FISH MONITORING PLAN
- DUNVEGAN HYDROELECTRIC PROJECT -

Prepared for

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1.0 INTRODUCTION

1.1 BACKGROUND

In 1998 Glacier Power Ltd., which is a wholly owned subsidiary of Canadian Hydro Developers, Inc., initiated feasibility studies for the proposed Dunvegan Hydroelectric Project (the Project). The Project consists of a low-head, run-of-river hydroelectric development on the Peace River located approximately 2 km west of the Highway 2 Bridge at Dunvegan Historic Park (Dunvegan) near Fairview, Alberta.

A partial condition of regulatory approval for the Project will be implementation of a Fish Monitoring Plan (FMP). Glacier Power Ltd., in cooperation with Alberta Sustainable Resource Development (ASRD) and Fisheries and Oceans Canada (DFO) are currently developing the FMP. As a basis for discussion, Glacier Power presented a document that identified the issues that needed to be addressed, the recommended approach, and associated methods (Glacier Power 2003). This was followed by a formal response by the regulatory authorities (DFO/ASRD 2004) and additional discussions culminating in a technical workshop held on 26 May 2004. This document describes the components and methodologies of the Fish Monitoring Plan to be undertaken as part of the Dunvegan Hydroelectric Project.

1.2 STRUCTURE

The FMP is designed to address several fish related issues. To facilitate discussions, the issues are grouped into categories, or components, and each issue is posed in the form of a question. There are three components of the FMP as follows -- fish passage, fish survival, and fish community characteristics. Table 1.1 provides a summary of components and associated questions to be addressed by the FMP. It should be noted that evaluation of change to habitat quality and quantity has been identified as monitoring requirements (DFO/ASRD 2004). These activities will be discussed in a separate document.

1.3 PURPOSE AND APPROACH

The purpose of the FMP is as follows:

1. Verify impact predictions.
2. Monitor compliance with regulatory conditions.
3. Evaluate effectiveness of mitigation measures.
4. Provide information for use as part of the adaptive management procedures.

The adaptive management procedures are outlined in the Project Description (CLP 2006) and the Fish Passage Rationale (NHC 2006).

Table 1.1 Components and questions addressed by the Dunvegan fish monitoring plan.

FMP Component	Sub-Component	Question
Fish Passage	General movement pattern	1. What is the timing, rate, and extent of fish movement? 2. What is the width and location of the fish movement corridor?
	Facility performance	3. Can fish locate fishway and bypass structure entrance? 4. What route is used by fish (structure and path within the structure)? 5. What is the rate of fish movement through the structure? 6. Can fish exit the structure?
	Fish characteristics	7. What are the species, numbers and sizes of fish that may need passage?
Fish Survival	Passage survival rate	8. What are the survival rates of fish that pass downstream?
	Passage route	9. What proportion of the population use each route?
Fish Community		10. Does the Project affect fish community characteristics?
	Community structure	• Species diversity
	Population structure	• Age and size distribution
	Population health	• Growth rate and body condition
		• Mortality rate
	Population size	• Abundance

The FMP will adhere to the scientifically based approach recommended by Environment Canada for environmental effects monitoring programs (ENVCAN 2004). The FMP also will follow five general principles as follows:

1. The FMP will be designed, and will be of sufficient effort and duration to detect a biological change in the fish community caused by the Project, if one exists. Biological change is defined as a measurable shift in a specified parameter (e.g., movement timing, species abundance, age structure) that could potentially influence the viability of a population.
2. The FMP will rely on statistical certainty as a basis for assessing biological change. When logistical constraints or natural variability precludes use of statistical certainty, two alternative approaches will be employed. The first is weight of evidence, which involves measurement of multiple variables to ascertain whether there is a biological change. The second is data trend, which requires the existence of spatial or temporal patterns in the data as an indication of biological change.
3. The FMP will use indicator fish species as the basis for monitoring biological change. Indicator species will be chosen based on their sensitivity to Project effects, their ecological importance to the fish community in this section of the Peace River, and their social importance. It should be noted that all species will be incorporated into some monitoring components (e.g., fish community characteristics).
4. When a biological change is detected, the FMP will be designed to ascertain whether the change is caused by the Project, and if so, what Project component is responsible. Additional focused monitoring will be undertaken until the issue is resolved.
5. The design of the FMP will be flexible and adaptive in order to effectively respond to unforeseen issues.

2.0 FISH PASSAGE

Measures to facilitate fish passage past the facility include use of fishways for upstream passage and use of exclusion devices in combination with sluicewayss for downstream passage. The document titled “Dunvegan Hydroelectric Project Fish Passage Rationale” provides a detailed description of these mitigation measures (NHC 2005). The following provides a concise description.

Two fishways, one along each river bank, will be operated during the open water season. The fishways are designed to pass fish at least 150 mm fork length using a series of weir - pool complexes. They will have dedicated flows at their bases to attract fish towards the entrances and baffled orifice systems at the upstream ends to control input water flows and provide exits into the headpond..

Downstream fish passage will involve seasonal exclusion of fish >300 mm fork length using trash racks in front of each turbine and guiding excluded fish to 10 sluiceways distributed across the face of the headworks structure. Individuals ≤300 mm may pass through the turbines or the sluiceways. Spillway operation may also facilitate downstream fish passage during high flow periods, although the spillway is not expected during the downstream migration period.

Issues of concern related to fish passage involve disruption of seasonal movements either by causing a delay or by complete blockage of upstream or downstream migrants. There are three sub-components to fish passage monitoring. These include general fish movement patterns, bypass facility performance, and characteristics of fish that may need passage.

2.1 GENERAL FISH MOVEMENTS

2.1.1 Approach

Question #1 - What is the timing, rate, and extent of fish movement in the Peace River?

Information that describes when, where, and how far fish move in the Peace River is needed for two reasons. First, it is required to ascertain whether all or part of a fish population must pass the Project structure. Pre-development baseline data generated using radio-telemetry (Mainstream 2004, 2006b) will provide a benchmark for comparisons to post-development fish movements. Second, the information is necessary to establish the appropriate window of operation of the bypass facilities and to adjust those windows as part of the adaptive management procedures.

Question #2 **-** *What is the location and width of movement corridors used by migrating fish?*

The fishways and bypass facilities are designed based on the assumption that fish concentrate in specific areas in the river channel during migration. It is assumed that upstream migrants are situated along the channel margins. Downstream migrants also may tend to follow the channel margins, but have a greater probability of using the entire river channel as a movement corridor. Information is required to confirm these assumptions and to ascertain whether there are changes to the movement corridors post-development. If assumptions are violated, adjustments to fishway and bypass facility operation would be implemented.

The approach and methodologies were developed based on recommendations from the preliminary fish movement study in 2002/03 (Mainstream 2004), discussions with ASRD and DFO, and results of the 2004 baseline fisheries study (Mainstream 2006a) and the 2004/05 fish movement study (Mainstream 2006b). These investigations provided information on fish community characteristics and fish movements, and established that the study design and methodologies were appropriate for the FMP. The following provides a concise summary of that information.

2.1.2 Indicator Species

Four indicator species that are an integral part of the fish community in the Dunvegan area will be used for monitoring general fish movement patterns as follows: goldeye, walleye, longnose sucker, and burbot. Goldeye are chosen because they are migratory, and therefore, their population may be most susceptible to movement delay or blockage. Walleye are chosen because they are an important recreational species that may move past the facility to access spawning habitats. Longnose sucker are used because it is ecologically and numerically the most important species in the Project area. Burbot are monitored because they represent a species with a weak swimming ability (anguilliform) and they may need passage to spawning sites during the winter period. Movement results indicate that goldeye are the only migratory population in the Project area; all other species are sedentary (Mainstream 2006a, 2006b).

2.1.3 Parameters

The monitored parameters will be as follows:

- Rate of movement
- Timing of movement
- Extent of movement
- Movement corridor (width and location)

2.1.4 Study Area

The study area will encompass the Dunvegan Project area (Km 919 to Km 983; from the confluence with the Peace/Athabasca Delta) as well as a large portion of the Peace River on either side. The downstream boundary will be located approximately midway up the Peace River near Vermillion Chutes (Km 326) and will extend upstream into British Columbia to the Peace Canyon Dam (Km 1150). The study area will be divided into two zones: the fish capture area and the fish tracking area.

The fish capture area used for the radio-implant component of the study will focus on the river section in the immediate vicinity of the proposed Project. The fish capture area will focus efforts on fish that reside in close proximity to the proposed development, which are those most likely to be affected.

The fish tracking area will encompass a large section of Peace River in order to accommodate all potential movements of fish. It will be divided into two sections designated as Core or Extended. The Core area represents a river section where the majority of fish movements are expected to occur and within which standardized, regular tracking effort can be expended. It will extend 399 km along the Peace River from the confluence of the Notikewin and Peace Rivers (Km 670) upstream to the Alberta/British Columbia boundary (Km 1069). The Extended area represents an expansion of the Core area into upstream and downstream sections where tracking will be conducted at a lower intensity in an attempt to locate all radio-tagged fish. The Extended area will be 824 km in length and will include the Peace River from Vermillion Chutes (Km 326) to the Peace Canyon Dam, BC (Km 1150).

The lower sections of several tributaries near their confluences with the Peace River will be included in the fish tracking area on an opportunistic basis. These include the Notikewin, Cadotte, Smoky, Clear, and Beatton rivers. Tracking will be extended into these watercourses when fish movement into the tributary is suspected.

2.1.5 Study Period

Fish will be implanted in spring (early May). Movements of radio-tagged fish will be monitored at regular intervals for the life of the radio tags, which will be approximately 15 months.

2.1.6 Methods

High frequency coded radio transmitters will be used to monitor fish movements. Tracking of radio-tagged fish will be accomplished from the air and ground. Timing, rate, and extent of movements will be delineated using aerial tracking.

The width and position of movement corridors used by fish, and general rate of movement will be characterized by mobile ground tracking. Ground tracking will be conducted from a boat to document the position of radio-tagged fish in relation to the channel margin. Signal strength in combination with triangulation will be used to establish the fish position to within ± 5 m.

2.1.7 Effort

Fifteen sexually mature individuals of each indicator species will be implanted with radio tags for a total of 60 radio-tags. Fifteen fish per species is deemed a sufficient sample size to describe general movement patterns. The information will be used for descriptive purposes; therefore, there is no requirement for large sample sizes to develop statistical certainty. If monitoring results suggest that a sample size of 15 tags per species is not sufficient due to fish mortality, radio-tag failure, or variable movements, an increase in sample size will be considered.

Aerial tracking will occur at regular 10 to 14-day intervals for the life of the radio tags, which is approximately 15 months. Each tracking flight will include the Core Area to ascertain movement patterns, timing of movements, and rate of movements. As a minimum, every fifth tracking event will include the Extended Area to delineate the maximum spatial extent of fish movements.

Ground tracking from a boat will occur opportunistically during periods when radio-tagged fish exhibit upstream (spring) or downstream (fall) movements in the vicinity of the Project.

2.2 EFFECTIVENESS OF PASSAGE FACILITIES

2.2.1 Approach

The primary goal of this monitoring component is to ascertain the efficiency of fish passage in terms of fish species and sizes passed, as well as speed of passage through the facility. Fish passage facilities will be designed to allow fish to pass through the headworks structure without unreasonable delay. Unreasonable delay is defined as the amount of time that would cause a significant impact to the viability of a fish species population (e.g., prevent access to spawning sites during the spawning period). An objective measure of unreasonable delay will be defined following discussions with regulators.

The efficacy of the proposed mitigation strategy is based on assumptions related to fish size and swimming ability. Empirical data are required to confirm these assumptions, to identify locations exhibiting potential passage impediment, and to guide timely adjustments to facility operation as part of the adaptive management procedures. Specific questions that will be addressed by this component are as follows:

Question #3 – Can fish locate fishway and bypass structure entrances?
Effective fish passage depends in part on a fish's ability to quickly locate the entrance of a fishway or bypass structure.

Question #4 -- What passage route is used by fish?
This question includes two levels of resolution. The first involves establishing whether specific structures are used more frequently than others. The second involves establishing the route or path used by fish within the fishways.

The fish passage facilities will provide multiple upstream and downstream passage routes. Initial operation of the facilities assumes that there will be no specific preference by fish for a particular structure (e.g., left or right fishway). If fish exhibit preference for a particular structure, then steps may be taken to adjust the operation of the fish passage facilities to accommodate this preference, thereby maximizing the effectiveness of mitigation. This could involve adjusting the location and magnitude of flows. This approach also will be applied to fish use of a particular route or path within the fishways.

Question #5 -- What is the rate of ascent through the fishways?
Question #6 -- Can fish exit the fishways?

These questions will be addressed for the same reason given for Question #3. Effective fish passage depends in part on a fish's ability to quickly ascend and then exit a fishway in order to prevent an unreasonable delay in fish movement.

2.2.2 Methods

<u>Radio-telemetry</u>
Radio-telemetry will be the primary method used to address fish passage questions #3 to 6. Techniques developed by LGL Limited (www.LGL.com) and Grant Systems Engineering (www.grantsystems.com) to monitor fish passage at other hydroelectric facilities will be used for this purpose (English et al. 2003, Nass *et al.* 2003, Robichaud *et al.* 2003a). A detailed description of the fish passage radio-telemetry monitoring plan is presented in Appendix A. The following provides a general overview of the plan.

There will be two types of movement examined using radio-telemetry. They include movements of fish as they approach the headworks structure (i.e., within several km) from upstream or downstream (Approach Movements) and movements of fish as they physically pass the headworks structure (Passage Movements). There is the possibility of a third type of movement, which is Residence Movements (i.e., fish that choose to reside in the immediate vicinity of the headworks structure). Residence movements will be quantified to establish that they do not represent a delay in passage, but will not be integral to the fish passage questions.

Approach Movements will be collected using a combination of automated tracking using remote aerial arrays and manual tracking. This sub-component will characterize the timing and rate of movement, and the route used by fish as they approach the structure. A remote aerial array station will be established several kilometers upstream and downstream of the headworks structure to detect approaching fish. Each array station will be located in an area that maximizes the ability to detect radio tag signal and that allows sufficient time to manually track fish movements. Once a fish is detected at the remote aerial array station, ground tracking will be used to collect data as the fish moves towards the facility. Potential limitations of this approach pertain to the ability to collect data in a timely fashion once a fish is detected and excessive headpond water depths that may hinder detection of radio tag signals.

A more detailed delineation of fish movements is required in the immediate vicinity of the structure, as well as in and around the fish passage facilities. Radio tagged fish will be monitored using an integrated tracking (*MITAS – multiprotocol integrated telemetry acquisition system*) and data processing (*Telemetry Manager*) system. The combined system has several advantages over other techniques such as PIT (Passive Integrated Transponder) tags, acoustic telemetry, and hydro acoustics. First, the techniques will enable collection of data needed to address all questions pertaining to fish passage. Second, the system equipment is readily available and can be easily modified to accommodate site-specific conditions. Third, it is a proven technique that has been used at other hydroelectric facilities (English et al. 2003, Nass et al. 2003, Robichaud et al. 2003a). Finally, it provides real-time information that describes coarse scale fish locations (i.e., detection zones - e.g., left forebay vs. right forebay, spill bypass 1 vs. 2, left fishway entrance outside vs. left fishway entrance inside), which can be used to guide the adaptive management procedures.

The *MITAS* system involves deployment of several strategically placed aerial and underwater antennae. Antennae will be placed in each upstream passage facility, each spill bypass route, and along the face of the headworks structure. The detection zone of each antenna (or combined series of antennas) will be defined to allow relative or coarse scale positioning of the fish in proximity to the Project headworks. The location information will be sent to a central receiver/data logger for synthesis and storage. Data processing will be performed by computer programs (*Telemetry Manager*) developed specifically for this purpose by LGL Limited.

One limitation to using radio-telemetry is that it requires the capture, tagging and release of fish and only monitors the tagged population. Therefore, a relatively low sample size (n=15 for each indicator species) is expected, and non-target species will not have radio-telemetry data. To address this issue a second approach will be used to compliment the radio-telemetry component.

Fish Capture

Non-lethal fish capture techniques that include boat electrofishing and fish traps, in combination with manual sonar will be used to characterize the fish community in the immediate vicinity of the facility. The information will supplement the radio-telemetry program, provide data for the indicator species, all other species and sizes of fish, and serve as an early warning system regarding the effectiveness of the fish passage facilities (i.e., identify concentrations of fish adjacent to the facility). Parameters to be monitored will include fish abundance, species composition, size distribution, and areas of fish concentration.

2.3 CHARACTERISTICS OF FISH THAT MAY NEED PASSAGE

2.3.1 Approach

The potential effect of the Project on a fish population will depend, in part, on the proportion of the population (i.e., number and life stage) that may need to pass the structure. Presumably, for a species that would typically pass the Project site to spawn (e.g., goldeye), the population would have a higher likelihood of being affected compared to a species that passes only a portion or none of its population (e.g., longnose sucker). To address this issue, the number and size of fish that may need passage needs to be quantified. A second potential issue is whether the passage facilities have sufficient capacity to pass large numbers of fish, if necessary.

Question #7 -- What are the species, numbers and sizes of fish that may need passage?

The radio-telemetry techniques described in Section 2.2 will provide information that describes movements of selected fish species and life stages. They will not provide data that quantifies numbers, sizes, and composition of species that may need passage; therefore, alternate techniques are needed.

2.3.2 Methods

The FMP will characterize fish that may need passage using a combination fish count traps in the fish passage facilities and a fish capture program in the immediate vicinity of the headworks structure. A fish count trap will be placed at the upstream end of each fishway to collect fish that successfully move through the structure. Collected fish passing through the structure will be identified to species, enumerated, measured for size, and marked with a uniquely numbered tag.

A fish capture program undertaken as part of the fish community component (See Section 3.0) will be used to collect the same information from fish in the immediate vicinity of the headworks structure (1 km upstream and downstream). The data from the fish count traps and fish capture programs will be compared to ascertain what portion of the fish community (numbers, species and sizes) passes the facility. In addition, comparisons of species composition, size distribution, and abundance upstream versus downstream would be used to evaluate the assumption that the project has not affected fish movements.

These data will provide indirect evidence that fish bypass facilities are effective at passing all species, numbers, and sizes of fish because the proportion of the sampled population that attempts to pass will not be quantified. As such, examination results from multiple monitoring components will be used to make this determination. These include radio-telemetry, manual sonar and in particular, comparisons of upstream and downstream fish community characteristics.

2.3.3 Additional Information

In addition to addressing issues regarding effectiveness of the passage facilities, data from this monitoring sub-component provides an opportunity to quantify population characteristics for migratory species such as goldeye. Goldeye are expected to move through the facility each year, which allows development of a long term mark-recapture program (Gazey 2004) that will provide the following information:

- Estimate of population size
- Estimate of population mortality
- Estimate of recruitment rate into the population

In order to collect this information, the program will have the following characteristics:

- Conducted over multiple years.
- Use a tag that can be retained by fish for many years. Passive Transponder Tags (PIT tag) are an appropriate marking system because they are retained for many years and they allow use of an automated detector to facilitate continuous monitoring.
- Precision and success of the study would depend on the proportion of the population that is marked and recaptured.

This monitoring option will be discussed with regulators.

3.0 FISH SURVIVAL

The Project has the potential to affect the survival of fish populations by modifying access to and characteristics of important habitats, and/or by influencing the survival of fish that pass through the headworks structure (upstream or downstream). Access to important habitats is specifically related to fish passage, which is dealt with in Section 2.0; alteration of important habitats is discussed in the Dunvegan Fish Habitat No Net Loss Plan (Mainstream 2006c). This section of the FMP addresses specifically the potential for decreased fish survival caused by downstream passage of fish through the headworks structure.

The effect of the Project on fish population survival will depend on the downstream passage route selected by fish, the number of fish that may need passage, and the survival rates of those fish. Based on the mitigation strategies to be employed, it is assumed that downstream migrants ≥300 mm length will excluded from the turbines and use the sluiceways, and spillway (when available). Smaller fish <300 mm will not be excluded, and therfore, may pass through the turbines. Survival rates of all fish that use the sluiceways is assumed to be very high, as are the survival rates of smaller fish (<300) that pass through the turbines. Empirical data are required in order to confirm that the assumptions regarding survival rate are correct and to confirm size specific use of passage routes. Each of these will be addressed using specific techniques. The questions to be addressed are as follows:

Question #8 -- What are the survival rates of fish that pass downstream through the facility?
Question #9 -- What proportion of the population uses each downstream passage route?

3.1 TURBINE PASSAGE SURVIVAL

3.1.1 Approach

Turbine passage survival will be evaluated using a controlled experimental design in combination with a repeated measures statistical analysis. Marked fish of a specific size (<300 mm and >300 mm fork length) will be released upstream of an operating turbine and then retrieved following passage through the unit. The results will be used to quantify instantaneous survival and delayed survival. The experiment will be repeated several times to achieve a specific level of statistical power (Power=0.80). A control group of marked fish will receive identical treatment, with the exception that the fish will pass through a bypass structure. Use of a bypass structure for the control group will establish whether the assumption of high survival is correct. If the assumption is violated the results will represent relative survival (turbine versus bypass survival) rather than absolute survival.

3.1.2 Methods

The preferred species for this experiment will be longnose sucker and mountain whitefish. Longnose sucker are the most numerous and widely distributed in the Project area. Mountain whitefish are also numerous immediately upstream of the project area. Use of these species will ensure that sufficient numbers can be collected for the experiment. It is acknowledged that other species such as goldeye, likely are more sensitive to passage; however, their numbers are too low to provide a useful sample size. If requested by regulators, attempts will be made to include goldeye as a test species for this monitoring component.

Test fish will be collected using nonlethal methods immediately preceding the experiment. Controlled release of fish will be achieved using a conduit placed in front of the turbine intake port. Retrieval of fish following passage will be achieved by use of one of two methods. A fish collection net similar to a design employed by other turbine survival experiments (Stone and Webster 1992) and that are currently being used to monitor entrainment into large irrigation canals can be used. (Steve Heibert, Biologist, US Fish and Wildlife Service, Denver Colorado, pers. comm.). If this method is deemed unfeasible due to logistical constraints the study will use the HI-Z Turb'N Tag and recapture technique (Canada Patent 2 016 607) described by Heisey et al. (1992). The HI-Z tag allows estimates of direct effects of turbine passage without causing mortality or injury during recapture by forcing tagged fish to the water's surface for retrieval. In addition to the HI-Z tag, each fish will be given a unique numbered Floy tag prior to release for tracking survival of individual fish.

All recaptured fish (control and treatment) will be held in pens for at least 24 hr to determine delayed survival.

3.2 PASSAGE ROUTE

3.2.1 Approach

If turbine passage adversely affects fish survival, monitoring of passage route would be required in order to estimate overall population survival during passage. Potential passage routes include the turbines, the fishways, the spillway, and the passage facilities. Overall population survival will depend, in part, on the proportions of the population that pass through the turbines versus other routes. Radio-telemetry is an appropriate method to calculate this proportion (Robichaud et al. 2003b). This monitoring component will be designed to ascertain the proportions of fish populations and sizes of fish that pass through the turbines versus the remaining downstream passage routes.

3.2.2 Methods

The methods described under Section 2.0 will be used to examine passage route. A larger numbers of radio-tagged fish can be used to improve certainty regarding passage route. A larger number of tags also will accommodate the need to stratify the sample by fish size in order to test the assumption that fish ≥300 mm in length are prevented from passing through the turbines. Longnose suckers and mountain whitefish will be the preferred test species due to their availability in the project area. However, attempts will be made to test species such as goldeye, which have the greatest probability of violating the fish size exclusion assumption.

Small short-life radio transmitters that can be effectively attached externally will be used for this study component. Fish will be tagged and then released immediately upstream of the facility and their movements monitored using the monitoring system described in Section 2.0.

The information will be used to provide a relative measure of population survival associated with passage through the facility. The proportion of the sample that passes through the turbines will be multiplied by the survival rate generated using the approach described in Section 3.1 to predict the relative fish population survival rate.

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4.0 FISH COMMUNITY CHARACTERISTICS

4.1 APPROACH

The Peace River fish community could be influenced by the Project in a number of ways if the mitigation measures are not effective. The goal of this monitoring component will be to ascertain fish population response to potential mortality associated with fish passage and alteration to fish habitat. The most direct approach to ascertain whether there is an effect is to monitor fish community characteristics.

Several regulatory agencies have identified study designs and sampling protocols to monitor fish community characteristics potentially affected by development (AQUIMIN 1996; ENVCAN 2002 and 2004). Unfortunately, techniques available to monitor fish communities in large fluvial systems such as the Peace River have logistical constraints that hinder the ability to effectively monitor change (Sawada *et al.* 2002). Patchy fish distribution, inherently high natural variation, and variable effectiveness of sampling equipment are issues that need to be addressed if the FMP is to provide reliable data.

A comprehensive research program designed to identify and test sampling protocols for large river fish communities recently has been completed in the upper Peace River in British Columbia (P&E 2002, Mainstream and Gazey 2003, 2004, 2005, 2006). The results of this five-year study have established that sampling protocols can be developed to effectively monitor selected characteristics of large river fish communities. These protocols, which are described below, will be used in this FMP.

4.2 INDICATOR SPECIES

Five indicator species potentially sensitive to Project effects, that are present in good numbers, and that can be effectively sampled have been chosen for monitoring. Species to be targeted include: longnose sucker, mountain whitefish, goldeye, walleye, and burbot. Of these species, longnose sucker will be the primary indicator fish for the following reasons. It is a resident population; therefore, seasonal changes in abundance caused by immigration and emigration will not confound the results. It is a reasonably abundant population thereby allowing collection of a sufficient sample size needed to document change with statistical certainty.

Low numbers of the remaining indicator species will limit their usefulness for monitoring selected components such as fish abundance. They have been included because of their social importance and/or their potential sensitivity to Project effects. For these species, weight of evidence and data trends likely will be the methods used to detect change rather then statistical certainty. Although these five species populations will be specifically targeted, all other species encountered during monitoring will be enumerated.

4.3 PARAMETERS

The parameters to be monitored will be as follows:

- Community structure
    - Species diversity
- Population structure
    - Age and size distribution
- Population health
    - Growth rate
    - Body condition
    - Mortality rate
- Population size
    - Relative abundance
    - Density estimate

Previous experience with the five indicator species suggests that community structure, population structure, and population health parameters can be measured with the appropriate level of statistical certainty given the proposed level of sampling effort assuming Type I and Type II errors set at $\alpha = 0.1$ and $ß = 0.2$, respectively. It is likely that population size parameters will need to rely on trend analysis and weight of evidence in order to ascertain change.

Population mortality rate will be calculated using catch-curve survivorship, which is based on the frequency of ages within the sample.

Relative abundance indices are inherently variable making it difficult to detect change in relative abundance. For this parameter, initial analyses will involve use of abundance categories (e.g., scarce versus numerous). Abundance category status will be established based on the probability distribution around the mean catch rate (number of fish per unit of sample effort). A change in category status will indicate a change in absolute abundance. Abundance category designations for each species will be developed during discussions with DFO and SRD.

Low recapture rates and migratory behaviour for the target species also preclude use of standard closed-model density estimation methods to establish population size. As such, an indicator of population size can be developed by multiplying expected catchability (q) by catch rate. Q values will be generated either using baseline data from the Project area or using catchability values developed for similar species by other studies (Mainstream and Gazey 2004).

4.4 STUDY AREA

The FMP study area will encompass four zones as follows:

- A 20 km upstream (control) zone immediately adjacent to the upper extent of the headpond
- A 26 km headpond zone
- A 6 km tailrace zone immediately adjacent to the headworks facility
- A downstream (control) zone (20 km)

This approach will allow comparisons of fish community characteristics between zones. It is assumed that potential Project effects on resident fish populations will be manifested in the headpond and tailrace zones and these changes can be detected by comparing the results to the two unaffected upstream and downstream control zones.

Sampling will occur only in the mainstem Peace River and not in tributaries. Fisheries inventories in 1999 established that tributaries in the Project area are not important to fish populations (RL&L 2000).

4.5 STUDY PERIOD

Seasonal differences in fish abundance have been documented in the Project area (RL&L 2000; Mainstream 2006a). The changes are likely caused by changes in fish numbers and differences in sampling effectiveness. To account for seasonal differences, initial monitoring will be stratified into spring, summer, and fall seasons. Initial monitoring includes pre-development baseline studies and post-development start-up studies (see Table 1.2 for definition). If initial sampling establishes that seasonal differences can be consistently identified, monitoring will be reduced to a single season. The decision to reduce seasonal sampling frequency will be made during discussions with DFO and SRD.

It should be noted that additional sampling associated with other monitoring components may also occur (e.g., monitor fish concentrations next to facility), but this activity will not be an integral part of the fish community component.

4.6 METHODS

Capture methods will be specific to the sampling conditions, and the species and life stage targeted. Boat electrofishing and burbot traps will be the methods used to collect large-fish (>150 mm length) in river sections exhibiting normal water velocities and water depths (all zones except the lower headpond). Work in the upper Peace River has established that other techniques are ineffective (P&E 2002). Boat electrofishing would allow sampling of all major habitats and a large segment of the population. Burbot are not effectively sampled by boat electrofishing; therefore, specially designed burbot traps will be used to capture this species. These traps have been used successfully in British Columbia and were effective during the pre-development studies at Dunvegan (Mainstream 2006b).

Boat electrofishing effectiveness will be reduced adjacent to the facility following headpond formation because of increased water depth. In this area an alternate sampling method such as gillnetting will be implemented as a way to monitor fish community characteristics at this location. Use of an alternate technique will preclude comparisons of catch rate data. However, Q values specific to this technique can be developed to ascertain changes in population size.

Beach seining will be used to monitor the small-fish (<150 mm length). Although beach seining is not an effective technique due to the patchy distribution of small-sized fish in fluvial systems such as the Peace River, the data are needed to monitor changes in species composition, recruitment, and to collect biological data.

4.7 EFFORT

Ideally, sampling effort would be sufficient in order to detect a statistical change when one exists. The initial baseline monitoring program completed in 2004 (see Mainstream 2006a) used a sample size of 20 large-fish sites and 15 small-fish sites in each of the monitored zones. For future sampling the present downstream zone will be delineated into the 6 km tailrace zone, which will contain 6 large-fish and 6 small-fish sites, and the true downstream zone, which will contain 20 large-fish sites and 15 small-fish sites.

It is assumed that this effort will be sufficient to collect appropriate samples of fish for most measurements of biological characteristics. In general this assumption was correct (Table 4.1). Sample sizes for all but rare species exceeded 15 fish. Sample sizes of the numerically dominant species were greater than 100 fish.

Table 4.1 Number of fish recorded during fish sampling in the Peace River in the Dunvegan Study Area (all seasons and methods combined), 2004.

Species	Downstream	Headpond	Upstream
Sportfish			
Arctic grayling			2
Bull trout	3	11	8
Burbot	46	36	19
Goldeye	37	34	24
Kokanee	1	2	3
Lake whitefish	1		2
Mountain whitefish	102	115	184
Northern pike	16	7	3
Rainbow trout			1
Walleye	25	14	9
Non-Sportfish			
Brook stickleback			1
Flathead chub	91	104	54
Lake chub	727	1173	220
Longnose dace	127	209	109
Longnose sucker	339	424	628
Northern pikeminnow	2		1
Redside shiner	35	27	62
Slimy sculpin	4	10	9
Spoonhead sculpin		8	
Spottail shiner	1		
Trout-perch	4	5	2
White sucker	6	14	9

As stated earlier, relative abundance indices of fluvial fish populations are inherently variable making it difficult to detect change in relative abundance. This is particularly problematic for fish species that exhibit low densities and patchy distributions (P&E 2002). Pre-development baseline data collected in 2004 were evaluated using power analyses to ascertain whether the proposed sampling effort is sufficient to detect a statistical change in relative abundance. For the purposes of this evaluation the statistical design was a two sample t-test as the statistical design (Year 1 abundance compared to Year 2 abundance). Type I and Type II errors were set at $\alpha = 0.1$ and $ß = 0.2$, respectively. Magnitude of change that would need to be detected was assumed to be 10%, 25%, and 50%. Data for three large fish species representing different categories of abundance were used for the assessment. They included longnose sucker (high abundance), mountain whitefish (moderate abundance), walleye (low abundance).

Results of the assessment indicate that the proposed sampling effort will be sufficient to detect a statistical change in abundance at the 50% level for longnose sucker, which is the most abundant large-fish species in the project area (Table 4.2). For mountain whitefish, the moderate abundant species, sample sizes would need to increase to 32 to detect a 50% change. For the low abundance species walleye, no amount of reasonable sampling effort would be sufficient to detect a statistical change in relative abundance.

These results are typical for fish communities in Alberta's large fluvial systems. Low precision of catch rate estimates, as evidenced by the large coefficient of variation, make it difficult to achieve the target statistical power of 0.80.

It should be noted that the power of the analyses will improve when more than two years of data become available. Multiple years of data will allow use an alternate statistical design (one-way analysis of variance), which segregates treatment effects (year) from within treatment effects (within year) in sample variation (Sokal and Rohlf 1981). Although there will be an improvement in the statistical power of the analysis, the magnitude of this improvement cannot be predicted until the yearly data become available. As such, the FMP must assume that the ability to detect change in relative abundance will be similar to that depicted in Table 4.2 until additional data become available.

Table 4.2 Relative abundance summary statistics and analysis of statistical power using data from three representative fish species recorded in the Project Area during 2004.

Species	**Abundance Categories**		
	Longnose sucker (High)	**Mountain whitefish (Moderate)**	**Walleye (Low)**
Relative Abundance Parameters[a]			
Mean Catch Rate (No. fish/km)	0.65	0.02	0.03
Standard Deviation	0.29	0.16	0.08
Coefficient of Variation (%)	45	79	249
Statistical Power			
10% Change	0.17	0.13	0.10
25% Change	0.53	0.26	0.11
50% Change	0.96	0.61	0.16
Sample Needed to detect 50% Change	11	32	353

[a] Data collected during summer from the headpond zone used for the analysis (see Mainstream 2006a). Values based on log-transformed data.

[b] Type I and Type II errors set at $\alpha = 0.1$ and $ß = 0.2$, respectively.

Most of the indicator species fall between the moderate and low abundance categories; therefore, increasing sampling effort even a moderate amount will not improve the statistical power of the analyses. Statistical comparisons of relative abundance should be restricted to the more abundant species. As outlined in Section 4.3, use of abundance categories would be more appropriate for the remaining indicator species.

5.0 PROPOSED MONITORING SCHEDULE

The FMP will collect information during post-approval/pre-construction, construction, and operation phases of the Project. The post-approval/pre-development phase may be a period of one to two years when project design, equipment purchases, and contract arrangements are initiated. The construction phase is a two year period whereby the second year will entail instream construction. The operational phase begins following facility commissioning. The frequency of sampling will vary depending on the monitoring component and the Project phase. Table 5.1 provides a summary of monitoring activities during these three phases of the Project. This monitoring schedule may change pending final review by regulatory agencies.

A total of two years of fish community baseline data and two movement studies (each consisting of one and one half years each) will be available prior to the construction phase. Baseline fish community inventories were completed in 1999 (RL&L 2000) and in 2004 (Mainstream 2006a). Fish movement data were collected in 2002/03 (Mainstream 2004) and 2004/05 (Mainstream 2006).

Table 5.1 Proposed monitoring schedule and frequency, Dunvegan Fish Monitoring Plan.

Component		Post-Approval/Pre-Development	Construction	Operation
Fish community characteristics		1 year	-	3rd year; then once every three years
Fish passage	General movements	1 year	1 year	1st and 2nd year
	Facility performance	-	-	1st and 2nd year
	Fish characteristics	-	-	Annually
Population mortality	Passage survival rate	-	-	Once during 1st year
	Passage route	-	-	1st and 2nd year

Following Project approval and prior to the commencement of instream construction, a third year of fish community baseline and movement studies would be completed. Monitoring of general fish movements will continue during the instream construction phase (year two of project construction). This will add to the baseline data and will be used to evaluate potential post-construction effects.

Several monitoring programs specific to fish passage and fish survival will be undertaken during the first year of fill Project operation. They include a continuation of the general fish movement study, monitoring the effectiveness of upstream and downstream passage facilities, and estimation of fish passage survival and downstream passage route selection. These programs will be repeated during the second year of full operation with the exception of the survival study.

Glacier's rationale during the first two years of operation is to focus the monitoring program on the effectiveness of the fish passage facilities and survival of fish passing through the turbines, and to make necessary adjustments in operations of these facilities. The results of the fish passage studies would be reviewed annually with regulatory agencies. In the third year of operations this would be followed by the first year of fish community post-development monitoring. The fish community studies would be repeated every third year over a six-year period. A three-year cycle is deemed sufficient because a number of years will be needed before potential changes in the fish community become apparent.

The proposed monitoring schedule will provide sufficient information to address the questions posed by the Fisheries Monitoring Plan. In addition, the schedule ensures that the appropriate amount and type of effort is committed to the FMP prior to and immediately following full Project operation in order to ensure that information is available to make adjustments to Project operation, if warranted.

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APPENDIX A

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EA1780

Monitoring Plan for Radio-tagged Fish at the Dunvegan Project

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18 January 2006

EA1780

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INTRODUCTION

As part of continuing studies on the movement of resident fish in the Dunvegan Project area, as outlined in the Fish Monitoring Plan – Dunvegan Hydroelectric Project (FMP-DHP, Mainstream Aquatics Ltd.), a multi-year radio-telemetry study is being proposed as part of a Fish Community Monitoring Program (FCMP).

1 STUDY OBJECTIVES

The over-riding objective of the Monitoring Plan is to "address fisheries issues within the categories of fish community characteristics, fish passage, and fish survival". As partial fulfillment of achieving this over-riding objective, the Glacier Power Ltd. has designed a program of four supporting Strategies:

- Verify impact predictions;
- Monitor compliance with regulatory conditions;
- Evaluate the effectiveness of mitigation measures; and
- Provide information for use as part of the adaptive management plan.

The details of these Strategies are described in the Monitoring Plan and will not be reiterated here. As part of these Strategies, Glacier Power Ltd. has requested the preliminary design of a radio-telemetry array for the Dunvegan Project to address the following facility performance questions (numbered as in the FMP-DHP):

1. What is the timing, rate, and extent of fish movement?;
2. What is the width and location of the fish movement corridor?;
3. Can fish locate the fishway and bypass structure entrances?;
4. What route is used by fish (structure and path within the dam)?;
5. What is the rate of fish movement through the structure?;
6. Can fish exit the structure? and
9. What proportion of the population use each route?

We present below the tasks, responsibilities and deliverables of LGL Limited in supporting Glacier Power Limited's goals.

2 STUDY DESIGN

2.1 Timing and Operations

A multi-year radio-telemetry monitoring program at the Dunvegan Project is proposed to cover the years following commissioning. Radio tags with an expected life of 1+ years will be implanted into approximately 60 fish, and monitored at the Dunvegan Project using fixed-station receivers. In addition, the study area will be surveyed using mobile tracking methods according to an activity schedule and consideration of the latest position data. Capture and tagging of indicator species (goldeye, walleye, sucker, and burbot) will be conducted at Dunvegan Project. Fish will be tagged on an as-they-come basis up to the total tag allocation.

2.2 Telemetry Array

There are a variety of factors which need to be considered with respect to the setup and maintenance of a telemetry array, especially when it is around a hydro dam where the time frame for detection can be limited. Materials, labour, and timing of activities need to be coordinated effectively to maximize the likelihood of success, and minimize expenditures and facility down-time. To this end, familiarity with the project area, experience with the setup of hardware, and proven maintenance and diagnostic protocols are crucial (Robichaud et al. 2003a, b). This is especially true for new or modified installations where unexpected circumstances arise, and quick but functional solutions are required. LGL's experienced personnel are uniquely qualified (eight years operating telemetry arrays at Mid-Columbia River dams) to effectively setup and maintain the proposed radio-telemetry array and collect the required data.

As hydraulic conditions at the projects can be very intense, and that monitoring equipment will be deployed into these harsh environmental conditions, LGL and its subcontractors will not be responsible for decreased system performance, equipment replacement costs, reinstallation costs, or any other costs as the result of damage to or loss of monitoring equipment while in use by Glacier Power Ltd. In addition, Glacier Power Ltd. will be liable for any additional material or labour costs incurred by LGL or its subcontractors, and replacement of any damaged or lost equipment, as a result of equipment damage or loss. We assume that Glacier Power Ltd. will provide appropriate engineering and mechanical support for the design, fabrication, installation, and removal of deployment mounts associated with this study.

2.3 Overall Design

The fixed-station telemetry array proposed for the study includes:

- Three aerial detection zones for the Head-works tailrace;
- Three aerial detection zones for the Head-works forebay;
- Eight underwater detection zones in each 200 m upstream bypass;
- Ten underwater detection zones for the 0.4 m sluiceway bypasses;
- Ten underwater detection zones for the 0.6 m orifice bypasses;
- Seven underwater detection zones for the 14 m spillways;
- Left and right remote upstream gateway aerial; and
- Left and right remote downstream gateway aerial.

In addition, mobile tracking surveys will be conducted in the Dunvegan Project area by Glacier Power Ltd. and will be incorporated into the overall database.

After consultation with representatives from Glacier Power Ltd., the telemetry array will have the following characteristics (see respective Figures with antennas in yellow, and detection zones in red):

- Multiple antenna aerial arrays on the upstream and downstream head-works monolith will provide approach and egress information for upstream and downstream moving fish. These arrays will provide a detection zone to aid in the determination of upstream/downstream passage events (Figure 1);
- The sluice and orifice arrays will include a single dipole in each bypass for a total of 20 antennas. Each bypass will be monitored as an individual detection zone (Figure 2);
- The spillway underwater array will include a series of a dipole antennas mounted on either side of each spillbay, for a total of 14 antennas (combined to record as seven antennas). Each spillway will be monitored as an individual detection zone (Figure 3);
- The upstream bypass will be partitioned by eight sets of dipole antennas mounted in strategic locations (Figure 4); and
- Remote aerial arrays upstream and downstream of the dam (location to be determined) will consist of a two-antenna array to provide detection of fish moving into and out of the Dunvegan Project Area.

The proposed overall design will provide residence times of tagged fish in close proximity (<100 m) to the head-works (Question 1), predominant approach routes to the dam (Question 2), a route specific assessment of upstream movement through the fishways, and downstream movement through the main head-works structure bypass facilities (Questions 3 and 4), upstream and downstream passage times (Question 5), an estimate of passage efficiency for the upstream bypass (Question 6), and an assessment of the proportion of the tagged population using each bypass route (Question 9). In the event that a downstream passage event is determined from the over-riding telemetry array, and no detection is evident in the fishway, spillway, sluice and orifice arrays, it will be assumed that the fish moved downstream via a turbine route (non-specific). In addition, the remote fixed-station arrays will provide the timing of entrances and exits into the project area.

2.3.1 Radio-Telemetry Receivers and Antennas

We propose to use two different telemetry receivers. For aerial antennas, the receiver will be a Grant Systems Engineering (GSE) ORION Digital Spectrum Processing Unit (DSP) with programmable frequency bands ranging from 148.000 to 152.000 MHz and capable of monitoring three antennas. For underwater antennas, a GSE MITAS system (incorporating individual ORION's) will processes signals over the same wide band of frequencies and numerous antennas (up to 50) simultaneously. Aerial antennas will be adjusted to limit the range of aerial antennas on the head-works structure such that detections will only be recorded when fish are in specific passage route encounter zones (left, right, and center). The aerial antennas will be four-element 150 MHz aerial yagi antennas from GSE. All aerial antennas will be set up with an angle of declination of approximately 10°.

Underwater antennas will likely be mounted on trolley & rail systems to provide efficient setup and maintenance. Aerial antennas will be attached below the deck surface using a pole mount. Remote fixed-station arrays will use a 30' communications tower to employ aerial antennas. The size of the detection zones will be measured pre-season by moving an active tag of known position progressively away from the antenna(s) while monitoring detections on the receiver. Individual antennas will be grouped to form specific detection zones using combiners (Minicircuits, Brooklyn, NY). Arrays will be balanced using attenuators (JFW Industries, Indianapolis, IN) or taps (GSE). Various other devices such as GSE power inserters and trunk amplifiers will be used to complete the system. Signal transmission lines will be made from various forms of 50 ohm coax (Belden, Richmond, IN).

Radio-tagged fish passing the dam will be detected on aerial and/or underwater antennas. The fish will be tracked in the forebay, at zones along the dam face, within the dam passage routes themselves, and in the tailrace. For all tagged fish with adequate detection histories, we will determine approach route, movements within the forebay, migration time, time required to pass each dam, the dam passage route and whether or not it passed to an upstream or downstream detection zones. To assess approach routes, we propose to deploy an array of aerial antennas on the forebay and tailrace side of the head-works structure. Detections from these arrays will allow us to determine whether fish approach the dam along the left bank, right bank, or down the middle of the channel. We will also be able to estimate the proportion of fish using each passage route and the overall fish passage efficiency for the dam.

LGL will have the responsibility, in cooperation with Glacier Power Ltd., of coordinating the procurement and installation of all required equipment and supplies, and ensuring the installation of equipment in a manner that suits the needs of the Project Superintendent. The first task associated with setup is for LGL to conduct a reconnaissance survey of the dam with Glacier Power Ltd. personnel to evaluate the proposed array design. The survey will serve to identify any design issues and to find solutions. Setup tasks that need to be coordinated between LGL and Glacier Power Ltd. will be identified, and the timing of installation activities will be confirmed. Subsequently, the design specs can be finalized, and orders developed for materials and fabrication of deployment mounts. As materials arrive and are inventoried, installation can begin with a focus on deployment of surface hardware including receivers and trunk lines. Underwater components and mounts will be assembled in preparation for deployment. Prior to deployment, all line connections will be assembled and a surface test of all equipment conducted. LGL and GSE crews will be on-hand to assist and direct Glacier Power Ltd. in the deployment of the components into the water. Field testing of the array will be conducted as the array is installed.

3 Data Collection

LGL personnel, in cooperation with representatives of Glacier Power Ltd., will be responsible for monitoring and maintaining the functionality of the array throughout the entire study period. To accomplish this, we have prepared a system check protocol to provide clarity and certainty for field personnel that will be servicing the systems. Field personnel form the first line of Quality Assurance / Quality Control in our data management procedures. Using custom diagnostic tools (LGL's *Telemetry Assessor* software), personnel will be able to quickly assess the status of each array upon downloading. Each telemetry station will be visited on a regular basis to ensure proper operation and to download data. A secondary level of QA/QC is conducted by our Database Manager prior to analysis to ensure all files are accounted for and that the correct file formats are achieved. Geo-referenced mobile tracking surveys by Glacier Power Ltd. representatives will be conducted to supplement the fixed-station data.

"Beacon" radio tags will be strategically placed on underwater and aerial arrays to collect baseline information on system performance and functionality. On underwater arrays, beacon transmitters will be installed on every combined antenna on the spillway, sluice and orifice antennas. Beacon tags will also be installed on the aerial arrays. Operationally, beacon radio-transmitters on the underwater arrays will be programmed to emit coded bursts with 5 s interval, for 1 min of every hour (12 bursts per hour). Beacon tags on the aerial arrays will be programmed to emit coded bursts with 2.5 s intervals, for 1 min of every hour (24 bursts per hour). Interpretation of the signals recorded by the telemetry receivers will provide an operational status on these systems with every download. Beacon tags are an instrumental quality control feature for complex telemetry arrays, and have been crucial for documenting operating efficiency in prior studies (Robichaud et al 2003a, b).

Data generated from ORION and the MITAS computer will be automatically saved as daily files. ORION will transfer data to a computer via an internal VHS radio. At the end of each day, the MITAS computer will automatically transfer the file via a high-speed Internet connection to the LGL FTP site. In addition, MITAS automatically produces an analysis of the acquired telemetry signals, which will be emailed each day to technical personnel for evaluation of system operation.

4 Data Processing

Data analyses throughout the study period and post-season will be performed using *Telemetry Manager*, and other computer programs developed in Visual FoxPro by LGL Limited. These are the same programs that have been used successfully in prior studies and will be instrumental in providing in-season results to dam managers (English et al. 2003, Nass et al. 2003, Robichaud et al. 2003a). The *Telemetry Manager* imports raw ASCII data files collected by the MITAS and ORION systems. After importing the files, the *Telemetry Manager* constructs an initial database containing records for each logged data transmission from the tagged fish. The *Telemetry Manager* then edits the database to remove records that do not meet the criteria identified for valid data records. Examples of invalid data include background noise at the projects, records with a signal strength that is below a set threshold, single records for a given frequency-code-location combination, and records that are recorded before the official release time and date. The *Telemetry Manager* then constructs an operational database that summarizes the time of arrival and departure from each detection zone. Queries of the operational database specify subsets of tagged fish for use in specific comparisons and analyses. There will be three phases associated with preparing the databases for the behavioural analyses including: 1) data verification during the field season; 2) data verification after the field season; and 3) exploratory analyses.

5 Data Analysis

5.1 Tracking effort and Array Performance

A summary of the monitoring effort and an assessment of the performance of each array will be conducted to provide a context for the collected data. This will include an assessment of the number of beacon signals detected in each detection zone. In addition, patterns of first and last detection will be examined for consistency.

5.2 Definition of Passage and Residence Times

Strategic deployment of receivers and antennas will make it possible to determine the amount of time that fish were present in the tailrace, fishway entrances, fishways, and forebay (Question 1). Passage times will be calculated from benchmark dates and times corresponding to the first and last detection of a given radio-tagged fish at specific locations (Question 5). At Dunvegan, the benchmark times for upstream moving tagged fish will be:

1) first detection in the tailrace;
2) first detection at the fishway entrance of passage;
3) last detection at the fishway entrance of passage; and
4) last detection at the fishway exit.

From these benchmark times, passage times will be calculated for the following passage segments:

Segment	Time	Name
A)	1 to 2	Tailrace Passage time
B)	2 to 3	Entrance Passage time
C)	3 to 4	Fishway Passage time
D)	1 to 4	Project Passage time

Using benchmark times at each of the monitored locations, upstream passage efficiencies (Question 6) will be calculated as:

Approach Efficiency = No. of approaches / No. in the tailrace
Entrance Efficiency = No. of entrances / No. of approaches
Fishway Efficiency = No. of exits / No. of entrances
Passage Efficiency = No. of exits / No. in the tailrace

In addition to the above standard passage segments, we will conduct detailed analyses of the time tagged fish spent in and between detection zones (i.e., residence time) in the fishways (Question 1). The residence and passage times for each radio-tagged fish will be determined by working backwards through a sequence of detections. The fishway of ultimate passage and the respective passage time will be determined by identifying a sequence of detections in the ascent of a fishway, starting with detections in a fishway exit zone. These metrics can be stratified by use of the left and right upstream bypass if sample sizes are sufficient. The same types of efficiencies can be calculated for downstream moving fish as well (residence times in the forebay and at the project).

5.3 Definition of Fall-back and Drop-back

For the purpose of analysis, a fall-back will be defined as a tag that was detected at a fishway exit and subsequently detected at the tailrace or a fishway entrance without any detections at antennas monitoring the inside fishway zones (Question 4). Drop-back fish will be defined as those tags in a detection zone that were subsequently detected in zones directly downstream.

5.4 Travel Times

Times required to pass from one detection location to another (i.e., to pass successive river or project sections, Question 3) will be calculated as the time between the last detection at an upstream reference location and the first detection at a more downstream reference location, with no subsequent upstream detections. Medians will be used to describe average travel times (and hence rates) since the distribution of values tend to be strongly skewed to the right (Robichaud et al. 2003a). Confidence limits of the medians will be calculated using the method described in Zar (1984). Time required to pass dams will be calculated as the time between the first detection in the forebay and the moment of dam passage (recorded on the bypass arrays).

5.5 Approach Route

Using the first detection of a tagged fish, the general approach route (left, right, and center) of upstream and downstream moving fish will be described (Question 1).

5.6 Movement Patterns

Movement patterns (sequential detections) will be assessed using the *Telemetry Manager* software. For every possible pair of detection zones (and separately for each direction), the program will calculate the number of fish that moved between them (Question 2). The relative frequency of movements between a given pair of detection zones will be represented graphically using arrows of different colour, along with a summary of the zone of last detections. In addition, the movement pattern of individuals in the project area can be presented.

5.7 Passage Route Use and Flow Effectiveness

The proportion of tagged fish detected using each specific passage route at the project will be calculated (Question 5). Rates of water flow through each passage route, measured by Glacier Power Ltd., will be used in appropriate analyses. Flow effectiveness will be calculated as the proportion of fish traveling through a passage zone *relative* to the proportion of flow through that zone.

5.8 Project Operational Conditions

Comparisons of metrics between operations can be performed given sufficient sample size (Questions 1-5). For example, if the operational configuration of the dam is modified in response to observed movement patterns, the metrics can be compared to determine if there was a subsequent response in behaviour by the tagged population (see Robichaud et al. 2003a).

5.9 Statistical Methods

When only two groups will be compared, two-tailed t-tests will be used, and ANOVAs will be used otherwise. Homogeneity of variance will be examined with O'Brien's test, and when rejected, the Welch ANOVA will be used. Non-parametric tests will be used when data are non-normally distributed.

6 Reporting

We propose to provide Glacier Power Ltd. with a monthly monitoring update on standard in-season information including the number of tags released, number of tags detected by zone, and preliminary passage metrics including classification of upstream and downstream passage events. Initially, analysis and reporting will cover the first year of the study. An end-of-the-year report will include analyses appropriate to the sample sizes observed, and will include summary tables, maps, and graphs typical and customary to reports previously prepared by LGL. Key aspects will include timing, abundance, and passage metrics.

7 References

English, K.K, C. Sliwinski, B.L. Nass, and J.R. Stevenson. 2003. Assessment of adult steelhead migration through the Mid-Columbia River using radio-telemetry techniques, 2001-2002. by LGL Limited, Sidney, BC for Public Utility District No. 2 of Grant County, Public Utility District No. 1 of Chelan County, and Public Utility District No. 1 of Douglas County.

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Robichaud, D., K.K. English, J.R. Skalski, B.L. Nass, J. Lady, C. Sliwinski and A. Blakely. 2003a. Effects of various spill methods on Chinook smolt behaviour at Wanapum and Priest Rapids Dams, 2003. Prepared by LGL Limited, Sidney, BC for Public Utility District No. 2 of Grant County.

Robichaud, D., K.K. English, C. Sliwinski, B.L. Nass, A. Blakley, and C. Grant. 2003b. Chinook smolt survival at Wanapum and Priest Rapids Dams with various spill configurations, 2003. Prepared by LGL Limited, Sidney, BC for Public Utility District No. 2 of Grant County.

Zar, J. H. 1984. Biostatistical analysis, 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, NJ. 718 p.

FIGURES

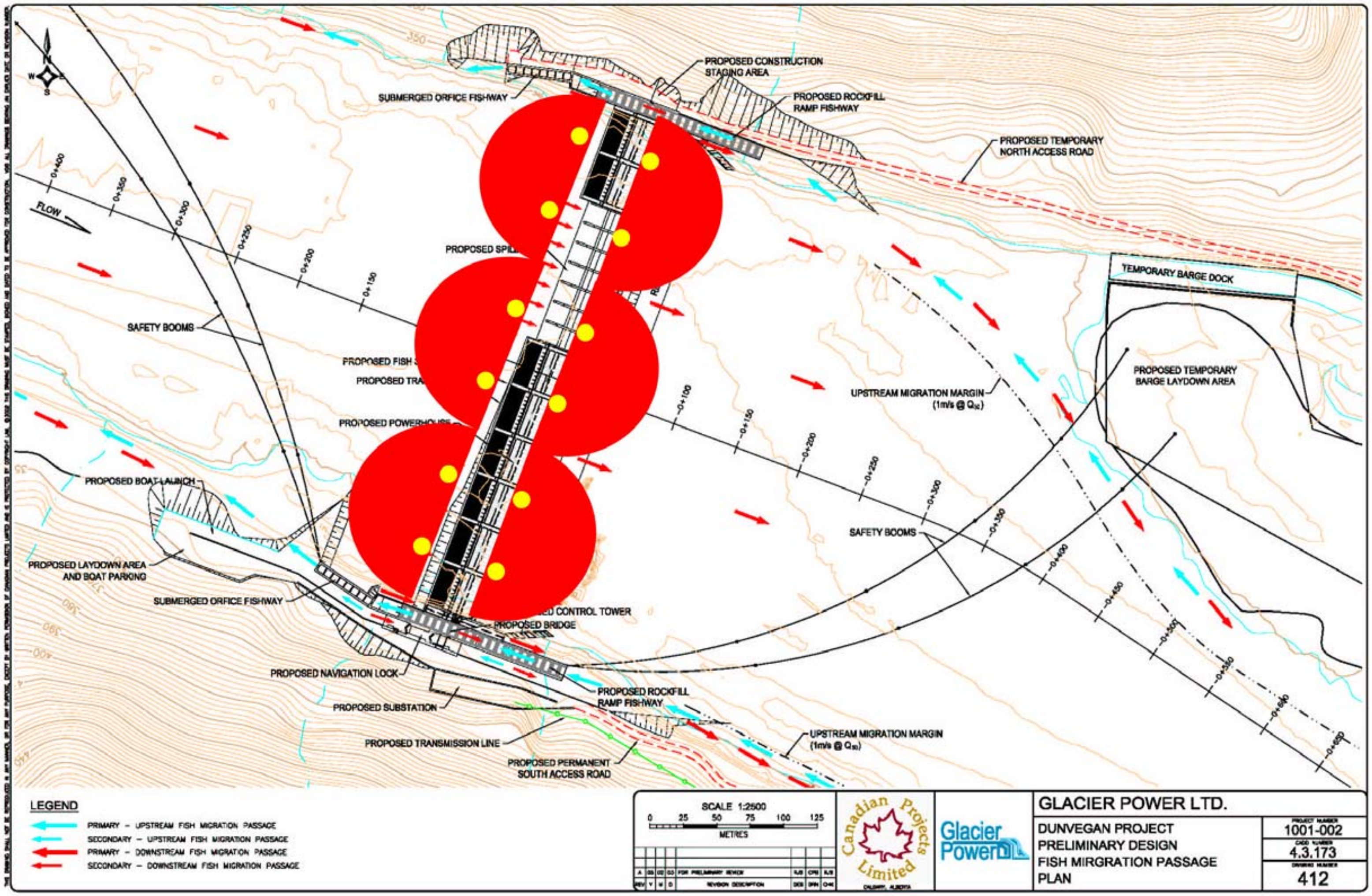

Figure 1. Proposed aerial radio-telemetry arrays for the Dunvegan Project. Antennas are located on the forebay and tailrace sides of the structure.

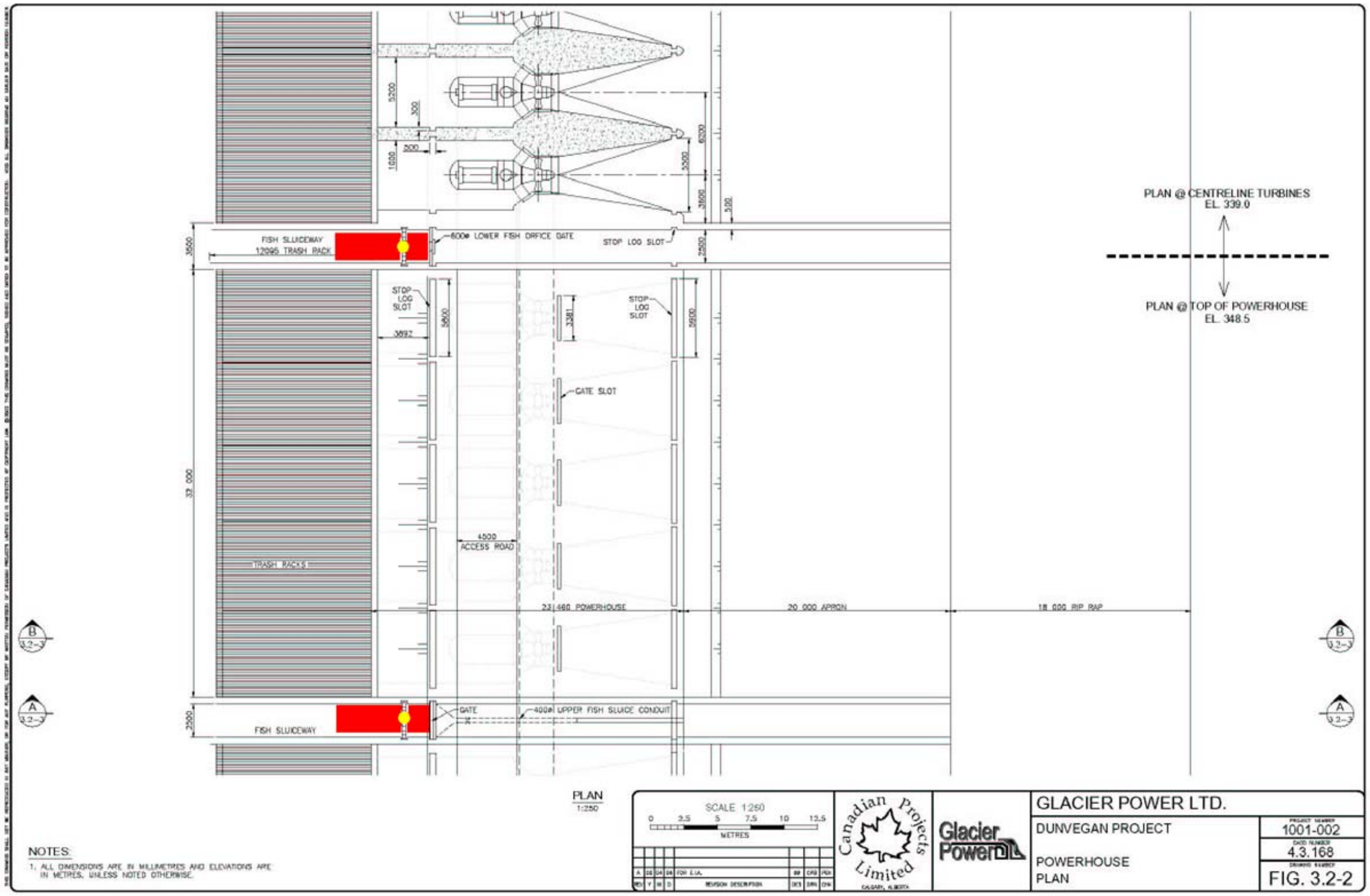

Figure 2. Proposed underwater radio-telemetry arrays for the Dunvegan Project sluice and orifice fish bypass structures. Antennas are located on the forebay side of the structures.

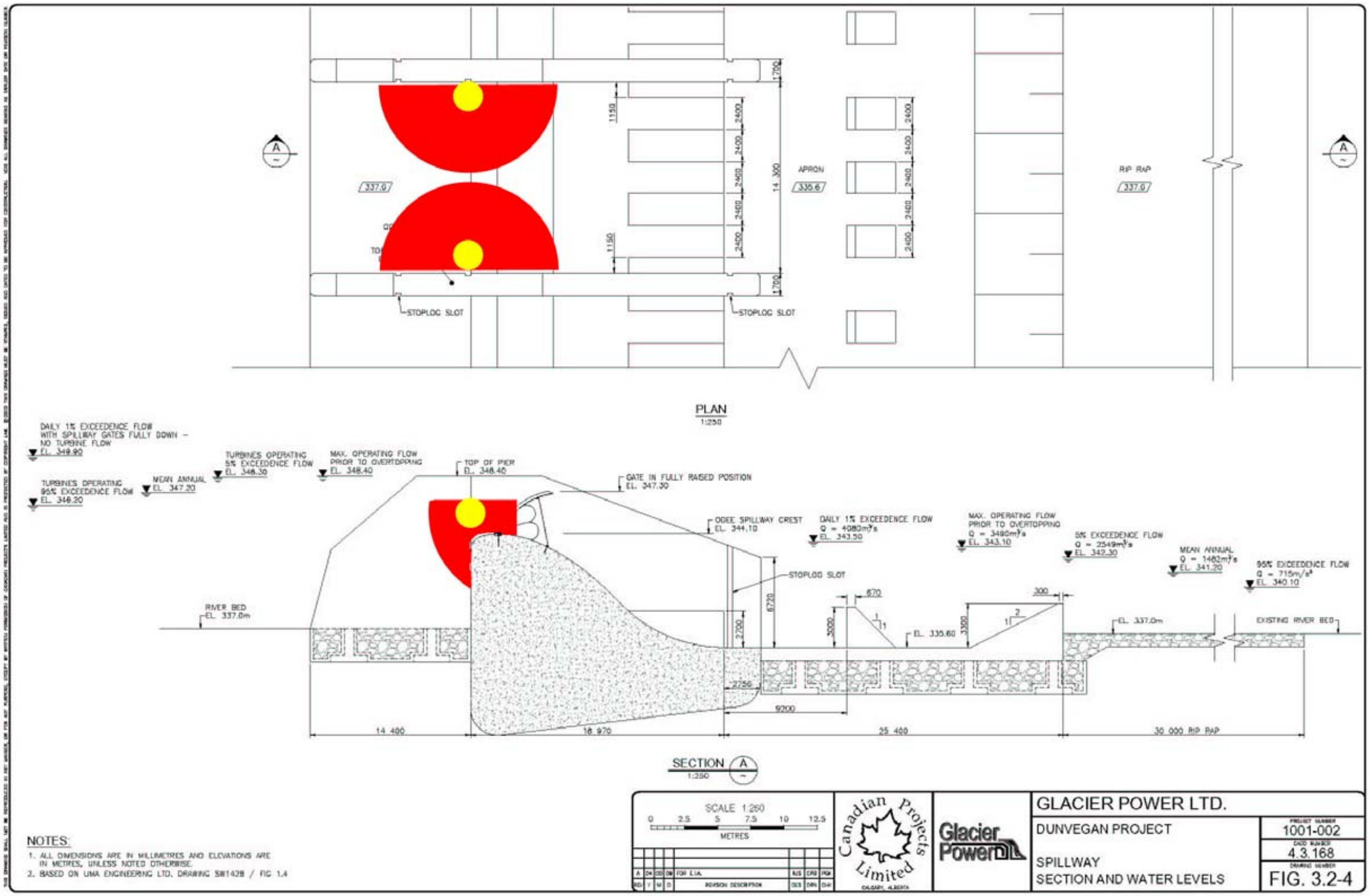

Figure 3. Proposed underwater radio-telemetry arrays for the Dunvegan Project spillways. Antennas are located on the forebay side of the structures.

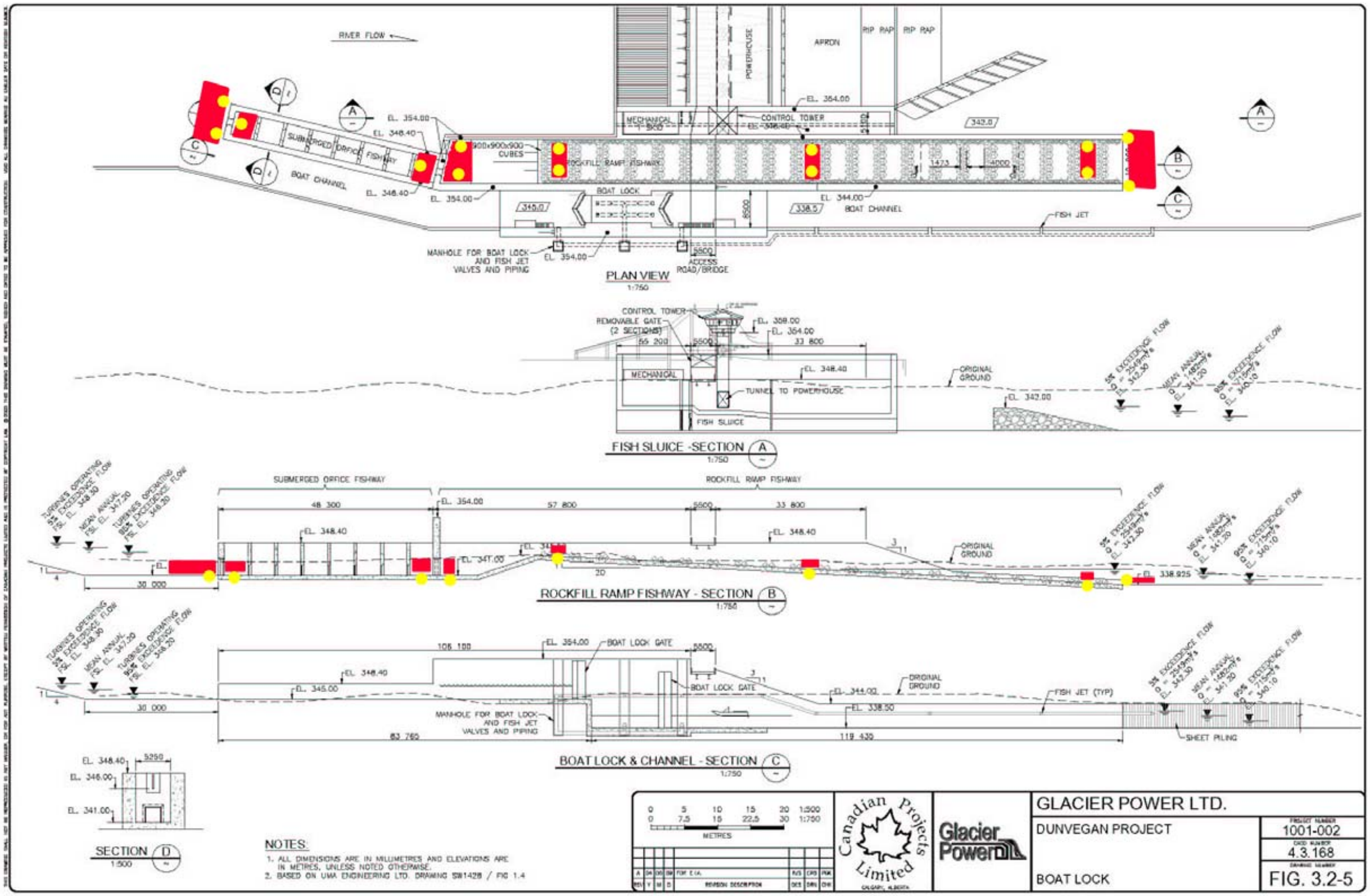

Figure 4. Proposed underwater radio-telemetry arrays for the Dunvegan Project fishways. Antennas are located in eight separate locations of the left and right structures.