds requiring an EIA: the proposed 39 million cubic meter head pond exceeds the 30 million cubic meter exemption limit. Additionally, the Director of Environmental Assessment determined that the Dunvegan project should be reviewed under AEPEA due to the project's location on the Peace River and the fact that it is a new hydroelectric facility. On June 7, 2001, the director of environmental assessment and compliance advised the EUB and NRCB that the EIA was complete pursuant to section 51 of the Environmental Protection and Enhancement Act (Natural Resources Conservation Board 2001).

Included within the EIA is a brief statement of project need. It states; "the purpose of the Dunvegan project is to build and operate a 40 MW hydroelectric generation facility in the northwest area of the province, which is presently undergoing significant economic growth accompanied by a deficit in local electrical generation. Glacier power believes that the Dunvegan project will be in the public best interest by providing base load energy (335,000 MWh/yr) with a capacity factor of over 90 percent, to a location in the province that is seriously lacking in electrical generation. The project will also displace approximately 300,000 t/yr of greenhouse gas emissions, that would otherwise be generated by either natural gas fired or thermal coal generation" (Glacier Power Ltd. 2000). Since the time of the EIA preparation, plans have been amended to include a second 40MW turbine for a total of 80MW (Natural Resources Conservation Board 2001).

This paper will examine and discuss the various biological aspects of the Dunvegan project EIA. The examination will primarily focus on the impacts to water quality, the terrestrial ecosystem, the aquatic ecosystem, the hydrology, and the geology as it relates to the watershed. A detailed discussion of the possible effects to fish, ice formation, and the flow regime are included. In order to gather insight into the differences between theory and practical application, identification and clarification of incongruities, and to propose solutions for the better understanding of differences an exhaustive literature review was undertaken as part of the analysis.

THE EIA PROCESS

According to the literature, environmental impact assessment is potentially a multidisciplinary, objective decision-making tool with respect to alternate routes of development and selection process technology, as well as project sites. It is ideally an anticipatory mechanism, which establishes quantitative values for parameters indicating the quality of environment before, during, and after the proposed development activity, thus allowing measures that ensure environmental compatibility. EIA essentially involves baseline data collection on air, water, land, noise, biological, and socioeconomic components of the environment. The EIA process requires the identification of potential impacts, prediction of significant impacts, and evaluation of impacts on a commensurate scale ultimately leading to delineation of an environment management plan (Goyal and Deshpande 2001).

The understanding and management of environmental impacts associated with hydropower projects has progressed considerably over the last 20 years, as a result of studies, monitoring, follow-up, and increased regulatory requirements. Experience gained worldwide has improved project planning and design, as well as improved development of comprehensive environmental mitigation programs. These developments have all helped avoid or reduce the severity of a large number of impacts typically associated with hydropower. Some of the most common mitigating procedures regarding biological and environmental impacts include: integrating the preservation of biodiversity and productivity in project designs; optimizing flow regimes downstream of a reservoir; improving fish passage for valuable migratory species at hydropower dam sites; improving sedimentation management in reservoirs; limiting water quality problems through good site selection; and managing reservoir eutrophication and water contamination problems during operation (IEA Hydropower Agreement (n.d.)).

In Canada, responsibility for environmental assessment is divided between the federal government, the provinces, and the territories. The federal environmental assessment process is generally triggered when projects affect an area of federal responsibility, involve federal support, or entail potential transboundary impacts. Beginning in the 1970s, several major northern projects were subject to the Environmental Assessment Review Process (EARP), which was enacted in 1973. In 1995, EARP was replaced with the Canadian Environmental Assessment Act (CEAA). This change had important implications because the act makes explicit reference to the need for the environmental assessment process to foster sustainability (Mulvihill and Baker 2001).

A number of ambitious environmental assessment exercises have taken place in Canada's northern regions since the 1970s. Northern Canadian environmental assessment processes are expected to address a number of substantive and process orientated issues, including the following: ecological sustainability, timing, scale, distribution of risk, and the benefits and impacts of the proposed projects. Despite these criteria, approaches to environmental assessment, and in particular the scoping phase, still tend to vary considerably in northern Canada (Goyal and Deshpande 2001).

In the past, large-scale energy projects have framed several of the environmental assessment (EA) processes in the north. Considerable resources have been applied, not only to the EA processes themselves, but also to the general pursuits of EA process development through research institutes and other initiatives. However, some have argued that there has been a steady erosion of the fairness, comprehensiveness, and integrity of EA in the most recent northern projects (Mulvihill and Baker 2001).

THE DUNVAGAN SITE

The majority of current development projects along the Peace River involve either oil and gas exploration and refining, or hydroelectric power generation. The Peace River is well known for its hydroelectric development potential and is controlled by two hydroelectric facilities located in British Columbia, the W.A.C. Bennett Dam which has a total generating capacity of 2730 MW, and the Peace Canyon Dam which forms Dinosaur Lake near Hudson's Hope. Williston Reservoir provides storage for the Bennett Dam, while Dinosaur Lake functions as a run of river reservoir. These two dams operate together to generate hydroelectric power (Alberta Environment 2002, Government of British Columbia 1987).

The Dunvegan site was selected for the project based on a number of factors. The Peace River flows through three major jurisdictional boundaries, the Province of British Columbia, Province of Alberta, and Wood Buffalo National Park. The majority of the remaining hydropower potential falls within Alberta's jurisdictions. The project fits within the natural river channel banks and pre-Bennett flood conditions, such that inundation due to the head pond is minimized. The foundation conditions of the river channel banks and bed are well suited to support the head works structure, and deep-seated failure of the bedrock is thought to be highly unlikely. The run of river hydroelectric facility is not expected to change the river flow regime downstream, and therefore ice formation and breakup through the Dunvegan area is not considered to be a deterrent to project development (Glacier Power Ltd. 2000).

The Dunvegan project is designed to increase the water level in the river at the head works by 6 meters to create adequate differential for the operation of the 80 MW low head hydroelectric facility. The head pond created by the head works structure will extend approximately 26 kilometers upstream, will inundate between 100 and 150 hectares of the land, and will be contained within the natural river channel banks below the pre-Bennett 1:100 year flood level (Glacier Power Ltd. 2000).

Dunvegan Alberta is a recognized provincial historic site. The area provides for a high level of recreational use. Activities include boating, fishing, horseback riding, camping, and hiking. Both private and government facilities exist at the site and include a tourist center, RV park, boat launch, market garden, teahouse, antique store, playground, and mini golf course. The selection of this site is contrary to recommendations contained within the IEA Hydropower Agreement Technical Report on Hydropower and the Environment (n.d.). This report states that "protected natural and heritage sites are by definition exceptional...selected alternatives should avoid development in these sites". It is probable that construction of a hydroelectric facility near Dunvegan will exacerbate the already extensive human impact in the area. This in turn, may encourage the extirpation of sensitive species. The facility may also negatively impact recreational use and tourism in the area.

DESIGN AND GEOLOGY

There are a number of disagreements within the literature regarding the conceptual design of the project. Firstly, climate and hence runoff, can change significantly over time and thus climate change is important for hydrological modeling and forecasting. Some geomorphic processes are known to occur at decadal or even centennial timescales, and their effect on extreme flows is therefore rarely incorporated in the existing hydrograph records upon which forecasts are based (Blackburn and Hicks 2002). Simple extrapolation of the existing record is therefore only appropriate for preliminary studies, but inappropriate for flood plain and alluvial fan risk management, as is the case with Dunvegan. The common assumption with these analyses is that floods are generated by snowmelt and/or rainfall. However, there are numerous examples where peak flows have been observed that exceeded the 200-year flood discharge calculated by regional analyses. These events can often be traced to processes such as debris flows, slumps and rock avalanches, dam ruptures, glacial lake outbursts, and even beaver dam failures. Streams of all sizes are therefore subject to unusual floods caused by geomorphic rather than hydro-climatic processes (Jakob and Jordan 2001, Matthias and Jordan 2001). Given that the site is located in an area with extremely variable geology and climate, the implications of these processes on the river and proposed dam structure do not appear to be adequately addressed within the EIA.

Secondly, the area is known to have unstable geology and be prone to active erosion and slumping. Steep, clay riverbanks and valley sidewalls exist along much of the river valley. These banks are generally susceptible to slope failure, and small sections occasionally slide into the river contributing to the natural sedimentation regime (Government of British Columbia (n.d.)). Within the last 60 years, at least seven major landslides have occurred in the tributaries of the Peace River; they rank among the largest in Alberta's history. Five of these landslides have occurred in the past decade: the 1990 Saddle River landslide (approximately 30km SW of the site); the 1990 Eureka River landslide (approximately 40km NW of the site); the 1995 Spirit River landslide (approximately 5km SE of the site); the 1990 Hines Creek landslide (approximately 15km NW of the site); and the Vessall Creek landslide (1993 and 1997). Earlier landslides include the 1939 Montagneuse River landslide, and the 1959 Dunvegan Creek landslide (on site). The Eureka River landslide, at 50M m3, is one of the largest historical landslides within the interior plains of Canada. All of these landslides are reactivated, retrogressive or enlarged, translational earth slides. Each landslide occurred in quaternary sediments deposited within a pre-glacial valley. Their volumes range from about 30 to 80M m3. In every case, a landslide dam and reservoir was created (Cruden and Miller 2000).

Numerous dormant and abandoned large landslides have been recognized within each, or most, of the sedimentary units within the Spirit River, Hines Creek, Eureka River, and Montagneuse River watersheds. All of these watersheds are very near the proposed site, and the Hines Creek joins the Peace River at Dunvegan. Each of the surficial units has distinct properties; instability within each unit is distinguishable by depths of rupture surface, size, and affect on river morphology. The Spirit and Eureka Rivers have longitudinal profiles that can be divided into two contiguous reaches; a steep lower reach in which most landslides occur, and a gentle upper reach with little or no instability. As the tributary streams incise into each sedimentary deposit, the volumes of the landslides increase, as do the effects of the landslides on stream processes. At present, the Peace River valley has eroded as much as 275 meters below the prairie level in the region. The tributaries of the Peace River were unable to erode at the same pace as the Peace River, and many developed convex longitudinal profiles similar to those of other tributary systems in Alberta (Cruden and Miller 2000). This means that while the Dunvegan site provides steep banks required by the project, the banks are prone to erosion, and lower reach landslides. It is very likely that the project will impact, and possibly accelerate these processes within the main river and adjoining tributaries.

Reservoir induced seismicity used to be considered as a strange unintentional environmental phenomenon. Currently, reservoir induced seismicity is recognized mostly as an environmental and dam safety related concern, which is largely understood but for which there are limited means of prediction on a consistent basis. The strength of induced seismic activity ranges from moderately sized damaging earthquakes, with a range of failure on a scale of kilometers, through to rock bursts, and down to micro-seismic emissions, which are mostly sensed by instrumentation and have a range of failure on a scale of meters. Historically, the development of large reservoirs for power generation was the first type of engineering activity that significantly affected the earth's crust, and seismicity is associated with such stress modifications. Other induced seismic activities are related to mining, fluid injection and disposal, fluid withdrawal, geothermal activity, enhanced oil recovery, and storage of oil and gas underground; mostly associated with micro-seismic activity generated by the gas pressure variations (Vladut 1999).

With the exception of mining, all of the above activities are very common in the vicinity of Dunvegan. In Alberta, oil and gas production have been linked to a number of earthquakes, most of them minor. Smaller earthquakes have also been linked to stream injections, and rapid gas extraction. This is thought to be due to stress changes in the rock formations, which lead to increased fracturing and faulting triggering small earthquakes (Vladut 1999). In 2001, two earthquakes occurred in the vicinity of the Dunvegan site. The first had an epicenter near Dawson Creek, approximately 120 km from the site, and had an intensity of 6.5 on the Richter scale. The second occurred near Fort St. John, approximately 200 km from the site, and had an intensity of 4.0 on the Richter scale (personal observations, local TV news).

While the Dunvegan project does not involve the building of a conventional dam, it does involve the impoundment of water. The building and impoundment of the reservoir may create a large column of pressure on the underlying bedrock (Vladut 1999). Even if the pressure created by the 6 m column of water at the head works is not substantial enough to create reservoir induced seismicity, it may combine with the effects of oil and gas activity in the area, to destabilize the geology at Dunvegan. The IEA Technical Report on Hydropower and the Environment (n.d.) indicates that projects in zones of strong seismicity should be designed with appropriate criteria, in order to reduce risks such as dam failure. Since the EIA considers the site to have stable geology, this issue was not adequately addressed in the document.

ICE REGIME

The EIA states that the ice regime effects are expected to extend roughly 80 km downstream, and some 200 km upstream into the province of British Columbia. Ice formation affects many natural processes in a river system, including the type and availability of habitat, dissolved oxygen levels, and flow patterns (Alberta Environment 2002). Addressing this issue is of paramount importance because numerous ice related problems have developed as a result of the Bennett Dam construction. Currently, the town of Peace River, approximately 100 km downstream of the Dunvegan site, experiences flooding and ice damming as a result of the Bennett Dam. The two major factors influencing the severity of ice jams are higher water levels at the time of ice cover formation and relatively smaller tributary flows (Alberta Environment 2002).

The community of Tangent, located 80 km downstream of Dunvegan, relies on ferry service for transportation in the open water months, and an ice bridge during freeze up. It is conceivable that changes to the ice regime 80 km downstream, could create ice dams that would prevent both ferry and ice bridge use. It is also possible that the timing of ice formation and breakup, could be altered in unpredictable ways due the influences of variable climate and the cumulative flow regime effects of the three hydroelectric facilities. Though this potential effect is considered in the EIA, no mitigation measures are outlined. Considering the lack of mitigation measures and the high probability of ice related problems, this possible impact is not adequately addressed in the EIA.

The literature also indicates that structures, which are in contact with naturally occurring ice during the winter months, can be subjected to considerable forces due to thermal expansion of the ice. As the temperature increases, the ice sheet expands and if this is prevented by a structure, substantial forces can be generated. These forces are especially important for structures such as low head dams, water intakes, gates, spillways and bridge piers; all of the structures will be present at the Dunvegan site upon completion of the project. In the case of low head dams, the ice forces, which are independent of reservoir depth, may be comparable to the forces due to hydrostatic pressure. The ice forces may even control the design. Using an ice load of 146 kN/m suggested by the Canadian Dam Safety Association for concrete dams, the overturning moment due to ice is greater than that due to hydrostatic pressure, for reservoir depths of less than 9.5 meters (Azarnejad and Hrudey 1997). These criteria will apply to the Dunvegan structure. Therefore, overturning considerations due to ice forces, and mitigation measures should have been included in the EIA.

Other factors that can have some influence on thermal ice loads include: the elastic foundation effect of the underlying water; the geometry of the reservoir; shoreline features; stiffness properties of the resisting structure; and cracking activity in the ice. Later in winter when the ice is thicker, there may be more variation in the thickness throughout a reservoir. During these periods, the temperature variations that contribute most to thermal pressure occur primarily in the upper layers of the ice, and are not likely to change much throughout the ice sheet. The temperature distribution throughout the thickness is, in general, non-uniform. Combined with the nonlinear material behavior of the ice, this gives rise to a nonlinear distribution of stress through the thickness (Azarnejad and Hrudey 1997). The EIA contains no detailed discussion of ice forces or thermal ice loads for the Dunvegan area.

Cracking is another important aspect of the behavior of an ice sheet, as it responds to significant temperature fluctuations. It has been observed that most common cracks are dry. These are tensile cracks that form during cooling periods, and do not penetrate to the bottom surface of the ice cover. However, they can still have a significant effect on the stress within an ice sheet. The boundary effect can also be important in ice sheet behavior. This occurs when the ice cover is bonded to the shore or a hydraulic structure. In this circumstance, water level fluctuations can change the buoyancy force from the underlying water. Field data indicate a correlation between ice forces and changes in water level. It is suggested that the influence of water level on ice forces, is a nonlinear geometry affect arising from arching action (Azarnejad and Hrudey 1997). These forces may be significant to ice formation and behavior above the dam structure; due to the substantial and highly variable water level fluctuations from the Bennett dam, they require further consideration in the EIA.

It is possible that the Dunvegan hydroelectric project may produce some benefit to the river by altering ice formation. In cold climates, dissolved oxygen threats are often greatest during winter when ice cover resists re-aeration for 4 to 6 months. Limited information exists on dissolved oxygen conditions in ice covered rivers, but the depletion of dissolved oxygen under ice cover is generally attributed to a lack of re-aeration as a result of ice cover, inputs of oxygen depleted groundwater, and oxidation of organic material. Although the importance of these factors in controlling under-ice oxygen regimes has long been recognized, little information is available on the cumulative effects of anthropogenic loadings of oxygen consuming waste on river dissolved oxygen regimes during winter (Chambers *et al* 1997). There are several sewage, pulp and paper, and industrial effluent discharge points upstream of Dunvegan (Government of British Columbia 1987). The hydroelectric facility may benefit the river by providing a section of open water for re-oxygenation during the winter months, although currently low dissolved oxygen content is not believed to be a problem in the Peace River (Alberta Environment 2002).

FLOW REGIME AND SEDIMENTATION

The EIA states that the Dunvegan project will not affect the flow regime of the Peace River downstream of the structure, and flooding effects in the head pond will be minimal. The main parameters which decide the impacts related to the establishment of a reservoir are: the reservoir level; water turnover time; the size and depth of the reservoir; water level fluctuations especially in the drawdown zone; the hydrological management regime; and optimum compensation flows including what is commonly referred to as minimum flows. These parameters vary greatly in significance, depending upon the climate and geographical zone in which the reservoir is established. The increase in water level after impounding is usually one of the greatest impacts of hydropower projects, as it involves flooding of land and a total change in the ecosystem. This will mainly affect the aquatic life in general, and migrating fish in particular, but also the terrestrial life in the surrounding land area be impounded, and the ecotone between the terrestrial areas and the running river (IEA Hydropower Agreement (n.d.)).

During operation of the head pond, the water retention time will be about 8 hours. Shallow sloped bank sections and some islands and side channel areas will be noticeably affected by inundation. The effects of flooding are expected to diminish towards the top of the head pond. At approximately 22 kilometers upstream of the head works structure, head pond levels are expected to be within the present daily water level fluctuations (Glacier Power Ltd. 2000). It is worth noting however, that these daily water level fluctuations are not natural, they result from water releases from the Bennett Dam (Government of British Columbia 1987, Alberta Environment 2002). Usually hydraulic management has a profound impact on the ecological characteristics of fauna and flora in the reservoir area as well as downstream, particularly in the reservoir and along the river-banks (IEA Hydropower Agreement (n.d.)).

A major part of the more serious impacts connected to hydropower development, regardless of geographical area or climatic zone, is related to changes in the natural hydrology of the actual watershed and watercourses (IEA Hydropower Agreement (n.d.), Kelly and Rudd 1997, Rosenberg *et al* 1997). Within the head pond area, inundation is expected to occur along the channel margins and is not expected overtop the existing river banks in most areas. However, the hydrology of the area is not well documented and therefore changes to groundwater base flow or levels may be unpredictable or undetectable (Government of British Columbia 1987, Alberta Environment 2002). The main tributaries found in the Dunvegan project area include the Hamlin, Dunvegan, Hines, and Boucher creeks and Ksituan, Saddle (Burnt), and Leith Rivers. Numerous unnamed tributaries are also present. The Ksituan River and Hamelin Creek have their confluence located within the proposed head pond, while Dunvegan Creek and Hines Creek have their confluence located immediately below the head works (Government of British Columbia 1987, Alberta Environment 2002). It is expected that the head pond will extend 800 to 1000 meters into the lower Ksituan River, and will alter tributary sediment fans, sand bars, and some islands within the main river (Glacier Power 2000).

One shortcoming of the EIA is that it makes mention of several upstream effects but not in the context of flow regime alteration. Therefore, it fails to conclude that the flow regime upstream of the project will be significantly altered even if the flow regime downstream is not. These alterations include an additional 150 hectares of water surface area contained just below the 1:100 year flood level; alterations of the flow velocity from 0.9 m/s (5 hours) to eight hours (deeper and slower flows in the head pond); change in water depth and temperature possibly stratifying parts of the water column; the partial and permanent inundation of two tributary systems and all side channels; and the flooding of some small islands. Additional upstream effects are likely to include changes to sand bars due to sediment deposition that may adversely affect boat navigation and alter water/energy flow and nutrient dispersal patterns.

The changes to the flow regime are also expected to affect sediment transport processes within the watershed (Glacier Power 2000). Currently, many sections of the river are becoming narrower as sediment accumulates along the shoreline. Islands and sand bars are growing in some regions. Many of the small side channels and backwater sections have been blocked off by silt and are slowly drying out (Alberta Environment 2002). Dams usually retain sediments; resulting in various problems like dam siltation, increased downstream erosion, and profound changes in the physical, chemical and biological characteristics of the estuary (Alberta Environment 2002, Rosenberg *et al* 1997). This might indirectly affect groundwater levels and the whole biotic environment of the watershed, with subsequent effects on the agriculture and fisheries (IEA Hydropower Agreement (n.d.)). Currently, the regulation of flows and particularly a reduction of peak flows have reduced the ability of the Peace River to move course textured sediment supplied by tributary streams and valley slope erosion (Alberta Environment 2002). Formation of the head pond will cause course textured sediment to be deposited near the upstream end of the head pond, which has the potential benefit of creating potential spawning beds but the negative effect of making river boat navigation difficult due to shifting deposits, particularly following peak flows or flood events.

The sediment load, turbidity, and total dissolved solids within the water of the Peace River are controlled by two factors; water releases from the Bennett Dam, and water flow from tributaries. Sedimentation during spring breakup and from major summer rainfall events contribute substantial natural amounts of sediments to the river resulting in high-suspended solids and high turbidity (Government of British Columbia 2000). Much of the sediment, which infiltrates the river in this manner above the Bennett Dam, is trapped by the dam. This means that the major contribution of sediments to the river between the Bennett Dam and Dunvegan comes from the numerous smaller tributaries downstream of the dam (Alberta Environment 2002). All of the tributaries mentioned in the EIA are seasonal streams; they contribute to the Peace River mainstream only during spring runoff or excessively heavy rainfall and these contributions are critical for the functioning of downstream ecosystems (Government of British Columbia 1987, Government of British Columbia 2000). The potential trapping of sediments by the Dunvegan project will ultimately reduce substances available downstream to the Peace/Athabasca Delta.

The EIA identified no adverse effects to water quality from sedimentation and concludes that the project will result in negligible overall effects. The EIA also states that suspended sediment concentrations during much of the year are high and therefore sediment related concerns during the construction and operation phases are not anticipated. This statement is not supported by the literature. The IEA Hydropower Agreement Technical Report on Hydropower and the Environment (n.d.) states that hydrologic changes resulting from dams and reservoirs on a river system may increase the process of sedimentation. This process is variable depending on the sediment load of the river, the residence time of the water, the reservoir configuration, and watershed management practices. Sites with characteristics that minimize this process should be prioritized (IEA Hydropower Agreement (n.d.)). Considering the potential effects of the above variables and the number of tributaries contributing to the sediment load in the Dunvegan area, this process does not appear to have been given adequate consideration in the EIA.

The EIA also concludes that since other developments in the area have not resulted in serious contaminant issues, the mobilization of sediments from the head pond should not result in the release of contaminants into the aquatic environment. This statement is also contradicted by the literature which indicates that under low flow conditions like those in the head pond, contaminated sediments settle to the bottom sooner than under normal circumstances. This is because certain contaminants known to exist in the Peace River (pulp mill/municipal effluent discharge), enhance the natural flocculation of sediments in the environment (Government of British Columbia 1987, Government of British Columbia 2000, Alberta Environment 2002, Scrimgeour and Chambers 2000). It is possible that the lower flow rate and higher retention time of the water in the reservoir will result in this kind of sedimentation, possibly concentrating pollutants in the head pond. Since many contaminants tend to adsorb to sediments, the higher amount of sediments in the Dunvegan area will likely result in higher contaminant levels as well (Alberta Environment 2002). Contaminants, which are dissolved, neutrally buoyant, mass conservative substances, will be transported and mixed by advection and diffusion. Since most rivers have a large width-to-depth ratio, dissolved substances rapidly become uniformly mixed in the vertical direction (Putz and Smith 1998). Therefore, it is also possible that dissolved contaminants may be redistributed further downstream, possibly in the vicinity of the Fairview water intake.

It is also possible that the Dunvegan dam will re-suspend some sediments locally, and transport nutrients and contaminants downstream. The

EIA states that contamination in the Peace River is not a concern but the literature indicates the contrary. Higher levels of PCBs, chlorinated resin acids and PAHs in the Peace River occur upstream of the Smoky River, including Dunvegan, and are thought to be related to sediment transport/deposition processes (Alberta Environment 2002). Studies also suggest a possible PCB source in the upper reaches of the Peace River basin because levels recorded in the lower reaches cannot be attributed to any local sources. Levels of chlorinated and non-chlorinated organic contaminants in sediments from the Peace River are also high (Government of British Columbia 2000).

WATER QUALITY AND CONTAMINANTS

There is some evidence of industrial contamination as determined by the presence of certain contaminants in sediments and fish tissues. Most of the contaminants of interest are less likely to be found in water and other parts of the aquatic environment. Levels of PCBs, resin acids, and PAHs are higher than reference locations in sediments above the confluence with the Smoky River. This area includes the Dunvegan section of the river. High PCB levels in burbot from the Peace River have been found to be an order of magnitude higher than found in burbot from tributaries of the Peace River. PCB levels in the sediments exceed the interim Canadian Sediment Quality Guidelines for the protection of aquatic life. Levels of PCDD/Fs in sediments are low but detectable. Mercury concentrations in sediments and fish tissues throughout the river have not changed since the late 1980s and are considered low. High levels of free retinoids in burbot from the lower portion of the Peace River suggest physiological stress but the cause is unknown. Metallothionein levels in fish, indicative of heavy metal detoxification, tend to increase from upstream to downstream on the Peace River (Alberta Environment 2002). The EIA fails to consider how the project may affect the biotransport and bioaccumulation of these contaminants in future.

The project design addresses the issue of water quality in the following way: the spillway design causes sufficient turbulence downstream to promote gas exchange at the outlet of the turbines and the elimination of methane and organic matter. Therefore, the structure promotes oxygenation downstream of the dam, allowing a rate of dissolved oxygen that satisfies the aquatic fauna support criteria (Glacier Power Ltd. 2000). In Alberta, the level required to protect aquatic organisms in surface waters is set at 5 mg/L under the Alberta Surface Water Quality Objectives. Federally, the Canadian Council of Ministers of the Environment list higher objectives for cold and warm water organisms, especially for the early life stages of fish and aquatic organisms. Generally accepted chronic requirements are greater or equal to 6 mg/L for adult fish belonging to the salmon family and greater or equal to 5 mg/L for all other fish species (Alberta Environment 2002). The Dunvegan project will likely not affect dissolved oxygen concentrations in a negative way. Provided that the steps indicted by the EIA are taken to reduce the likelihood of hypersaturation of atmospheric gasses in the turbines, no negative effects should occur. However, this is but one of many variables concerned with water quality. This limited approach in insufficient, and further variables should be assessed in the EIA (nitrogen, phosphorous, chlorine, silica etc.).

During winter, dissolved oxygen levels tend to decrease naturally, along the length of the ice-covered River. This decrease is not thought to be sufficient to threaten aquatic life. There are however, noticeable sags below major effluent discharges from communities and industry. At times, these discharge sites fall below the aquatic life criteria. Currently, the water quality of the Peace River is, generally, in the natural state. Provincial water quality objectives set for fecal coliforms, dissolved oxygen, and turbidity to protect recreation are being met, although fecal coliforms sometimes exceed drinking water objectives in the river. Data is insufficient to ascertain whether objectives set for inputs of trace metals and certain organic and inorganic contaminants are being met (Alberta Environment 2002).

The effects of nutrient pollution on streams and rivers, large rivers in particular, have been minimally investigated to date. Investigations into the effects of nutrient addition on lotic ecosystems have largely focused on nutrient dynamics (spiraling, exchanges amongst nutrient pools) or the mechanisms regulating nutrient mediated responses of aquatic biota. Studies have been completed almost exclusively in small streams with little or no anthropogenic disturbances. They indicate that phosphorus supply is largely controlled through geomorphic processes such as weathering and erosion, whereas nitrogen is derived from biological processes in stream and in the drainage basin, as well as atmospheric exchange (Schimgeour and Chambers 2000).

Between the BC-Alberta border and Dunvegan, a distance of 120 kilometers, there are no anthropogenic point source waste discharges. At Dunvegan, variables such as color, and turbidity, suspended solids, and dissolved phosphorus show higher seasonal maximum levels than upstream. Metals in excess of the working criteria for aquatic life at Dunvegan include all metals found in excess at sites upstream in British Columbia (copper, lead, mercury, cadmium, iron, manganese, selenium) plus silver (Government of British Columbia 1987, Alberta Environment 2002). This information was not included in the EIA though it should have been because the dam may increase the biotransport and bioaccumulation of these substances. Additionally, the EIA references the Northern River Basins Study as an information source for the document, but the EIA statements regarding contamination issues are contrary to those contained in the source. Therefore EIA statements regarding water contamination and baseline water quality cannot be considered accurate.

FLORAL AND FAUNAL IMPACTS

Impacts on aquatic invertebrate fauna and aquatic flora like algae, losses, and higher plants are most commonly affected by construction activities together with fish diversity, fish migration, and fish stocking. The terrestrial fauna like birds, mammals, and insects, and the terrestrial flora especially in the draw down zone, as well as in relation to tree cutting, are mainly affected by the construction activities. A good number of mitigation and compensation measures have been developed to reduce the negative effects on biotic life. Some important mitigation measures include fish ladders and fishways or other bypass facilities to aid migration; technical designs to minimize aquatic life mortality; the minimum flows during critical periods for aquatic life; water level management to mitigate effects of draw down; protection or re-establishment or improvement of habitat for endangered species; scheduling of works which disturbs wildlife only during non-sensitive time periods; development of forest; wildlife and watershed management and monitoring plans; and re-vegetation programs (IEA Hydropower Agreement (n.d.)).

The EIA agrees with the literature on this point and states that most of the effects to the terrestrial environment will occur as a result of the construction process. Removal of vegetation cover will be required at the proposed site for access roads, laydown areas, and the power transmission line. Some clearing of trees may be required on islands and tributary areas closest to the facility prior to flooding. Approximately 24.84 hectares of native vegetation, plus 2.37 hectares of non-native vegetation will be affected by construction. (Glacier Power Ltd. 2000). Potential effects during construction on soils and vegetation include alteration to, or loss of, significant vegetation features representative of a region loss and/or; alteration of habitat for rare species; and loss or erosion of vegetation community function due to soil mixing (Rosenberg *et al* 1997). According to the EIA, the small area affected by construction and the existence of other abundant plant communities in the immediate area, suggest that the effect of construction on significant plant communities will be non-significant.

Field observations revealed that the area to be inundated is vegetated with mixed boreal forest, shrubs, and native prairie grassland species. Some of the prairie grass and plant species occur within a very small range occupying steep, dry, hilltops and slopes. These plants are vital for slope stability and the prevention of erosion as well as for providing habitat. Currently, very little native prairie grassland remains in the area. Most of the once extensive grasslands of this sub-region have been cultivated and only small, scattered remnants remain in native cover (Alberta Natural Heritage Information Centre 2002).

The project area falls within the Dry Mixedwood Boreal Forest Natural Sub-region of Alberta. There are four potential significant plant community types identified within the local project area: balsam poplar forests on alluvial flood plain terraces and islands (important wildlife habitat; high rare plant potential; fire refugia); diverse steep south to west facing slope grasslands on solonetzic soils (regionally significant; disjunct or range extension species present; often grazed); vegetation communities associated with active to stabilized mass wasting processes (rare plant habitat); and sub-old to old paper birch or white spruce stands (high biodiversity value with nutrient rich under stories; high rare plant potential) (Alberta Natural Heritage Information Centre 2002).

The project site supports a diverse and representative faunal community typical of the Dry Mixedwood and Peace Parkland ecoregions and the Boreal Forest Natural Region (Alberta Natural Heritage Information Centre 2002). The scale of the impacts on fauna is known to vary depending on the climatic zones, size of the affected area, diversity of the substitute habitats available and the species present. Flooding land areas impacts the use of breeding, rearing, and feeding areas as well as migratory routes of the species involved (IEA Hydropower Agreement (n.d.), Rosenberg et. al 1997).

The EIA indicates that 3 confirmed and 1 unconfirmed rare plant species have been identified in the local project area during field investigations. However, the EIA also indicates that the field investigations occurred only east of the proposed head works, and only during the late summer of 1999. This limited geographic area and timeframe cannot be considered a complete scientific survey of plant species, populations, and distributions. Investigations need to be broadened to include surveys at early and late phonological stages of plants, a full taxonomic inventory for both sides of the head works, upstream and downstream banks, islands, tributaries, roads and power line right-of-ways. A comprehensive assessment including detailed inventories of habitat and wildlife, including information regarding the preferential use of habitat by wildlife should have been included in the EIA. Additionally, genetic studies of rare and endangered plants within the affected area should be conducted. This is necessary because the river represents a large geographic barrier to gene flow and therefore genetically distinct populations may exist.

The literature indicates that in the context of preservation of biodiversity, rare, threatened, or vulnerable species deserve close attention with respect to the EIA process. The development of hydroelectric projects should not compromise the survival of such species, should avoid as much as possible the habitats which support them, and allow for their preservation in the long-term. Habitats are not of equal quality, some are poor, others richer. In richer habitats, rates of reproduction are usually much higher than death rates. As these habitats support large numbers of individuals from various species, they should be protected as much as possible (IEA Hydropower Agreement (n.d.). The Dunvegan area can be considered rich habitat with very high diversity. The area supports numerous animal, fish, and bird species. Dunvegan also supports a wide variety of plant communities, nesting, and breeding grounds (Alberta Natural Heritage Information Centre 2002). The steep valley slopes and lush vegetation prohibit disturbance allowing for the maintenance of a relatively natural ecosystem.

Water development projects affect a higher number of species than any other resource extraction activity (~30%). Water flow disruption and water diverging are among the most destructive categories of water development. Overall, animals tend to be affected more than plants. The project has the potential to affect wildlife within the area by several means: direct alteration of habitat structure and composition resulting from the head pond and construction of facilities; indirect habitat alteration caused by entrainment of the silt/bed-load or through altered microclimate; direct disturbance related to habitat loss as a result of wildlife avoidance of humans; physical blockage of wildlife movements; increased probability of mortality due to accidents, predation, and hunting; and increased intra- and inter-specific competition for habitat and associated resources (IEA Hydropower Agreement (n.d.), Rosenberg et al 1997).

At certain phases of their lifecycles, species are more sensitive to disturbance, for instance at the time of reproduction. The literature indicates that disturbance activities should be avoided during key life cycle stages (IEA Hydropower Agreement (n.d.). The EIA indicates that construction will be a continuous activity for approximately two years. This continuous activity is likely to represent a significant barrier to migration and reproduction of wildlife in the Dunvegan area.

The river corridor provides valuable habitat for fish, animals, aquatic organisms, insects, and birds. River riparian areas and river valleys provide important habitat and habitat connectivity for ungulates, bears, and migratory birds. The Peace River valley is known to support 44 species of mammals (one endangered, two of special concern), 200 species of birds (five endangered, one threatened, and two of special concern), seven species of reptiles and amphibians (two of special concern), and several thousand invertebrate species, including two species of Lepidopterans which are of special concern. Land use and human activity, have reduced habitat suitability for many species within the area (Alberta Natural Heritage Information Centre 2002).

The project will result in the permanent and seasonal flooding of a number of near-shore ecosection subunits, primarily associated with the river island and shoreline ecosections resulting in local habitat fragmentation (Glacier Power Ltd, 2000). Habitat fragmentation occurs when a number of dams and access roads are built along a River system, as is the case with the Peace River. This has the potential to subdivide species into small, isolated local populations that may lose genetic variability to inbreeding and genetic drift. Erosion of genetic variability may further reduce fitness and adaptive potential. Among populations, loss of genetic variability leads to convergence to one type and a narrow range of options for that species. Habitat simplification resulting from fragmentation may further exacerbate the situation (Rosenberg *et al* 1997).

It is possible that the creation of a reservoir may also make new habitats available that are favorable for maintaining animal populations. For example, bank morphology favorable to the development of littoral or wetland zones, the presence of half submerged tree trunks and the development of macrophytes, may promote the use of the reservoir by bird life. Currently, the main stream of the Peace River is not frequented by waterfowl due to the high flow rate. The creation of a reservoir may encourage more river use by various species of geese, ducks, cranes, swans, and herons.

The EIA identified numerous technical limitations such as a lack of quantitative site-specific data that made sediment quality, benthic algae, and invertebrates unsuitable for use as valued environmental components. This statement is contradicted by the literature. Past studies of benthic communities in the Peace River in Alberta, concluded that the benthic invertebrate community in the vicinity of Dunvegan is characteristically different from other reaches of the Peace River, likely as a function of the habitat characteristics that defined this area. The project area contains two general types of benthic algae and invertebrate communities: hard substrate communities associated with swift water and large particle sizes, and soft substrate communities associated with slower water velocity and small particle sizes. Due to the high water velocities in the main channel, this part of the aquatic habitat is likely to support hard substrate communities whereas the softest of substrate communities are likely to be restricted to habitats in low velocity areas found near short areas. The latter habitats currently account for a relatively small percentage of the total aquatic habitat within the project area (Alberta Environment 2002). Based on these requirements, it is expected that changes to sediment quality resulting from the facility will affect the benthic communities and result in a shift in community composition in the Dunvegan area.

Northern River Basins studies on large aquatic invertebrates indicate that these organisms are experiencing contaminant related stress in certain river reaches. Overall, the studies revealed no significant effects from sediments on the survival, growth, or fertility rates of macroinvertebrates (Alberta Environment 2002). The large majority of ecological studies on autotrophic organisms of flowing waters have concentrated on streams and small rivers. However, it is known that large rivers can support substantial benthic primary production. Unfortunately, there is a persistent misunderstanding that the phytoplankton of large rivers is sparse and consists primarily of detached benthic forms suspended in the water column (Wehr and Thorp 1997).

Navigation dams may significantly reduce current velocity and densities of benthic phytoplankton. Studies indicate that temperature increases, and current velocity decreases, are the main factors affecting phytoplankton densities in large rivers. Studies also suggest that densities are inversely related to flow conditions. Nutrient profiles have been found to be significantly different near navigation dams. Combined with reduced current velocity, nutrient (especially phosphorus) spiraling links are shortened, and biotic processes may enhance availability (Wehr and Thorp 1997).

The literature indicates that navigation dams have significant, but subtle effects on selected parts of the phytoplankton community. No general pattern for the effects of dams has been described with respect to phytoplankton densities, but densities of benthic species are known to be significantly lower just above low head dams. Temperature and current velocity are known to be important regulators of total density and the density of major phytoplankton groups. Water residence time is of critical importance in rivers, impoundments, and lakes. This information suggests that small and sometimes statistically non-significant reductions in current velocity may allow bottom dwelling species to settle out of the water column. Even though this may have negligible effects on the total community, changes in the discharge from navigation dams may have complex effects on river phytoplankton. Re-suspension may increase total cell densities, especially benthic, and may also dilute planktonic numbers. Extended high flow periods may cause shifts in community composition and reduce inter-pool differences within the river. The data also suggest that biotic regulation by grazing zooplankton may also play an important role in the distribution and composition of phytoplankton communities within river ecosystems (Wehr and Thorp 1997).

Tributary rivers tend to have greater total densities of phytoplankton with a greater proportion consisting of colonial cyanobacteria, green algae, and diatoms. Despite large differences in densities of certain forms, effects of these tributaries on the main river are not large. Tributaries also have few important effects on zooplankton communities within the main river. It is suspected that the lack of strong tributary affects is the result of a considerably larger total flow in the main river than in smaller tributaries (Wehr and Thorp 1997). Therefore, it is unlikely that phytoplankton recruitment from the tributaries around Dunvegan will compensate or stabilize population changes resulting from the facility.

Based on the literature, the benthic community in the downstream portion of the head pond will likely become more characteristic of those associated with slower flowing water and finer particle size, than what currently dominates. It is also possible that invertebrate densities could decrease in areas of the head pond were smaller grained sediment is expected to deposit. The absence of mitigation or enhancement measures dealing with the problems of habitat losses can limit re-colonization by zooplankton and the food chain depending on it (IEA Hydropower Agreement (n.d.)). This is the case at Dunvegan, where significant changes in benthic organisms are likely.

The overall impact of the project on the algae and invertebrate communities at a regional scale is rated as non-significant by the EIA. The local adverse effects, however, are likely to be very significant. It is possible that changes to invertebrates and zooplankton populations will affect phytoplankton community composition and abundance. Species shifts will likely result, but the magnitude, distribution, and species involved are difficult to predict. These changes may also have implications further up the food chain in the fish community. The EIA did not directly address the issues of phytoplankton or planktonic/benthic chlorophyll levels and this represents a very large shortcoming in the document, considering their role as primary producers in the aquatic food chain.

Within a regional context, fisheries values are high in the Peace River and its tributaries, which provide spawning/rearing, migration and overwintering habitat for seven sport fish species, including salmonids (Government of British Columbia 1987). The fish community in the Dunvegan project area consists of several populations and a range of species, each of which could be affected differently by the development. Sport fish species known to inhabit Dunvegan include bull trout (locally endangered), arctic grayling (locally endangered), rainbow trout, mountain whitefish (locally endangered), walleye, perch, and northern pike. Non-sport species include: longnose sucker, flathead chub, white sucker, northern squawfish, burbot, and goldeye. A number of minnow species are also known to inhabit site specific areas of the river and its tributaries. Species such as goldeye, walleye, and flathead chub residing in the area are known to be migratory, while species such as burbot, northern pike, longnose sucker, and white sucker are regarded as resident (Government of British Columbia 2000).

The mainstream of the Peace River provides limited amounts of high-quality fish habitat. Few records are available to confirm the occurrence of spawning in the mainstream Peace River. Most information is based on subjective evaluations of habitat quality and/or the presence of fish in spawning condition. The channel is relatively shallow throughout, which limits its potential as overwintering habitat, and water velocities are generally high. Habitats that provide refuge from high water velocities are not abundant. Unique in-stream habitats such as backwaters, scholes, and rapids are present but in limited abundance. This situation is further exacerbated by daily anthropogenic fluctuations in the flow regime that further reduces the quality of available habitat (Government of British Columbia 2000).

The regulated flow regime resulting from the Bennett Dam has resulted in an altered temperature regime, a reduced capacity to transport sediments, changed ice regime, and created diurnal water level fluctuations (Peters and Prowse 2000). Fish that require tributary habitats for spawning and rearing purposes during summer and fall are severely restricted due to the seasonal flow patterns. Similarly, the tributaries cannot provide overwintering habitat for fish or refugia from adverse conditions in the mainstream Peace River (Government of British Columbia 2000, Alberta Environment 2002).

The Dunvegan area provides marginal habitat for cold water species and the presence of a hydroelectric facility may further reduce the quality of this habitat (Government of British Columbia 2000). Temperature changes in the water will likely manifest as large diurnal fluctuations rather than longitudinal variations in the water temperature. Given the relatively high flow velocities within the head pond, the convective transported energy is much larger than the diffusive transport, complete mixing should occur in all three dimensions. Therefore, the cool water/cold water fish species transition zone must shift upstream or downstream depending on each individual fish's ability to circumnavigate the facility barrier (Committee on Inland Aquatic Ecosystems 1996, Rosenberg *et al* 1997).

The EIA indicates that two critical fish habitats are located within the project area. A walleye spawning area at kilometer 17 of the proposed head pond area, and a northern pike spawning area located at kilometer 9 adjacent to a non-active side channel. Flow regulation by the Bennett Dam dewaters both critical habitats on a daily basis. Although the tributaries provide seasonal habitat for cyprinid and sucker species, they are incapable of supporting resident sport fish and have limited value to sport fish populations residing in the mainstream Peace River (Government of British Columbia 2000). Therefore, the head pond operation may have positive effects on the fish community by creating additional spawning and overwintering habitat within the project area.

Aquatic fauna and fish in particular, sometimes travel long distances to provide for their specific needs. The physical and chemical features of the river channel and water are forever changing. Consequently, fish species living in these aquatic environments are confronted with extreme seasonal and environmental fluctuations. A key strategy for many species is extensive movement. Extraordinary variation in life strategies exists between species. Fish require specific habitats to complete the various stages of their lifecycles. The physical structures of the riverbanks, beds, and channel features of the mainstream river are known to be important fish habitat features (Alberta Environment 2002). Physical structures and especially dams constitute barriers to such migrations (IEA Hydropower Agreement (n.d.)). The project activities are likely to adversely affect the fish community in two ways; both are related to fish movements upstream and downstream.

Operation of the head works structure will hinder or block upstream fish movements, whereas entrainment of downstream migrants into the tributaries could result in fish mortality. The head works represents a long-term barrier to upstream fish passage. Fishways will allow fish movements past the structure, but their effectiveness will be restricted to larger fish, greater than 250 millimeters long. The fishways will facilitate upstream passage of adult fish of most species, but smaller fish and younger age classes of larger fish will not be able to move past the head works. The fishways are a vertical slot type design with multiple inlet levels to accommodate the greatest possible head pond level variation (Glacier Power Ltd. 2000).

Various fishway systems are used to overcome or bypass barriers, and to sustain upstream and downstream fish migrations and species diversity over a range of habitats. Swimming ability and fish responses are important for translating biologically meaningful parameters into suitable hydraulic conditions, and design criteria for building fishway systems. Guiding and attracting different species to entrances of bypass systems is a difficult task and may well be the determining factor in fish passage effectiveness, particularly when wide rivers, large regulated flows and a variety of species are involved, as is the case with the Peace River. Often many species and many different size fish have competing biological and hydraulic criteria. Unique features at each site affect the flow patterns, fish movements, and migration path, emphasizing the importance of tailoring fish attraction solutions (Katopodis 2002).

Most fish species will use various fish passage facilities, provided they can readily locate them or be guided to them, their lifecycle requirements are met, and their abilities are well matched with hydraulic conditions. Facility choice depends on fish habitat management objectives, site conditions, range of water levels, passageway hydraulics, operational constraints, construction materials, maintenance, and economics. The fish entrance, biological requirements, and passageway hydraulics are the most critical aspects for effectiveness (Katopodis 2002). Currently, the Dunvegan project is considering a number of fish passage systems; no design has been agreed upon. A fish movement study is presently underway on the Peace River for suckers, walleye, and goldeye species (Reichert 2002). It is hoped that this information will be available soon and aid in the project design.

The successful downstream passage of emigrating fish is necessary to sustain, increase, or restore fish stocks within the river ecosystem. The EIA indicates that all fish will be forced to pass downstream through the project head works regardless of its population group. The bulk of the Peace River discharge will be directed through the turbines and the trash racks will not physically exclude fish from entrainment. Most fish passage models, like those used in the Dunvegan EIA, assume a generalized turbine passage survival rate of 70 to 85 percent. These models however, do not make a clear distinction between the direct (immediately upon turbine passage) and indirect effects that may occur over time (Mathur *et al* 1996).

Hydraulic model studies from some hydro dams have shown that the intake guidance screens installed to exclude fish from transport through turbines, causes the flow to redistribute downward toward the intake floor and accelerate. Such screens are planned for the Dunvegan project. Fish entrained in the accelerated, redistributed flow tend to pass near the turbine area rather than the hub. The passage of fish through the blade tip area maybe more detrimental than passage through the hub because of a higher strike probability. The flow redistribution may also increase fish mortality by exposing fish to more severe changes in pressure conditions. Furthermore, it is suspected that the gaps between the turbine hub and runner blades pose additional risks to fish survival because flows from the upper area of the turbine intake may draw entrained fish to the hub area (Mathur *et al* 1996).

A number of recommendations for mitigation measures in the area of fish protection are contained within the literature. These include; biotop adjustments; creation of spawning areas; fish stocking; general fish population management; long-term data sets for fish population and detailed knowledge of fish biology; minimum flows and optimum compensation flows; and population biology (IEA Hydropower Agreement (n.d.)). With respect to the Dunvegan EIA, there is a lack of information regarding the fish populations in the Peace River at Dunvegan. Additionally, the EIA appears to focus on species with commercial or recreational value, with subsequent investigations into fish population dynamics involving only 3 species (2 migratory, 1 resident). There is a need for further study focused on all fish populations, their communities, and their place in the aquatic ecosystem near Dunvegan. This lack of data combined with the lack of mitigation measures in the EIA is viewed as a serious shortcoming.

INUDATION PRODUCTS

The production of methylmercury, ammonia, and greenhouse gas exchange may also result from the inundation and of dryland containing organic materials (Kelly and Rudd 1997, Rosenberg *et al* 1997). The EIA rates these potential effects as negligible, since most of the land to be inundated by the head pond is located within the active floodplain. However, it is important to recognize that the area is contained within a 1:100 year flood plain, and significant plant growth and organic matter accumulation occurs within a 100-year time span. This is particularly significant given the fact that flood events within the main river have been rare and with reduced water volume, since the construction of the Bennett Dam in 1967 (Environment Canada 1999, Government of British Columbia 1987, Peters and Prowse 2000). This trend has eliminated the river's ability to flush nutrients, sediments, and debris from the river channel resulting in an accumulation of organic material.

The release of greenhouse gases (CH4 and CO2) caused by the flooding of organic matter in forested peat lands like those in the Peace River valley may be connected with reservoir creation (Kelly and Rudd 1997). On the temporal scale, greenhouse gas emissions from northern boreal reservoirs slow with time but may last longer than 100 years where peat has been flooded. The following factors may be involved in regulating the intensity and duration of greenhouse gas emissions after reservoir creation: the amount of flooding involved; the age of the reservoir; the amount of plants biomass and soil carbon flooded (boreal ecosystems approximately 10 kg C/m2); and the geographic location of the reservoir. Estimates of greenhouse gas emissions from Northern Canadian reservoirs indicate that some reservoirs with a high ratio of surface area to energy production can approximate or greatly exceed emissions from power plants using fossil fuels. However, this is not believed to be the case for run-of-river installations like that proposed for Dunvegan. It is believed that these kinds of installations are much less polluting than power plants run by fossil fuels (Rosenberg *et al* 1997). The EIA appears to be accurate in its assessment of this environmental effect.

Methylmercury is an inorganic molecule produced mainly by bacteria from inorganic mercury naturally present in materials flooded during the course of reservoir creation. Typically methylmercury bioaccumulation in fish is confined to the reservoirs themselves and short (less than 100 km) distances downstream. Temporally, methylmercury contamination in reservoirs can last 20 to 30 years or more. Research in northern Canadian reservoirs has revealed that methylmercury in fish can reach very high levels. Predatory fish such as pike and walleye have been found with 6 times the background levels or more than 7 times the Canadian marketing limit of 0.5 *u*g/g. Mean concentrations in predatory fish almost always exceed 1.0 *u*g/g in northern reservoirs. Levels in predatory fish usually remain elevated for two to three decades following impoundment, whereas levels in water and zooplankton remain elevated for 10 and 10-15 years, respectively. This difference between fish and lower trophic levels is probably the result of a longer half-life of methylmercury in fish, and a slower turnover of fish populations. Downstream transport of methylmercury is probably due to fish feeding on injured fish. It has not been confirmed whether concentrations of methylmercury in predatory fish from reservoirs are sufficiently high to affect their populations (Rosenberg *et al* 1997).

Methylmercury elevation in fish is also related to the degree of flooding of terrestrial areas involved in reservoir creation. A high proportion of land flooded, compared to the final surface area of the reservoir, produces higher methylmercury levels than those with a low proportion of the surface area to flooded land. This relationship explains why methylmercury levels in reservoirs created by flooding river valleys are much higher than those in already existing lakebeds. It has also been demonstrated that a greatly enhanced rate of conversion from inorganic mercury to methylmercury occurs in newly flooded sediments of reservoirs compared with natural lake sediments. Natural wetlands in the northern boreal ecosystems are sites of methylmercury production and important sources of methylmercury to downstream ecosystems. All organic materials (Moss, spruce boughs, and prairie sod) add to methylmercury bioaccumulation. Removal, burning, or covering of vegetation and soil organic matter prior to flooding is recommended for reducing the severity of the mercury problem. Alternatives would be to minimize the area flooded when creating reservoirs and avoid flooding natural wetland areas (Rosenberg *et al* 1997). These recommendations and mitigation measures appear to have been considered in the Dunvegan EIA.

MICROCLIMATE EFFECTS

Parameters like temperature, wind, precipitation, evapo-transpiration, humidity, fog formation, and greenhouse gas emissions can have effects on the local climate. Some of the changes in these parameters arising as a result of a hydropower projects are difficult to distinguish from annual climatic fluctuations. However, some of these induced modifications to the local climate may be permanent (IEA Hydropower Agreement (n.d.)). It is suspected that changes in these variables will occur locally and may profoundly affect microclimates in the Dunvegan area. These changes will likely be difficult to quantify in the short-term, but long-term may be indicated by ecological shifts. For example, an increase in water temperature may induce the eggs of fall spawning fish to hatch prematurely and could affect their survival. Whereas, sustained low temperatures during warm months may support cold water species such as trout in areas that otherwise would not provide appropriate temperature regimes. At the same time, temperature alteration may suppress other important native fish and aquatic species (Committee on Inland Aquatic Ecosystems 1996). Where ice cover forms, near-shore zones may be clogged by frazil ice, and this may affect the availability and quality of near-shore winter habitat for fish (Alberta Environment 2002). A local increase in humidity may also result from ice fog generated by longer ice-free periods and cold temperatures.

CUMULATIVE ENVIRONMENTAL EFFECTS

While the cumulative environmental effects sections of the EIA were voluminous, they were lacking in several areas. Most of the sections site technical boundaries or a lack of data as reasons for incomprehensive or absent effect assessments. However, the literature indicates that a great deal of river and site specific information is available (Alberta Environment 2002). Additionally, the EIA indicates that the time required for ample baseline studies was not available. This statement is surprising since project feasibility studies were initiated in 1977 (Natural Resources Conservation Board 2001). Given this timeframe, some baseline studies should have been completed on aquatic invertebrates, fish, phytoplankton, water quality, and potential cumulative effects. This information would have been invaluable for quantifying potential effects using field data and statistical analyses. Instead, the cumulative effects assessment is based on scientific knowledge which was for the most part not site specific, existing literature which was not fully utilized, previous studies which were either very old or incomplete, and professional judgment which is highly subjective (Glacier Power 2000). The literature indicates that this shortcoming is common in northern regions because of the vastness and remoteness; baseline data are often incomplete and cumulative effect assessment are just beginning to take place with few clear guidelines, methodologies, or practices in place (Goyal and Deshpande 2001).

If the Dunvegan facility is constructed the Peace River will become a series of reservoirs between dams. Because biotic communities are structured along resource gradients and downstream communities are at least partly dependant on upstream processes the cumulative environmental effects could be very significant to the ecosystem. Impoundment along river courses can interrupt natural longitudinal energy transport gradients, causing longitudinal shifts in physical and chemical variables, which in turn cause biotic shifts. This mechanism ultimately effects biodiversity. Transportation of sediment and organic matter to downstream reaches is interrupted by reservoirs and eventually affects carbon and nutrient cycling. This has already been observed in the Peace/Athabasca Delta as a result of the Bennett dam (Peters and Prowse 2000, Rosenberg *et al* 1997). Furthermore, intermittent and permanent aquatic habitats outside the main channel are also important to normal river functioning; and the predictable advance and retreat of water onto floodplains are thought to control adaptations in most biota. Consequently it is vital, that cumulative changes apparent in nature, which have resulted from various projects, are described and analyzed. The assessment of cumulative impacts serves to clarify the pressures concentrated on the environment, which may accumulate in the long-term, and in large geographic areas (IEA Hydropower Agreement (n.d.)).

After head pond formation, it is likely that the total quantity of pre-existing aquatic habitat will remain unchanged, but the quality will be altered and the diversity will be lower. The magnitude of these changes will depend on the flow conditions. Sediment deposition will likely cause the most significant changes in habitat quality. The predicted head pond flow regime will affect the availability and quality of potential new habitats. The effect of the head pond on water levels will lead to reductions at many sites during low to moderate discharge, which will cause frequent dewatering. Changes in water levels will cause increased water flow over scholes and side channels; result in increased near-shore gravel accumulation near the apex of gravel fans; and cause the deposition of incoming bed-load. Upstream beyond the 25 km mark, the limited effect of the head pond on water levels during low to moderate flow will make all suitable fish habitat unavailable (Glacier Power 2000).

Increased water depth, reduced water velocity, and increased sedimentation will alter the characteristics of fish habitats in the head pond to the point where they no longer retain their original function. Specific zones that will be altered include existing shallow water areas with gravel and cobble materials that are potential spawning areas for walleye and sucker species, as well as feeding and overwintering areas for all fish species. Tributary mouths are likely to infill with fine particles resulting in frequent dewatering and a reduction in small fish rearing habitat. Small fish rearing areas in general are likely to decline in abundance due to the presence of deep water in the head pond. However, this increased water depth combined with lower water velocity may enhance and increase the amount of overwintering habitat available to fish, provided the food chain is not so altered that prey species become scarce around Dunvegan. It is possible that productivity in the Dunvegan area may decline. Perhaps the greatest disadvantage of the project is that it will restrict upstream passage of fish to greater than 250 mm in length and therefore not all species or age classes of fish will be able to pass upstream (Glacier Power 2000).

The terrestrial environment will likely not be as affected as the aquatic one; animals will probably be affected more than plants. Habitat fragmentation or loss, combined with increased disturbance will likely have the greatest impact on animals. Locally, erosion and flooding and/or dewatering are likely to increase in many areas and plant communities will be required to shift and colonize new suitable areas.

CONCLUSIONS

The Dunvegan EIA was thorough in that it touched on the many possible environmental effects that may result from the project. The document addressed all of the necessary requirements outlined in Canadian environmental legislation. Overall, however, the document was severely lacking in qualitative and quantitative data, and particularly baseline data.

The document also failed to use all of the relevant literature effectively. Therefore, the conclusions made regarding the environmental impact of the project are not well supported and lack credibility. Additionally, many biotic subjects within the document were lacking in mitigation measures, and therefore, the associated environmental effects should only be viewed as a best-case scenario. The document additionally failed to include and consider numerous guidelines outlined by the hydropower industry for environmental impact assessment and mitigation. There was also an apparent lack of consideration for the status of numerous endangered, threatened, and vulnerable species in the Dunvegan area.

AUTHOR'S POST SCRIPT

In April 2003, the NRCB denied the request for hydroelectric development at Dunvegan based primarily on ice and fish concerns. At that time, the fish population/migration study was incomplete. The Dunvegan project is no longer considered viable, but two similar facilities have been proposed further upstream near the British Columbia/Alberta border. The author would like to thank the hydro developer mentioned in this document for the complete and forthcoming information supplied.

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