Ash River Water Use Plan:
Monitoring Program Terms of Reference:

January 18, 2005

Assessment of Adult Fish Passage at Dickson Falls During Pulse Flow Releases from Elsie Lake Dam

1.0 MONITORING PROGRAM RATIONALE

1.1 Background

The Consultative Committee (CC) for the Ash River Water Use Plan (WUP) expressed concern that flow conditions at Dickson Falls in the lower Ash River during August and September may impede the upstream passage of adult summer-run steelhead trout and other salmon species. As a result, the WUP includes a provision for two pulse flow releases during this period to provide flows at Dickson Falls that were predicted to facilitate steelhead passage (Wong 2001). The proposed pulse flows are to average 10 $m^3 \bullet s^{-1}$ over 48 hours (measured at the Moran Creek gauge), and will coincide with rainfall events and the presence of steelhead at the base of Dickson Falls. The benefits of these pulse flows to fish passage were uncertain and the CC recommended that steelhead passage be monitored. This document outlines a monitoring program that will assess the benefits of these pulse flows to fish passage.

The migration of all fish species during pulse flows was of interest to the CC. Sudden increases in discharge are known to stimulate and facilitate the upstream migration of adult salmonids. However, flow regulation on the Ash River can potentially affect migration by limiting such pulses in discharge, which would normally occur during natural inflow events[1]. The decisions to monitor the migration of summer-run steelhead was premised on them being a proxy for migration conditions for all species, including adult coho and Chinook salmon. Flow conditions that stimulate and facilitate steelhead migration should also be beneficial to the migration of other species. Currently, summer-run steelhead are the only species known to surmount Dickson Falls.

The monitoring program described here is based on the proposal approved by the CC (see Appendix O of Anon 2003). Appendix A outlines modifications from the original proposal and the rationale for the changes.

1.2 Management Questions

The key management questions are:

1) Do the pulse flow releases during August and September improve steelhead passage at Dickson Falls, and thus increase the number of steelhead present upstream of the falls?

2) What is the appropriate magnitude and hourly flow release to maximize steelhead passage?

For the purposes of the monitoring program, it is assumed that improved passage conditions for summer-run steelhead during August and September will benefit summer-run steelhead at the population level. Tests of this assumption are beyond the scope the program. For

[1] Jim Lane noted in his review of these Terms of Reference that the precipitation event that commonly occurs near the third week of July should also be considered for the pulse flow release.

example, it is not clear whether natural pulses outside of August and September are sufficient to allow steelhead passage. In addition, the adult escapement upstream of Dickson Falls that is needed to fully seed available habitats with juveniles has not yet been determined. The program also assumes that flow conditions that facilitate steelhead migration will benefit the migration of other species.

A general comparison of steelhead passage during pulse flow release and non-release periods will address the first question. A more detailed evaluation of fish passage during alternative flow release configurations will provide information to help resolve the second question.

1.3 Detailed Hypotheses about the Ecological Impacts of Operational Change

The primary objective of the monitoring study is to reduce uncertainty related to the benefits of a pulse flow release to the passage of adult steelhead at Dickson Falls. As such, the ecological hypotheses[2] that will be examined are:

H_1: Flow conditions at Dickson Falls during August and September hinder adult steelhead migration.

H_2: The pulse flow release improves the rate of adult steelhead migration past Dickson Falls.

H_3: The magnitude and duration of the pulse flow release affects steelhead passage at Dickson Falls.

The Ash River Fish Technical Subcommittee reviewed existing data, visited Dickson and Lanterman Falls, and applied their expert judgement to estimate the pulse flow required to stimulate and enable adult steelhead to migrate upstream past Dickson Falls. While opinions as to the required magnitude and duration of the flow release varied (Wong 2001), the assessment suggested that a pulse flow of 10 $m^3{\bullet}s^{-1}$ over 48 hours should be sufficient to stimulate adult steelhead migration. The monitoring program will examine this conclusion.

Currently, the understanding of the environmental cues that stimulate steelhead to migrate and the conditions that enable steelhead to pass partial migration barriers is limited. In addition, hydraulic conditions in Dickson Falls are complex and hence difficult to model under varying flows. These uncertainties have lead to alternative sub-hypotheses on the benefits of higher flows to steelhead passage, and limit the ability to predict the flow conditions that facilitate passage. For example, higher flows can improve passage by increasing backwatering and creating deeper plunge pools that increase leaping ability, or hinder passage by increasing water velocity and turbulence in plunge pools. Similarly, a number of factors are believed to stimulate steelhead migration, including flow conditions, water temperature, light intensity, turbidity, changes in barometric pressure and olfactory cues. A combination of environmental factors may produce ‘optimal conditions’ to elicit a migratory response. Previous observations at Dickson Falls, for example, noted more frequent leap attempts as flows receded after a peak in discharge (BCCF 2002), similar to other telemetry studies on Vancouver Island. Thus, the ramp-down period at the end of the

2 For clarity, the hypotheses are stated as alternate hypotheses. Analyses will test the null hypotheses of no effect or difference.

flow release may be important for steelhead passage. The experimental flow releases and associated monitoring will provide information to reduce these uncertainties.

Discussions with members of the Fisheries Technical Committee during the development of these Terms of Reference suggested that both the magnitude and duration of the pulse flow should be examined in order to reduce the key uncertainties. Therefore, experimental flows that vary these characteristics will test whether a higher peak flow of shorter duration provides better passage than a lower magnitude release over a longer period (Fig. 1).

1.4 Key Water Use Decision Affected

The key water use decision affected by the results of the monitoring program will be whether pulse flow releases from Elsie Lake Dam are needed to improve fish passage at Dickson Falls. If pulse flows are beneficial, results should also help to determine the magnitude, duration, and hourly flow regime of the pulse flow releases. This decision has important implications for ecological and power generating values. Steelhead were a species of high interest to the CC and opportunities to improve access to the Middle Ash River were highly valued. Alternatively, releasing water may result in foregone generating opportunities or reduce the water available to maintain fish spawning and rearing flows in the lower Ash River. During dry years, each pulse flow will result in approximately 611 MWh of foregone power generation worth $46,000 (based on August 2004 energy prices).

2.0 MONITORING PROGRAM PROPOSAL

2.1 Objective and Scope

The primary objective of the monitoring study is to assess the benefits of the pulse flow release to steelhead passage at Dickson Falls. A secondary objective is to reduce uncertainty related to the appropriate magnitude and hourly flow regime of the pulse flow release to maximize steelhead passage. The study area will include sections of the middle and lower Ash River and focus on Dickson Falls. While fish passage at Lanterman Falls is also a concern, monitoring will focus on Dickson Falls because passage at Dickson Falls is believed to be more difficult.

While the methodology for the monitoring program focuses on steelhead migration, all fish species observed will be reported.

Because steelhead passage may be affected by annual variations in steelhead abundance, precipitation, discharge, and water temperature, monitoring will occur during 5 years to examine a range of environmental conditions. In addition, two experimental flow configurations will be employed during each of the 5 years to address the second objective.

2.2 Approach

Steelhead passage at Dickson Falls will be assessed using snorkel counts, radio telemetry and direct observations of steelhead passage. Repeated snorkel counts will determine the abundance and distribution of fish in sections of the Ash River. Steelhead passage over Dickson Falls will be inferred from the relative abundance upstream and downstream of the falls. The timing of successful steelhead passage at Dickson Falls will be determined using radio telemetry. Passage rates at Dickson Falls and the distance migrated during flow release and non-release periods will measure the benefits of the flow release. The relation between the timing of successful passage (measured at a fixed receiver) and discharge (measured at a pressure transducer) will help determine the discharge that best facilitates passage. Observations of steelhead leap attempts at Dickson Falls will provide additional information on migration routes and the environmental conditions that stimulate steelhead to migrate.

Monitoring will be implemented in an adaptive approach (Table 1). Snorkel counts and leap observations will occur during each of the five years. Currently, the migration timing for summer-run steelhead is not known precisely, but is believed to be from mid-July to late-October. Snorkel counts during year 1 will provide information on the timing of the steelhead migration, which will help to determine when steelhead could be captured and tagged for a pilot telemetry program in year 2. If the pilot telemetry program shows that tagging is feasible, a full telemetry program will occur in years 3 and 5.

Table 1: Annual schedule for the primary monitoring tasks

Year	Snorkel	Telemetry	Falls observations
1	Y	-	Y
2	Y	Pilot	Y
3	Y	Y	Y
4	Y	-	Y
5	Y	Y	Y

An experimental design with two flow release configurations will help determine the magnitude and hourly flow regime that maximizes steelhead passage. The experimental pulse flows are designed to use the same volume of water[3] (the water budget) over the duration of the pulse flow and to remain within the maximum ramping rates for the facility (see section 4.4.2 of the WUP). Two experimental flow release treatments will test whether a higher or lower peak flow benefits steelhead passage at Dickson Falls. Experimental Flow A will ramp up to 10 $m^3 \bullet s^{-1}$ over 3 hours, remain at 10 $m^3 \bullet s^{-1}$ for 42 hours, and ramp down over 11 hours. Experimental Flow B will ramp up to 20 $m^3 \bullet s^{-1}$ over 5 hours, remain at 20 $m^3 \bullet s^{-1}$ for 11 hours, and ramp back down to 3.5 $m^3 \bullet s^{-1}$ at the maximum ramp rate over 17 hours (Fig. 1). Given the constraints of the water budget, these flows differ in the magnitude of peak flow, duration of the ramping periods, and duration of the entire pulse flow (Fig. 1). While it would be preferable to vary only one of these factors for each flow, the water budget constrains the ability to do so. For example, Flow B may be of sufficient magnitude but may be too short in duration to allow all steelhead to pass. Conversely, Flow A may be of sufficient duration but too small in magnitude. Table 2 outlines the annual schedule for the experimental flow treatments.

The 20 $m^3 \bullet s^{-1}$ peak for treatment Flow B was selected based on existing information on steelhead passage at partial barriers on other river systems, and also to provide sufficient contrast with treatment Flow A. While each river system and falls is unique, observations at other coastal systems suggest that summer-run steelhead pass partial barriers at flows ranging from 50 to 100% of mean annual discharge. For the Ash River, this is equivalent to 14 to 28 $m^3 \bullet s^{-1}$. During the WUP process, most expert predictions suggested that a higher

[3] The Water Comptroller Order for the Ash River (dated Oct 4 2004) specifies that the total water budget for the two pulses is a maximum of 40 $m^3 \bullet s^{-1} \bullet$days. This is equivalent to 13 $m^3 \bullet s^{-1} \bullet$days per pulse, after subtracting the 3.5 $m^3 \bullet s^{-1}$ base flow.

proportion of steelhead would pass Dickson Falls at flows greater than 10 $m^3 \bullet s^{-1}$, including flows up to 25 $m^3 \bullet s^{-1}$ (Wong 2001).

A number of factors will affect the exact configuration of the pulse flow releases (measured ~20 km downstream at the Moran gauge), and these configurations will only approximate the hydrographs in Fig. 1. These factors may limit the contrast between Flows A and B. Dam operations do not have precise control over the discharge measured at the Moran Gauge because 1) there is a lag between dam releases and measurements at the Moran Gauge, 2) natural inflows downstream of the Elsie Lake Dam fluctuate greatly, especially during rainfall events, and 3) flow releases are implemented manually and with restrictive ramping rates. For instance, historic discharge records (1961-2003) show that flows at the Moran Gauge up to 10 $m^3 \bullet s^{-1}$ during August and September occur on average during one in three years. These flows frequently occurred from pulses in natural inflows while dam releases remained constant. A new flow gauge installed upstream of Dickson Falls (described below) may assist with this planning.

Fig. 1: Hourly discharge for two experimental flow configurations for the Ash River pulse flow release

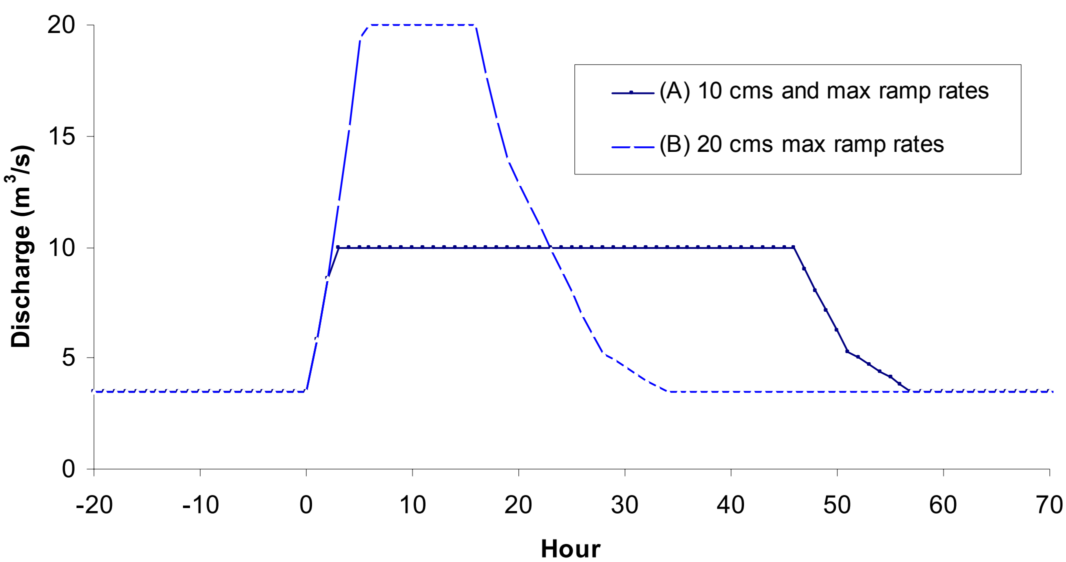


Table 2: Annual schedule for the experimental pulse flow releases. Year refers to year of monitoring.

Year	First release	Second release
1	Flow A	Flow B
2	Flow B	Flow A
3	Flow A	Flow B
4	Flow B	Flow A
5	Flow A	Flow B

An important uncertainty in the design of the monitoring program is the potential for low summer-run steelhead returns during the monitoring period. In addition, section 4.4.1 of the WUP indicates that pulse flow releases will not occur if steelhead are not observed at the base of Dickson Falls. Thus, low returns may affect monitoring by 1) limiting the ability to tag steelhead and observe leap attempts and 2) cancelling the pulse flow. Decision rules will need to be developed to determine 1) whether enough steelhead are present in a given year to warrant the telemetry and falls observation components of the monitoring program, and 2) whether enough steelhead are present to initiate a pulse flow. For example, it is not clear how many steelhead must be observed at the base of Dickson Falls to initiate a pulse flow. Similarly, if returns are low in a given year, it may be more effective to postpone monitoring and use the monitoring resources in the following year.

2.3 Methods

2.3.1 Task 1: Snorkel counts

Snorkel counts will document the abundance and distribution of all fish species in four sections of the Ash River. Four snorkel counts will be completed during each year of monitoring. Each swim will include the 4 sections used during previous surveys (Table 3). The four surveys expected to occur in early-July, mid-August, early-September, and late-September. Snorkel counts will follow WLAP protocols.

Table 3: Snorkel sections for the Ash River.

Section	Length (km)	Description
1	1.2	Confluence of Elsie Lake spillway channel and low level outlet channel downstream to first left bank tributary
2	2.7	Ash Island Falls to logging spur access located 1.0 km downstream of Mainline Bridge crossing
3	1.2	Dickson Lake outlet to Dickson Falls Pool
4	4.4	Old bridge upstream of Lanterman Falls to confluence with Stamp River

2.3.2 Task 2: Telemetry

> Note: While these Terms of Reference were developed based on the use radio tags, alternative tracking technologies (i.e., acoustics tags) may also be well suited to the monitoring. Given the frequent advances in tracking technology, alternative technologies will be considered for the monitoring.

Tagging

During years 2, 3 and 5 of the monitoring program, adult steelhead will be captured and tagged in June or July (i.e., depending on steelhead abundance and water temperature in the Ash River), prior to the window for the pulse flow releases during August and September. Ten steelhead will be tagged for a pilot telemetry program in year 2. Twenty steelhead will be tagged each year during the telemetry components in years 3 and 5.

Steelhead will be captured by angling or seining in the Lower Ash River downstream of Dickson Falls and, if possible, upstream of Lanterman Falls. Snorkel counts will help determine the timing and locations to capture steelhead. A Lotek model MCFT-3A radio tag (or a comparable tag) will be inserted into the stomach of captured fish following the procedures outlined in Korman et al. (2002). Fork length and gender of tagged fish will be recorded. Fish will be held long enough to allow recovery. Behavioural changes following handling and tagging fish are a concern. Therefore, fish movements immediately following release will be monitored by mobile telemetry and with fixed receivers (described below). It is possible that tagged fish may migrate downstream out of the Ash River, and, therefore, be lost from the study.

Tracking

Two fixed telemetry receivers will be installed to track the movements of tagged steelhead. One fixed telemetry receiver will be installed immediately upstream of Dickson Falls to track the movement of steelhead past the falls. The receiver will record the time that fish successfully pass the falls. A range test prior to installation will ensure that fish upstream of Dickson Falls are tracked and that signals from fish at the base of the falls are not. A second receiver will be installed upstream of Lanterman Falls. This configuration of the fixed receivers will help to determine in which of three sections tagged fish are holding: 1) upstream of Dickson Falls, 2) between Dickson Falls and Lanterman Falls, and 3) downstream of Lanterman Falls. Additional mobile tracking will confirm the location of the tagged fish (described below). This configuration will also help to determine whether fish move back downstream and when fish pass Lanterman Falls. Operation of the fixed receivers will begin when fish are tagged and continue until the end of the second pulse flow release. The key indicators collected will be the timing of fish passage at Dickson Falls (Table 4).

Mobile tracking will include two components. First, limited mobile tracking during each day that leap attempt monitoring occurs will determine whether tagged fish are present at the base of Dickson Falls. Second, more extensive mobile tracking will determine the location of tagged fish during three periods for each pulse: 1) the start of the control period, 2) prior to the start of the pulse, and 3) immediately following the pulse. Tracking during these periods will allow comparison of movements during the control and pulse periods.

Table 4: Monitoring tasks and measurement variables for the Ash River steelhead passage monitoring program. The relation between these measurement variables and environmental data such as discharge, water temperature, time of day, and light intensity will be examined.

Task	Key measurement variables
1 Snorkel count	1: Relative distribution of steelhead upstream and downstream of Dickson Falls
2 Telemetry	2a: Distance migrated during control and pulse periods
	2b: Timing of and discharge during falls passage
3 Direct observation	3a: Leap attempts per unit time
	3b: Successful leap attempts per unit time
	3c: Migration route

2.3.3 Task 3: Observations of leap attempts

Leap attempts at Dickson Falls will be observed to compare passage attempts, success and migration routes during the flow release and during non-release periods. Observations will provide information primarily on the stimulation to migrate. Previous observations of steelhead passage (Griffith 1993, Burt 2001, BCCF 2002) documented the topography of Dickson Falls and likely migration routes (Fig. 2). The 2.5 m vertical leap to Step 6 appears to be the point of most difficult passage, though the success of leap attempts at other steps is also low (BCCF 2002).

Leap attempts will be monitored during each year of the monitoring program. Observations will occur during daylight hours and follow the methods in BCCF (2002). Crews will record the number, location in the falls (e.g., leap from Step 2 to 3; Fig. 2), species, and success of each leap over a one-hour period. Observations will include all steps of the falls with an emphasis on the steps deemed most difficult for passage, likely the leap to Step 6 or to Step 7 (Fig. 2). Leap attempts at each step will be recorded separately. Fish observed swimming in sections of the falls will also be noted. Water and air temperature, turbidity, time of day and weather conditions will be recorded. The key variables to be collected are leap attempts per unit time, successful leap attempts per unit time, and migration routes (Table 4).

For each experimental flow release, observations will occur during three different periods: 1) during the pre-release control period, and if feasible, 2) during the peak of the pulse and 3) during the ramp-down. Fig. 3 outlines the timing windows for the observations. The ramp-up will likely occur at night for public safety concerns and, therefore, leap attempts cannot be observed. Two one-hour observation events will occur during each of these three periods—one during mid-day and the other during the morning or evening—for a total of 6 one hour observation events for each pulse flow. As diel cues may affect steelhead migration, observation periods will be classified as either morning (within 2 hours of morning civil twilight), evening (within 2 hours of evening civil twilight) or mid-day. The daily timing of the observation events during the peak of the pulse and the ramp-down may need to be adjusted to correspond with the timing of the pulse flow, and it may not be logistically feasible to obtain observations during each period. During site visits for falls observations, data from fixed receivers and pressure transducers can be download and mobile tracking at the base of Dickson Falls can also occur.

The control period prior to the release (Fig. 3) will be examined since flows during the period following the release will likely be affected by gradually receding natural inflows from the rainfall event.

Fig. 2: Topography and likely migration routes for steelhead at Dickson Falls. Steelhead may also leap from Step 4 to 6 or Step 3 to 6 (BCCF 2002). Reproduced from Griffith (1993) with additions from Burt (2001).

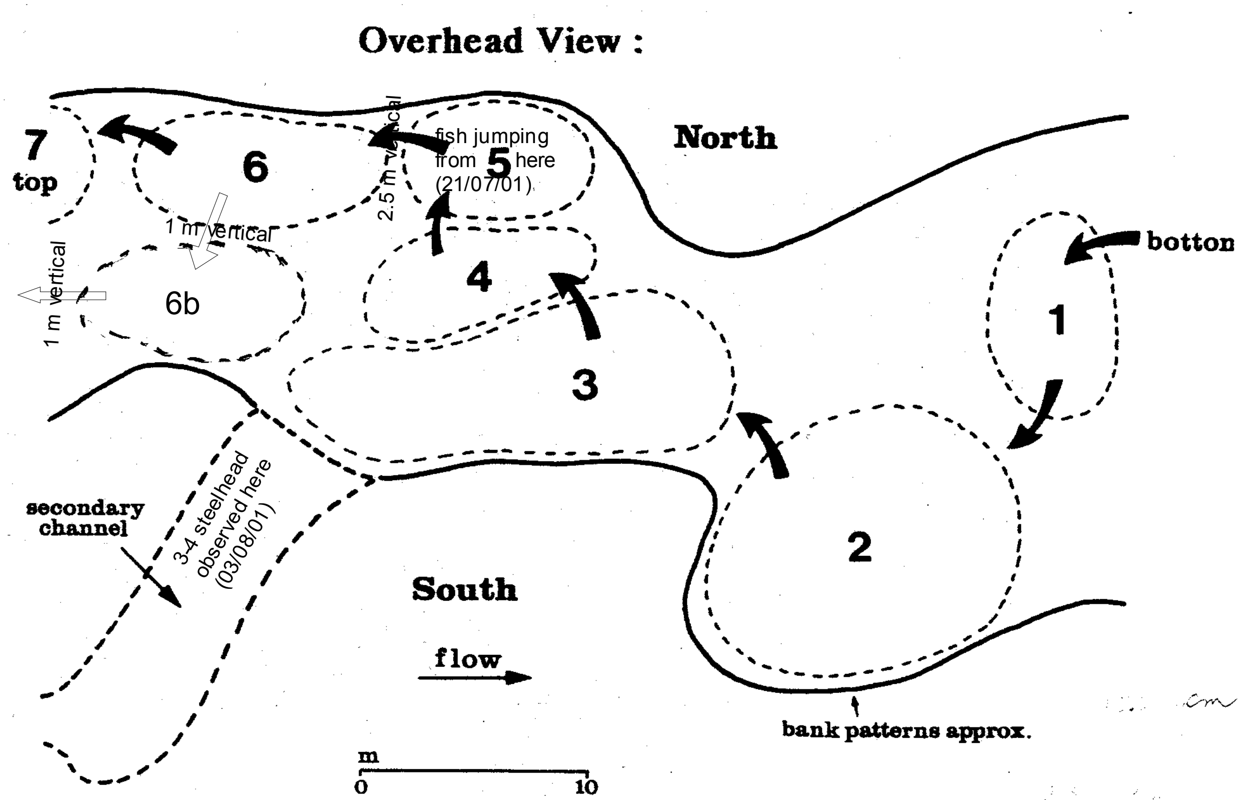
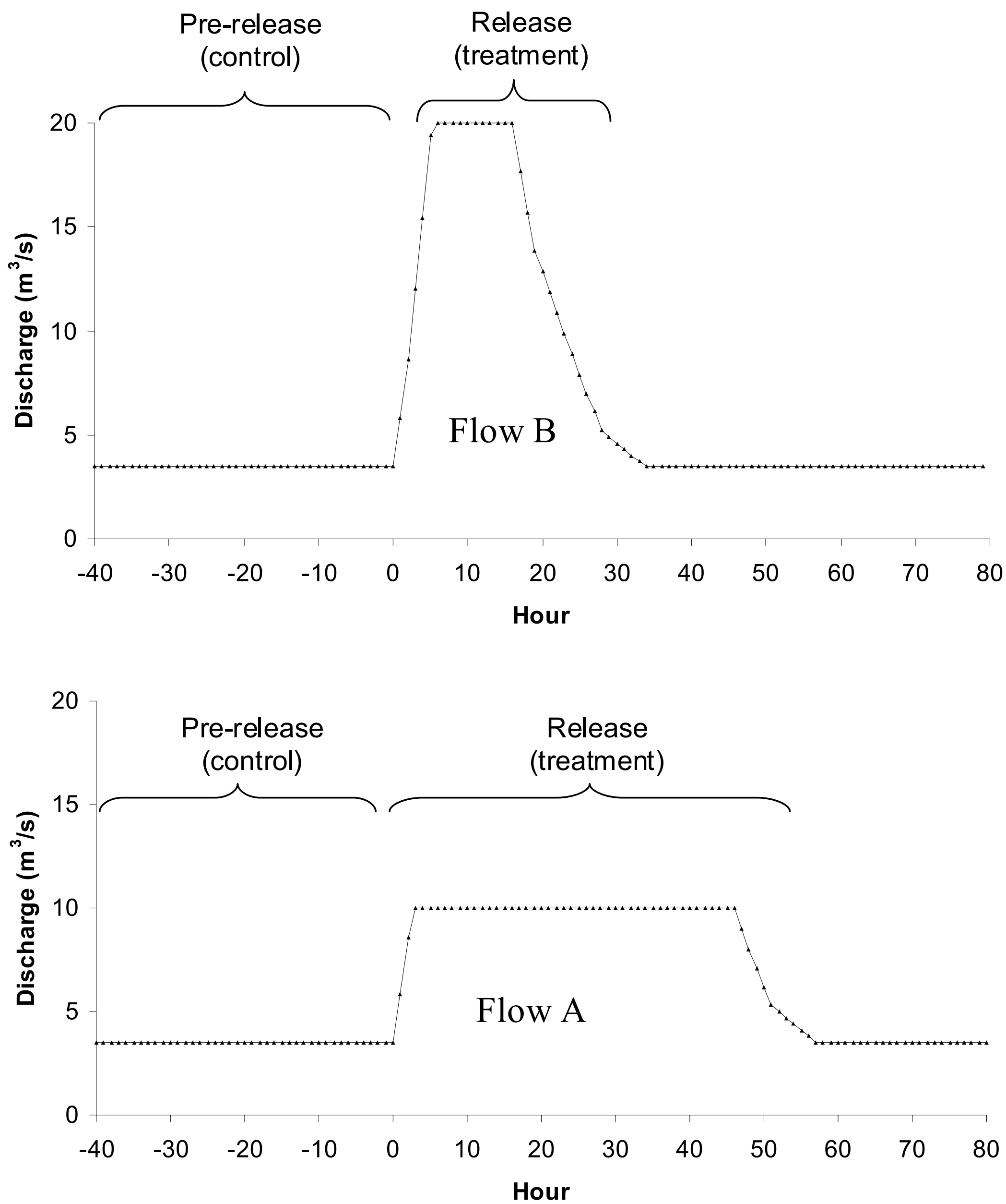


Fig. 3: Timing windows for leap attempt observations at Dickson Falls for the pulse flow releases.



2.3.4 Task 4: Discharge, stage and light intensity

The relation between steelhead passage and flow conditions (measured as absolute discharge and/or rates of change) will be examined to help identify the flow conditions that are most suitable for passage. Discharge at Dickson Falls is difficult to estimate from records of flow releases from the low-level outlet and discharge at the WSC gauge near Moran Creek because Dickson Lake buffers flows and significant natural inflows occur upstream and downstream of Dickson Falls, especially during rainfall events (BCCF 2002). Therefore, a pressure transducer and data logger will be installed at a suitable location near Dickson Falls to continuously measure river stage.

Installation and calibration of the pressure transducer (with temperature recorder), data logger and staff gauge will be completed according to accepted hydrometric standards (e.g., MELP 1998).

Since light intensity may stimulate steelhead to migrate, a logger to measure light intensity (e.g., Hobo LI or similar) will also be installed near Dickson Falls in an area unobstructed by overhanging vegetation. Similarly, records of barometric pressure will be obtained from a local climate station.

2.3.5 Task 5: Reporting

A detailed technical report outlining the findings as they relate to the ecological hypotheses and the key management questions will be prepared prior to the review of the WUP. A brief, summary data report will be prepared annually. Reports will follow the standard format that is being developed for WUP monitoring programs.

2.4 Interpretation of Monitoring Program Results

Interpretation of results for fish migration during pulse flows can be challenging because several physiological and environmental factors other than flow can affect migration. Previous pulse flow studies on the Puntledge River (Komori Wong Environmental and Bixby 2003, Taylor and Guimond 2004) and a study with Atlantic salmon in Europe (Thorstad and Heggberget 1998) suggest that pulse flows influence migration, though the patterns can be difficult to interpret.

The CC considered any benefits to steelhead passage to be biologically significant (see Table 4-6 of Anon 2003). The key monitoring results for this program will be the discharge during which steelhead pass Dickson Falls and the distance migrated during the control and pulse periods. However, both a quantitative comparison of fish passage during pulse and non-pulse periods and a qualitative assessment of migration behaviour may be needed to help interpret these results.

The timing of steelhead passage will be interpreted at two time scales. First, passage at the weekly time scale will be inferred from the distribution of steelhead upstream and downstream of Dickson Falls, enumerated during snorkel counts. Second, telemetry results will provide more detailed information (i.e., at the hourly time scale) on the timing of fish passage.

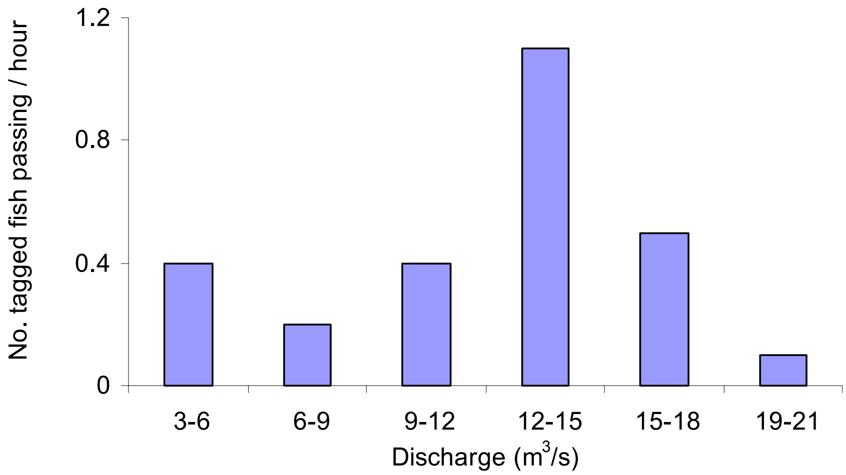
H_1: Flow conditions hinder migration

This hypothesis will be evaluated quantitatively based on the results for H_2 and H_3 below, and qualitatively based on the migratory behaviour of tagged fish. For example, if fish rapidly migrate upstream during non-pulse periods, then flow conditions would not appear to hinder migration. Conversely, if fish hold in the river for extended periods, and migrate in response to flow releases, then existing flow conditions would appear to hinder migration.

H_2: Pulse flows improve passage at Dickson Falls

The discharge during which each tagged steelhead passes Dickson Falls will provide general information on the relation between discharge and passage conditions (Fig. 4). The experimental design is not suited to a rigorous statistical comparison of fish passage at Dickson Falls during pulse and non-pulse periods (see Appendix B). Therefore, a statistical test of the distance migrated upstream during pulse and non-pulse periods will provide a quantitative comparison (see Appendix B for details on the analysis).

Fig. 4: Hypothetical data to illustrate the discharge during which fish migrate past Dickson Falls. These data would be obtained from the fixed telemetry station and flow gauge. This illustration would suggest that passage conditions are optimal at discharge from 12 to 15 $m^3 \bullet s^{-1}$, during the ramp-up or ramp-down portions for pulse B.



H_3: The magnitude and duration of the pulse affects passage

Results will be analyzed similar to those described for H_2 above. Data for the 10 $m^3 \bullet s^{-1}$ and 20 $m^3 \bullet s^{-1}$ pulses will be analyzed separately (see Fig. B1 in Appendix B).

Environmental data

The effects of environmental variables other than discharge (e.g., barometric pressure) on fish migration during release and non-release periods will also be examined. Results from leap observations will provide information on the stimulus to migrate, and, if steelhead are observed to successfully pass Dickson Falls, supplementary information on migration rates.

2.5 Schedule

Monitoring is scheduled to occur over a 5-year period. Sections 2.2 and 2.3 describe the general timing for each task.

Since the timing of the pulse flow is supposed to coincide with rainfall events and the presence of steelhead below Dickson Falls (see section 4.4.1 of the WUP), release timing will vary annually. Consequently, a protocol between the BC Hydro Generation Operations planning engineer and the field crew will need to be established for 1) communication, 2) safety, and 3) operating protocol.

2.6 Budget

The estimated total cost for the monitoring program is $179,521 without inflation costs. Table 5 summarizes the budget by labour and expenses. Costs are estimated in 2004 dollars and total inflation costs are included on the second to last line. The budget assumes that an existing BC Hydro or agency mobile telemetry receiver can be borrowed.

Table 5: Estimated costs for the Ash River steelhead passage study. Contingency and administration are calculated on field labour, and cover safety planning, regulatory approvals (permits), field management, and unforeseen weather or operational delays.

Task	Labour		Units					
		Daily rate	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total Cost
Snorkel count	Lead biologist	$500	4	4	4	4	4	$10,000
	Technician	$300	12	12	12	12	12	$18,000
Falls observations	Lead biologist	$500	2	2	2	2	2	$5,000
	Technician	$300	2	2	2	2	2	$3,000
Transducer installation	Lead biologist	$500	2					$1,000
	Technician	$300	4					$1,200
Tagging	Lead biologist	$500		5	5		5	$7,500
	Technician	$300		5	15		15	$10,500
Install receivers	Lead biologist	$500		1	1		1	$1,500
	Technician	$300		1	1		1	$900
Mobile Tracking	Lead biologist	$500		2	4		4	$5,000
	Technician	$300		2	12		12	$7,800
Data Entry	Technician	$300	1	2	2	1	2	$2,400
Reporting	Lead biologist	$500	2	3	3	2	3	$6,500
	Technician	$300	4	5	5	4	5	$6,900
	Contingency	5%	$470	$680	$1,030	$360	$1,030	$3,570
	Admin	10%	$940	$720	$2,060	$720	$2,060	$6,500
							Subtotal	*$97,270*
	Expenses	Unit Price						
	Accommodation	$100	26	36	58	20	58	$19,800
	Meals	$40	26	36	58	20	58	$7,920
	Truck	$100	13	18	29	10	29	$9,900
	Fuel	$40	13	18	29	10	29	$3,960
	Fixed receivers	$8,278		2				$16,556
	Fixed receiver battery	$130		2			2	$520
	Pressure transducer	$3,000	1					$3,000
	Radio tags	$294		10	20		20	$14,700
	Floy tags	$2		100				$200
	Light intensity logger	$220	1					$220
	Dry suit rental (daily rental)	$20	16	16	16	16	16	$1,600
	Turbidity meter (monthly rental)	$80	2	2	2	2	2	$800
	Fish collection permit	$25		1	1		1	$75
	Field supplies [a]	$200	1	1	1	1	1	$1,000
	Report reproduction	$400	1	1	1	1	1	$2,000
							Subtotal	*$82,251*
	Inflation	2%	$461	$1,908	$2,843	$1,324	$4,862	$11,399
		Total	**$21,331**	**$42,729**	**$35,898**	**$17,384**	**$38,177**	**$190,920**

[a] Includes stationary, angling supplies and steelhead holding tubes.

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Appendix A: Modifications from the initial proposal.

The monitoring approach for these Terms of Reference differs considerably from the proposal in Appendix O of the CC report for the Ash River WUP. The original proposal relied on before-after snorkel counts to reduce uncertainties. Discussions with agency staff, BC Hydro technical staff, First Nations fisheries staff, and a review of existing literature suggested that this approach could not determine the discharge at which steelhead pass Dickson Falls, a key piece of information. As a result, these Terms of Reference include radio telemetry to determine the exact time and discharge during which steelhead pass the falls. This combined snorkel and telemetry approach should provide more detailed information on steelhead passage and is more likely to reduce the uncertainties identified in the CC report.

With the snorkel approach, the timing of steelhead passage is inferred broadly from the number of steelhead counted upstream and downstream of the falls before and after the flow release, and the number of fish observed to pass the falls. A review of previous sampling suggested that this approach lacked the temporal resolution needed to reduce the key uncertainties. For example, previous observations during seven days in October 2001 (discharge 4 to 8 $m^3 \bullet s^{-1}$) using this approach could not determine the flow requirements for steelhead passage at Dickson or Lanterman Falls (BCCF 2002). During observations of leap attempts, no fish were observed to successfully pass either falls, though steelhead were observed upstream of both falls during snorkel swims. At Dickson Falls, only 3 of the 43 leap attempts by steelhead were successful, and no leaps successfully passed the most difficult leap to Step 6 (Fig. 2). None of the 48 leap attempts at Lanterman Falls were successful. These results suggest that leap attempt monitoring will provide information on the stimulation to migrate and migration routes. However, successful leaps (especially at the more difficult steps) will be rare and thus little information on the timing of successful passage, the key indicator for the monitoring program, will be obtained. Before-after snorkel counts may provide information on whether steelhead passed the falls. However, as with leap attempt monitoring, it will not provide information on the exact timing of passage (e.g., the discharge at which passage occurs) or the flow conditions during passage.

The telemetry approach overcomes these limitations by providing information on the exact timing of steelhead passage, which is needed to determine the optimal magnitude, timing and hourly flow release that maximizes steelhead passage. Telemetry data will be supplemented with direct observations of steelhead leap attempts at Dickson Falls, which will provide information on the factors that stimulate migration and the chosen migration routes over the falls. A potential limitation of the telemetry approach is that fish can experience behavioural changes following capture and tagging. Fish movements following tagging will be monitored to assess behaviour following tagging.

The annual cost for the combined snorkel and telemetry approach is higher than that proposed for the snorkel approach. (Table A1). Conversely, the snorkel approach had the risk of not collecting data if the timing of sampling could not be co-ordinated with the flow releases. For example, if a decision to initiate a flow release was made on short notice and crews could not snorkel prior to the release, then information on steelhead passage could not be obtained. The telemetry approach is not as sensitive to the timing of sampling because passage information is collected continuously by the fixed receiver. Telemetry also monitors fish passage at night. A large percentage of returning salmon pass the Stamp Falls fishway at night (Jeff Till, FOC, Nanaimo, personal communication) and approximately 10% of summer-run steelhead pass Columbia River fishways at night (Robards and Quinn 2002).

Table A1: Modifications in the current Terms of Reference relative to the original study proposal.

Item	Original proposal	Current Terms of Reference
Approach	Before-after snorkel counts	Snorkel counts and telemetry
Estimated total cost	$76,900 [a]	$179,521 [b]

[a] Costs from the original proposal were adjusted from 2003 dollars ($75,000) to 2004 dollars using an inflation rate[4] of 2.5%.

[b] Costs listed for the current Terms of Reference do not include inflation over the 5-year monitoring period

[4] Inflation rate from: www.bankofcanada.ca/en/inflation_calc.htm

Appendix B. Experimental design and statistical analyses of tagging data for migration during pulse flows.

The general approach is to compare the migration of tagged fish during the pulse flow with migration during a non-pulse control period. The migration of individual tagged fish is measured during both the control and treatment periods. Migration is measured either as the distance migrated, or the simply as nominal data of 'migrated' or 'failed-to-migrate' during each control and treatment period. Table B1 and Fig. B1 illustrate such data from a similar study on the Puntledge River.

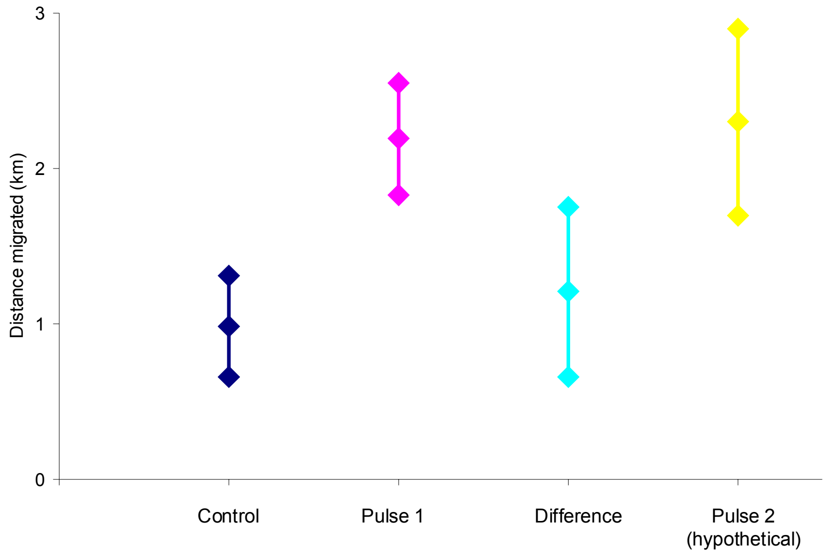
Table B1: Example data for the migration of tagged Chinook salmon in the Puntledge River during 2003 (from Taylor and Guimond 2004). Fish that migrated <0.6 km during the control or pulse periods were considered to have not moved. A subset of the data is presented.

	Continuous data (km)			Nominal data	
Fish	Control	Pulse	Difference	Control	Pulse
1	0	3	3	n	y
2	0	3.6	3.6	n	y
3	0.2	2.9	2.7	n	y
4	1.2	1.7	0.5	y	y
5	1.2	2.7	1.5	y	y
6	0.2	0.6	0.4	n	y
7	3.8	1.5	-2.3	y	y
8	0.2	4.5	4.3	n	y
9	0	4.3	4.3	n	y
10	0.2	3.6	3.4	n	y

The experimental design is a paired or repeated measures design because repeated measurements are taken on each individual tagged fish (i.e., one measurement during the control period, and another during the treatment period of the pulse). Paired designs are often more sensitive than completely randomized designs because the paired design accounts for the effect of variation among individuals. Alternative statistical methods are used to analyze paired or repeated measures designs because the designs violate the assumption of independence for 'standard' statistical methods (i.e., that all measurements are independent). Standard statistical methods would be employed if different tagged fish were measured during each period. For example, if one group of tagged fish was measured during the control, and a second group during the pulse, with a single measurement on each individual.

The difference between paired measurements can be analyzed using standard methods. A simple way to analyze paired, continuous data (here, the distance migrated) is to calculate, for each individual fish, the difference between the distance migrated during the treatment and control periods. Then, simply test whether this sample of differences differs from zero (e.g., with a t-test). Similarly, tests using nominal data (here, migrated or failed-to-migrate) would compare the number of individuals that migrated then failed-to-migrate during the control and treatment periods respectively, with the number of individuals that failed-to-migrate then migrated (e.g., using McNemar's test or the exact Liddell method).

Fig. B1: Graphical representation of the distance migrated during pulse and control periods. Data are as per Table B1 except that hypothetical data are illustrated for a higher magnitude pulse (Pulse 2). Error bars are 80% confidence intervals.



A challenge in the statistical analysis of the paired design is that the migration of individual fish must be measured during both the control and treatment periods—individuals that are not measured during both periods are often excluded from paired analyses. For the Ash River, the response variable 'distance migrated' can be measured during both the control and pulse. However, the nominal response variable cannot always be measured during both periods because fish that pass Dickson Falls during the control period cannot pass the falls during the pulse. Hence, a seemingly intuitive comparison of passage rates at Dickson Falls during the control and pulse periods cannot be analyzed statistically with the paired design.

Statistical power calculations

We calculated the statistical power to detect a difference in the distance migrated between the pulse and control periods (t-test that mean difference $\neq 0$). The CC considered any benefits to steelhead passage to be biologically significant (see Table 4-6 of Anon 2003). We used parameter estimates from data for tagged Chinook salmon on the Puntledge River (2003 pulse flow #1; Taylor and Guimond 2004) where the mean difference in migration distance between the control and pulse periods was = 1.2 km, with a standard deviation of the difference = 2.3. Using these parameters and $\propto = \beta = 0.2$ (power = 0.8)[5], 17 tagged fish are needed to detect this difference for a single pulse. The slightly larger sample size of 20 tagged fish in these Terms of Reference can account for possible tag loss, mortality, or downstream movement out of the study area.

[5] By setting $\propto = \beta$, no implicit assumptions are made regarding the relative consequences of Type I and Type II errors.

Elsie Reservoir Archaeological Investigations
Terms of Reference

1 Introduction

The Ash River Water Use Plan (WUP) process was initiated in September, 2000. The goal was to develop an operating regime for BC Hydro's Ash River facility and Elsie Lake Reservoir that all of the parties with interests linked to the Ash River and Elsie Reservoir could live with. Extensive consultation with First Nations, government agencies, and the public were carried out through the Ash River WUP Consultative Committee. The operating regime developed through these consultations is intended to provide a balance for water use interests including power generation, First Nations archaeology and traditional use, fisheries, wildlife, flood control, and reservoir recreational use.

The Ash River WUP Consultative Committee Report published its final report in June of 2002 and the draft Water Use Plan was submitted to the provincial Comptroller of Water Rights in 2003. The Consultative Committee Report recommends a preferred operating regime and monitoring programs to determine the effects of this operating regime on fish passage in the Ash River and on archaeological sites in the Elsie Reservoir.

This terms of reference lays out the proposed scope of work for monitoring archaeological resources in the Elsie Reservoir.

2 Baseline Archaeological Inventory and Impact Assessment

A baseline archaeological site inventory and impact assessment were carried out in August and October of 2001 during a deep drawdown of the reservoir for dam seismic upgrades (Hupacasath First Nation and Ethos Archaeology). This assessment discovered and recorded 26 new archaeological sites in the drawdown zone of the reservoir; 11 lithic scatter areas and 15 culturally modified trees (CMTs). Site significance was evaluated using criteria outlined in the BC Archaeological Impact Assessment Guidelines. One site was determined to be of high significance, four to be of moderate significance and the rest to be of moderate-low or low significance.

Impacts to the sites observed during the field work included erosion; forestry operations (logging, road building etc.), recreational users (4X4 and all-terrain vehicles disturb the sites) and “pot hunters” (artifact collectors that illegally remove artifacts).

The draft impact assessment report indicates that additional sites are likely in the permanently inundated portion of the reservoir. Additional sites may be discovered in the operational range of the reservoir.

The draft report recommends that site DiSh –17, the site categorized as having high archaeological significance, be investigated for the possibility of mitigation of erosion impacts through protective capping. The report further recommends that a mitigative salvage be carried out at the site to recover artifacts and samples for carbon dating.

Further reconnaissance work is recommended during future drawdowns (at or below 318 masl) to identify potential new sites and to monitor rates of erosion and artifact exposure from known sites. It recommended that known and discovered CMT sites are to be sampled for age analysis (tree ring counts). Through the Ash River WUP consultation process, BC Hydro agreed to give First Nations prior notice when the reservoir is planned to go below 318 masl elevation.

3 Work Completed to Date

In October of 2002, BC Hydro and Hupacasath First Nation agreed to move forward on investigation of erosion impacts and further characterization of the DiSH-17 site. An erosion monitoring system was established at the site in early October of 2002.

Further archaeological investigations of the site were carried out in mid-November of 2002 in order to delineate the extent of the site and assess the need for mitigative salvage work if erosion was substantial and other mitigation strategies were not feasible.

The erosion monitoring system at DiSH-17 has been visited six times since it was established. The erosion pins had to be reinstalled in October of 2004 due to vandalism of the original installation, most likely by motorcyclists or quad riders.

Preliminary results from the site indicate that erosion rates at the site are very slow. Erosion and deposition seem to occur at similar rates so the elevation of the site does not seem to be changing much. Summary tables of the data collected so far are available.

The archaeological investigations indicated that the site was less than 48 m X 65 m in dimension. Carbon dates from the site indicate a date of 6240 +/- 40 years before present. A final report for this work is pending. This report will include recommendations for the site that considers the extent of the erosion impact and the significance of the site.

4 Future Monitoring

The principle objective of future work in the reservoir is to determine whether the current operating regime used for the Elsie reservoir is having an impact on significant archaeological sites in the reservoir drawdown zone. This work is intended to investigate the extent of those impacts and in one case (DiSH-17) to assess protection options.

Archaeological work in Elsie Reservoir will concentrate on monitoring of impacts of reservoir operations on archaeological sites. The monitoring program will include three main components; annual monitoring of a known significant site (DiSH-17), evaluation of options to protect this site, and opportunistic surface surveys of other known sites during periods of low reservoir levels.

4.1 Annual Monitoring – DiSH-17

4.1.1 Objective and Scope

The purpose of the annual monitoring will be to determine the rate of erosion at site DiSH-17 and the magnitude of impact this erosion may be having on the archaeological resources at that site.

4.1.2 Approach and Methods.

A network of 25 erosion pins have been established at the site. This network is designed to provide information on the rate of erosion and deposition that may be occuring at the site.

Each erosion pin has a large flat washer placed over it at ground level. An initial measurement is made to determine the distance from the top of the erosion pin to the washer. As erosion occurs, the washer will drop and the distance between the top of the pin and the washer will increase. Any deposition will bury the washer and the distance from the ground surface to the washer will be a measure of the amount of deposition that has occurred.

The network is set up in a grid design over the extent of the site. All measurements will be used to determine an average rate of erosion and deposition at the site.

The magnitude of impact on the archaeological resources at the site will be determined by assessing the available information on the significance of the site (report on previous work due in March of 2005), the rate of erosion and deposition and the rate of artifact exposure at the site. The rate of artifact exposure will be determined through visits to the site by a Registered Professional Archaeologist when exposed artifacts are collected. The frequency of artifact exposure within the area monitored by erosion pins will be compared to erosion and deposition rates to determine artifact density at the site. This information will be combined with previously collected information on site significance and erosion and deposition data to inform future decisions on protection options for the site.

4.1.3 Schedule

The monitoring of Site DiSH-17 will be conducted opportunistically when reservoir levels allow access the site. The site is located at elevation 329 masl. Based on previous reservoir operations records, the site would be exposed on average 5 months a year. The monitoring frequency at this site will be twice per year, conditions allowing. BC Hydro and Hupacasath will collect the data that will be forwarded to an independent professional geoscientist or engineer who will maintain a database of the information and provide evaluation and summary reports

The monitoring will continue until the next WUP review (2010) or site protections are in place and no further monitoring is required.

4.1.4 Deliverables

Annual reports will be prepared for the erosion monitoring and artifact exposure aspects of the monitoring program. These reports, along with an executive summary, will be presented to the Ash Monitoring Committee, the Archaeology Branch, and the Water Comptroller.

4.2 Evaluation of Protection Options for DiSH-17

4.2.1 Objective and Scope

The objective of developing protection options for DiSH-17 is to prepare a list of alternatives for the protection archaeological resources at DiSH-17.

4.2.2 Approach and Methods

A draft archaeological assessment report for DiSH-17 is due in March of this year. This report will set out the findings of archaeological and erosion rate assessments of the site. These findings will be combined with information on site characteristics to prepare a summary of protection options for the site. This summary will be included to the draft assessment report on DiSH-17 and the final product presented to the BC Ministry of Sustainable Resource Management, Archaeology and Registry Services Branch (Archaeology Branch). Final recommendations on site protection will be provided by the Archaeology Branch.

Site protection measures information will provide a summary of potential methods to protect the site. These methods will be provided at a conceptual level including a summary of the pros and cons of each method including potential costs. The evaluation will also provide a recommendation on the preferred option and justification for selection of this method.

4.2.3 Schedule

The evaluation of protection options will proceed following the preparation of a draft report in March 2005. A final report will be completed and available by August 31, 2005.

4.2.4 Deliverables

The final deliverable will be a report including conceptual level discussions (and drawings if necessary), summary of pros and cons and potential costs for each option. This report will be provided to the Ash Monitoring Committee, the Archaeology Branch (as an appendix to the archaeology report on the site), and the Water Comptroller.

4.3 Opportunistic Monitoring

4.3.1 Objective and Scope

Opportunistic monitoring of known archaeological sites in the operational drawdown zone of the reservoir will take place on an opportunistic basis. The objective of the opportunistic survey will be to monitor the rate of artifact exposure at known sites in the reservoir.

4.3.2 Approach and Methods

Previously identified sites will be prioritized according to the significance criteria previously established and through consultation with Hupacasath First Nation. During periods of low reservoir levels, prioritized sites will be visited and surface artifacts collected. The use of systematic or “random walk” survey techniques at each of these sites is dependent on the professional judgment of the archaeologist involved. Subsurface testing may be required to further determine the significance of the site. Monitoring will be carried out until the next WUP review process takes place.

If site visits indicate ongoing loss of artifacts from a significant site, the site may begin evaluation similar to that in place for DiSH-17 prior to the WUP review. Erosion monitoring systems may be installed at these sites and protection (mitigation) measures evaluated. Mitigation measures will be dependent on site-specific variables such as access, mode of erosion, erosion rate, etc.

4.3.3 Schedule

The opportunistic monitoring of archaeological sites in the reservoir will occur on two occasions over the next five years. Monitoring will take advantage of low water levels in the reservoir to investigate known sites in the operational drawdown zone of the reservoir.

5 Work Contracts and Budgets

This terms of reference will be carried out through 3 separate contracts; a professional archaeologist to guide the work; a professional engineer to guide the erosion monitoring program and carry out the evaluation of protection options for Dish-17; and contracts for technical services and field support for both the archaeological and erosion monitoring components of the program.

5.1 Scope of Work – Registered Professional Archaeologist

The professional archaeologist will be responsible for guiding the ongoing archaeological investigations. This will include acquisition of necessary permits, field work, and completion of reports. It is anticipated that there will be a bidding process for this work with the successful applicant being mutually agreed by BC Hydro and the Hupacasath First Nation. Contracts will be awarded for a one year term and renewed annually based on performance of the contractor and upcoming scope of the work.

5.1.1 Annual Monitoring –DiSH-17

The archaeologist will be responsible for acquiring the necessary permits, supervising the collection of artifacts in the field, follow up reporting, and cataloguing of artifacts.

5.1.2 Opportunistic Monitoring

The archaeologist will be responsible for acquiring the necessary permits, supervising the collection of artifacts in the field, follow up reporting, and cataloguing of artifacts.

5.1.3 Budget

Task	Rate	Time	Expenses	Total	Frequency
Annual Monitoring – DiSH-17	$650.00/day	6 days	$600.00	$4,500.00	annual
Opportunistic Monitoring	$650.00/day	19 days	$1,452.00	$13,802.00	Twice in five years

5.2 Scope of Work – Professional Engineer or Geoscientist

The professional engineer or Geoscientist will be responsible for guiding the erosion monitoring program and development of protection alternatives. It is anticipated that an independent engineering firm selected based on qualifications and price.

5.2.1 Annual monitoring DiSH-17

This will include providing guidance for those collecting erosion monitoring data, compiling a database of erosion data for each site and reporting on their interpretation of the results.

5.2.2 Protection Options Report

They will also be responsible for the preparation of a report outlining the protection alternatives for DiSH-17. The report will consider archaeological significance of the site, extent of the site, erosion parameters for the area, cost effectiveness and success potential for all options. The report will present a recommended option based on these considerations.

5.2.3 Budget

Task	Rate	Time	Expenses	Total	Frequency
Annual Monitoring – DiSH-17	$776/day	3 days	$100.00	$2,428.00	annual
Protection Options Report – DiSH-17	$776/day	15 days	$100.00	$11,470.00	Once in 2005

5.3 Scope of Work – Technical Services and Field Support

The scope of work for technical services and field support is to work with the archaeologist and engineer in the field work, planning and follow up activities. The archaeologist and engineer will be required to use the Technical Services and Field Support contractors for these tasks.

5.3.1 Annual Monitoring –DiSH17

This contract will include opportunity to accompany BC Hydro personnel on field trips for collection or erosion data. It will also include responsibility for logistics of annual artifact collection surveys including watching reservoir levels for an appropriate opportunity, mobilizing the archaeologist, liaison with BC Hydro to ensure proper safety protocols are met, and providing the necessary field support for the work.

5.3.2 Opportunistic Surveys.

This contract will include the responsibility of monitoring reservoir levels and selecting an appropriate time to carry out the work, mobilizing the archaeologist and a field crew, liaison with BC Hydro to ensure proper safety protocols are met, and providing what technical support is needed for the survey.

5.3.3 Budget

Task	Rate	Time	Expenses	Total	Frequency
Erosion Monitoring DiSH17	$280/day	2 days	$50.00	$610.00	annual
Artifact Collection-DiSH17	$332/day	6 days	$600.00	$2,592.00	annual
Opportunistic Survey	$332/day	15 days	$525.00	$5,505.00	Twice in five years