Peace River Project Water Use Plan

Williston Reservoir Trial Wetlands

Implementation Year 1

Reference: GMSWORKS-17

Stage II Detailed Design and Cost Estimate

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STAGE II - DETAILED DESIGN AND COST ESTIMATE

GMSWORKS 17 - Williston Reservoir Wetland Demonstration Sites

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REPORT

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EXECUTIVE SUMMARY

In August of 2010, Golder Associates Ltd. (Golder) was retained by BC Hydro and Power Authority (BC Hydro) to develop detailed designs and associated construction costs of two demonstration wetland sites within the drawdown zone of Williston Reservoir. This project, GMSWORKS 17, is the second of a two stage study. In 2009 Golder (Golder 2010) initially inventoried and identified a number of opportunities to create wetlands in Williston Reservoir (GMSWORKS 16 – Williston Reservoir Wetlands Inventory). The broad objectives of GMSWORKS 16 and 17, originally identified in the Peace Williston Water Use Plan (PWUP 2003), include anticipated improvements to fisheries and wildlife habitat, riparian habitat along the reservoir's foreshore and potentially, dust control. BC Hydro selected two Wetland Demonstration Sites (WDS) from five candidates identified by Golder in 2009 for development, including WDS 6-2 (Airport Lagoon) and WDS 34 (Beaver Pond). A multidisciplinary team that included a Biologist, Geotechnical Engineer, Civil/Hydrological Engineer, Archaeologist and Land Surveyors completed a second set of surveys of WDS 6-2 and 34 in September of 2010. Very low reservoir water levels in fall 2010 were favourable to the completion of this work since the selected WDS would otherwise have been inundated by the reservoir during a more normal operating regime.

The proposed treatment at WDS 6-2 Airport Lagoon involves replacing two existing 1200 mm diameter culverts within a 150 m long by 9 m high causeway. The invert elevation of the existing culverts is approximately 664.5 masl, whereas the proposed replacement culverts will have staggered invert elevations, starting at 667.0 to 667.5 masl. The objective of this treatment is to create between 27 to 34 ha of permanently wetted habitat upstream of the causeway. It is estimated 13 to 16 ha of this newly created water body will be less than 1m deep. Raising the invert elevations of the culverts will also delay inundation of the treatment area by Williston Reservoir later into the growing season and shorten the period of inundation. This treatment will also reduce the extent of drawdown within the treatment area by 3 m. These changes are anticipated to produce conditions more conducive to natural colonization and persistence of aquatic macrophytes within the permanently wetted habitat and aid in development of a more robust and vigorous riparian zone. Establishing a permanent water body, in combination with anticipated benefits to vegetation, is expected to provide persistent habitat to the benefit of waterfowl, shore birds, terrestrial wildlife as well as fish and other aquatic biota. The estimated cost to complete this work is $375,896 for excavating culverts into place, or $440,115 for augering culverts into place.

At WDS 34 Beaver Pond, the proposed treatment is to create a water control structure using silts and sands dredged from the foreshore of Williston Reservoir to fill a series of geosynthetic bags. These bags, provided through Macaferri (MacTubes®), will create a low berm approximately 3 m in height with an invert elevation of 669 masl. This berm will act as a dam, inundating approximately 0.9 ha behind the dam when reservoir levels are below 669 masl, but allow flooding from the reservoir during higher water levels. Similar to WDS 6-2 Airport Lagoon, establishing permanently wetted habitat behind the berm is expected to shorten the extent of drawdown within the treatment area by 3 m. Reducing the drawdown at WDS 34 is also anticipated to encourage natural colonization and persistence of aquatic macrophytes within the permanently wetted habitat and growth of a more robust and vigorous riparian zone. Approximately 40% of the permanently wetted habitat in this area will be less than 1 m deep. Aside from objectives of providing more consistent habitat for wildlife and fish species to use, this treatment will also test the feasibility and durability of using geosynthetic bags as water control structures in Williston Reservoir's harsh conditions. If successful, this technique could have broader applications throughout the reservoir's drawdown zone. The estimated cost to complete this WDS is $229,476.

Study Limitations

This report has been prepared by Golder Associates Ltd. (Golder) for the benefit of the client to whom it is addressed. The information and data contained herein represent Golder's best professional judgment in light of the knowledge and information available to Golder at the time of preparation. Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by the client, its officers and employees. Golder denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents without the express written consent of Golder and the client.

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by BC Hydro and Power Authority (BC Hydro) to provide professional services for GMSWORKS 17, with the objectives of developing detailed designs and associated construction costs for two Wetland Demonstration Sites (WDS) in Williston Reservoir. GMSWORKS 17 follows up on an earlier study identifying opportunities to create wetlands in Williston Reservoir (Golder 2010, GMSWORKS 16 - Williston Reservoir Wetland Inventory). Development of wetlands within the drawdown zone of the Williston Reservoir follows recommendations from a multi-interest consultative process, the Peace Williston Water Use Plan (PWUP 2003). The PWUP (2003) includes input from provincial and federal regulatory agencies following direction of the British Columbia Comptroller of Water Rights. This consultative process was undertaken to identify recommendations for a preferred operating strategy for the Peace Hydroelectric System (PHS). Failing identification of changes in this operating strategy, potential alternatives in lieu of changes in operating constraints, known as non-operating alternatives, were identified (PWUP 2003). The non-operating alternatives discussed by the committee addressed a number of issues and proposed individual management plans, including: tributary enhancement; dust control; erosion control; access; navigation and safety; debris management; and riparian and wetland habitat enhancement.

GMSWORKS 16 involved preliminary investigations at 42 sites in Williston Reservoir during 2009, from which five candidate sites were identified and recommended for consideration as WDS (Golder 2010). These candidate sites included Site 6-2 (Airport Lagoon), Sites 15 and 16 (Unnamed), Site 34 (Beaver Pond) and Site 37 (Tony Creek). After review of these potential sites, BC Hydro requested Golder provide a proposal outlining the scope of work and estimated cost to complete detailed design and cost estimates (GMSWORKS 17) for Wetland Demonstration Site 6-2 Airport Lagoon (WDS 6-2) and Wetland Demonstration Site 34 Beaver Pond (WDS 34).

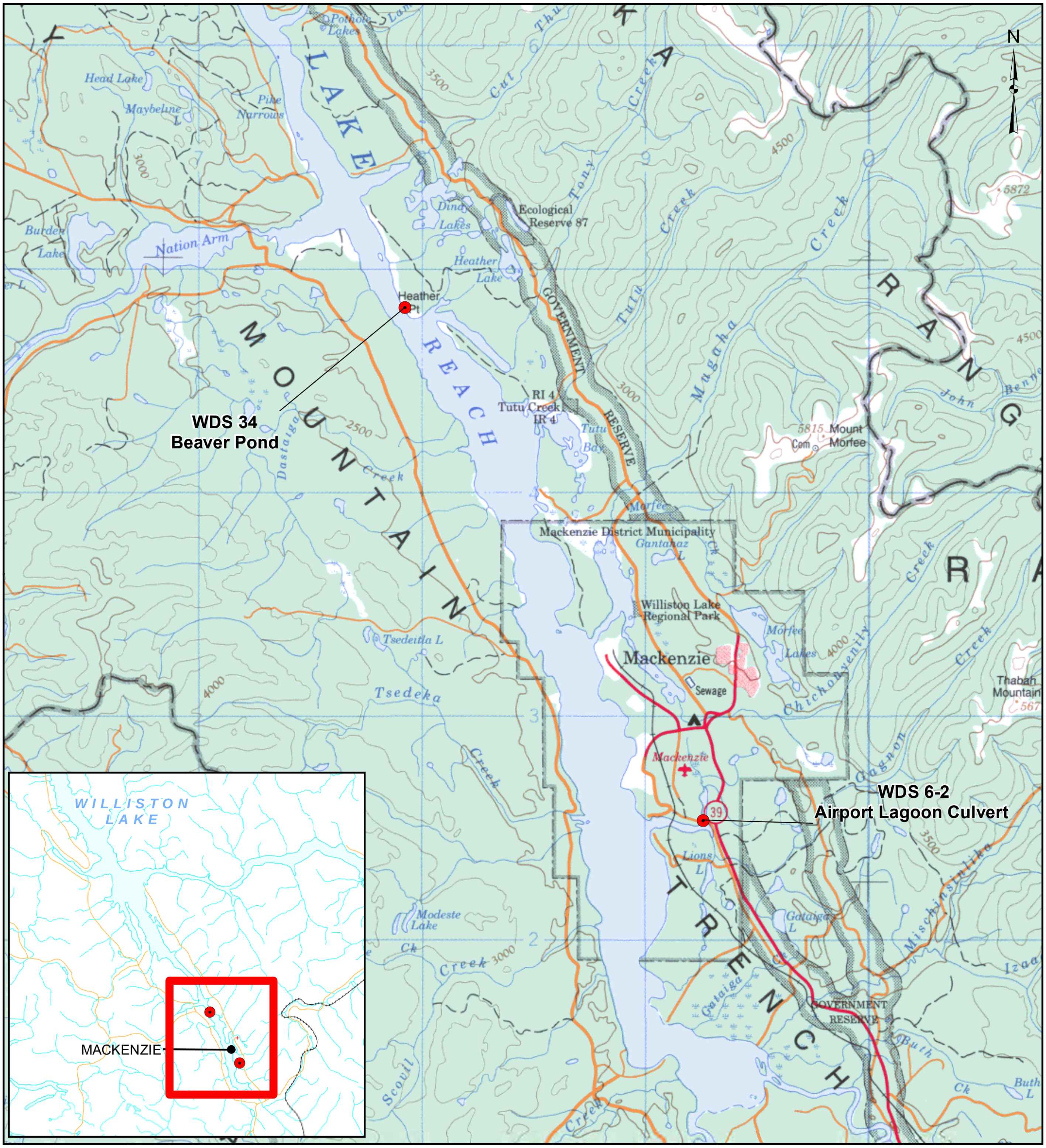
2.0 PROJECT OVERVIEWS

Both of the proposed WDS are located in Parsnip Reach, on the east side of Williston Reservoir. WDS 34 is the northernmost WDS and is located at Heather Point, approximately 28 km north of Mackenzie (Figure 1). WDS 6-2 is located approximately 7 km southwest of Mackenzie, immediately south east of the Mackenzie airport. Both WDS are within the drawdown zone of the reservoir (Figure 1).

WDS 34 is a small embayment off of Williston Reservoir, encompassing about 2.3 ha, that opens towards the northwest into Parsnip Reach. Two beaver dams and ponds, are located at the end of the embayment at approximately 670 metres above sea level (masl). The proposed treatment at this WDS calls for positioning silt / sand filled geosynthetic bags at the outlet of this embayment to create a berm, trapping water from an ephemeral stream and ground water seepage flowing into the embayment.

WDS 6-2 is a large lagoon isolated from the Williston Reservoir by a 150 m long causeway (Airport Lagoon Causeway), drained by twin 1200 mm diameter culverts. The causeway is part of a British Columbia Forest Service (BCFS) road servicing industrial users, primarily mills west of the causeway. The lagoon behind this causeway is approximately 1.9 km long and as wide as 650 m, occupying an area of approximately 73 ha at full pool (672.08 masl). The proposed treatment for this WDS is to permanently pond water in a portion of the lagoon by positioning two new culverts at an elevation 3 m higher than two existing culverts in the causeway.

File Location: N:\Graphics\2010\1492 Biosciences\10-1492-0076 BCH Williston Wetland Demo Sites\GIS\Figure 1.mxd   Print Date: March 16, 2011



LEGEND

● Survey Site

5 0 5

SCALE 1:250,000 KILOMETRES

REFERENCE

NTS Mapsheet 093O obtained from CanMatrix.

Projection: UTM Zone 10 Datum: NAD 83

PROJECT

GMSWORKS 17

WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES

STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE

LOCATIONS OF WETLAND DEMONSTRATION PROJECTS 6-2 AND 34 IN PARSNIP REACH

Golder Associates

Greater Vancouver Office, B.C.

PROJECT No. 10-1492-0076			PHASE No.	
DESIGN	MG	03-DEC-10	SCALE AS SHOWN	REV. 0
GIS	BKL	13-DEC-10	**FIGURE 1**	
CHECK	MG	13-DEC-10		
REVIEW	CM	16-MAR-11		

3.0 PROJECT AREA DESCRIPTION

Williston Reservoir was formed by impoundment of the Peace River by the WAC Bennett Dam, commissioned in 1967. The reservoir occupies an area of approximately 1773 km^2 and power generation from this reservoir is from the G.M. Shrum Generating Station. Immediately downstream of the WAC Bennett Dam, Dinosaur Lake is a run of the river reservoir created by construction of the Peace Canyon (PCN) Dam and associated generating station. These two developments collectively form the PHS. Williston Reservoir has an operating range of between 672.08 masl at full pool and 642.00 masl at full drawdown, although annual drawdown typically only varies between 10 and 12 m. BC Hydro explored the option of increasing full pool by 1.5 m to 673.76 masl in the 1980's, but did not implement this option (BC Hydro 1987). Full pool of the reservoir is normally reached in late June or early July, and the drawdown period occurs from September to April for most years (PWUP 2003).

Williston Reservoir consists of three major reaches, defined by the major watersheds within the Peace River that were impounded by construction of the WAC Bennett Dam. These reaches include Finlay Reach to the north and Parsnip Reach to the south which creates the 220 km length of the reservoir. Peace Reach bisects Finlay and Parsnip Reach near the middle of the reservoir and extends approximately 100 km east from its confluence with the Finlay and Parsnip Reaches to near Hudson's Hope (Figure 2).

Figure 2: The Williston Reservoir watershed showing the Peace Hydroelectric System (PHS) and the study area for GMSWORKS 16 and GMSWORKS 17.

The Williston Reservoir watershed encompasses five biogeoclimatic zones (BEC), including Sub-Boreal Spruce (SBS); Boreal White and Black Spruce (BWBS); Engelmann Spruce – Subalpine Fir (ESSF); Spruce-Willow-Birch (SWB); and Alpine Tundra (AT) (Hengeveld 2000). Most of the reservoir is situated in the SBS zone. The SBS zone occurs in the low lying areas around the Williston Reservoir and Parsnip Reach. Dominant species include hybrid white spruce (*Picea glauca engelmannii*) and subalpine fir (*Abies lasiocarpa*). Black spruce (*Picea mariana*) is a frequent dominant species on sites with poorer soils or soils which are acidic. Lodgepole pine (*Pinus contorta*) and aspen (*Populus tremuloides*) are common pioneer species although paper birch (*Betula papyrifera*) and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) are pioneer species on moist, rich sites. Interior Douglas-fir (*Pseudotsuga menziesii*) occurs on dry, warm, rich soil sites. Because of frequent fires and disturbance from logging, many forests in this zone are of mixed ages (MOF 1998).

Marshes occur around lakes and streams, usually with horsetails (*Equisetum* spp. and *Hippuris vulgaris*) and sedges (*Carex* spp.), but also with cattail (*Typha latifolia*), bulrush (*Schoenoplectus* spp.) and spikerush (*Eleocharis* spp.). Swamps with trees and tall shrubs occur mostly along stream courses or on the edges of lakes. Reed canarygrass (*Phalaris arundinacea*) and horsetails are common, along with shrubs such as Bebb's, MacKenzie's or Barclay's willows (*Salix bebbiana, S. prolixa, S. barclayi*) (MoF 1998).

4.0 METHODS AND RESULTS

4.1 Field Investigation

A survey of the two proposed WDS's was conducted on September 13 and 14, 2010 by a team of multi-disciplinary professionals from Golder, including a biologist, archaeologist, geotechnical engineer and a civil engineer. Vector Geomatics Land Surveying Ltd. (Vector) was sub-contracted to provide the survey crew and render topographic survey data.

The objectives of the site visit were:

- to orient team members to specifics of the two WDS's;
- to provide a statement of archaeological site potential and distribution within the selected project areas and act as an advisor to other disciplines regarding archaeological issues;
- to collect survey datum necessary for development of engineered drawings for construction of each WDS;
- to collect geotechnical information pertaining to underlying soil characteristics via test pit excavation;
- to collect fisheries information (species presence/absence) at WDS 6-2; and
- to collect other relevant information for the completion of each project.

These activities are described in greater detail below.

4.2 Archaeology

The Provincial Heritage Register (PHR) was accessed using Remote Access to Archaeological Data (RAAD) prior to field work, as well as during the preparation of this report. Based on available information, three archaeological sites are located within 3 km of WDS 6-2 (Table 1).

Table 1: Archaeological sites within 3.0 km of WDS 6-2 Airport Lagoon proposed treatment area.

Archaeological site	Site type	Distance to Airport Locality (m)
GhRs-2	Pre-contact Surface and Subsurface Lithics	1900 to the SE
GhRs-3	Pre-contact Surface Lithics	1950 to the SE
GhRs-4	Pre-contact Subsurface Lithics	2300 to the SE

The archaeological sites were all located during an archaeological inventory of the Mackenzie Forest District, by Western Heritage Services Inc. (1999). These three sites are associated with Lions Lake, on top of small topographical features including ridges, knolls and the shoreline of the lake.

There are no archaeological sites located within 3 km of WDS 34.

The footprint of the potential treatment area for WDS 6-2 and WDS 34 were examined during the preliminary field reconnaissance (PFR) conducted in 2009 (Golder 2010). At the time of the 2009 PFR, the exact scope and extent of construction activities associated with each WDS had not yet been identified. Rather, the PFR focussed on identifying areas of high and low archaeological potential within each proposed treatment area, and determining level of disturbance. Based on the 2009 visit, WDS 6-2 has low archaeological potential, due to low lying, gently undulating terrain with no topographical features. Similarly, WDS 34 was also determined to have low archaeological potential, due to low lying, featureless terrain, with an absence of defined topographical features. Areas of high archaeological potential are possible outside of the proposed treatment area, such as those noted in Table 1.

4.2.1 2010 Archaeological Survey

During the 2010 field visit, WDS 6-2 and WDS 34 were revisited with an interdisciplinary team of Golder professionals to determine the nature of construction activities and location of access roads. Geotechnical information pertaining to soil characteristics, via test pitting, was completed in consultation with the archaeologist on site to ensure test pits were located in areas of low archaeological potential.

The 2010 survey consisted of a visual inspection of each WDS to refine evaluations of archaeological potential completed in 2009 and to identify readily visible archaeological materials or features. Judgemental traverses were used. As part of the 2010 survey, field notes were written describing the terrain, and possible impacts to the WDS. Digital photographs were taken of notable terrain features as well as the general site. Areas likely to contain archaeological sites were identified during traverses, and included inspection of the ground surface for archaeological materials such as stone artifacts, faunal remains, or fire-altered rock. Areas of exposed ground, such as cut banks, road cuts and flood zones were inspected as well.

Archaeological potential for each WDS was evaluated and relied on biophysical characteristics that correlate with archaeological site locations. For example, portions of the WDS with raised and well-defined terrain and/or micro-topographical features, such as ridges and knolls (particularly if they possess views of surrounding terrain) are considered to have high archaeological potential. Areas considered to have low archaeological potential include: featureless slopes greater than 10%, disturbed and filled areas such as roads. Areas that have had surface sediments removed to an obviously sterile stratum, such as glacial till or bedrock, and low lying terrain with no defined topographical features are also considered to have low archaeological potential.

4.3 Survey Datum

The Datum for the coordinate and elevation system used during surveys of WDS is the UTM Zone 10, NAD83 (CSRS). Vector was retained to establish two pins of known elevation upon which their survey crew based their surveys. The pins were established with a Trimble R8 Dual Frequency GPS with a horizontal accuracy of ± 2 cm and a vertical accuracy of ± 5 cm geodetic. Geodetic coordinates are based on BC Active Control Point (ACP) in Fort St. John and checked against the ACP in Prince George. Vector WDS survey datum were collected by a two person crew using a Trimble R8 RTK system and Topcon 307 EDM Total Station instrument with a horizontal accuracy of ± 1 cm and a vertical accuracy of ± 1 cm (Appendix A - Photograph 1).

All units are in metric, and for plan drawings lengths less than 1 m are in millimetres.

4.4 Establishing Invert Elevations for Water Control at WDS

Invert elevations for the proposed WDS were established based upon topographic survey elevation for each location, relative to the hydrograph for Williston Reservoir (Figure 3).

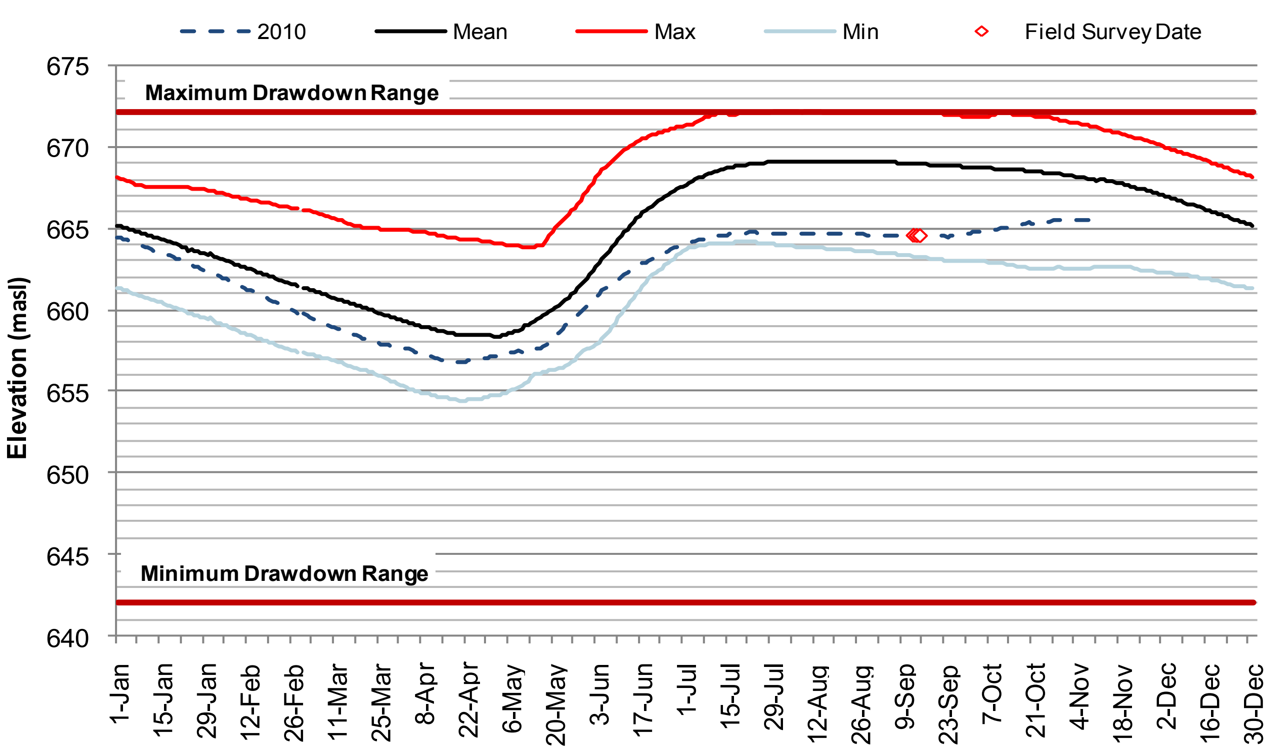


Figure 3: Average historical water level record for Williston Reservoir from 1984 to 2010 and the 2010 field survey period.

This analysis allowed simulation of the area of flooding within each WDS at various elevations. The intent of this simulation was to determine area of inundation, but also the estimated depth of inundation expressed as wetted habitat less than 1m deep and that over 1 m deep. The one meter depth was selected to represent an area of greatest productivity within a wetland relevant to light penetration and solar warming of water within shallow water wetlands (NWWG 1997). The frequency of flooding based upon the average reservoir levels was then considered under the premise of the higher the functional elevation of the WDS (described as the invert elevation of the water control structure), the less frequently the area will be flooded by rising water levels in the reservoir. Additionally, the higher the functional invert elevation of the proposed WDS, the smaller the annual fluctuation between the invert elevation of the WDS and the average and maximum reservoir water levels.

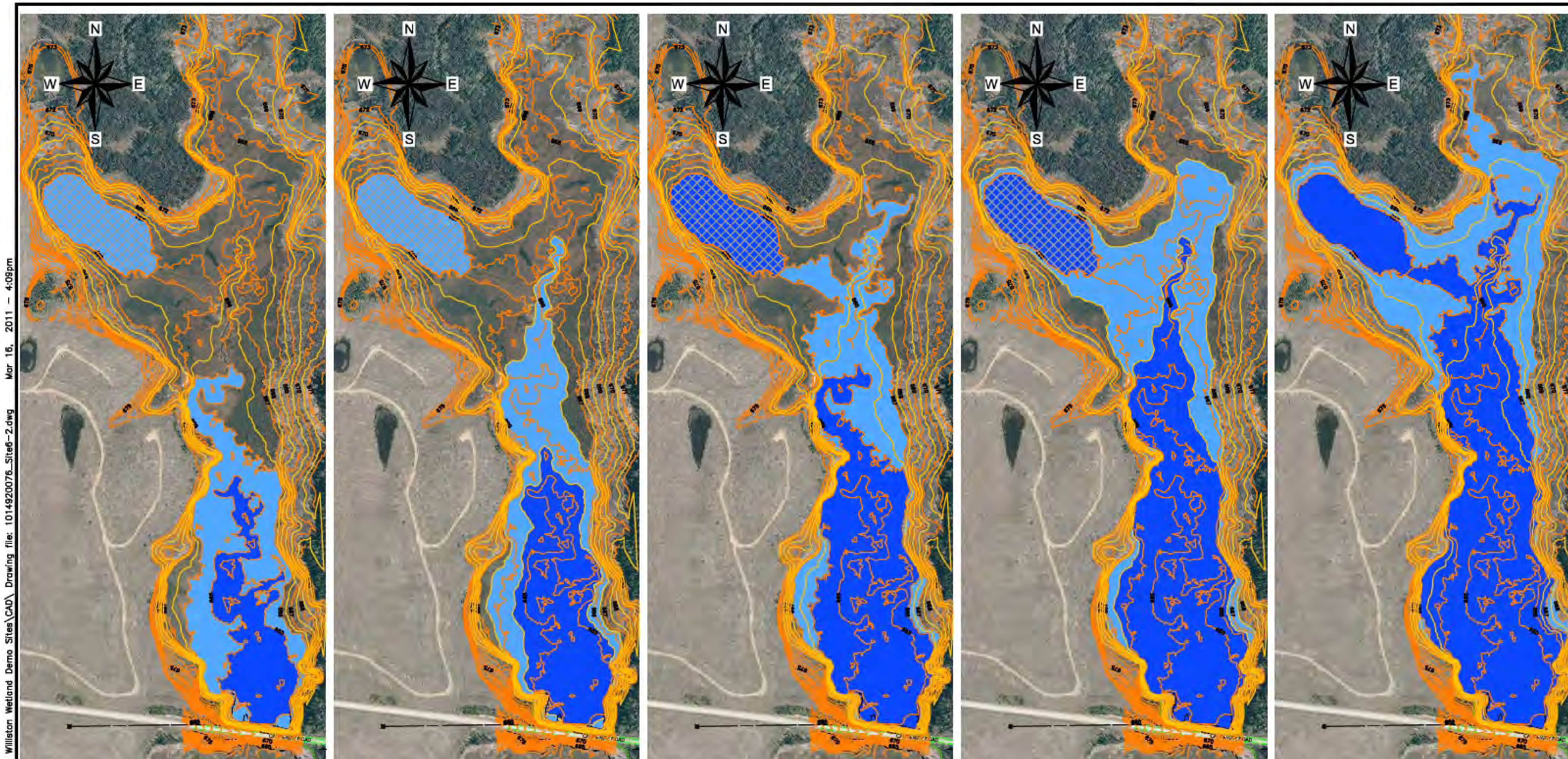
Results of this analysis for WDS 6-2 Airport Lagoon are depicted in Figure 4, the contour elevation (bathymerty) of which is based upon a combination of on the ground topographic surveys and Digital Elevation Modeling (DEM) based upon photogrammetry provided by BC Hydro.

Changing culvert invert elevations at 0.5 m increments between 666 masl through to 668 masl substantially increases total wetted habitat created at WDS 6-2, particular that which is less than 1 m in depth (Table 2).

Table 2: Inundation areas and related information used to identify invert elevations for water control structures at WDS 6-2 Airport Lagoon and 34 Beaver Pond.

Culvert Invert Elev.(masl)	**Inundation Area (ha)**			**% of total < 1m**	**Flood Duration (1)**			**Potential Draw Down**	
	> 1 m	< 1 m	Total		Start date	End Date	Total day	Mean (~669.1)	Max. (~672.08)
WDS 6-2 Airport Lagoon									
666.0	5.53	11.9	11.44	68%	19-Jun	4-Jan	200	3.1	6.08
666.5	9.64	12.01	14.96	55%	22-Jun	26-Dec	188	2.6	5.58
667.0	**17.43**	**9.6**	**27.03**	**36%**	**26-Jun**	**2-Dec**	**160**	**2.1**	**5.08**
667.5	**21.65**	**12.44**	**35.08**	**36%**	**1-Jul**	**23-Nov**	**146**	**1.6**	**4.58**
668.0	24.58	17.97	42.55	42%	6-Jul	9-Nov	127	1.1	4.08
WDS 34 Beaver Pond									
666.0	0	0.025	0.025	100%	19-Jun	4-Jan	200	3.1	6.08
667.0	0.025	0.249	0.274	91%	26-Jun	2-Dec	160	2.1	5.08
668.0	0.274	0.284	0.558	57%	6-Jul	9-Nov	127	1.1	4.08
669.0	**0.588**	**0.365**	**0.923**	**40%**	**6-Jul**	**10 -Sep**	**47**	**0.1**	**3.08**

(1) Based upon the mean of the hydrograph for the Williston Reservoir for the period 1984 to 2010 (i.e. Figure 3).



666.0M WATER ELEVATION
Total estimated wetted (ha): 17.43ha
Estimated wetted habitat > 1m depth: 5.53ha
Estimate wetted habitat < 1m depth: 11.9ha

666.5M WATER ELEVATION
Total estimated wetted (ha): 21.65ha
Estimated wetted habitat > 1m depth: 9.64ha
Estimate wetted habitat < 1m depth: 12.01ha

667.0M WATER ELEVATION
Total estimated wetted (ha): 27.03ha
Estimated wetted habitat > 1m depth: 17.43ha
Estimate wetted habitat < 1m depth: 9.6ha

667.5M WATER ELEVATION
Total estimated wetted (ha): 34.09ha
Estimated wetted habitat > 1m depth: 21.65ha
Estimate wetted habitat < 1m depth: 12.44ha

668.0M WATER ELEVATION
Total estimated wetted (ha): 42.55ha
Estimated wetted habitat > 1m depth: 24.58ha
Estimate wetted habitat < 1m depth: 17.97ha

LEGEND

- Flood Area of Basin with depth less than 1m
- Flood Area of Basin with depth greater than 1m
- Approximate Elevation Area Estimate from Ortho Photograph and Contour Data

REFERENCES

1.) **COORDINATE REFERENCE:** UTM ZONE 11n, NAD83
MAP REFERENCE: Base mapping provided by Vector Geomatics Land Surveying Ltd.

PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
AREAS OF INUNDATION(ha) WITH DEPTH LESS THAN 1M AND DEPTH GREATER THAN 1M AT WDS 6-2

Golder Associates
Kamloops, BC

PROJECT No.		10-1492-0076	FILE No.	1014920076_site6-2
DESIGN	MC	26-NOV-10	SCALE AS SHOWN	REV. 0
CADD	BKL	08-MAR-11		
CHECK	MC	08-MAR-11	**FIGURE 4**	
REVIEW	CM	16-MAR-11		

N:\Graphics\2010\1492 Biosciences\10-1492-0076 BCH Williston Wetland Demo Sites\CAD\ Drawing file: 1014920076_Site6-2.dwg Mar 16, 2011 - 4:09pm

Additionally, the potential range in water fluctuation (draw down) relative to the mean and maximum hydrographs for Williston Reservoir (Figure 3) is less as the invert elevation of the culvert is increased. Finally, the higher the culvert invert elevation, the area will not only be influenced by the reservoir water levels less frequently, the duration of this influence will be less. Selecting the most appropriate new invert culvert elevation involves a number of considerations. At 667.0 and 667.5 masl, the percentage of wetted habitat less than 1 m in depth is relatively less when compared to other potential culvert invert elevations, but these two elevations provide other advantages. A substantial amount of wetted habitat is still produced. The advantage of raising culverts to 667.0 masl is that a larger portion of mudflats will be maintained at the north end of the lagoon when reservoir elevations do not exceed 667 masl, providing additional habitat complexity for species such as shorebirds (Figure 4). The disadvantage of choosing 667 masl is the duration the area is flooded by the reservoir will be longer under an average reservoir operation regime than a culvert invert elevation of 667.5 masl and the potential draw down range becomes larger. The ratio of water deeper than 1m compared to water less than 1m in depth also varies substantially depending upon which culvert elevation is selected, this ratio varies from a high of 68% for 666 masl to a low of 36% for 667 and 667.5 masl. It should be noted that the actual amount (ha) of wetted habitat less than 1 m in depth is 3 ha less at 667 masl than at 667.5 masl. A final consideration in selecting the most appropriate culvert elevation is cost relative to hectare of habitat created. A culvert elevation of 668 masl provides the greatest amount of wetted habitat and wetted habitat less than 1 m in depth, but at the expense of available remaining mudflat for shore birds (Figure 4). Also, while the 668 masl alternative will potentially be influenced less frequently and for a shorter duration than other alternatives, it also reduces available freeboard at the causeway. Golder recommends either 667 masl or 667.5 masl be considered as the most appropriate elevation for culverts in this location, but suggests BC Hydro seek feedback from local stakeholders in making a final choice.

The same analysis was completed for WDS 34 to arrive at the most appropriate invert elevation for the water control structure at this feature, but the decision process was easier given 669 masl provides the largest amount of wetted habitat and the most habitat less than 1 m in depth. This elevation also allows recharge of water into the treatment area from the reservoir more frequently than if a higher invert elevation for the proposed structure at this location was established. This point considers the ephemeral nature of the water source for this site. The 669 masl elevation also recognizes cost savings due to limitations in the maximum available diameter of geosynthetic bags proposed for this site (3.1 m). A greater berm height would require more bags, stacked on top of each other.

4.5 Hydrologic Analysis & Assumptions WDS 6-2 Airport Lagoon

The following summarizes the hydrologic analysis that was used to design WDS 6-2 Airport Lagoon. A previous water balance analysis documented in Golder 2010 (Section 8.9) is considered sufficient for the design of WDS 34 and further analysis was not completed for this report.

For the purpose of positioning and sizing of new culverts at WDS 6-2, a design inflow into the treatment (impoundment) area was required along with the development of an elevation/area/storage curve for this area. The design inflow was routed through the treatment area and through the proposed culverts to assess the size of the new culverts at the targeted design water level (667.5 masl) established for WDS 6-2.

A design 100 year maximum annual snowmelt contribution to the reservoir was determined based on the historic maximum annual monthly snow survey data from the Morfee Mountain snow survey station. The Morfee Mountain station is located approximately 17 km northeast of the Airport Lagoon site and has an elevation of 1427 m. The elevations in the Airport Lagoon catchment area range from 762 m to 664.5 m at the inverts of the existing culverts through the causeway. The peak snow pack typically occurs during the months of April and May at which point the spring melt starts to occur. A statistical frequency analysis was used to estimate the 100 year April snow water equivalent based on the 43 years of snow water equivalent record from the Morfee Mountain station. The design melt was assumed to occur over a period of one month.

One hundred year single event rain on snow events were also estimated, based on the IDF curves for Mackenzie Airport and Prince George Airport. Prince George Airport was more conservative. The single event rain on snow events were considered but these provided significantly less inflow than the 100 year snow melt. The single rain on snow events also had little impact on the design water levels in the upstream wetland reservoir due to the relatively large storage volume and the associated attenuating effects of the wetland/reservoir.

The 100 year design inflow snowmelt that was used is considered to be quite conservative due to the difference in snowpack that would be expected to occur at the Airport Lagoon versus what occurs at the Morfee Mountain station at quite a higher elevation. The melt has also assumed to be completed within a month whereas the Climate Normal's appear to indicate that the melt may occur over a period of two months.

The US EPA Storm Water Management Model (SWMM) was used to assess the impact of flooding and overtopping of the causeway road based on the proposed culvert invert elevation 667.5 m (http://www.epa.gov/ednnrmrl/models/swmm/). The proposed culvert invert elevation of 667.5 m was pre-determined based on the assessment of the treatment area inundation versus elevation in relation to maximizing the wetland habitat. The SWMM model was used to route the inflow design event through the proposed wetland treatment area and through the culverts. The US EPA SWMM Model input requirements include; the design inflow, sub-catchment parameters, elevation/area table for the upstream treatment storage area, and the proposed culverts.

The sub-catchment parameters were determined based on the trim mapping and the available digital orthophotos. The sub-catchment was assumed to have a percent imperviousness of 20% based on the lakes, logging roads and portion of the airport. Assumed imperviousness is also considered a conservative estimate. Evaporation was also not considered in this analysis, therefore the results of the model are again, considered conservative in terms of culvert capacity and flood (over topping the existing road) risk.

The elevation/area curve for the treatment area was determined based on the available information, including both topographic surveys and DEM data provided by BC Hydro.

Overall, the results of the modeling are considered quite conservative based on the assumptions that have been made regarding the design inputs to the model.

4.6 Test Pits

A geotechnical test pit investigation was conducted at WDS 6-2 on September 13, 2010 and included excavation of three test pits, TP10-01 through TP10-03, to depths of approximately 2.8 m below existing ground surface. A small capacity rubber tracked excavator, owned and operated by Digger's Impact of MacKenzie, BC, was retained by Golder to facilitate the investigation (Appendix A- Photograph Set 2). In addition, three percolation tests (Appendix A - Photograph 3), were conducted at the WDS to assess the absorption rate of the near surface site soils as input to estimating the hydraulic conductivity.

The test pit investigation was conducted under the full time inspection of a member of Golder's geotechnical engineering staff who located the test pits in the field, logged in detail the encountered soil and groundwater conditions, and collected representative soil samples for visual classification and laboratory index testing.

Upon completion, the test pits were backfilled with excavation spoil and nominally compacted by the excavator.

The approximate locations of the test pits and percolation tests are shown on the plan view of attached design drawings and attached maps for WDS 6-2 (Appendix B - Design Drawing -1).

Due to access constraints, no investigation was conducted at WDS 34.

Subsurface conditions encountered at WDS 6-2 are described in Section 7.5 detailed descriptions of the encountered soil and groundwater conditions are presented in Appendix C - Record of Test Pits.

4.6.1 Laboratory Index Testing

Laboratory index testing was conducted on selected samples obtained from the WDS 6-2 test pit investigation and included a total of nine (9) natural water content determinations, two (2) Atterberg Limits determinations, and a single gradation analysis.

The laboratory index test results are presented on the test pit records and in Appendix D - Laboratory Test Results. Laboratory test results are also summarized in Section 7.5.

4.7 Design Drawings

Design Drawings were developed for each of the proposed wetland demonstration projects (Appendix B). Each drawing shows a Plan and Cross Section for each of the proposed structures. Profiles are provided as figures within the text of this report. The Plan at the bottom of the drawing shows the footprint of the proposed work that includes labelled section lines (A, B, C, etc.). Section A represents the longitudinal profile through the structure relative to the existing ground surface. Section B typically shows the cross section of the proposed structure relative to the existing ground surface. Chain lengths (m) starting at zero shown in the plan drawing correspond to those shown for each section line. For tendering and construction purposes for each project, technical engineering specifications supplied on the engineering drawings should be used in conjunction with the written design specifications contained in the "Description of Work" (Sections 7.8 and 8.7) and respective "Detailed Engineering and Construction Plans" (Section 7.10 and 8.9) within this report. **Comprehensive technical specifications covering materials, construction methods and payment for the work shown on the drawings should also be described in the Tender Documents as is normal practice**.

4.8 Ancillary Habitat Works

Additional structures designed to benefit wildlife in conjunction with the WDS can be installed at the discretion of BC Hydro. Placement of such structures is not included in cost estimates or designed drawings developed within this text, but may be suggested within the construction plan for each WDS (section 8.9.13 and 9.9.13. These structures are described as “ancillary habitat works”. Such structures rely upon the availability of native material. Appendix E provides further details of the following types of structures:

- **Coarse woody debris (CWD)** differs from LWD in that it is not fully submerged or surrounded by water (MacDonald 2008) and is directed at providing habitat for small mammals, amphibians, reptiles, and ground nesting birds. In the Williston Reservoir drawdown zone setting, such debris becomes LWD when submerged. In areas where submergence is expected, CWD must be suitably anchored to prevent loss or movement by floatation and/or water current during periods of inundation. Piles of CWD mixed with brush could be considered in areas above the drawdown zone.
- **Rock piles**. The intent of rock piles is to mimic rocky areas along streams, outcrops and talus fields to provide warm areas that slowly release the day’s heat during the evening, attracting reptiles and rodents which in turn provide food for predatory species (MacDonald 2008). The lack of rock in most areas of Williston Reservoir reduces the applicability of such structures; however, exposed cobble/boulder during construction could be set aside and incorporated into the WDS at strategic locations.
- **Loafing Logs**. These are logs which float on the surface of the water, away from the shore line to provide loafing areas for waterfowl and herptiles. Loafing logs would have to be able to be attached in such a way that they follow the water column as the water levels in the reservoir rise and fall.
- **Revegetation**. Revegetation, either through saving disturbed clumps of removed vegetation during excavation, reseeding, or staking with appropriate live cuttings may be considered for some aspects of work.
- **Raising Land**. Where possible and economically viable, materials removed or placed during construction could be shaped into small rises of land that extend near to or beyond the design invert elevation of WDS. Such areas could serve as platforms for revegetation and add habitat complexity in treatment areas being inundated by water.

5.0 REGULATIONS

Regulations and Acts that may apply to the WDS are identified in Golder (2010), which provides a more complete detailed explanation of the issues associated with the regulation. Below is a brief summary of the relevant regulations which may be considered during approval by provincial and/or federal agencies in order to construct a WDS. Recent changes in B.C.’s government ministerial organization have shifted permit application responsibilities away from the MoE and to the newly formed Ministry of Natural Resource Operations (MNRO). Permits issued through the Archaeology Branch are also delivered through the MNRO opposed to the Ministry of Tourism, Culture and the Arts.

Specific approvals relevant to each WDS are identified in Sections 7.10.1 and 8.9.1.

5.1 The Fisheries Act

The *Fisheries Act* is federal legislation that protects all fish and fish habitat in Canada. Section 35(1) provides broad prohibition of works that create a "harmful alteration, disruption or destruction" (HADD) of fish habitat unless authorized under section 35(2) of the Act. Section 36(3) prohibits the deposit of deleterious substances.

5.2 Navigable Waters Protection Act

This Act regulates any works built or placed in, on, over, under, through, or across any navigable water. For projects with the potential to impact navigable waters an application to the Navigable Waters Protection Division (NWPD) under Section 5(1) of the NWPA may be required prior to construction. Mitigation measures for navigational hazards are identified in approvals granted by the NWPD. These measures may range from simple signage to more complex measures such as lights and/or buoys or other issues that ensure boat navigation remains unhindered, depending upon the structures/changes being proposed. Placement of structures such as berms or ancillary habitat works within the inundation zone of Williston Reservoir may be considered a navigational hazard depending upon its location.

5.3 The Water Act

Section 9 of the *Water Act* regulates "changes in or about a stream" but allows certain activities to be undertaken when carried out in compliance with Part 7 of the *Water Act* regulations. This includes that water quality, fish and wildlife habitat and the rights of licensed water users are not compromised. Under this act, one may carry out a number of routine works, provided that the general conditions and notification requirements are met but an approval or licence is required in cases involving more complex works and for the short-term use, storage or diversion of water. British Columbia Dam Safety Regulations are part of the *Water Act* and may apply to some structures, depending upon the volume of water retained by the structure or the height water is being raised behind the structure.

5.4 The Heritage Conservation Act

All archaeological sites on provincial Crown or private land predating A.D. 1846 are automatically protected by the *Heritage Conservation Act* (*HCA*). Certain sites, including burials and rock art sites that have historical or archaeological value, are protected regardless of age. This protection includes penalties for unauthorized alterations, or changes, to a site undertaken without a proper permit in place. Any development for which land altering activities are proposed has the potential to alter archaeological sites. Examples of land altering activities include, but are not limited to: excavation, trenching, soil stripping, vehicle/machinery traffic, and dumping of fill, rip rap, or excavated sediment. Typically, Archaeological Overview Assessment (AOA) are completed as a first step and indicate the need for, and scope of, any additional archaeological studies (such as an Archaeological Impact Assessment, or AIA), if required. First Nation involvement is recommended in the completion of these steps. Detailed information about the *HCA* and First Nations involvement is identified in Golder 2010 (Section 2.2.4 and 2.2.4.1).

5.5 Wildlife Legislation

Both provincial and federal governments administer wildlife legislation, relevant to terrestrial and aquatic species. Wildlife legislation that might have a bearing on the projects includes the provincial *Wildlife Amendment Act* and the federally regulated *Species at Risk Act (*SARA*), Migratory Birds Convention Act,* and associated regulations.

A Wildlife Collection Permit will be required from the recently established Ministry of Natural Resource Operations (MNRO) to conduct any wildlife salvage work associated with the projects. For example, and perhaps most relevant is the possible need for a fish collection permit for fish salvages within the footprint area of any proposed works within the wetted area of a fish bearing stream.

SARA would only be applied to any identified aquatic and/or terrestrial listed species with critical habitat within the area of the proposed projects. Concern regarding the *Migratory Birds Convention Act* is the potential for disturbance or destruction of nesting sites. The *Migratory Birds Convention Act* would apply to any clearing of vegetation outside the identified breeding bird window related for the project areas (May 1 to July 1 – Golder 2010).

5.6 The Forest and Range Practices Act

The *Forest and Range Practices Act* (FRPA) and its regulations govern the activities of forest and range licensees in B.C. The statute sets the requirements for planning, road building, logging, reforestation, and grazing. Details of this act are pertinent to proposed access to WDS and in regard to any alteration and/or change to existing roads administered by the ministry of forests. Based upon review of provided documentation detailing plans by a proponent which may involve modifications to existing roads, construction of a new road, or opening of overgrown roads, review by other regulatory bodies and stakeholders through a referral process is normally required prior to the MoF issuing a permit for the proponent to proceed with proposed works. The MoF may issue special use permits or in some site specific instances, issue an authorization under section 121 of the FRPA. **BC Hydro may have certain exemptions in place that allow construction of roads leading to the Williston Reservoir for maintenance activities etc. which should be explored and verified relative to proposed treatments at proposed WDS**.

5.7 Other Legislation

The British Columbia *Weed Control Act* is designed to prevent the proliferation of identified noxious weeds (British Columbia Weed Control Act – Chapter 487 RSBC 1996). The *Weed Control Act* includes a list of weeds considered noxious throughout the entire province; it also includes a list of weeds considered noxious only in certain regions of BC.

The MNRO also will issue a Park Use Permit to any activities proposed to occur, or involve (such as road use by industry) in BC Parks.

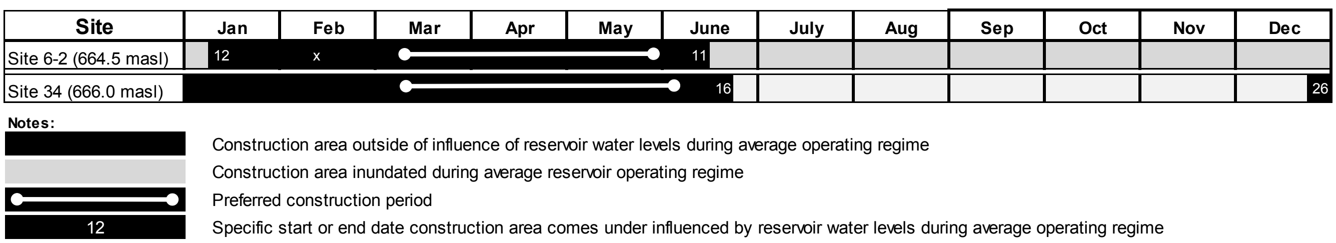
6.0 CONSTRUCTION PLAN

The following addresses common issues pertaining to construction plans for the two demonstration projects identified in Sections 7 to 11 of this report. The construction plan is supplemented with engineered drawings provided in Appendix A.

6.1 Schedule

Construction of the Wetland Demonstration Sites should be carried out as early in the spring as possible (late March thru to early May), typically a period of low reservoir levels and when the reservoir drawdown zone is exposed (Figure 5). However, BC Hydro should allow up to 6 months for achieving regulatory reviews and approvals. Permits for fish and/or wildlife salvages may take as long as two to 3 weeks. Notifications for instream works typically require less time than approvals in the Provincial and Federal regulatory environment (i.e. MOF, MNRO). Most provincial approvals require a 45 day referral period (30 days for Archaeology permits) for First Nations, while MNRO conducts it own internal review, whereas the DFO or the NWPD can take as long as 6 months to issue an approval. The NWPD has recently changed its approval process, allowing for some minor works to be signed off (after review) by the regional NWPD officer, opposed to requiring a minister's signature for more substantive works. Consequently, permitting procedures should be planned and initiated well in advance of the proposed schedule for construction. Ideally, an early spring construction period, for example, should begin the permitting process in October of the following year.

Figure 5: Proposed work window for construction of wetland demonstration WDSs 6-2 and 34, relative to the average operating regime of the Williston Reservoir.



The start of construction will depend upon the rate of filling of the reservoir and ground conditions. Construction should commence when the snow has gone to minimize issues relating to access, such as snow cover over roads, but also issues such as and ground frost which can impact excavation and compaction. Hence, sufficient time should be allowed for the exposed drawdown area to dry out easing machine access and excavation/transportation of site material. This could be as early as mid March to mid April in the study area. During average reservoir operating conditions, the ability to complete construction beyond the month of May will depend upon overwintering reservoir levels combined with the rate of rising reservoir water levels. If reservoir water levels rise beyond identified minimum elevations at which water begins to inundate the area of construction, isolation from rising water levels will be required, and work will not be able to be completed "in the dry", complicating both construction activities but also permitting requirements. It is recommended that construction be timed to be completed prior to water levels reaching approximately 664.5 masl for WDS 6-2 and 665.5 masl for WDS 34. Allowing a one to two week buffer between the anticipated end date of construction and the forecasted date at which reservoir levels are expected to reach the elevation of the area of construction is also recommended. During an average operation regime, reservoir levels are expected to reach 664.5 masl by June 11, and reach 665.5 masl by June 16. For example, construction should be planned so as to be completed by approximately June 1 for WDS 6-2 and June 5 for WDS 34 during average reservoir operation conditions.

An additional consideration, particularly where changes and/or modifications to MoF roads are being considered, is construction timing should coincide with periods of low use by the forest industry, such as spring breakup. Dates for of spring breakup are also variable, dependant upon how quickly snow cover dissipates and roads dry.

Construction contracts should also be tendered and awarded in ample time to allow sourcing and acquisition of materials (Sections 7.8.3 and 8.7.3) and securing regulatory permits required to proceed in construction of a WDS (Section 5.0 above and Sections 7.10.1 and 8.9.1 below).

6.2 Source Material

Source material will vary with the WDS. For WDS 34, source material is silt and sand dredged from the lakeshore. Woody debris along the shoreline may be considered for placement in and around the shores of the proposed inundation area as additional habitat features.

For WDS 6-2, source material will depend upon which technique is used to position new culverts into the causeway, either via excavation or augering. Preferred options for placement of culverts are discussed in further detail in Section 7.10.

A requirement for native source material is primarily for building a platform for the augering process, and also for construction of a coffer dam. Most of this material is expected to be gathered from the surrounding flood plain within the lagoon, but additional gravel, if required, is available from gravel pits adjacent the highway and west side of the causeway crossing Parsnip Reach. Some riprap will likely be required for construction of an apron along the face of the causeway at the outlet of the culverts.

For excavation, source material will be a combination of material removed from the causeway and replaced during placement of the new culverts. Additional gravel and rock will be used during compaction around the new culverts and final grading of the road. Rip rap, or potentially smaller rock placed into a gabion, could be used at the outflow of culverts.

The volume of the borrow material available, and the consistency of material from potential sources would need to be determined prior to construction.

6.3 Vegetation

Establishment of vegetation (both riparian and aquatic) within the drawdown zone of the reservoir is difficult due to the annual variability of Williston Reservoir levels (Abiola et al 2008). For example, in early June of 2009 during initial surveys of sites being identified as potential candidate WDS, areas were often barren of vegetation, or if present, vegetation often lacked diversity and/or vigour. During return visits to WDS 6-2 and 34 in September of 2010, more verdant growth of a variety of vegetation species was observed.

An extensive revegetation program is not proposed for treatment areas in this report. Rather, the intent of identified treatments at each WDS is to create conditions, through impoundment of water, that are conducive to natural colonization by revegetation. The supposition for the WDS identified in this text is that establishment of a consistent wetted perimeter is conducive to natural colonization of submergent and emergent vegetation within the wetted habitat. Stabilizing minimum water levels (reducing draw down) should also aid growth of a more robust and vigorous riparian zone around the wetted perimeter of the treatment area.

The reprieve from extended inundation of drawdown areas above 665 masl in 2010 allowed a variety of vegetation to grow within the foreshore of the reservoir, particularly where wet soils (by virtue of a water source) exist. The lower than average reservoir levels in 2010 (barely exceeding 665 masl for most of the summer) provided an unusually long growing season not normally expected in the current reservoir operating regime. In some areas, such as WDS 6-2, vegetation more appropriate to dry upland settings colonized the flood plain of this area (Table 3). The growing season was long enough to allow vegetation to grow, but not long enough for some species to become sexually mature and reproduce, such as fireweed found growing at WDS 6-2.

Table 3: Vegetation observed growing within the flood plain zone of WDS 6-2 and 34.

Common Name	Species/(Family)	Comments	Location	
cinquefoil	*Potentilla rivalis (Rosaceae)*	Native, prefers moist to wet ground, appropriate species for wetlands.	6-2	34
yellow cress	*Rorippa palustris (Brassicaceae)*	Native, prefers marshy ground, appropriate species for wetlands.	6-2	34
nodding beggar ticks	*Bidens cernua (Asteraceae)*	Native, prefers marshy ground, ponds ditches, appropriate for wetlands	6-2	
sedge	*Carex sp. (Cyperaceae)*	Species ID could not be verified due to lack of fruit or flower, but almost certainly native and is appropriate for wetland sites.	6-2	34
little meadow foxtail	*Alopecurus aequalis (Poaceae)*	Native and prefers moist to wet sites, appropriate for wetlands.	6-2	
marsh cudweed	*Gnaphalium uliginosum (Asteraceae)*	An introduced species which prefers open areas and wetter ground may persist in a wetland environment but is not likely to become a problem species.	6-2	
Cattail	*Typha latifolia (Typhaceae)*	Native to the area and is appropriate for wetland sites.		
fireweed	*Epilobium angustifolium (Onagraceae)*	Native and generally grows in open habitats, but will often disappear from wet sites and is generally not appropriate for wetlands.	6-2	34
narrow leaved hawkweed	*Hieracium umbellatum (Asteraceae)*	Native but prefers fairly dry, open meadows and clearings, and may disappear at very wet sites. Not appropriate for wetlands.	6-2	34
water smartweed	*Persicaria lapathifolia (Polygonaceae)*	Native macrophyte which prefers shallow water, shores and swamps, appropriate species for wetlands.	6-2	

The ability for macrophytes to survive variable water levels is impacted by the extent and duration of flooding. Most emergent macrophytes can survive inundation to about 0.7m. Long-term flooding at such depths or greater will curtail growth and establishment of emergent vegetation, except along the shallower edges (Mitsch and Gosselink 2000; USEPA 2000; Grosshans and Kenkel 1997; Coops et al. 2004). The persistence and quality of emergent vegetation will also be reduced by large fluctuations in water levels. Species able to tolerate greater disturbance including changes in water level will tend to persist and have more coverage. This includes, willows, cattails and other species that may dominate an area, rather than more conservative species like sedges, bulrushes and higher quality submerged vegetation (Mitsch and Gosselink 2000; USEPA 2000). Still, despite cattails and willows sometimes being considered "weedier species", they are native species which occur in natural wetlands in the Williston region. Persistence of these species would still be considered an improvement to existing conditions in much of Williston Reservoir's foreshore.

Willows (S*alix* spp) generally, and variants of the sandbar willow (*S. fluviatilis, S. interior, S. longifolia etc.*) specifically, are tolerant to a wide range of flood and sediment deposition /removal conditions as long as some portion of the plant stays above water. As such, willow and cattails are expected to colonize where water levels can be stabilized, although even these species will die if underwater for a sustained period.

Perennial macrophyte species including *Potamogeton* spp. (pondweed), water-milfoil (*Myriophyllum verticillatum* and *M. sibiricum*), yellow pond-lily (*Nuphar variegatum*), hornwort (*Ceratophyllum demersum*) and mare's tail (*Hippuris vulgaris*) can grow in waters of greater depth, and may be able to withstand larger fluctuations in water level than emergent species (Mitsch and Gosselink 2000; USEPA 2000).

Observed changes in macrophyte composition resulting from the relatively long growing season within the drawdown zone in 2010 was evident from the observed difference in coverage exhibited by *Callitriche* species at WDS 6-2 between years. It appeared this species was extensively distributed in 2009 (Golder 2010), but was not apparent during the 2010 survey. This may be related to conditions conducive to propagation of this species in 2009 which were not present in 2010. Studies of morphologically similar species in the genus *Callitriche* have found relatively aggressive colonization of available habitat due to wind pollination, seeds which float and are dispersed by waterfowl and small mammals. Seedlings of this genus are also capable of surviving being uprooted to float to new suitable habitat (McLaughlin 1974). However, species in the genus *Callitriche* may also be relatively sensitive to large disturbances such as water level fluctuations or sediment deposition (McLaughlin 1974). Consequently, this species may successfully colonize a large part of Airport Lagoon during good conditions and is then set back during disturbance years (such as too little water as observed in 2010). In subsequent years, it could re-establish, unless the site becomes dominated by other vegetation which prevents *Callitriche* from re-colonizing.

The available growing season prior to inundation dictates the type, vigour and reproduction to both submergent and emergent macrophytes as well as more terrestrial species of vegetation in the Williston Reservoir foreshore. The mean growing season for the Mackenzie area, based upon the Atlas of Canada (NRC 2010) is 140 days. This information was taken from a series of 1:200,000 scale maps (considered a coarse scale), but using this criteria, Table 4 provides an indication of the growing period within the area in proposed WDS.

Table 4: Growing season for terrestrial vegetation within the Parsnip Reach area of Williston Reservoir.

Length	Mean	Start	End	Mean Frost Free	Source
160 days	140 days	April 30-May 5	Sept. 25-Oct. 6	60 days	Atlas of Canada
92 days	n/a	1-Jun.	Aug. 31	75 days	Internet [(1)]

Notes

The Atlas of Canada defines growing season as number of days with an average temperature over 5.6° C (42° F)

(1) Unaccredited reference in websites: District of MacKenzie (http://www.district.mackenzie.bc.ca/climate.php) and the Province of BC (http://www.hellobc.com/en-CA/Geography/Mackenzie.htm)

Under normal reservoir operating conditions, vegetation is only expected to actively grow during May and part of June before reservoir levels rise far enough to inundate most of the foreshores, and that little if any growing season would be left before reservoir elevations drop near the end of September. An exception is a year like 2010 when an extended growing season was available in foreshore areas above approximately 665 masl.

Website information for the Town/District of MacKenzie and the Province of BC is unaccredited and undated, however, the identified 92 day growing season may refer more specifically to ornamental or crop (non-native) plants rather than to native vegetation. Native vegetation is generally able to tolerate a greater amount of frost at night than non-native crops or ornamental plants, however, the 92 day growing season may have implications to establishment of new native vegetation relative to established vegetation. Specifically, germination of seeds may occur for some native species prior to June, but it is unlikely such species will become well enough established to naturally reproduce during normal reservoir operations as suggested by (Abiola et al 2008).

Consequently minimizing drawdown by establishment of permanently wetted areas using water control structures will also delay inundation from the reservoir and lengthen the functional (spring) growing period. Establishing a permanent water body will not only benefit colonization of submergent and emergent macrophytes within the treatment area, reducing the extent (drawdown) and period of inundation should aid stabilizing the riparian vegetation zone around the perimeter of the treatment area.

Establishing vegetation is key in developing wetlands and increasing the productivity and suitability of this habitat for use by aquatic and terrestrial wildlife. At present, vegetation that can grow within the drawdown zone of the reservoir can only be opportunistically utilized by wildlife opposed to providing consistent habitat, due to the reservoir operation regime.

7.0 WDS 6-2 AIRPORT LAGOON

7.1 Description

WDS 6-2 is located approximately 7 km southwest of Mackenzie and adjacent to the southeast corner of the Mackenzie Airport. The area represents a 1.9 km long by about 650 m wide (at its widest) bay occupying approximately 73 ha within the drawdown zone of Williston Reservoir (Figure 6). The Airport Lagoon Causeway, as it is referenced in this text, was built by the Ministry of Forests (MoF) over 25 years ago (K. Herzog MoF, November 2009, pers. comm.). It is isolated from Williston Reservoir by the causeway, which is drained by the two twin 1200 mm diameter culverts flowing into a downstream embayment (Appendix A - Photograph Set 4 and Photoset 13). This downstream embayment receives water from the Airport Lagoon and a second modest sized unnamed creek which flows from Lions Lake (hereafter referred to as Lions Creek). The second embayment is also isolated from the Williston Reservoir by a second larger causeway also drained by culverts located 1.5 km west of the Airport Lagoon Causeway. The Airport Lagoon Causeway connects forest service roads on the east and west side of the embayment, and is a main arterial road for industrial traffic (logging and mining traffic) access to saw mills located adjacent to Williston Reservoir immediately west of the causeway.

7.2 Project Rationale

The proposed treatment is to raise the water level in the lagoon to address objectives of water storage and water control in order to create permanently wetted habitat regardless of reservoir water levels. Stabilizing a suitable minimum water level will reduce the range of annual drawdown in the lagoon. It is anticipated this change will facilitate colonization of submergent and emergent vegetation into the permanently wetted perimeter of the treatment area and also enhance the riparian zone to the benefit of wildlife such as wading birds, waterfowl and amphibians.

7.3 Project Objectives

The treatment at WDS 6-2 is designed to maintain a minimum water level in the treatment area by stabilizing the minimum drawdown in the area at between 667 to 667.5 masl (Figure 7). This elevation range maximizes the amount of shallow water less than 1 m deep, and reduces the drawdown effect for the area by 3 m, while still maintaining sections of mudflats near the north end of the lagoon. A culvert invert elevation of 667 masl retains a large area of mudflat near the northern end of the treatment area that can be utilized by shore birds. A culvert invert elevation of 667.5 would reduce drawdown within the treatment area relative to reservoir operating conditions and provides a longer period of time in which the reservoir does not influence the treatment area. Large amounts of shallow water increase light penetration and solar warming maximizing aquatic productivity during the spring growing season and other periods when reservoir water levels do not exceed the new invert elevation of the culverts. Stabilizing water levels in the spring will provide consistent spring habitat for amphibians particularly if reservoir levels remain low and do not exceed proposed invert elevations for the new culverts. The area will also provide a staging area for spring (and potential fall depending on reservoir levels) migrations of water fowl, including deeper water habitat (> 1m) for diving birds while maintaining shallow water habitat for dabbling waterfowl.

LEGEND

Major Contour (1m Interval):	
Minor Contour (0.25m Interval):	
Bushline:	
Creek/ Edge of Water:	
Road:	
Top of Bank:	
Bottom of Bank:	
Spot Elevation:	
Test Pit Location:	
Percolation Pit Location:	

Low Archaeological Potential
High Archaeological Potential
Unsurveyed Area

0 50 100 150 200 250
METRES

REFERENCES

1.) **COORDINATE REFERENCE:** UTM ZONE 11n, NAD83
MAP REFERENCE: Base mapping provided by Vector Geomatics Land Surveying Ltd.
IMAGERY: Base imagery provided by BCHydro

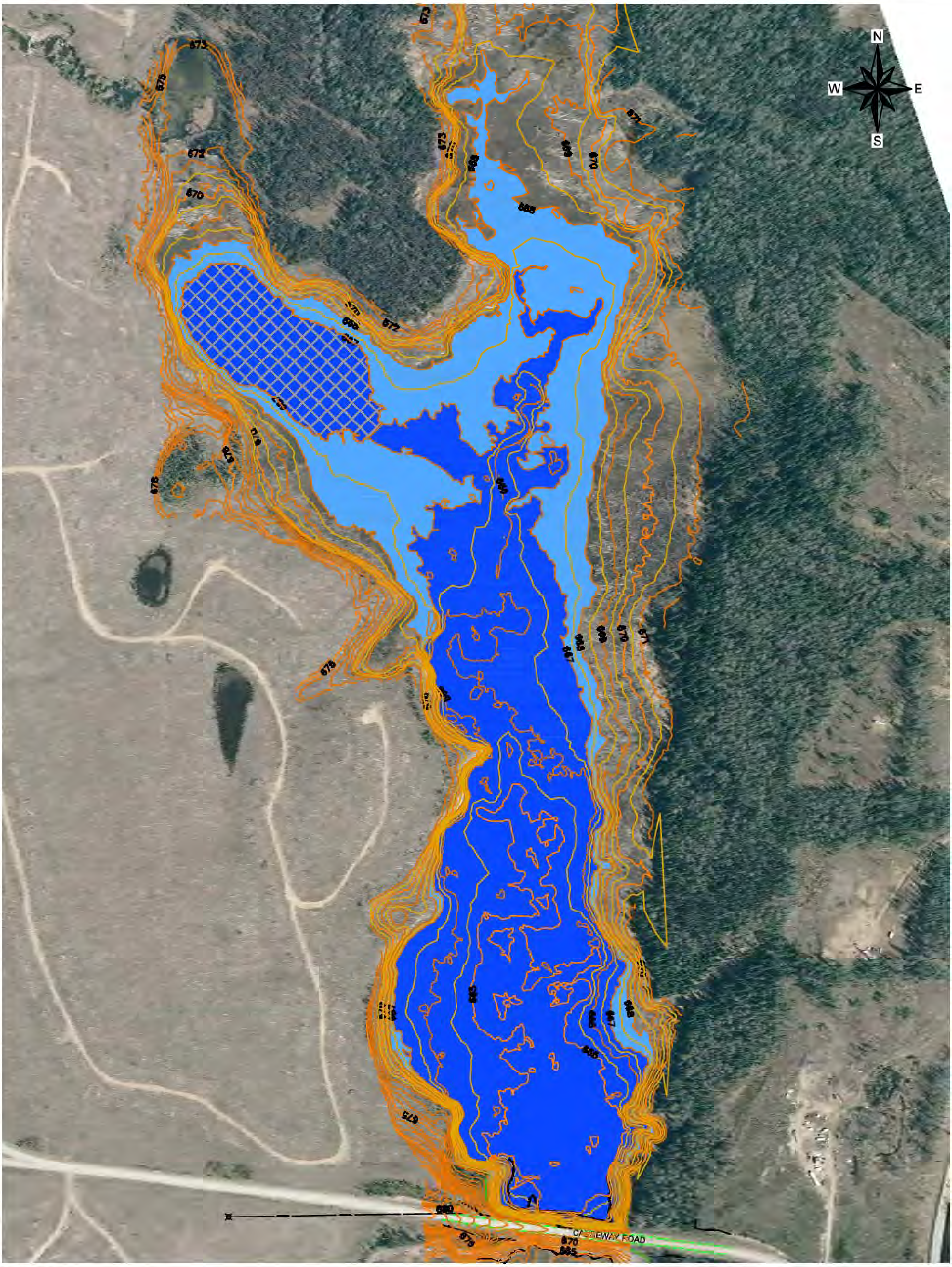
PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
AN ORTHOPHOTO OF WDS 6-2 AIRPORT LAGOON SHOWING FEATURES AND AVAILABLE BATHYMETRY

Golder Associates
Kelowna, BC

PROJECT No.		10-1492-0076	FILE No.	10-1492-0076_Site6-2
DESIGN	MG	06-DEC-10	SCALE AS SHOWN	REV. 0
CADD	BKL	13-DEC-10		
CHECK	MG	13-DEC-10		
REVIEW	CM	16-MAR-11		

FIGURE 6



LEGEND

Major Contour (5m Interval):	
Minor Contour (1m Interval):	
Bushline:	
Creek/ Edge of Water:	
Road:	
Top of Bank:	
Bottom of Bank:	
Flood Area of Basin with depth less than 1m (12.44ha)	
Flood Area of Basin with depth greater than 1m (21.65ha)	
Approximate Elevation Area Estimate from Ortho Photograph and Contour Data	

REFERENCES

1.) COORDINATE REFERENCE: UTM ZONE 11n, NAD83
MAP REFERENCE: Base mapping provided by Vector Geomatics Land Surveying Ltd.
IMAGERY: Base imagery provided by BCHydro

PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
THE ESTIMATED INUNDATION AREA IN AIRPORT LAGOON BY RAISING WDS 6-2 INVERT ELEVATION TO 667.5masl

Golder Associates
Kelowna, BC

PROJECT No.		10-1492-0076	FILE No.	10-1492-0076_Site6-2
DESIGN	MG	06-DEC-10	SCALE AS SHOWN	REV. 0
CADD	BKL	13-DEC-10		
CHECK	MG	13-DEC-10		
REVIEW	CM	16-MAR-11		

FIGURE 7

The proposed new invert elevation of the culverts will not prevent the influx of water from the reservoir during mid summer to late fall during normal operations; however, it is expected that stabilizing the water levels of this area to a minimum drawdown level of either 667 or 667.5 masl will aid establishment of submergent and emergent vegetation within the treatment area. Such vegetation would be beneficial to aquatic invertebrates, fish, waterfowl and shorebirds. Stabilizing minimum drawdown levels is also expected to be beneficial in establishing a more resilient riparian zone adjacent the lagoon. Ancillary wildlife habitat works could include a small area of raised land associated with the platform required for augering if this technique is used to position new culverts.

The effectiveness of this proposed treatment should be assessed by monitoring fish and wildlife use in the area, and the establishment/stabilization of riparian habitat as well as emergent and submergent vegetation.

7.4 Current WDS Conditions

Currently, the Airport Lagoon rises and falls with Williston Reservoir elevations, but is unaffected by reservoir water levels below approximately 664.5 masl (Figure 8). The lagoon is free draining below 664.5 masl and only impounds a small amount of water (~ 4.5 ha) when reservoir elevations are below 664.5 masl. Conditions in 2010 were unusual in that WDS 6-2 consisted of low-lying marshland for most of the growing season (Appendix A - Photograph Set 5) since reservoir levels barely exceeded 665 masl, and only small impoundments of water near the causeway were inundated by rising reservoir levels and only for a short period of time. Normally, the marsh observed during the fall of 2010 is short lived and vegetation is under developed due to a limited growing season due to rising reservoir levels during the spring towards annual high water elevations some 5 to 8 m higher (669 masl on average but potentially as high as 672.08 masl) than observed in the fall of 2010.

The periodicity of impoundment of water in the lagoon fluctuates with seasonal water levels in the reservoir, which can be highly variable from year to year.

Based upon average reservoir operating conditions for the period 1984 to 2010, the Airport Lagoon is outside the annual influence of the reservoir between mid - January and mid – June for approximately 151 days. The influence of the reservoir can be over 300 days during years of high water levels or not at all if reservoir levels do not exceed 664.5 masl, such as observed for most of 2010. As such, the wetted habitat of Airport Lagoon fluctuates between 4.6 ha (including the pond in the northwest corner of the lagoon) when reservoir levels are at or below 664.5 to approximately 73 ha when the reservoir reaches full pool (672.08).

Vegetation observed (Table 3 – Section 6.3) growing in 2010 included a combination of species associated with both wet and dry grounds (Appendix F).

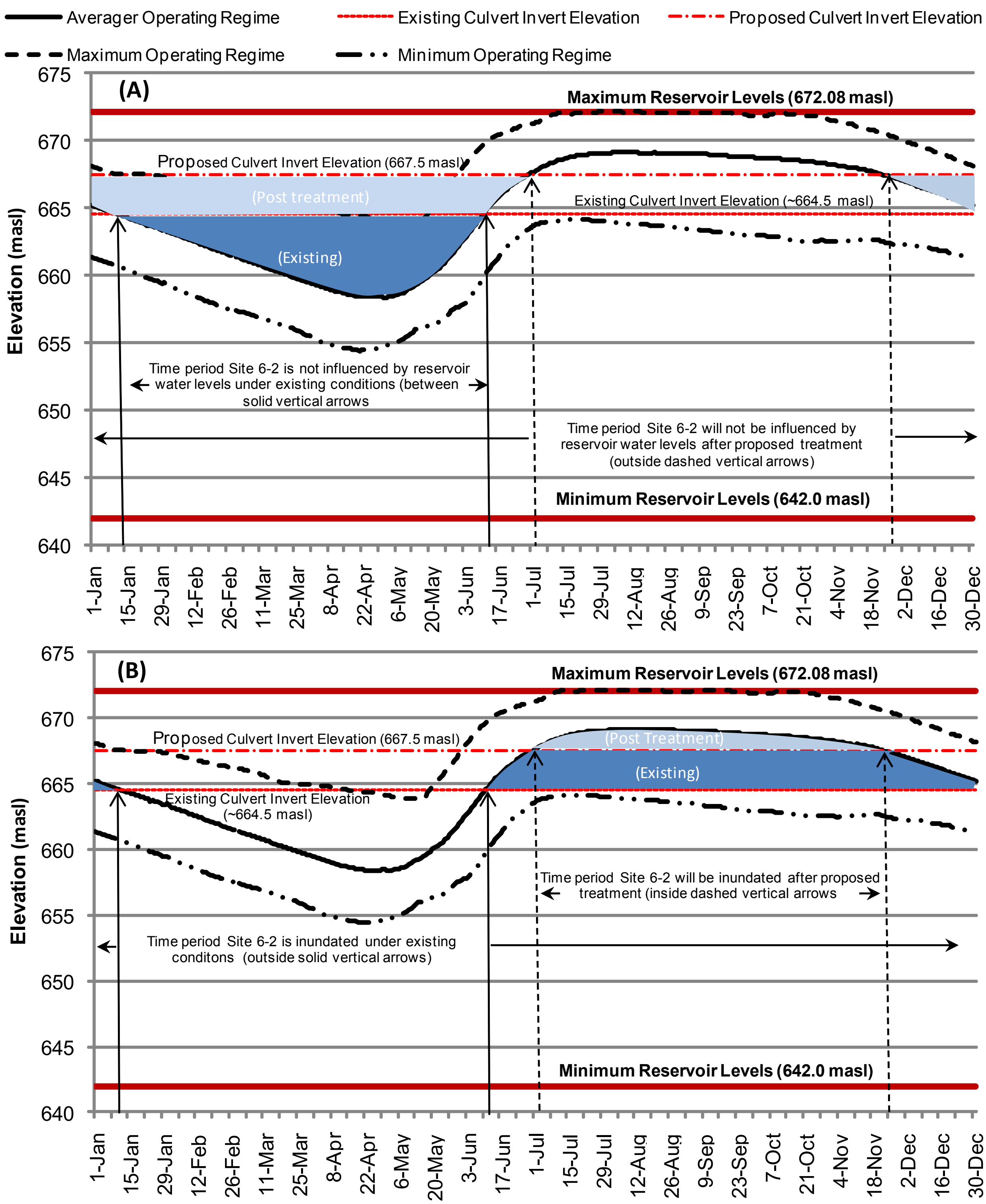


Figure 8: Illustration of how changing the culvert invert elevation at WDS 6-2 will alter (A) the length of time WDS 6-2 will not be influenced by reservoir operations comparing pre and post treatment conditions, and (B) the length of time WDS 6-2 will be inundated by reservoir operations comparing pre and post treatment conditions when compared to the average of the Williston Reservoir hydrograph for the period 1984 to 2010.

A variety of wildlife was observed within the area of the Airport Lagoon during surveys completed in 2009 and 2010. Waterfowl observed in June of 2009 included a single unidentified white swan (*Cygnus* family) and a pair of Canada geese (*Branta canadensis*). In September of 2010, flocks of Pintail ducks (*Anas acuta*) and Northern Shoveler ducks (*Anas clypeata*) were observed. Additionally, an active osprey (*Pandion haliaetus*) nest was observed along the east shore of the lagoon in 2010. Numerous unidentified tadpoles within the larger stream flowing into the east arm of the lagoon were also observed in 2009, suspected to be offspring from Western toad (*Bufo boreas*), Columbia spotted frog (*Rana pretiosa*) and/or wood frogs (*Rana sylvatica*), all of which have been reported to be present in and around Parsnip Reach (Henngeveld 1999 and 2000). Heengeveld (1999 and 2000) has also documented the presence of long toed salamanders (*Ambystoma macrodactylum*) in Parsnip Reach. Finally, water snails, likely from the family *Physidae* (possibly *Physella gyrina*), both alive and dead were observed throughout the area in 2009.

The Airport Lagoon provides marginal habitat for rearing fish. In its present state, fish can only access WDS 6-2 when reservoir levels meet or exceed the existing culvert invert elevation of approximately 664.5 masl. On average, this means the culverts present a barrier to fish migration from mid January to mid June in most years, thereby excluding use of upstream habitat to adfluvial spring spawning species. The species captured by minnow traps placed upstream and downstream of the causeway during the September 2010 survey period were restricted to cyprinids and cottids (Appendix A - Photograph Set 6 and Photograph 7). There is no spawning habitat within the streams feeding into the lagoon that could be considered suitable for recreational important species such as kokanee (*Oncorhynchus nerka*), rainbow trout (*Oncorhynchus mykiss*), whitefish (subfamily *corrigoninae*), burbot (*Lota lota*), Arctic grayling (*Thymallus arcticus*) or bull trout (*Salvelinus confluentus*). Rather, the lagoon likely offers rearing and foraging opportunities for these species when reservoir levels are high enough to allow passage through the culverts. Suspected resident species, identified through minnow trapping, include slimy sculpin (*Cottus cognatus*) and prickly sculpin (*Cottus asper*). The presence of juvenile cyprinids, possibly redside shiner (*Richardsonius balteatus*) suggest some suitable spawning habitat may be present for this species within the lagoon.

7.5 Subsurface Conditions

The soil descriptions provided in this report are based on commonly methods of classification and identification employed in geotechnical practice. All references to percent composition in the following text refer to weight. Classification and identification of soil involves judgement and Golder does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice. Detailed descriptions of the subsurface conditions are presented in the Record of Test Pits in Appendix D. The stratigraphic boundaries shown on the test pit records are inferred from non-continuous sampling, observations during test pit excavation, and laboratory test results. These boundaries represent transitions between soil types rather than exact planes of geologic change. Subsurface conditions may vary both with depth and laterally across the WDS.

Test pit TP10-01 was excavated near the base of the Airport Lagoon Causeway within the lagoon and test pits TP10-02 and TP10-03 were located on the causeway fill slope; consequently, subsurface conditions encountered at test pit TP10-01 will be described separately than those encountered at test pits TP10-02 and TP10-03.

7.5.1 Lagoon Test Pit TP10-01

Upper Sands

Loose sand was encountered from ground surface to a depth of approximately 0.9 m below ground surface. The sand stratum is described as a loose, moist, brown, medium grained sand which grades to loose, moist, grey, medium to coarse grained sand at a depth of approximately 0.5 m below ground surface. A total of two (2) natural water content determinations were conducted on samples of the sand stratum obtained during the test pit investigation and were found to range from approximately 18 to 22 percent.

Soft Silty Clay

Soft, moist to wet, grey, silty clay, trace sand was encountered below the loose sand deposits and extended to a depth of approximately 1.1 m below ground surface.

A single natural water content was conducted on a sample of the clay stratum and was found to be approximately 74 percent.

Fibrous Peat

Soft, moist, dark brown to black, fibrous peat was encountered below the silty clay stratum and extended to a depth of approximately 1.4 m below ground surface.

A single natural water content determination was conducted on a sample of the peat and was found to be approximately 394 percent.

Lower Sands

Loose, moist, blue grey, silty fine sand containing organics (wood fragments) was encountered below the peat and extended to a depth of approximately 2 m below ground surface where the stratum transitioned to a loose, wet, blue grey, coarse sand, trace to some silt to a depth of approximately 2.8 m where the test pit excavation was terminated due to achieving the maximum depth of excavation possible with the excavation equipment.

A total of two (2) natural water content determinations were conducted on samples of the lower sands obtained during the test pit investigation and were found to range from approximately 30 to 33 percent.

7.5.2 Causeway Fill Slope Test Pits TP10-02 and TP10-03

Test pit TP10-02 is located on a relatively level bench on the embankment fill slopes and test pit TP10-03 is located on the upper embankment slopes. Test Pit TP10-03 consisted of an approximately 2.8 m vertical cut into the embankment slope and the depths described in the test pit records are based on depth from top of cut and do not necessarily indicate the thickness of the encountered fills. Test Pit TP10-03 is meant to verify the conditions encountered at test pit TP10-02.

Loose to Compact Sand Fill

Loose to compact, moist, brown sand was encountered at test pit location TP10-02 and extended to a depth of approximately 2.5 m. The sand fill included a layer of firm, moist, light brown, silt fill from 0.7 to 0.8 m depth. The sand fill was encountered at the top of cut at test Pit TP10-03 to a depth of approximately 2 m below top of cut.

A single natural water content determination was conducted on a sample of the surficial sand fill collected from test pit TP10-02 and was found to be approximately 15 percent.

In addition, a natural water content determination (ASTM D2216-98), and an Atterberg Limits determination (ASTM D 4318-05) were conducted on a sample of the silt interlayer encountered at test pit TP10-02. The laboratory test results indicate the natural water content is approximately 28 percent, the Liquid Limit is approximately 35 percent, and the Plastic Limit is approximately 26 percent. The results of the Atterberg Limits determination indicate the material is described as ML, consisting in this case, of silt *with slight plasticity*.

A single washed sieve analysis was conducted on a sample of the silt interlayer and was found to comprise approximately 3 percent sand and 97 percent fines, by weight.

Silt Fill

Firm, moist, blue grey, silt, trace sand was encountered below the sand fill. Test pit TP10-02 was terminated within the silt fill at a depth of approximately 2.8 m due to achieving the maximum depth of excavation possible with the excavation equipment. The silt fill is interpreted to represent the core material of the Causeway. At test pit TP10-03, fine sandy silt, trace to some clay grading to silt was encountered below a depth of 2 m from top of cut and extended to a depth of approximately 2.8 m from top of cut where the test pit was terminated.

A single natural water content and Atterberg Limits determination was conducted on a sample of the silt obtained from test pit TP10-02. The laboratory test results indicate the natural water content is approximately 33 percent, the Liquid Limit is approximately 37 percent, and the Plastic Limit is approximately 28 percent. The results of the Atterberg Limits determination indicate the material is described as ML which, in this case, consists of silt *with slight plasticity*. In addition, the results of the Atterberg Limits determination are similar to those from the clayey silt interlayer encountered in the overlying sand fill at test pit TP10-02 and are interpreted to come from the same or similar source.

Groundwater Observations

Seepage was observed at test pit TP10-01 at a depth of approximately 2 m below ground surface. Upon completion of the test pit excavation, and prior to backfilling, the water level within the test pit was measured to be approximately 2.6 m below ground surface.

Test pits TP10-02 and TP10-03 were dry during test pit excavation and prior to backfilling.

Percolation Test Results

A total of three (3) percolation tests were conducted along the lower fill slopes associated with the Airport Lagoon Causeway as shown on the plan view of attached design drawings (Appendix B - Design Drawing -1) and attached maps for WDS 6-2. The percolation test holes were hand excavated and were approximately 0.3 m by 0.3 m in plan and excavated to approximately 0.4 m depth. The percolation test holes were pre-soaked prior to conducting the percolation tests. Percolation rates and hydraulic conductivity estimates are presented in Table 5.

Table 5: Percolation test results.

Test Location	Percolation Rate	Estimated Hydraulic Conductivity, K_s
Percolation Test 1	6 minutes/cm	0.01 to 0.001 cm/s
Percolation Test 2	5 minutes/cm	0.01 to 0.001 cm/s
Percolation Test 3	3 minutes/cm	0.1 to 0.01 cm/s

Percolation test results are sensitive to variations in soil type and stratification. The hydraulic conductivity estimates in Table 5 are representative of the sandy, near surface fills and should not be used for estimating the hydraulic conductivity of the causeway core materials.

7.6 Land Ownership

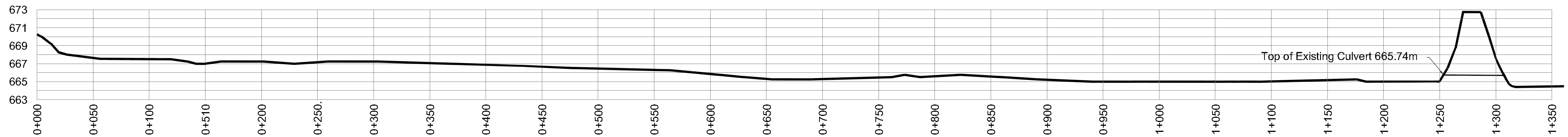
The treatment area is within the drawdown zone of the reservoir, which is crown land. The areas bordering the west side of the reservoir are identified as private land, associated with logging licences and the adjacent cut blocks.

7.7 Physical and Hydrological Conditions

The contributing catchment area for the water supply contributing to WDS 6-2 - is estimated to be approximately 17.3 km^2. The watershed is forested and includes a number of small lakes, forestry roads and a portion of the airport lands. Google Earth imagery indicates that clear cut logging activities have occurred within the watershed. The watershed essentially drains from the northeast to the southwest, culminating in a 1.9 km basin (Airport Lagoon). This lagoon extends about 1.9 km upstream of the causeway, and is the treatment area for WDS 6-2. Elevations within the catchment area of the Airport Lagoon water supply range from approximately 762 m to 664.5 m (the invert elevation of the existing twin 1200 mm diameter CSP culverts crossing the Airport Lagoon Causeway. The basin of the lagoon itself is relatively flat, most of it is below 667 masl, with steep foreshores leading to the full pool elevation of the reservoir (672.08 masl) along the east, west and south shores of the lagoon (Figure 9).

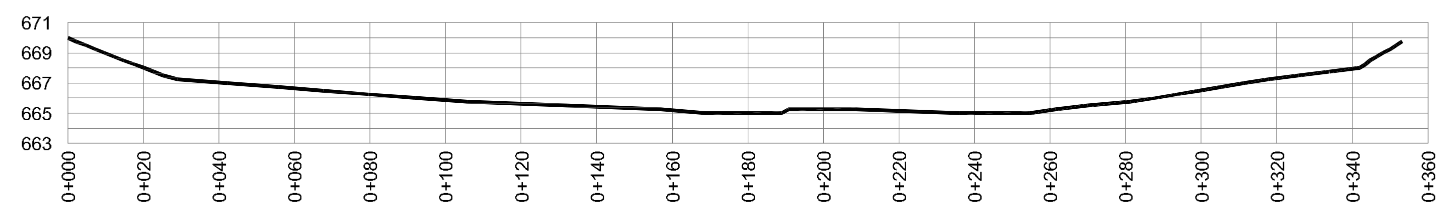
The causeway isolating the Airport Lagoon from Williston Reservoir proper is approximately 150 m long by 9 m high to the lowest point on the road, and over 40 m wide at its base narrowing to 12 m wide at the road surface. The twin 1200 mm diameter culverts are located at the bottom, and nearer the west end of the causeway. Invert elevations of these culverts are 664.64 and 664.577 masl. The twin 1200 mm culverts are exhibiting signs of failure, with sections of both downstream outlets broken away from the main pipe, and collapsing interior walls within visible lengths of each culvert (Appendix A - Photograph Set 8 and 9).

The Airport Lagoon basin is bisected by a small creek, only visible at low water, which receives inflow from various drainages entering the lagoon, the largest of which are two unnamed streams. The larger of these two streams flows from Tom and Eunice Lakes and feeds into the north east arm of the lagoon. A second smaller stream flows from a small unnamed lake into the west arm of the lagoon. The area (ha) and periodicity of water impounded in the lagoon fluctuates with seasonal water levels in the reservoir, which can be highly variable depending upon snow pack, precipitation, and water requirements for power generation. At reservoir elevations below approximately 664.5 masl, the lagoon is unaffected by reservoir water levels and assumed to be representative of its pre-impoundment. The small pond in the northwest corner of the lagoon occupies approximately 2.8 ha and appears to be a permanent feature at water levels less than approximately 668 masl (Appendix A - Photograph 10, Figure 6).



SECTION A

VERTICAL SCALE 1:500 HORIZONTAL SCALE 1:4000



SECTION B

VERTICAL SCALE 1:500 HORIZONTAL SCALE 1:2000

REFERENCES

1.) **COORDINATE REFERENCE: UTM ZONE 11n, NAD83**
MAP REFERENCE: Base drawing provided by Vector Geomatics Land Surveying Ltd.

PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
ELEVATION PROFILES OF WDS 6-2 AIRPORT LAGOON ALONG CROSS SECTIONS A AND B

Golder Associates
Kamloops, BC

PROJECT No.	10-1492-0076	FILE No.	1014920076_site6-2
DESIGN	MG	26-NOV-10	SCALE AS SHOWN REV. 0
CADD	BKL	13-DEC-10	
CHECK	MG	13-DEC-10	**FIGURE 9**
REVIEW	CM	16-MAR-11	

Based upon average reservoir operating conditions, the area is outside the influence of the reservoir proper between mid - January and mid – June (~150 days) most years. The influence of the reservoir on Airport Lagoon can be as long as 300 days during years of high water, or not at all when water levels do not exceed 664.5 masl such as was observed for most of 2010.

For the purpose of designing the proposed culverts, the design inflow into the treatment area for WDS 6-2 was required along with the development of an elevation/area/storage curve for this WDS. A design 100 year maximum annual snowmelt contribution to the reservoir was determined to provide a greater input to the reservoir than using a design 100 year single event rainfall or rain on snow event.

The Mackenzie Airport and the Prince George Airport climate stations are two Environment Canada stations closest to the project site. Precipitation data are available from the Mackenzie Airport climate station from 1971 to 2007, and at the Prince George Airport climate station from 1943 to 2007. Intensity-Duration Frequency (IDF) curves for the two stations were compared and the Prince George Airport IDF provided more conservation rainfall intensities for the various return period events. 100 year design rainfall hyetographs were developed based on the Prince George Airport IDF curves. A snow melt contribution was then determined based on a theoretical snow melt equation with input from the Mackenzie Airport Climate Normal's. The snowmelt contribution was then added to the rainfall hyetograph resulting in a rain on snow event hyetograph.

Historic Snow Survey data is available for the Morfee Mountain station which is located relatively close to the project site. The historical records (1968 to 2009) indicate that the peak snowfall depths occur in the months of April and May after which the snow pack starts to reduce due to the spring melt. A statistical frequency analysis was performed on the annual maximum Snow Water Equivalents for the month of April. The 100 year snow water equivalent for the month of April was estimated to be approximately 1300 mm. Based upon the Mackenzie Airport Climate Normal's, the snow pack appears to be depleted over a period of about two months. To be conservative, the snow pack has been assumed to melt within one month. The 100 Year snow water equivalent of 1300 mm, melting over a period of one month, was used to create a design hyetograph, which was used as input into the U.S. EPA SWMM 5 Storm water Management Model. A single event hyetograph was developed having a constant snowmelt rate of 1.8 mm/hr over a 30 day period. This event is assumed to be quite conservative, due to the difference in accumulated snowpack that would occur at the higher elevation of Morfee Mountain versus the elevations within the Airport Lagoon catchment area.

7.7.1 EPA SWMM Model Development

Results from inputs of data into the SWMM Storm Water Management Model (Ver. 5) (U.S. EPA) were used to assess the size of the proposed culverts and the associated impact of the design event on the maximum water levels obtained within the treatment area and the associated freeboard on the causeway. The model results are considered conservative based on the following:

1) The percent imperviousness of the catchment area has been assumed to be 20%;

2) No evaporation has been considered;

3) The flow attenuation from the small lakes within the catchment area has not been considered; and

4) The 100-Year snow pack has been assumed to melt within one month rather than say over a two month period which appears to be a typical melt period.

The design snowmelt was assumed to melt during the month of May based on an assessment of Climate Normal's for Mackenzie Airport. The maximum water levels in the Williston Reservoir typically occur by mid July, Backwater effects due to the water levels in the Williston Reservoir were not considered to be a factor on the routing of flows through the proposed culverts.

The model was developed by delineating the catchment area to the Airport Lagoon based on an imported geo-referenced bitmap image of the 1:20,000 Trim mapping of the area. The catchment parameters included:

- Catchment Area = 1724.6 ha (17.3 km^2)
- Catchment Slope = 0.013 m/m
- Percent Imperviousness = 20% (based on airport, roads, cleared areas and lakes)
- Infiltration – Green Ampt – Soils (Silty Clay – based on soil test pits)
  - Suction Head = 290 mm
  - Conductivity = 0.51 mm/hr
  - Initial Moisture Deficit = 0.25 (Fraction)

The elevation/surface area curve for the treatment area was determined based on the surveyed information and the developed DTM (Table 6).

Table 6: Airport Lagoon - upstream elevation/area curve

Depth (m)	Contour Elevation (masl)	Surface Area (m^2)
0	665.0	33,853
0.5	665.5	70,036
1.0	666.0	114,410
1.5	666.5	149,596
2.0	667.0	177,135
2.5	667.5	350,800
3.0	668.0	425,500
3.5	668.5	462,200
4.0	669.0	498,900
4.5	669.5	531,750
5.0	670.0	564,600

Areas were determined for 0.5 m elevation increments from the existing base elevation of 665 m to 670 m. The minimum causeway elevation is approximately 672.7 m. We could not reasonably estimate contour elevations above the 670 m elevation based on the available information.

Based upon the above analysis, two 1200 mm galvanized CSP culverts with staggered inverts by 0.5 m are proposed as replacements for the existing culverts. In our proposal the lower culvert (C1), will have an upstream invert elevation of 667.5 m. The culverts have been designed with 0.5% slopes. Galvanized culverts have been specified for replacement culverts due to observed corrosion on the existing culverts.

Model Results

Based on twin 1200 mm diameter culverts with upstream invert elevations of 667.5 m and 668.0 m for proposed replacement culverts with water elevations in the treatment area set at 667.5 m, the following results were obtained:

1) A maximum water level of 669.72 m was reached in the upstream wetland/reservoir. The minimum road elevation is approximately 672.70 m, resulting in approximately 3 m of freeboard.

2) The two culverts are submerged at the inlet during the 100 Year event.

3) The velocity at the outlet of the culverts and down the proposed Gabion Mat Apron was approximately 4.6 m/s.

The modeling results show that there is adequate freeboard on the causeway, based on the proposed twin 1200 mm diameter CSP or the optional 1800 mm culvert design.

7.8 Description of Work

7.8.1 Approaches

WDS 6-2 is a water control structure. Construction at WDS 6-2 is anticipated to include installation of the new culverts and decommissioning of the existing culverts. Either two (2) x 1200 mm or 1 x 1800 mm culverts can be installed. In the 1200 mm configuration, a single *working* pipe is recommended for the design invert elevation and a second, backup or spillway pipe, should be installed at a slightly higher elevation such that if the lower pipe reaches capacity or becomes plugged, the upper pipe can drain the overflow (Appendix B - Design Drawing -1).

A single 1800 mm diameter CSP culvert has the equivalent end area as the proposed twin 1200 mm diameter culverts. The variation in cost for purchase and delivery of a single 1800 mm culvert compared to two 1200 mm culverts is nominal. Some savings may be realized in the amount of material required to be excavated for a single 1800 mm culvert compared to that required for two 1200 mm culverts due to a slightly narrower base of the bottom of the excavation. Similarly, the proposed gabion mat could be slightly narrower for the 1800 mm culvert. These savings are not expected to be nominal however, and have not been included in the cost estimate provided in Section 7.8.4.

During installation of the new, raised culverts, it is understood that the Airport Lagoon Causeway road is to remain open to forestry, mining, and recreational users. The contractor is responsible for maintaining vehicle access across the Causeway during construction and installation of the new culverts at WDS 6-2. Four (4) concepts for installing the new culverts were reviewed, the first involving augering and pipe jacking culverts under the causeway, while the others call for excavation to position new culverts into place. The concepts were reviewed based on feasibility, costs, maintaining traffic flow during construction. Based on the results of this review, Pipe jacking (Horizontal augering) and Excavation in combination with a sheet pile wall are two recommended methods to position new culverts.

The type and location of new culverts (either corrugated steel pipe [CSP] or smooth steel pipe) will depend upon the method used to place the culverts.

If augered (pipe jacking) into place, culverts will be located approximately 60 m east of the existing culverts and smooth bored. Access to the area of the old culverts and the floodplain of WDS 6-2 (if augering is used) will be gained by improvements to an existing ramp approaching the existing culverts from the west on the north side of the causeway.

If excavation is used, then the new culverts can be placed approximately 10 m east of the existing culverts and will be CSP. In either case, the new culverts will be placed at a higher elevation than the existing set of culverts.

New culverts should be placed during low water levels in the spring, preferably after snow has melted from the work area, and ground frost has dissipated but prior to reservoir elevations rising beyond 664.5 masl. The invert elevations of these culverts will be slightly staggered, one at 667.5 and the other at 668.0 masl. It is recommended that culvert gradient not exceed 0.5% as this will facilitate access by both juvenile and adult fish species, given the length of culvert (Parker, 2000).

A short semi circular log boom is proposed to be anchored around the inlets of the new culverts as protection against potential plugging from the influx of floating debris. This boom would replace steel cages presently in place that serve a similar function for the existing culverts (Appendix A - Photograph 11).

A log boom as shown in the attached design drawings is specified to protect the inlet of the culverts from debris and ice. Consideration may be given to re-establishment of the existing cage given potential stress from the effect of fluctuating water levels on a log boom and associated static anchors.

The old culverts will not be removed; rather, they will be filled with either “Cellcrete”, “Controlled Density Fill” or grout, once the installation of the new culverts is completed. This is a common technique used to filled culverts to prevent there collapse as they deteriorate.

Construction is expected to last two to three weeks, depending upon the method employed, not including time required for obtaining necessary permits, discussed in more detail in Section 7.10.1.

7.8.2 Methods

Horizontal augering under the causeway will minimize potential disruption and/or conflicts with road use, but it is anticipated to be the more expensive method (Section 7.8.4 below). Excavation as a means to replace the culverts will cost less, but cause more traffic disruption since the causeway cannot be closed without disruption of industrial traffic. Options for alternate routing of traffic utilizing the causeway exist, but would have to be verified and agreed upon through discussions with the MOF, local industry users of the road and the District of MacKenzie and potentially the Ministry of Transportation and Infrastructure (MOTI). The practicality of an alternate route would be influenced by issues related to road weight limits along the alternate route (such as the highway leading to Mackenzie) and potentially vehicle licensing issues related to heavy haul off road vehicular traffic operating on public highways. Regardless of the selected installation method, or potential alternative routes, some method of traffic control is still expected for certain phases of work (i.e., mobilization of machinery, delivery of materials, detour signage etc.). Traffic control could include a combination of flag persons (depending upon the task) and signage during construction.

Augering

Augering will require positioning of a platform on which to station machinery during placement of the new culverts. This platform is expected to be constructed from onsite sediment within a dry section the lagoon, potentially supplemented with some gravel as a cap. Upon completion of the work, the auger platform would be pulled back from the road and piled to an elevation exceeding 667.5 masl, and left in place after construction as an area of raised land. This area is expected to become an island during lower reservoir levels and an area of shallow water during maximum reservoir levels that exceed the newly established culvert invert elevations.

Excavation

Excavation in combination with the use and installation of a sheet pile wall along the centreline of the causeway will reduce the amount of excavation required to place culvert(s).

Traffic can be diverted to one side of the sheet pile wall while trenching and culvert installation proceed on the other side. Upon completion of backfilling, traffic can then be diverted to the opposite side of the road followed by trenching and installation of the remaining culvert section. Upon removal of the sheet pile wall, the road structure may be reinstated. It is anticipated that excavation as a means to replace the culverts will cost less than augering / pipe jacking, but may cause more traffic disruption, and take longer.

Plugging Culverts

Plugging of the old culverts will commence once the new culverts are in place. Infilling the existing culverts with grout or other suitable material is considered a feasible means of sealing the culverts. Isolation of the old culverts will be accomplished by construction of a small coffer dam around the inlet of the existing culverts, using material excavated from the substrate material in the lagoon. The ends of the culverts will then be blocked to prevent inflow or water. It is unlikely inflows of water into the lagoon are great enough to cause impoundment levels of water within the lagoon to reach the elevation of the new culverts prior to plugging of the old. However, pumps can be used to keep the work area dry and to redirect water through the newly established culverts during plugging of the old culverts. Stand pipes placed in the culverts will be used to pump grout into the entire length of each of the old culverts to establish a plug and prevent potential for slumping of the road surface as these old culverts continue to deteriorate. Once plugs are dry, the blocked ends of the culvert will be excavated and cut off and covered with native material.

Seepage and Scour Control

As the decommissioned culverts will be underwater for potentially significant periods of time, consideration should be given to provision of seepage control measures to mitigate potential piping issues. Once the existing culverts are filled with either Cellcrete or Controlled Density Fill, the upstream ends of the culverts should be exposed and a grout curtain installed to form an anti-seepage collar, and a subdrain should be installed at the downstream end for safe relief of seepage, if any should occur. Similarly, the newly placed culvert(s) should be provided with seepage control measures. Anti-seepage collars have been specified near the upstream ends of the culverts (Appendix B - Design Drawing -2). This will minimize the potential for piping that could occur adjacent to the walls of the proposed culverts. At the downstream end of the culverts, a free draining well compacted sand and gravel zone has been specified to allow any moisture to freely drain out of the embankment near the culvert outlets.

To protect against scour at the inlet and outlet, gabion mat aprons have been specified rather than the standard riprap protection due to the limited availability of riprap in the Mackenzie area (Appendix B - Design Drawing -2).

The upstream and downstream ends of a suitably keyed in, cobble infilled, gabion mat or rip rap apron shall be installed extending approximately 2.5 m and 10.0 m from the culvert ends respectively. In addition, the use of a suitable filter cloth to filter the silt from the drain and to minimize the potential for piping and erosion is recommended and shown in the design drawings.

Geotechnical

The following applies where excavation and trenching as a means to install the culverts is considered.

Based on the materials encountered at WDS 6-2, temporary cut slopes should be no steeper than 1.5H : 1V. Temporary fill or embankment slopes may also be no steeper than 1.5H : 1V provided the fill material is uniformly compacted to a minimum 97 percent Standard Proctor Maximum Dry Density at a moisture content within five (5) percent of the Optimum Moisture Content. Should steeper temporary slopes be required, consideration may be given to the use of trench boxes, or equivalent shoring methods, in accordance with relevant Worksafe BC regulations.

Upon completion of the culvert installation, the road structure and embankment fills should be reinstated. The existing road structure is not known at the time of reporting; consequently, a recommended road structure is specified on the design (Design Drawing D-1). It is recommended that embankment fills be uniformly compacted to a minimum 95 percent Standard Proctor Maximum Dry Density at a moisture content within five (5) percent of the Optimum Moisture Content. Compaction specifications for the recommended road structure are provided on the Design Drawing D – 1.

7.8.3 Materials

Gabion Mat Apron – The Gabion Mats shall be filled with hard, durable, 3” to 8” round cobble stones. The Gabion Mat will be coated with PVC for corrosion protection. The outlet apron is proposed to extend down to elevation 664.5 m (approximately 10 m from the outlet of the new culverts). The inlet apron is proposed to extend approximately 2.5 m beyond the inlet of the culverts.

Culverts – Galvanized Corrugated Steel Pipe (CSP) culverts have been specified due to the possible corrosive soils and water as evidence based on the condition of the existing culverts. The anticipated service life of the Galvanized culverts is 100 years. Twin 1200 mm diameter galvanized CSP culverts are proposed, one is approximately 36.4 m long and the other is approximately 33.4 m long.

Anti-Seepage Collars – Galvanized CSP anti-seepage collars are specified to prevent piping adjacent to the culvert. The collars extend 600 mm beyond the edge of the 1200 mm diameter culvert thereby forming a square collar 2.4 m x 2.4 m.

Non-woven Geotextile – Nilex 4551 non-woven geotextile has been specified for under the Gabion Mat and the free draining compacted sand and gravel near the outlet of the culverts.

Log Boom – It is envisioned to use large diameter logs that may be available locally. These will be cabled together using a corrosion resistant cable. The logs will form an arch around the inlet of the culverts to protect against debris and ice.

Deadman Anchors – Deadman anchors will be required to anchor the log boom at either end. Various types of anchors can be used including but not limited to: concrete blocks, steel plate anchors or cross plate anchors. Specific anchors have not been specified at this time.

Road Sub-Base Material – Road sub-base material is required if the open trench method is used. The road sub-base material is specified as a 550 mm thick layer of 40 mm minus crushed gravel.

Road Base Material - Road base material is required if the open trench method is used. The road base material is specified as a 150 mm thick layer of 19 mm minus crushed sand and gravel.

Compaction Specifications – Granular fills shall be placed in loose lifts no thicker than 300 mm. Sub Base materials shall be compacted to a minimum of 100% Standard Proctor Maximum Dry Density (SPMDD) at a moisture content of 5% of the Optimum Moisture Content (OMC) for compaction. Bas materials shall be compacted to a minimum of 100% SPMDD at a moisture content of 5% of the OMC for compaction.

Free Draining Well Compacted Sand & Gravel – To minimize the potential for piping near the outlet of the culvert, a zone of free draining well compacted sand and gravel is specified near the outlet of the culverts.

Culvert Bedding – A concrete bedding layer for the proposed culverts.

7.8.4 Cost Estimates

The following summarizes the Class B construction cost estimates for the two alternative methods of construction, Open Excavation (Table 7) and Pipe Jacking (Table 8). This cost estimate was prepared following the Canadian Consulting Engineers of BC (CEBC) which defines a Class B estimate as having an accuracy of +/- 15% to 25%. Such estimates are prepared after site investigations and studies have been completed and the major systems defined. A 25% contingency has been added to the estimate to reflect the accuracy of the Class B estimate and the potential for changes in the costs of labour and materials between now and when construction occurs, and to accommodate any potential over run. The size of the contingency is subject to BC Hydro internal processes when considering tendering of this work, but a 25% contingency is not unusual for planning purposes.

Cost of HST and for a client representative such as an engineer is not included in this estimate. A preliminary cost for an environmental monitor (EM) has been included, recognizing the EM commitment can vary depending upon selection of a contractor and the construction methodology and plan proposed by this contractor, not to mention variation in rates between firms providing environmental monitoring services. The cost for 1 day of an archaeologist's time **has been included to delineate areas of high potential on the ground prior to start of construction but costs for an Archaeological Monitor have not been included** in the cost estimate since the proposed construction plan anticipates no further need for archaeological monitoring based upon areas assessed to date. A requirement for further archaeological work and related regulatory permitting will be dependent upon the bids received upon tendering that may consider alternative approaches to completion of this work. As with the EM, the cost of the Archaeological Monitor (AM) can vary between firms providing such services.

Details of cost estimates are provided in Appendix G.

Table 7: Estimated cost to install new culverts at WDS 6-2 Airport Lagoon by excavation.

Description	Cost
Common Quantities for Both Alternatives [(1)]	$102,557
Open Excavation Quantities	$198,160
Sub-Total	$300,717
25% Contingency	$75,179
Total =	**$375,896**

Table 8: Estimated cost to install new culverts at WDS 6-2 Airport Lagoon by horizontal augering.

Description	Cost
Common Quantities for Both Alternatives [(1)]	$102,557
Horizontal Auguring Quantities	$249,535
Sub-Total =	$352,092
25% Contingency	$88,023
Total =	**$440,115**

(1) Common quantities include costs such as scour and seepage and scour control.

7.9 Considerations

7.9.1 Reservoir Operating Regime

Based upon mean annual water levels for the Williston Reservoir for the period 1984 to 2010, reservoir levels will exceed the proposed invert elevation of the new culverts (667.5 masl) from approximately mid July to late November (about 146 days) for most years, opposed to 216 days for current conditions. This change includes adding 21 days of extra growing season into the summer (to about July 12) for established vegetation in the treatment area.

7.9.2 Construction Related Impacts to Wildlife

Using a worst case scenario, construction noise may temporarily deter some wildlife and waterfowl from using the lagoon until construction is completed. Targeting completion of work early prior to early May should avoid the most sensitive breeding seasons for birds. Given all work is immediately adjacent a road which is heavily utilized by logging trucks and other vehicle traffic, the additional noise from construction is expected to be minimal to that already occurring.

Wildlife use in the area is likely closely associated with available vegetation and wetted habitat. A loss of mudflats and low-lying terrestrial vegetation within the proposed footprint of the treatment area is expected. However, similar mudflats will persist in the northern end of the lagoon and the shoreline of the treatment areas and will persist as long as it is not flooded by reservoir levels in excess of 667.5 masl. The addition of 35 ha of wetted habitat stabilized at an elevation of 667.5 masl will be suitable for use by both dabbling and diving waterfowl migrating through the area during the spring or whenever reservoir elevations do not exceed the new invert elevation of the culverts.

7.9.3 Construction Related Impacts to Aquatic Life

Potential impacts and benefits to fish habitat can be described as short term and long term. Short term impacts are related to construction activities and the foot print of construction. Long term impacts/benefits are those resulting from the expected permanent inundation of treatment area and from the newly established invert elevation of the new culverts.

Short Term Impacts

The only in stream works will be associated with the plugging of the old culverts, which will require isolation of the work area and control of potential caustic run-off associated with the grout anticipated to be used to plug the culverts. Positioning of a small coffer dam prior to plugging the culverts should minimize potential for run off, but downstream containment should also be considered during this procedure. The area within the footprint of the coffer dam and associated containment areas (at both upstream and downstream ends of the old culverts) should be isolated and salvaged of fish prior to plugging the old culverts.

Positioning of new culverts, regardless of if excavation or augering is used will occur outside of the wetted perimeter of the lagoon during the low water period in the spring.

The proposed gabion apron to protect against scour at the outlet of the culverts will displace minimal vegetation (Appendix A - Photograph Sets 2, 8 and 12). This structure, over the longer term, will likely add habitat complexity when inundated compared to existing conditions.

Some existing vegetation will be lost during upgrades to the access ramp leading to the old culverts, and during construction of the drill platform (although it is anticipated most of the drill pad can be placed in an area presently lacking vegetation). It is expected that this vegetation will naturally re-establish itself, but some planting of cuttings and/or seeding may be considered within the impacted areas nearing the upper end of the drawdown zone.

Long Term Impacts/Benefits

The primary long term impact to existing fish and aquatic habitat within the lagoon is expected to be a change in the period when this habitat is accessible to adfluvial fish species migrating upstream from the reservoir. As indicated earlier, WDS 6-2 can only be accessed when reservoir levels meet or exceed the existing culvert invert elevation of approximately 664.5 masl, which on average means the culverts present a barrier to adfluvial fish migration (from the reservoir) from mid January to mid June in most years. By increasing the invert elevation of the culverts to 667.5 masl, potential movements of adfluvial fish will be delayed to later into the summer by approximately 21 days based upon average operating conditions (Figure 8 above). However, fish species presently utilizing the lagoon appear to be restricted to cyprinids and cottids, which typically do not engage in extensive migrations (McPhail 2007). Further to this, a similar, second causeway/culvert structure located downstream of the proposed treatment area likely already limits movements of adfluvial fish migrations in the spring. Most fish migrating into the lagoons created by these two causeways for spawning are likely attracted to Lion Creek (downstream of the Airport Lagoon Causeway) since it contains substrates suitable for spawning salmonids and cyprinids alike (Golder 2010, McPhail 2007).

Any delay in access to the Airport Lagoon by species currently utilizing this habitat will be outweighed by creation of more consistent rearing and foraging opportunities. A stabilized impoundment area should improve small fish habitat throughout the year in Airport Lagoon. Downstream migration of fish out of the lagoon, if it occurs, should remain unaffected by raising the invert elevation of the culverts.

It is unknown if water quality, such as changes in temperature and oxygen content within the impounded area of airport lagoon will be altered from what normally occurs in this area. Water circulation persists year round into the lagoon. There is a steady inflow supply of water from the Airport Lagoon's catchment area into the lagoon, and out flowing water occurred even during the drier, low water conditions observed in 2010. Increases in water temperature generally result in increased productivity in any water body, which if combined with an available nutrient supply, may alter productivity of vegetation, including aquatic macrophytes but also algae. An objective of the proposed treatment is to encourage aquatic productivity, not only of invertebrates, but also of aquatic macrophytes. Expected increases in productivity are consistent with the objectives of then proposed treatment. Most years, it is expected water supply to the lagoon from upland areas will be supplemented from inflows of water from the reservoir when reservoir levels exceed the invert elevation of the newly positioned culverts. The potential for algae blooms would be greatest during summer months years when reservoir waters do not contribute water to the area. Cooler ambient air temperatures during the spring (to early June) and potentially fall when the area only receives inflows from the catchment area for WDS 6-2 will likely moderate potential for algae blooms.

7.9.4 Geotechnical Considerations

Pipe jacking is considered a feasible means for installation of the new culverts from a geotechnical perspective. Based on the test pit investigation and our interpretation of the results, the embankment materials are considered suitable for pipe jacking. In addition, pipe jacking methods will minimize potential disruption and/or conflicts with road use, and eliminate the need for backfilling and compaction resulting in a faster construction schedule, but it is the more expensive method.

Plugging the existing culverts and installation of new culverts at a higher invert elevation is considered to be a feasible means of raising water levels at WDS 6-2 from a geotechnical standpoint. The width of the causeway embankment at the existing culvert locations is approximately 46 m. Raising the culvert elevation by some 3 m will raise the water level such that the embankment width at the new culvert elevation will be approximately 25 to 30 m; consequently, raising the invert elevation by some 3 m is not anticipated to adversely impact the ability of the causeway embankment to handle the additional load due to increased water levels.

The silt fill material encountered at test pit TP10-02 is interpreted to represent the core of the causeway embankment. Typical ranges of hydraulic conductivity for the silt core is estimated to range from 10^{-3} to 10^{-5} cm/s which is considered to be sufficiently impermeable for the purposes of retaining water.

Based on the test pit TP10-01, sandy soils are present at depth and may extend laterally below the causeway embankment potentially providing a hydraulic connection for groundwater flow beneath the embankment. Neither the soils below the embankment, nor site preparation below the embankment could be confirmed as such an investigation would require excavation or drilling on the embankment. However, ponded water was observed on the upstream side of the embankment and water flow was observed through the downstream end of the culverts, indicating that leakage below the embankment may be relatively slow or not a significant concern. Moreover, it is anticipated that over time, natural processes such as the development of vegetation and other biological processes will result in decreasing the hydraulic conductivity of the surficial fills and the potential for subsurface leakage.

7.9.5 Archaeology

During the field investigation, a surface inspection was undertaken to identify any archaeological material within the proposed treatment area. Exposures including the banks adjacent the draw down zone of the reservoir and road exposures in the proposed treatment area were also examined. No archaeological material was identified during the field visit. Geotechnical investigations consisted of the excavations of three test pits, roughly 1 m x 3 m in size, to characterize subsurface soil and groundwater conditions (see sections 4.6 and 7.5). The test pits were excavated within the reservoir draw down zone of the WDS, and along steep slopes (Appendix A - Photograph 2). The location of the test pits were determined to have low archaeological potential, and were monitored throughout the test pitting.

Otherwise, WDS 6-2 and the proposed treatment area has low archaeological potential. The areas subject to disturbance from construction activities are low lying, generally featureless, with a gently slope (1-2%) to the northwest, and steep slopes (>15%) are located along the sides of the existing causeway road (Appendix A - Photograph Set 12 and 13). Disturbances in the treatment area include surface materials, that are affected from erosion caused by the fluctuating water table, and the man made causeway. This causeway and the existing culvert represent areas that are heavily disturbed. Surface sediments consist of sand, silt and subrounded and rounded clasts.

7.9.6 Public Safety

The installation of new culverts at elevations of either 667.0 or 667.5 masl will reduce the freeboard which presently exists at the causeway. However, conservative modeling (Sections 4.5 and 7.7.1) based upon the US EPA SWMM model, indicates there will still be adequate freeboard under the new conditions. In completing this model, the results for the one month snowmelt inflow design event indicate that during the peak high water events at the lagoon, there will still be approximately 2.86 m of freeboard available between the top of the road and the lagoon's water level (for culverts positioned at 667.5 masl). The 24 hour rain on snow event provides much less inflow to the upstream treatment area than the one month snowmelt event, consequently, the 24 hour event results in an even a lower water level in the lagoon, and therefore greater freeboard.

During construction, appropriate signage and traffic control may be required for public and industrial traffic along the access road. The Project Team does not anticipate other public safety issues once construction is complete.

7.9.7 Recreation

Aside from being on a regular circuit for observing birds by representatives of the Mackenzie Nature Observatory, there are no additional identified recreational opportunities in the area that would be impacted, or created by the completion of this WDS.

7.9.8 Other

Since this WDS is proximate to the Mackenzie Airport, and has the potential to increase bird use of this area, consultation with the local Airport Authority should occur prior to proceeding with the proposed works.

Both augering and excavation as methods to place new culverts in the causeway may be impacted by the depth of the frost level in the road. Work should occur after ground conditions thaw.

Plugging existing culverts should occur prior to reservoir water levels exceeding 664.5 masl.

7.10 Detailed Engineering and Construction Plan

7.10.1 Regulations

Fish habitat improvements typically only require notifications as per Section 9 of the *Water Act* and Part 7 of the *Water Act* Regulations. However, the complexity of WDS 6-2 would likely require an approval since raising water levels by 3 m could involve the Dam Safety Act (Table 9). Instream works associated with plugging culverts has the potential to contribute deleterious substance (grout contaminated water) into the wetted habitat, and as such, this aspect of the work should be referenced as a specific Environmental Protection Plan (EPP) with appropriate Best Management Practices (BMPs) in the Environmental Management Plan (EMP). Placement of new culverts, although outside the window of least risk to fish and fish habitat, can be accomplished "in the dry" and should only require notification. Contouring the drill pad into an island (if horizontal augering is employed) should be considered a habitat improvement, thereby only requiring notification. The placement as well as contouring of such a pad must be coupled with appropriate mitigation strategies to minimize issues of sedimentation. While the DFO may accept a notification for proposed work at WDS 6-2, such a procedure may only be considered by the DFO if BC Hydro has past precedence for completing works within the draw down zone of Williston Reservoir. A letter of advice should be considered the more appropriate route for construction of WDS 6-2, however, BC Hydro should be prepared for a review should the DFO request it. Reviews (either via a letter of advice and/or an approval) typically take more time than initially assumed, and a timeline of 6 months is not unusually for completion of such processes. Design drawings and associated aquatic information in addition to an appropriate EMP and associated EPP for specific construction related activities at WDS 6-2 should be included with the notification/approval process to the MNRO. This assures the regulatory body a means of verifying appropriate BMPs will be in place that are sufficient to mitigate against identified short and long term impacts arising from this work.

Cost to complete permitting have been included in the budget, but the amount of labour required to complete permitting can be highly variable, depending upon results of the regulatory review. For example, regulators may request provision of additional documentation, or request additional details that could add to the cost in securing necessary permits.

A fish collection permit for scientific purposes should be obtained for fish salvages from areas associated with upstream isolation and/or downstream containment required to complete plugging of the old culverts.

Additionally, a road use permit will be required from the Ministry of Forests for any works on roads administered by the ministry. Technically, this includes using the road for any industrial purpose (transporting crews and equipment to the WDS).

Table 9: A summary of required permits for completion of proposed treatments at WDS 6-2

No.	Name	DFO Section 35(2)		NWPD		Water Act Section 7		Water Act Section 9		MoF	HCA
		Notify	Approve	Review	Approve	Notify	Approve	Notify	Approve	Road Use Permit	
6-2	Airport Lagoon	x?		x?		x			x?	x	AOA AIA(1)

(1) Requirements for permitting related to any change in proposed works that require, as an example, expansion into areas of high archaeological potential (lay down areas, storage areas etc.) final determination of trail routes from barge or road access to WDS 34

? = Decision for notification opposed to approval will require review by relevant agency to verify. Potentially a letter of advice may be issued.

If the construction and/or treatment area is expanded beyond the area surveyed during the 2010 PFR (Figure 7 above), then the completion of an AOA at WDS 6-2 will determine if further archaeological assessment such as an AIA is required. Completion of an AIA would require a permit from the MNRO. It is important that the identified areas of high archaeological potential proximate to WDS 6-2 be clearly marked on the ground prior to the onset of construction by a qualified archaeologist as a means of avoidance of such areas. The proposed treatment area at WDS 6-2 will not inundate any areas not already within the existing draw down zone of Williston Reservoir and no land-altering activities are proposed for this area; otherwise this would qualify as disturbance under the *HCA* and thereby require an AIA, and possibly additional archaeological work.

An approval may be required from the NWPD for ancillary habitat works such those described in Section 7.10.13 below (creation of hummocks of raised land) if BC Hydro wishes to proceed with such work. Culvert replacement is considered a minor works by the NWPD depending upon issues of sinuosity and channel width. Again, because of the complexity and setting of the proposed works at WDS 6-2, review is likely required by the NWPD officer before a decision is made.

At a minimum, BC Hydro should allocate 45 working days for completion of approvals by agencies, and at least an additional 10 working days or more for review by agencies if the WDS can proceed as an approval. AIA's, if required, have a 30 working day referral response time from First Nations and additional time should also be anticipated for issuance of the permit (Golder 2010).

7.10.2 Project Area

Airport Lagoon occupies an area of approximately 73 ha, however, the proposed treatment is expected to create permanently wetted habitat approximately 35 ha in area, with 16.5 ha of this wetted habitat expected to be less than 1 m in depth. The footprint of the treatment area for WDS 6-2 will be minimal, consisting primarily of the platform
(~60 m^2) created for the positioning of the auger drill rig (if used), improvements to the access ramp leading to the proposed work area (~480 m^2), and construction of the gabion matt on the downstream side of the culverts (~111 m^2). The total estimated area of these impacts is approximately 650 m^2, recognizing that this area represents impacts to marginal brown field habitat (the causeway and an unvegetated area within the reservoir drawdown zone) as its current condition.

7.10.3 Design Life

Design life is pertinent to the log boom protecting the inlet and the culverts themselves. The design life of the proposed log boom is uncertain and will depend on the size and type of logs available. The logs can be periodically monitored and replaced as necessary. Galvanized culverts are expected to last approximately 75 years.

7.10.4 Maintenance and Monitoring

Maintenance will be related to removal of floating debris that may accumulate in front of the culverts and potentially to the erosion protection apron placed at the culvert outlets.

Monitoring should address issues related to construction activities, the durability and permanence of the proposed culverts and associated maintenance arising from such monitoring. Debris load adjacent the log boom, the condition of the culverts over time and potential erosion at the outlet should be monitored.

Construction monitoring by a qualified Environmental Monitor, based upon specific environmental protection plans within an EMP as discussed in Golder 2010 (Appendix A) will be required as a condition of regulatory notifications and/or approvals. The EMP developed for WDS 6-2 must consider tasks specific to the construction plan within both this document, but also as proposed by the successful contractor awarded the work. For example, use of cellcrete as suggested in Section 7.8 should be addressed as a specific EPP addressing use of concrete and containment of associated waste and run-off within the EMP developed for this project. Note that the successful construction contractor may propose alternative methods of construction that may alter the extent of monitoring and relevant EPPs within the EMP. An Archaeological Monitor may or may not be required, depending upon final construction plans proposed by the contractor awarded through the tendering process. If the successful bid is able to limit construction activities to areas of low archaeological potential as described in this report, it is expected that work construction activities would follow chance find procedures similar to those identified in Appendix A of Golder 2010 rather than have a full time archaeological monitor on site.

Environmental related monitoring should focus upon changes to the habitat, such as establishment of both terrestrial and aquatic vegetation, but also upon use of the area by wildlife and fish. Monitoring habitat use by wildlife normally requires collection of baseline data for comparison between pre and post treatment conditions. Observations of bird use in this area is being collected by the MNO, however, the extent of this data is unknown. BC Hydro has also identified GMSMONS 15 as a 10 year study to examine the success and effectiveness of proposed WDS. Use by fish species is limited to the visual observations (Golder 2010) and minnow trap results completed by Golder in September of 2010.

7.10.5 Water Flow at Proposed Structures

Water current is expected to affect the proposed structure in three ways:

1) **Flows from Water Sources**

   The effects of water flow into the lagoon and through the culverts will be most severe during spring freshet and/or rain on snow events during the spring and fall. Water balance analysis was completed to address appropriate culvert sizing to ensure sufficient freeboard is available during high water period.

2) **Bidirectional flows during flooding and recession of water associated with annual operations of the reservoir**

   Flows will occur due to the flooding and recession of water associated with the operation of the reservoir. It is expected that these flows will be most severe during receding water levels because impounded water behind the dike is expected to have a higher hydraulic head. The velocity and duration of flow through the culverts will depend upon the differential in hydraulic head between the waters on each side of the causeway. Water balance analysis indicates the existing culvert size (1200 mm) accommodates this flow. Inflows will be less severe than outflows since the treatment area will always contain water, and thus there will be little or no hydraulic head during inflows from rising reservoir levels. Erosion control at the outflow of culverts will prevent ingress of erosion into the causeway.

3) **Wave wash**

Minimal erosion from wave wash is expected, supported by the fact that this causeway has been in existence for over 25 years with no obvious impacts to either the upstream or downstream interfaces of the structure resulting from wave action.

Wave erosion on the downstream interface of the causeway is limited (on average) to periods when reservoir levels approach or exceed 664.5 masl (June and January of each year). These conditions remain unchanged as a result of the proposed treatment.

The upstream interface of the causeway will be exposed to wave wash year round given the proposed treatment is to raise water levels to a meet a minimum drawdown elevation. Although the orientation of inundation area for the lagoon is north to south, the fetch is limited to less than 1 km, which tempers build up of waves.

7.10.6 Water Levels

Airport Lagoon has potential to vary in water level between the new invert elevation of 667.5 masl and full pool of 672.08 masl, over a potential range of 4.7 m. Under average operating conditions, reservoir levels most frequently reach 669 masl, and therefore the average rise in water level is expected to be about 1.5 m above the designed invert elevation of the newly placed culverts, peaking between late July and early September in most years.

Water levels over-topping the road causeway as a result of positioning a culvert at a higher invert elevation is not anticipated. The SWMM Stormwater Management Model conservatively estimates 3 m of freeboard at the causeway during the period of peak snow melt, which precedes peak reservoir elevations by 2 to 3 months.

7.10.7 Water Depths

The deepest part of the treatment area will be adjacent the causeway, in the old stream channel. At full pool (672.08 m), water depths in this area are about 9 m. When not under the influence of the reservoir, the deepest water in the treatment area will be approximately 4.5 m however, it is estimated over between 9.6 ha (667.0 masl) and 12.44 ha (667.5 masl) of the inundated area will have water depths less than 1 m.

7.10.8 Functional Criteria

The functional criteria for the culverts are to allow waters upstream of the causeway to rise until the culvert invert elevation has been reached. Culverts will accommodate bidirectional flow from both the lagoon water sources and the reservoir. The culverts will accommodate 1:100 flood events form the lagoon water sources. Retaining water on the upstream side of the causeway will create a permanent water body upstream of the causeway.

An additional functional criterion is to maintain the structure of the existing road surface with no impacts to its present industrial use by public and industrial vehicle traffic.

7.10.9 Wildlife Enhancement and Revegetation Works

Ancillary habitat work proposed for this WDS includes adapting the platform required for augering (if this method is used) into an area of raised land.

The following ancillary habitat works have not been considered in the costing of this WDS, but offer additional options to increase habitat complexity within the permanently wetted area of the lagoon. These options include creating a number of small hummocks of land throughout the existing alluvial plain of the Airport Lagoon that exceed the designed invert elevation for the new culverts. Such hummocks could be vegetated and offer perching or loafing areas at designed invert elevations, and shallow water areas when submerged by rising reservoir water levels. Such an ancillary habitat option will likely require additional regulatory review as discussed in section 7.9 above.

8.0 WDS 34 BEAVER POND

8.1 Description

WDS 34 Beaver Pond is located approximately 28 km north of Mackenzie (by road) on the east side of the reservoir, near an area known as Heather Point. This feature is an inlet and associated shallow basin embayment at the upstream end of the inlet. The inlet opens to Williston Reservoir to the northwest and is separated from the mouth of large bay fed by Tony Creek (hereafter called Tony Bay) to southwest by a low divide across Heather Point (Figure 10). Two beaver ponds are located in this divide.

8.2 Project Rationale

The proposed treatment is to construct a berm from geo-synthetic bags to trap water in the embayment, thereby acting as a water control structure to store water. This will create a permanently wetted body of water when reservoir levels are below the designed invert elevation of the berm (669 masl). Similar to WDS 6-2, the expectation at WDS 34 is that creating a permanent water level, drawdown will be minimized in the area, encouraging establishment of macrophytes and enhancing the riparian zone adjacent the perimeter of this new water body. This treatment will benefit wildlife such as wading birds and herptiles and potentially fish.

8.3 Project Objectives

The treatment at WDS 34 is designed to maintain a minimum water level at 669 masl (Appendix B – Design Drawing -3). This elevation represents a compromise which maximizes shallow water habitat less than 1m, reduces the range of drawdown in the treatment area, and minimizes the amount of time the area is flooded. The proposed treatment will facilitate aquatic productivity in an area which is otherwise dry at reservoir elevations below 666 masl. Like WDS 6-2, stabilizing a minimum water level at 669 masl will provide wetland habitat for amphibians during the spring. Creating a permanently wetted area should facilitate establishment of submergent and emergent vegetation and a resilient and more vigorous riparian zone adjacent the perimeter of the treatment area.

Another objective of this project is to test the use of geosynthetic bags as water control structures from locally available silt and sand as a means for impounding water. If successful in impounding water and able to withstand the harsh environmental conditions in the Williston Reservoir, geosynthetic bags may have broader applications throughout the reservoir.

LEGEND

Major Contour (1m Interval):	
Minor Contour (0.25m Interval):	
Bushline:	
Creek/ Edge of Water:	
Spot Elevation:	
Proposed Structure:	
Low Archaeological Potential	
Unsurveyed Area	
High Archaeological Potential	

REFERENCES

1.) **COORDINATE REFERENCE:** UTM ZONE 11n, NAD83
MAP REFERENCE: Base mapping provided by Vector Geomatics Land Surveying Ltd
IMAGERY: Base imagery provided by BCHydro.

0 15 30 45 60 75
METRES

PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
AN ORTHOPHOTO OF WDS 34 BEAVER POND SHOWING FEATURES AND AVAILABLE BATHYMETRY

Golder Associates
Kamloops, BC

PROJECT No.	10-1492-0076	
DESIGN	MG	26-NOV-10
CADD	BKL	13-DEC-10
CHECK	MG	13-DEC-10
REVIEW	CM	16-MAR-11

FILE No. 1014920076_site6-2
SCALE AS SHOWN REV. 0

FIGURE 10

N:\Graphics\2010\1492 Biosciences\10-1492-0076 BCH Williston Wetland Demo Sites\CAD\ Drawing file: 1014920076_Site34.dwg Mar 16, 2011 - 4:50pm

8.4 Current WDS Conditions

Similar to many other small embayments throughout the Williston Reservoir, habitat conditions at WDS 34 Beaver Pond vary with reservoir levels. The area is completely submerged at water levels in excess of 670 masl, but gradually dries out as the reservoir recedes. During the September 2010 site visit, most of the established vegetation was terrestrial in nature as the proposed treatment area had remained free of water throughout the summer. The same area was covered with a thin layer of algae near seepage sources, when surveyed in June of 2009 (Golder 2010), but was otherwise sparsely covered by vegetation.

In June of 2009, water sources included various seepages from the shoreline adjacent the embayment, and a small ephemeral stream flowing from the beaver ponds. In September of 2010, the area was virtually dry with the exception of the primary channel draining the beaver ponds, which although showing no overland flow, still exhibited signs of ground water flow near it's confluence with the reservoir (Appendix A - Photographs 14 and 15).

Topographic survey datum confirms previous visual estimates from orthophotos, specifically; the invert elevations for the beaver dams are near 670 masl (Golder 2010). The upper dam has an invert elevation of 670.3 masl, whereas the lower dam's invert elevation is 669.7 masl. Both beaver ponds were full of water in June 2009, whereas only the upper most beaver pond had water in it in 2010, but 1.5 m below the crest of the upper dam (668.8 masl) (Appendix A - Photographs 16 and 17).

Elevations of these beaver dams, combined with visual observations and orthophoto data, suggest that WDS 34 may be prone to flooding from the reservoir from two directions at water levels at or approaching full pool (672.08 masl). Ingress of water is normally from Parsnip Reach, south east through the inlet leading to WDS 34, but water may also flow northwest over the divide between WDS 34 and Tony Bay.

Old cut blocks and associated access roads and trails servicing these cut blocks may provide land access to within 200 m of the WDS. This road is overgrown and could not be used to access WDS 34 during the 2010 survey by a pickup truck. Consequently, construction of WDS 34 requires that the road is either reopened, or equipment is barged to WDS 34.

In addition to beaver structures, shore birds (family Raillidae) and moose sign were seen at Beaver Pond in 2009 (Golder 2010). Western toad (*Bufo boreas*) were found at a site immediately southeast of WDS 34, but within Tony Bay. Consequently, WDS 34 is well positioned to provide habitat for western toad. In 2010, a common garter snake (*Thamnophis sirtalis*) was also captured at WDS 34.

The functional range of elevations for wetted habitat within the proposed treatment area of WDS 34 is 666 to 670 masl (Figure 11). Much of the flatter topography of the embayment, opposed to the narrow steep sided foreshore of the inlet leading to the embayment, lies between 668 and 669 masl as a bench feature on the north eastern side of the WDS (Appendix A - Photograph 19 and 20, Figure 11).

By virtue of the narrow inlet leading the embayment, the treatment area is well protected from wind and wave action in the main arm of Parsnip Reach, as evidenced by relatively little debris observed along the shores in this area and few signs of erosion.

Vegetation observed growing within the treatment area in 2009 was restricted to surface algae in the low lying areas and some grass and riparian shrubs (willow) along the perimeter near the 670 masl elevation. In 2010, perimeter vegetation was supplemented with sparse growth of grass and some sedge within the embayment.

8.5 Land Ownership

The treatment area is within the drawdown zone of the reservoir, and is considered crown land. Road access to the area is through a combination of Park Land, crown land and possibly licensed tenure areas.

8.6 Physical and Hydrological Conditions

The entire inlet, including WDS 34 Beaver Pond, is approximately 450 m long by 140 m wide at its widest point. The first 300 m of the inlet has steep foreshores, and is approximately 140 m wide near its mouth before narrowing to 70 m prior to the embayment, the focus of WDS 34. The proposed water control structure will be positioned just beyond the narrowing of the inlet, or about 300 m from its confluence with Parsnip Arm of Williston Reservoir. The relative shallow sloped, level widening that forms the embayment is approximately 130 m long by 140 m wide, and occupies an area of about 2.3 ha.

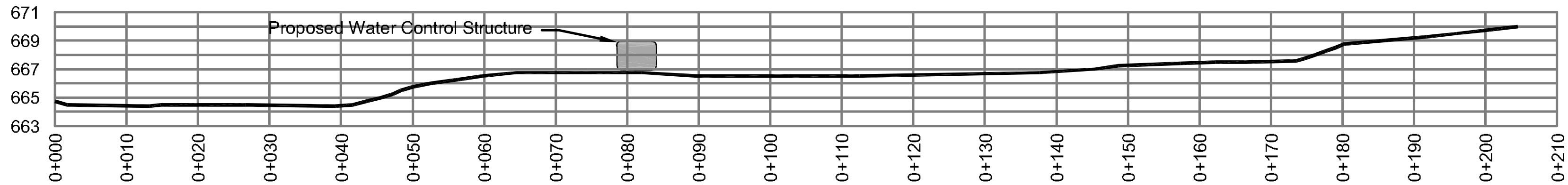
A small ephemeral stream originating from upland beaver ponds and a series of small ephemeral seepages drain into this embayment during the spring and into the early summer. Only the ephemeral stream showed any sign of water during the September 2010 site visit.

A rudimentary water balance completed by Golder (2010) indicated inflows into WDS 34 are suitable for meeting the objective of impounding water during most years. The ephemeral stream flowing into WDS 34 is small, with a drainage area of about 0.5 km^2. The berm anticipated for this WDS will be “L” shaped, with the long end of this “L shape” about 60 m long and the short arm about 45 m long, totalling 105 m (Appendix B - Design Drawing -3). The berm will be about 3 m high, with an invert elevation of 669 masl. The previously completed water balance (Golder 2010) considered an invert elevation of 671 masl for the proposed water control structure, and estimated that inundation will be achieved for most of the year, but will drop to a maximum of 5 cm below the berm crest during dry years. This year’s observation of a 1.5 m drop in the upper beaver pond from the upper beaver dam crest suggests drops in water elevation when this WDS is not recharged with water from the reservoir may be larger than that estimated from the water balance. Still, the lower design invert elevation (669 masl) should be able to be maintained during most years, particularly considering flood water contributed when reservoir water levels exceed 669 masl. On average, flooding is expected for most years under the present reservoir operating regime during the summer months (Table 10), although the duration and extent of this inundation will vary from year to year. Inundation by the reservoir should facilitate maintenance of water levels in the area, and facilitate establishment of vegetation in and around the treatment area.

8.7 Description of Work

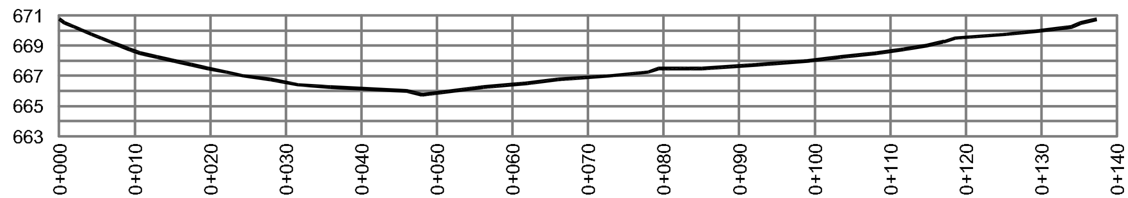
8.7.1 Approaches

WDS 34 is a water control structure, to be constructed from the positioning of a series of silt and sand filled geosynthetic bags. Silt and sand to fill these bags will be sourced from the reservoir foreshore, delivered from a land based dredge. The design invert elevation for the water control structure is approximately 669 masl, not accounting for potential settling. The amount of settling can not be estimated at this time since WDS 34 could not be accessed without clearing the old logging road leading to the adjacent cut block. Consequently test pits could not be excavated to conduct geo-technical analysis of the underlying soils. Regardless, a final invert elevation between 668 and 669 masl will still meet the objectives of the proposed treatment.



SECTION A

VERTICAL SCALE 1:500 HORIZONTAL SCALE 1:1000



SECTION B

VERTICAL SCALE 1:500 HORIZONTAL SCALE 1:1000

REFERENCES

1.) **COORDINATE REFERENCE: UTM ZONE 11n, NAD83**
MAP REFERENCE: Base mapping provided by Vector Geomatics Land Surveying Ltd

PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
ELEVATION PROFILES OF WDS 34 BEAVER POND ALONG CROSS SECTIONS A AND B

Golder Associates
Kamloops, BC

PROJECT No.		10-1492-0076	FILE No.	1014920076_site34
DESIGN	MG	10DEC10	SCALE AS SHOWN	REV. 0
CADD	BKL	13DEC10	**FIGURE: 11**	
CHECK	MG	13DEC10		
REVIEW	CM	16-MAR-11		

Table 10: Summary of water level inundation by month for the Williston Reservoir.

Month /masl	Percent of Time Water Level is at or Greater Than Identified Reservoir Elevations (masl)											
	662	663	664	665	666	667	668	669	670	671	672	672
April	16.9%	9.3%	7.2%	3.3%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
May	24.3%	13.7%	8.9%	4.8%	4.0%	3.1%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
June	85.8%	75.0%	64.3%	54.1%	41.0%	30.4%	19.2%	12.7%	6.0%	1.9%	0.0%	0.0%
July	100%	100%	96.6%	87.8%	83.0%	76.7%	63.2%	45.9%	28.2%	21.6%	8.0%	5.7%
Aug.	100%	100%	96.7%	93.3%	85.4%	80.8%	73.3%	60.0%	38.3%	26.7%	11.3%	10.5%
Sept.	100%	99.3%	96.7%	95.6%	83.2%	78.3%	73.4%	53.0%	42.0%	27.6%	6.7%	4.2%
Oct.	100%	96.7%	96.7%	93.5%	81.6%	78.2%	67.5%	50.0%	35.1%	15.9%	1.2%	0.3%
Month /masl	**Average Number of Days Water level Exceed Identified Reservoir Elevations (masl)**											
	662	**663**	**664**	**665**	**666**	**667**	**668**	**669**	**670**	**671**	**672**	**672**
April	5.1	2.8	2.2	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
May	7.5	4.2	2.8	1.5	1.2	1.0	0.2	0.0	0.0	0.0	0.0	0.0
June	25.7	22.5	19.3	16.2	12.3	9.1	5.8	3.8	1.8	0.6	0.0	0.0
July	31.0	31.0	29.9	27.2	25.7	23.8	19.6	14.2	8.7	6.7	2.5	1.8
Aug.	31.0	31.0	30.0	28.9	26.5	25.0	22.7	18.6	11.9	8.3	3.5	3.3
Sept.	30.0	29.8	29.0	28.7	25.0	23.5	22.0	15.9	12.6	8.3	2.0	1.3
Oct.	31.0	30.0	30.0	29.0	25.3	24.2	20.9	15.5	10.9	4.9	0.4	0.1
Total	161.3	151.3	143.1	132.6	117.0	106.6	91.2	68.0	45.9	28.7	8.3	6.4

Access to the area can be gained either by opening the logging road leading to overgrown cut blocks from the main forestry trunk road from Mackenzie or by barging equipment to the WDS. Regardless of barge or road access, about 200 m of undisturbed, primarily coniferous forest will have to be cleared as an access trail to WDS 34. The steep foreshore of the inlet leading to the treatment area may also provide access to the WDS).

8.7.2 Methods

The combination of a small bulldozer and excavator will be required to provide access for trucks, personnel, materials plus support for the dredge equipment at the WDS location. Prior to placement of the geosynthetic bags, the excavator will install a small clay or silt plug into the existing creek channel and the bulldozer will level this area to 666 masl for placement of the empty bags. The next operation is to set two 3.0 H x 7.3 wide geosynthetic bags, one which is 60.9 long and one which is 45 long at the prepared zones (Appendix A - Photograph 20, Appendix B - Design Drawing -3). These bags will be connected by a 150 mm HDPE fill pipe to an HY 85 Hydraulic Dragflow dredge pump in close proximity, downstream, to the bags in preparation for filling.

The geosynthetic bag filling rate will vary depending on the ratio and volume of solids pumped, the dredge will be turned on and off during the filling operation to let the bags drain as required and prevent damage from over pressurization. The geosynthetic bags will also be allowed to dewater overnight. The filling operation for the two tubes is expected to take three to four days.

After the completion of the filling operation all equipment will be demobilized and the area will be surveyed for completion of the as built drawing. Remaining excavated material from ground preparation should be contoured against the upstream side geo-synthetic bag to create a more natural look and slope that can act as a base for natural accumulation of sediment and organics to facilitate colonization of vegetation.

8.7.3 Materials

The proposed geosynthetic bags will be supplied by Maccaferri Canada (MacTubes ™) made from a 2 Ply OS500pp Flint Technical Fabric designed for installation in severe arctic conditions. Appendix H provides technical specifications for this product. Additional information is included in Appendix H regarding the performance of geo-synthetic bags on the GISSAC project (Eureka 2009) in arctic and ice conditions.

Macaferri **requires 12 to 14 weeks for ordering of custom built geosynthetic bags.**

8.7.4 Cost Estimates

The estimated cost to complete WDS 34 is $228,476 details of which are provided in Appendix G. A summary of these costs are as follows in Table 11.

A 15% contingency has been added to the estimate to reflect the accuracy of the estimate and the potential for changes in the costs of labour and materials between now and when construction occurs, and to accommodate any potential over run. The size of the contingency is subject to BC Hydro internal processes when considering tendering of this work.

Cost of HST and for a client representative such as an engineer is not included in this estimate. A preliminary cost for an environmental monitor (EM) has been included, recognizing the EM commitment can vary depending upon selection of a contractor and the construction methodology and plan proposed by this contractor, not to mention variation in rates between firms providing environmental monitoring services. The cost for a single day of an archaeologist's time **has been included to delineate areas of high potential on the ground prior to start of construction but costs for an Archaeological Monitor have not been included** in the cost estimate since the proposed construction plan anticipates no further need for archaeological monitoring based upon areas assessed to date. A requirement for further archaeological work and related regulatory permitting will be dependent upon the bids received upon tendering that may consider alternative approaches to completion of this work. As with the EM, the cost of the Archaeological Monitor (AM) can vary between firms providing such services.

Details of cost estimates are provided in Appendix G.

Table 11: Estimated costs to construct WDS 34 [1].

Item	Cost
Mobilization/Accommodation	$37,700
Geosynthetic Bags	$100,000.
Production Dredging	$47,200
Environmental (Permitting and Monitoring)	$12,475
Archaeology	$1,300
15% Contingency	$29,801
Total [1]	**$229,476**

[1]**Notes**: HST not included

Cost for client representatives (on site engineer, environmental monitor and additional archaeological studies) are not included

The above estimate assumes access of equipment to WDS by either overland via existing road network or by barge. Permitting requirements may be less complex if equipment is barged to the WDS, but this access method may add some cost to mobilization of equipment to the WDS.

Cost of HST and for client representatives, such as an engineer, environmental monitor or additional archaeological studies **are not included in this estimate**.

8.8 Considerations

8.8.1 Reservoir Operating Regime

Based upon historic mean annual water levels for the Williston Reservoir, flooding will exceed the proposed invert elevation of the water control structure (669 masl) from approximately July 26 to September 10 (47 days) under the average operating regime (Figure 12). Table 10 (Section 8.6) summarizes of the average number of days the 669 masl water level is exceeded by the reservoir operating regime on a monthly basis.

8.8.2 Construction Related Impacts to Wildlife

Conflicts with wildlife values at WDS 34 are expected to be minimal and temporary. As with WDS 6-2, noise during construction may temporarily deter some wildlife from entering the area. Disturbance to beavers that may still inhabit the upland ponds is expected to be restricted to noise, although it is unknown if beavers still reside in the area. Aside from the existing dams and a beaver lodge, beaver were not sighted during either site visit, and may no longer utilize the area. Regardless, construction activities will only occur through the day, whereas beavers are typically most active between dusk and dawn. It is possible that beavers, may utilize the proposed geosynthetic berm as a base to construct a new dam at an even higher elevation that that proposed. Such an impact would not be considered detrimental to this WDS.

Seasonal mudflats within the treatment area will become inundated, but mudflat created around the margin of the treatment area will persist except during periods of freezing and/or the reservoir exceeding 669 masl. A solitary rail was (family *raillidae*) was observed utilizing mudflats along the basin of the area in June of 2009, but not in September of 2010.

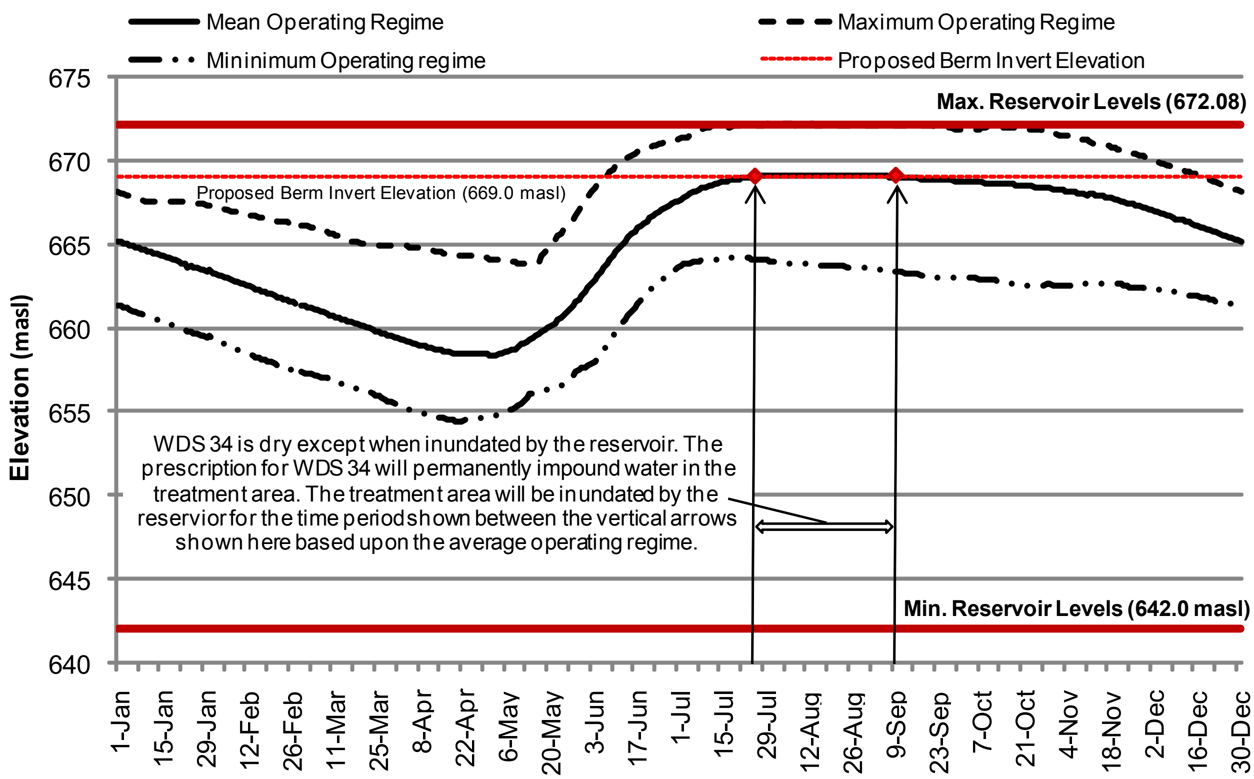


Figure 12: Illustration of how the proposed impoundment of water resulting from a berm created by positioning of geo-bags at WDS 34 will be influenced by the reservoir operating regime when compared to the Williston Reservoir hydrograph for the period 1984 to 2010.

8.8.3 Construction Related Impacts to Aquatic Life

Short Term Impacts

Short term impacts to fish habitat may result during construction related activities such as dredging required to fill the geosynthetic bags. The primary concern is suspension of sediment in the foreshore and the potential to impinge or suck up rearing cyprinids or other fish species that may be passing through foreshore habitat. The foreshore of Williston Reservoir proximate to WDS 34 offers marginal fish habitat since there is a lack of vegetation and the substrate is fine sand and silt with no gravel or rock in the substrate. As such isolation of the dredge area and potentially fish salvaging from this contained area should be considered prior to commencement of work. Some LWD with the wetted perimeter of the inlet prior to reaching the location for the proposed water control structure may provide habitat for rearing fish, and disturbance or removal of such LWD should be avoided during dredging. Short term impacts would be mitigated through appropriate BMPS identified in and EMP and the presence of an EM as discussed in Golder (2010) and in Section 8.9.1 below.

Long Term Impacts/Benefits

The primary long term impact resulting from the proposed works is potential for entrapment of fish which migrate into the area during periods of high water. This is only a concern if seepage occurs and thus the area experiences dewatering, with associated observations of fish mortality becoming apparent during monitoring programs. Overtime, natural accumulations of sediment and organics against the structure are anticipated to reduce potential for seepage (Section 8.9.8 below).

The primary focus of this WDS is not to increase fish habitat and/or fish rearing opportunities as much as it is to determine if the treatment meets objectives of creating wetland habitat. However, the area may provide seasonal rearing and foraging opportunities to rearing fish if water depths of 3m can persist within the treatment area.

8.8.4 Archaeology

During the field investigation at WDS 34, a surface inspection was done to identify any archaeological material. Exposures, including inundated soils, banks adjacent of the reservoir draw down zone, and tree stumps in the proposed treatment area were also examined. No archaeological material was identified during the field visit.

The banks along the inlet leading to the WDS (embayment) and most of the proposed treatment area are steeply sloped (> 15%). Terrain within the basin of the treatment area is gently undulating, with a small discrete ridge to the northeast of the creek (Appendix A - Photographs 18 and 19). Surface materials are exposed and affected by erosion due to seasonal flooding by the reservoir. Surface sediments consist primarily of silts, with some sand and clay, and minimal clasts.

The location of the short access trail to the WDS is currently undetermined, as discussed in section 8.71. Regardless, the archaeological potential of both proposed routes, which traverse short sections of undisturbed forest, will need to be determined prior to construction of this trail.

8.8.5 Public Safety

The primary concern related to public safety is related to boat navigation and the NWPA. The water control structure at WDS 34 Beaver Pond can become submerged at certain water levels. Although a “blind” inlet, it is possible that this WDS could present an obstruction to boat traffic navigating into this inlet when reservoir levels exceed the invert level of the proposed structure.

8.8.6 Recreation

There are no recreational opportunities gained or lost by construction of WDS 34 Beaver Pond.

8.8.7 Other

There may be opportunities for joint funding as identified in Section 9.3 below.

8.9 Detailed Engineering and Construction Plan

8.9.1 Regulations

Golder believes this project will require an approval under Section 9 of the *Water Act* and Part 7 of the *Water Act* Regulations because of the impoundment of water and associated construction requirements (Table 12). Placement of the geosynthetic bags can be done primarily in the dry, although a small flow should be expected from the ephemeral stream during the spring that may require a temporary diversion. Filling of these bags requires a fluid slurry from dredging silt and sand from an isolated section of the lake foreshore to fill geosynthetic bags. Finally, because water storage will be in excess of 1 m in height (although the impoundment is relatively small), the *Dam Safety Act* may when combined with in stream activities may require an approval opposed to notification.

Table 12: A summary of required permits for completion of proposed treatments at WDS 34 (1).

No.	Name	DFO Section 35(2)		NWPD		Water Act Section 7		Water Act Section 9		MoF	HCA
		Notify	Approve	Review	Approve	Notify	Approve	Notify	Approve	Road Use Permit	
34	Beaver Pond		x?		x?	x			x?	n/a(1)	AOA AIA(2)

(1) Park use permit likely required for access trail to WDS 34 from the old logging road and for clearing vegetation from the old logging road bed.

(2) Requirements for permitting related to any change in proposed works that result in, as an example, expansion into areas of high archaeological potential (lay down areas, storage areas etc.) necessitates final determination of trail routes from barge or road access to WDS 34

? Decision for notification opposed to approval will require review by relevant agency to verify. Potentially a letter of advice may be issued.

Developing an appropriate Environmental Management Plan (EMP) and associated Environmental Protection Plans (EPP) for specific construction related activities at WDS 34 should be included with the notification/approval process to the MNRO. This assures the regulatory body a means of verifying appropriate BMPs will be in place that are sufficient to mitigate against identified short and long term impacts arising from this work. Further details regarding the need for an EMP are discussed in Section 8.9.4 below and by Golder (2010).

A referral to the DFO of the proposed works is suggested. Although a Regional Operational Statement (ROS) is in place for dredging, proposed dredging at WDS 34 does not fit within the intent of this ROS, hence referral and potentially seeking a letter of advice from the DFO is recommended.

A fish collection permit for scientific purposes should be obtained for any proposed fish salvage work, as may be required to isolate the dredge area Section 9.8.3.

Wild life salvage permits may be required from MNRO should there be a need for salvaging of wildlife, such as amphibians, but such salvaging is not anticipated for this WDS considering it is presently a dry basin.

Dredging, but also placement of proposed geo-synthetic bags at this WDS will also need to be referred to the Navigable Waters Protection Division (NWPD). The treatment at WDS 34 Beaver Pond is unlikely to substantially interfere with navigation, rather, this project may be considered a minor works and therefore the NWPD may complete a review under Section 5(3) of the NWPA opposed to requiring an approval. This distinction can only be made after referral to a representative of the NWPD.

Access through the existing roads has to be verified with BC Parks, and may require obtaining a park use permit from the MNRO. At present, part of the area which this road crosses appears to be within park land; however, orthophotos (Google World) suggests logging is also ongoing in this area. Under MoF jurisdiction, such changes and use of the road by industry would either require a special permit or obtaining an authorization from the MoF, assuming replanted/regrowth of trees are large enough for the cut blocks to revert to the crown. Otherwise permission to access the area may be required from the licensee working the cut blocks. A road use permit is also required by all industrial users of Forest Service Roads, in this case, the east side Parsnip Trunk road. Barging equipment to WDS 34 will not require a road use permit, although an access trail from the Parsnip Reach foreshore to the construction site may require a cutting licence from the MoF and may have other environmental implications related to the breeding bird window and Section 7 of *Water Act* regulations.

If the treatment area is expanded beyond the area surveyed during the 2010 PFR (Figure 9), then the completion of an AOA at WDS 34 will determine if further archaeological assessment such as an AIA is required. Completion of an AIA would require a permit from the Archaeology Branch. An important note is that the forested area, which was not surveyed at WDS 34, may contain as of yet un-identified areas of high archaeological potential which may be affected when building the access trail or other construction activities. An AOA is recommended in these unsurveyed areas prior to development.

8.9.2 Project Area

The entire embayment within the proposed treatment area is approximately 2.3 ha; however, the expected area of inundation from the proposed treatment is estimated to be about 0.9 ha. The footprint of the proposed water control structure at WDS 34 is approximately 730 m^2, representing the area occupied by the geosynthetic bags.

Some disturbance (tracking and ploughing) to dredge sand and silts along the foreshore of the reservoir is expected. Given fine sand and silt substrate in this area is highly mobile, such ground disturbance will likely not be apparent after a cycle of flooding and recession by the reservoir.

The old logging road leading to WDS 34 is approximately 13 km long, half of which would have selective removal of overgrown trees within the road bed to walk in tracked equipment. The amount of disturbance associated with this activity is difficult to anticipate as the condition of the road and the size regrowth is unknown. Similar disturbance is expected during creation of access trails to the foreshore of WDS 34 either from the overgrown logging road or if barge access occurs, from the reservoir foreshore. The expected area of disturbance is expected to be less than 1500 m^2.

8.9.3 Design Life

The geosynthetic bags supplied by Macaferri are made from Flintex 2 ply OS500pp high tenacity polypropylene fabric designed to retain shape and be inert to biological degradation and resist most naturally encountered chemical alkalis and acids. The life span indicated by the supplier of this product is 10 years, but expected lifespan is 50 years or more (Pers. Comm. John Smith GAIA. Dec. 2010).

8.9.4 Maintenance and Monitoring

No maintenance issues are anticipated at this time. However, post construction monitoring should focus upon the durability of the structure, the ability of the structure to retain water, colonization of the wetted habitat and wetted perimeter of the treatment area by vegetation, and use by wildlife and fish. In particular, monitoring fish use should occur to identify potential issues of entrapment and/or fish mortality. BC Hydro has identified GMSMONS 15 as a 10 year study to examine the success and effectiveness of proposed WDS. Use by fish species is limited to the visual observations (Golder 2010) and minnow trap results completed by Golder in September of 2010.

As discussed in Section 7.10.4, provision of a Qualified Environmental Professional as an Environmental Monitor will be a condition in the regulatory notifications and/or approval process. The EMP developed for WDS 34 must consider tasks specific to the construction plan within both this document, but also as proposed by the successful contractor awarded the work. For example, use of a shovel dredge and related dredging activities as suggested in Section 8.7.2 should be addressed as a specific EPP within the EMP. Again, it is important to note that the successful construction contractor may propose alternative methods of construction that may alter the extent of monitoring and relevant EPPs within the EMP specific to WDS 34. An Archaeological Monitor may or may not be required, depending upon final construction plans proposed by the contractor awarded this work through the tendering process. If the successful bid is able to limit construction activities to areas of low archaeological potential as described in this report, it is expected that work construction activities would follow chance find procedures similar to those identified in Appendix A of Golder 2010 rather than have a full time archaeological monitor on WDS.

8.9.5 Water Flow at Proposed Structures

Water current is expected to affect the proposed structure in three ways.

1) **Flows from Water Source**

   Water flow from ephemeral stream flowing over the bags. This is expected to be minor given the small flow from the ephemeral stream (Golder 2010), and the low gradient of this stream.

2) **Bidirectional flows during flooding and recession of water associated with annual operations of the reservoir**

   Flows will occur due to the flooding and recession of water associated with the operation of the reservoir, but is again expected to be minor.

3) **Wave wash**

   The effects of wave wash upon this WDS are minimized by the protected nature of the inlet, almost perpendicular (north west) to the predominant north – south and south – north wind direction experienced in Parsnip Reach.

8.9.6 Water Levels

Water level at WDS could vary as much as 3m, between the treatment elevation of 669 masl and full pool of Williston Reservoir 672.08 masl. Under the average, reservoir operating regime 669 masl can be exceeded from May to November and the percentage of time reservoir levels exceed 669 masl each month ranges from 12.7% of the time in May to 60% of the time in August (see Table 10 – Section 8.6).

8.9.7 Water Depths

The deepest part of the treatment area will be 3 m, adjacent to the centre of the structure. At full pool (672.08 m), water depths in this area could reach 6m. When not under the influence of the reservoir, an estimated 0.37 ha (40%) of the inundated treatment area will have water depths less than 1m.

8.9.8 Geotechnical Information

Due to access constraints, a geotechnical investigation was not conducted at WDS 34. Consequently, subsurface information is not available for the WDS. Consideration may be given to excavating one (1) to two (2) test pits at the WDS to assess the near surface soil and groundwater conditions prior to construction. The surficial soils at the WDS typically comprise silty sand to sand, and some silt based on visual observations. Such material may facilitate leakage below the water control structure should these deposits extend below the base of the water control structure. However, it is anticipated that over time, natural processes such as the establishment of vegetation will decrease the potential for leakage.

In addition, should clayey deposits be encountered at depth during a subsurface investigation, consideration may be given to the use of these deposits for plugging and levelling the ephemeral stream channel.

It is understood that the water control structure can accommodate some settlement. If settlement is a concern, a test pit investigation may be appropriate for assessing the susceptibility of the near surface soils to settlement.

8.9.9 Functional Criteria

The functional criteria for the water control structure at WDS 34 are to impound water upstream of structure until the invert elevation (669 masl) has been reached. Water will be allowed to freely flow over the structure at full impoundment, thereby creating a permanently inundated area when the reservoir level is below the invert elevation of the culverts.

8.9.10 Wildlife Enhancement and Revegetation Works

Ancillary habitat work proposed for this WDS could include anchoring of large woody debris around and within the treatment area. Such debris should be anchored and placed prior to construction of the water control structure and subsequent inundation.

9.0 RECOMMENDATIONS

The following recommendations are made for completion of the proposed WDS and/or consideration in building of future WDS.

9.1 Public/First Nation Consultation

Conceptual ideas and project objectives related to GMSWORKS 16 and 17 were discussed amongst stakeholders, First Nations and Regulators as part of the earlier Water Use Planning process for Williston Reservoir (PWUP 2003). However, specific plans and related locations of proposed WDS identified in this text, and the process followed in selecting these WDS (Golder 2010), have yet to be introduced to various interested parties involved in development of the PWUP. It is recommended that some opportunity for feedback be developed from these parties prior to construction of either of these WDS. Golder's experience from similar work (CLBWORKS 29A) completed in Revelstoke Reach of the Arrow Lakes Reservoir (Golder 2009a, Golder 2009b) indicates public consultation is an important step towards acceptance of proposed developments. Such consultation has the potential to facilitate regulatory approval, and garner First Nation and local stakeholder support. A better understanding of the process followed, not only in the selection of potential WDS but eventual design and construction of such works by stakeholders and First Nations may also aid in the selection and development of future opportunities.

In addition to the recommendation to seek feedback from local interested parties is the aspect of First Nation involvement in the field work associated with such projects. As identified in Golder 2010 (GMSWORKS 16), a prudent practice that is consistent with the British Columbia Association of Professional Archaeologist (BCPCA) Code of Conduct is the Responsibility to Cultural Groups. In addressing this responsibility, Golder routinely invites representatives of the local First Nations to participate in the fieldwork portion of an archaeology project. However, given direction from the BC Hydro contract liaison, combined with the nature of the proposed scope and timing of fieldwork, local First Nations were not invited to participate in the field components of either GMSWORKS 16 or GMWORKS 17. As such, local First Nations have had no opportunity to review these WDS locations or raise archaeological concerns they may have. In order to address this concern, Golder recommends that input from the appropriate First Nations be sought so that any archaeological concerns regarding candidate WDS can be identified and addressed. It is Golder's understanding that the study area is located within the traditional territories of the Tsey Keh Dene Band, West Moberly First Nation, Halfway River First Nation, Saulteau First Nation and Mcleod Lake Indian Band.

9.2 Joint Funding Opportunities

There may be opportunities for additional funding from other government agencies or industries working in the Williston Reservoir area to share costs in completion of the WDS.

An immediate consideration is commencement of discussions with the MoF since the existing culverts are near the end of their life and exhibiting failure. Consequently, upgrades and/or replacement to the existing structures will likely be required in the near future. Since the causeway is a forest service road under the jurisdiction of the MoF, it is recommended that BC Hydro enter into discussions with the MoF regarding potential for sharing the cost of replacement and upgrades to this structure.

In addition to potential cost sharing arrangements with the MoF, Golder has been approached by Talisman Energy Ltd. which is seeking opportunities to mitigate against potential impacts to aquatic habitat from water intake work they are completing near Geddes Bay of Peace Reach. Golder has already facilitated continued discussions between BC Hydro and Talisman representatives through exchange of contact information. It may prove beneficial to both BC Hydro and Talisman to work together in a joint funding option to build either one or both of the proposed WDS.

Future WDS that BC Hydro may anticipate constructing based upon the success of GMSWORKS 17 may benefit from joint funding opportunities. Potential for joint funding is linked to consultation initiatives with stakeholders, industry and First Nations (Section 9.1 above). Although many such groups often look to BC Hydro for funding, there are sometimes projects that have been discussed in other circles, or initiatives started but never completed, that through open house demonstrations (Golder 2009b) and/or other means of consultation (Golder 2009b) may be able forge links to supplemental funding sources. For example, GMSWORKS 16 identified that the MoF at one time discussed raising a Forest Service Road near the end of Mugaha Bay as this road is often impassable when reservoir levels are high, making access to a locally popular berry picking area inaccessible (Golder 2010, Appendix B). Raising the road even slightly could be beneficial to Mugaha Bay 1 (Site 39), a locally important wetland used for public awareness by the Mackenzie Nature Observatory (MNRO) through their migratory bird tagging station. Ducks Unlimited Canada, MNRO and the Peace Williston Fish and Wildlife Compensation Fund have all looked at potential works at this site in past years (DUC 2009, Courbold 1991a, 1991b and 1992).

9.3 Work Windows Relative to Williston Reservoir's Operating Regime

BC Hydro is well aware of issues of access to foreshore areas of Williston reservoir related to the reservoir operating regime and as such, the difficulty in completion of work within lower elevations of the drawdown zone. This includes costs to complete construction typically related to the difference between working at WDS when dry opposed to wet.

For the identified projects, it is important to anticipate construction periods as early in the spring as possible. It is difficult to predict from year to year if a fall construction period will be available based upon weather and reservoir conditions. While some work may be completed during the winter, issues of snow clearing and ground frost (particularly as it relates to compaction) is required.

A spring construction period requires that construction occur outside the fish work window for all species in the Williston Reservoir (July 15 to August 15 – Appendix I). This period corresponds with peak water elevations within the Williston Reservoir when the Wetland Demonstration sites are completely inundated. The identified work window could be expanded if only some species utilize the areas in and around each WDS. For example, if only rainbow trout and whitefish utilize the area, the work window could extend from July 15 to September 1, but these dates still correspond to high water periods in the reservoir. By planning spring construction, works can be completed in the dry, lessening the need to add complexity to regulatory issues associated with completing work during higher water levels. Some work may otherwise require an approval, rather than notifications if anticipated construction can not be completed in the spring. Timelines for review of in stream works by regulatory agencies can also increase substantially when approvals are required. While the time to compile information and submit applications for approvals is relatively short (2 to 3 days), the timeline for processing can be substantial. Typically, the MNRO works on a 45 day referral period for review by First Nations, but a review by the DFO or NWPD for a job requiring approval can take 6 months or more based upon the complexity of the project. Consequently, it is also important not to underestimate timelines regulatory agencies take even to review applications for notifications, let alone approvals of in stream works. Additionally, clearing of shrubs and trees (if required) should be outside the breeding bird window identified for the Parsnip Reach area (May 1 to July 1).

Finally, the ability for BC Hydro to tender and award construction contracts does not always mesh with the identified construction period, particularly when recommended construction methods require special order equipment or materials. For example, Macaferri **requires 12 to 14 weeks for ordering of custom built geosynthetic bags**. Culverts for WDS 6-2 will also have to be pre-ordered and delivered on site in anticipation of an early spring construction period.

9.4 Archaeological Considerations

The assessment of archaeological potential of the proposed WDS in the inundation zones of Williston Reservoir was hampered due to changes to the landscape that have occurred as a result of construction of the reservoir. Flooding has caused both deposition and erosion of sediment to occur throughout the inundation zone, which has altered the landscape and affected terrain and other characteristics that are commonly used to determine archaeological potential. In the event that construction activities are extended beyond those surveyed during the 2010 PFR, additional archaeological work may be required to address additional archaeological concerns caused by land-altering activities. Golder (2010 - Section 3.2.3) further discusses considerations for archaeological potential.

10.0 CLOSURE

Golder trusts this report meets the needs of BC Hydro in construction of a Wetland Demonstration Site in Parsnip Reach of Williston Lake. Further questions and/or requests for material can be made to Mr. Mike Galesloot of Golder at (250) 828-6116.

GOLDER ASSOCIATES LTD.

Mike Galesloot, R.P.Bio. Senior Fisheries Biologist	Curtiss McLeod, P. Biol. Principal/Senior Fisheries Biologist

MG/CM/aw

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APPENDIX A

Site Photographs

Photo 1: Surveyors from Vector completing topographic surveys of the basin at Site 34.

Photo 2: A mini-excavator was used to dig test pits at the base of the north side of the causeway.

Photo 3: Conducting a percolation test at Site 6-2

Photograph 4: View downstream (south) from the Airport Lagoon causeway towards Lions Creek at the basin between the 2 causeways when Williston Reservoir levels were at approximately 664.5 masl (top) during September 2010 compared to same view (bottom) when Williston Reservoir levels were at approximately 667 masl in June of 2009.

Photograph 5: View upstream (north) from the causeway at the Airport Lagoon basin when Williston Reservoir levels were at approximately 664.5 masl (top) during September 2010 compared to same view (bottom) when Williston Reservoir levels were at approximately 667 masl in June of 2009.

Photo 6: Left - A prickly sculpin (Cottus asper) and right, a slimy sculpin (Cottus cognatus) were captured during minnow trapping at the airport lagoon in September of 2010.

Photo 7: This juvenile cyprinid was recovered dead and battle beaten in one trap making identification difficult, however, it may be a Redside shiner (Richarsonious balteatus) or possibly a Northern pike minnow (Ptychochcheilus oregonensis).

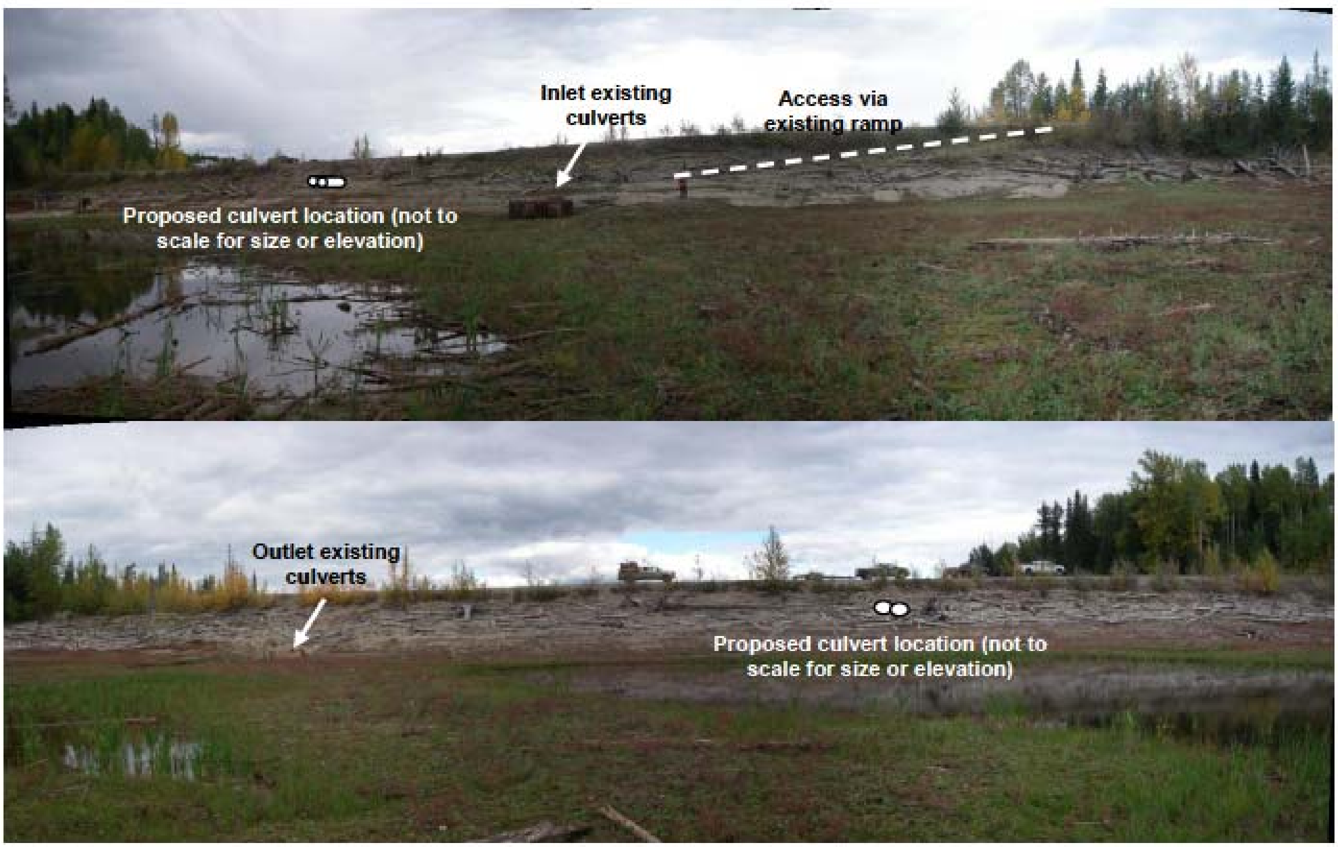
Photograph 8: Various views of the outlet of the two culverts on the south (downstream) side of the berm.

Photograph 9: Both culverts are showing signs of collapse. As is apparent from photosets 5 to 7, the existing culverts servicing the Airport Lagoon are in a state of disrepair, and are likely near the end of their service life.

Photograph 10: This small pond in the north west corner of WDS 6-2 is a permanently feature when the area is not inundated by the reservoir.

Photograph 11: Various views of the trash rack protecting the inlets of the 2 culverts on the north (upstream) side of the causeway.

Photo 12: The base of the north (upstream) side of the causeway viewed west (left) and the base of the south (downstream) side of the causeway viewed east (right).



Photograph 13: Top - A view south (downstream) towards the causeway in September 2010, showing locations of existing features. The top of the cage is approximately 666.5 masl. Bottom - a view north (upstream) towards the downstream side of the causeway. Note the location of proposed new culverts is approximate and is not to scale for elevation or size. Design Drawing 1 in Appendix B provides these details.

Photo 14: Despite low water levels in the reservoir, and a comparatively dry year in 2010 relative to conditions in 2009, flow, albeit minor, was still observed in the small channel leading from the beaver pond to the inlet. Given the small catchment area for this stream, and a lack of water in the channel nearer the beaver pond, ground water feed is suspected. The small channel shown here would be excavated to the clay layer (if present) and plugged to provide a level surface to place Geosynthetic bag water control structure.

Photo 15: Another view of the small flow of water from what is apparently a ground water source.

Photo 16: The above two pictures show the difference in water levels between the main beaver pond as seen in June 2009 (top) compared to September 2010 (bottom).

Photo 17: The beaver ponds were almost completely dry during the field survey conducted in September 2010. This view south shows the smaller pond downstream of the main pond.

Photo 18: A view northwest from the beaver pond towards the inlet of Site 34, showing the proposed inundation area if the site was to be flooded. The white dotted line approximates the location proposed for the MacTubes™.

Photo 19: A view south east from the inlet towards the beaver pond. The white dotted line approximates the proposed positioning of the for the MacTubes™.

Photo 20: A geo-synthetic bag, similar to what would be used for WDS 34 Beaver Pond, being filled with dredged material.

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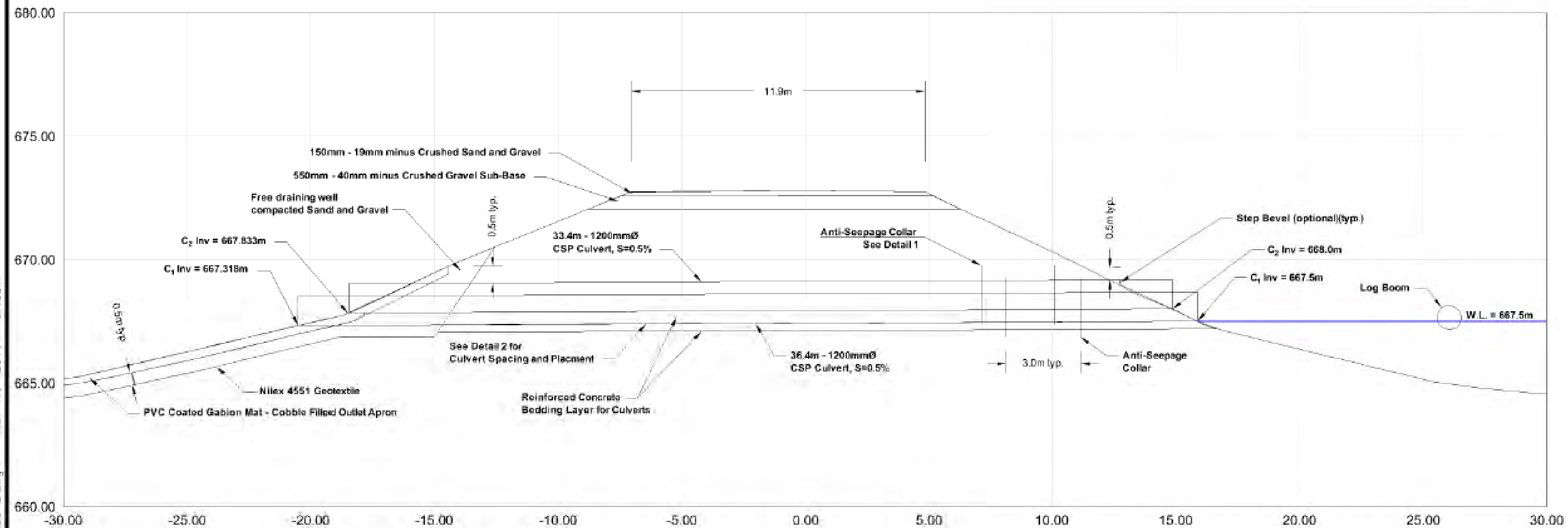
APPENDIX B

Design Drawings

Section A-A'



0 10 20 30 40 50
METRES

NOTES

1.) All culvert couplings to be type universal dimple coupler with 9" w ide x ⅜" thick neopream strip gaskets.

2.) **Spec for Gravel Road** :
550mm thickness of 40mm minus crushed gravel sub base, topped w with
150mm thickness of 19mm minus crushed sand and gravel.

3.) **Compaction Specs** : Granular fills should be placed in loose lifts no thicker than 300mm. Sub base materials should be compacted to a minimum 97 percent Standard Proctor Maximum Dry y Desity at a moisture content within 5 percent of the Optimum Moisture Content for compaction. Base materials should b e compacted to a minimum 100 percent SPMDD at a moisture content within 5 percent of the OMC for compaction.

REFERENCES

1.) COORDINATE REFERENCE: UTM ZONE 11n, NAD8 83
MAP REFERENCE: Base mapping provided by Vector Geomatics Land Surveying Ltd.

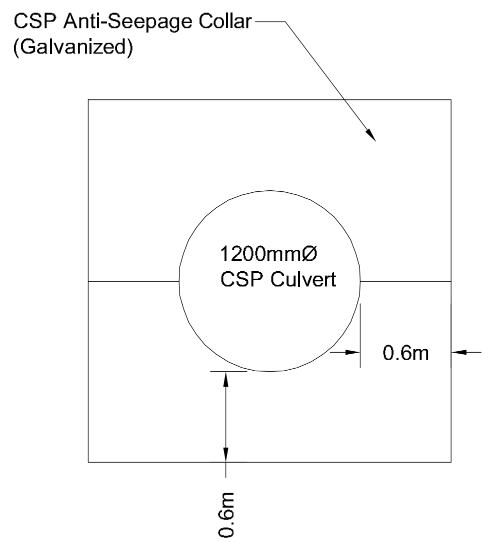
PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
WDS 6-2 AIRPORT LAGOON SECTION AND LOCATION PLAN

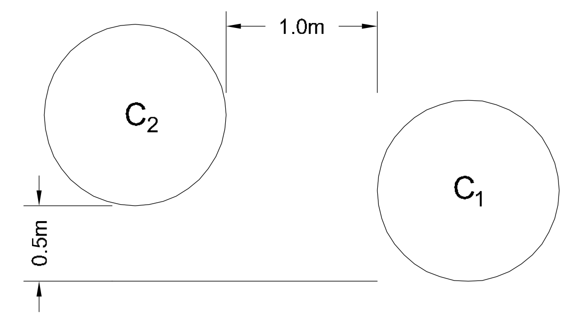
Golder Associates
Kamloops, BC

PROJECT No.		10-1492-0076	FILE No.	1014920076_site6-2
DESIGN	MG	26-MAY-10	SCALE AS SHOWN	REV. 0
CADD	SKL	13-DEC-10		
CHECK	MG	13-DEC-10		
REVIEW	CM	16-MAR-11		

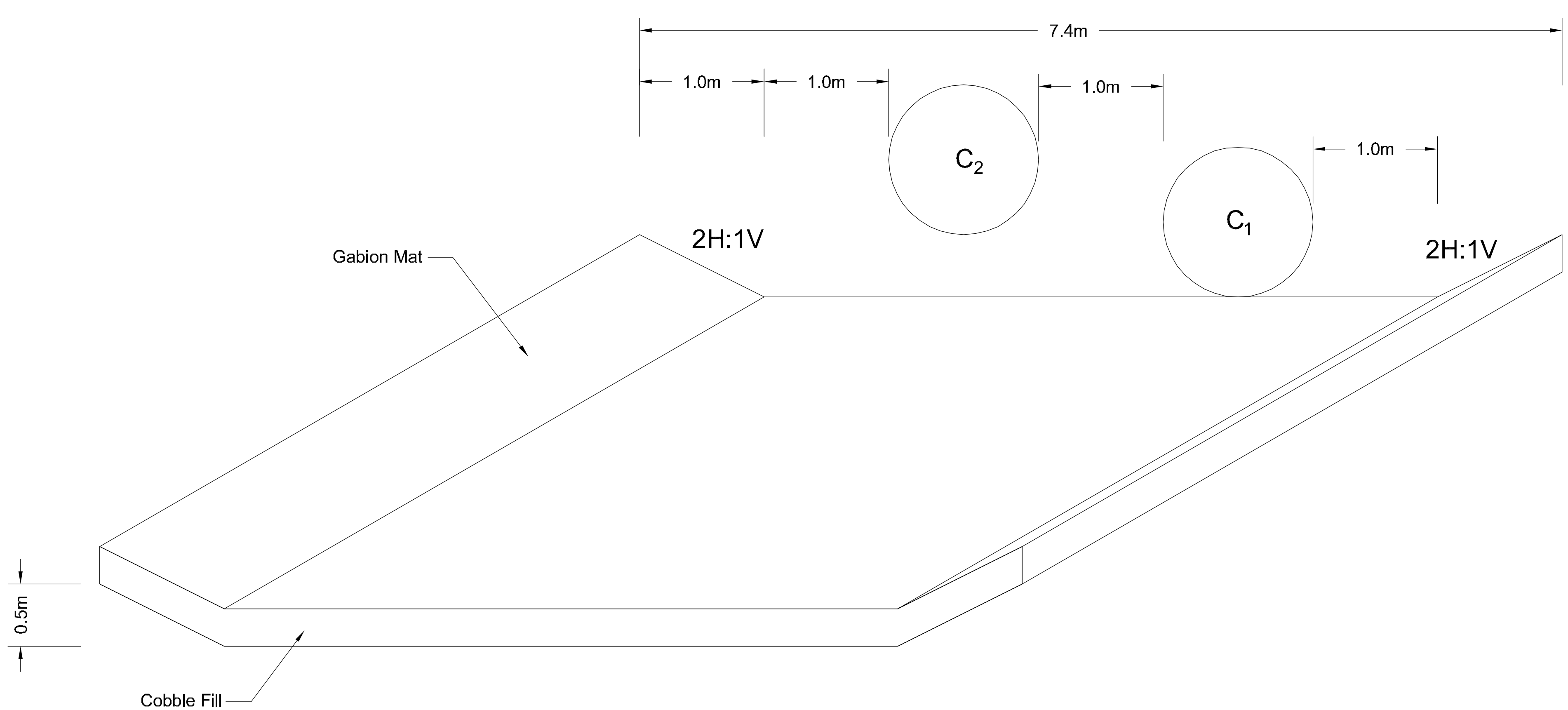
DESIGN DRAWING 1



Detail 1
Anti-Seepage Collar



Detail 2
Culvert Spacing and Placement



Detail3
Gabion Mat - Cobble Filled Apron

NOTES

1.) All culvert couplings to be galvanized bolt type universal dimple coupler with 9" wide x $\frac{3}{8}$" thick neopream strip gaskets.

PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
WDS 6-2 AIRPORT LAGOON
SECTION DETAILS

Golder Associates
Kamloops, BC

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DESIGN	MG	26-NOV-10	SCALE AS SHOWN	REV. 0
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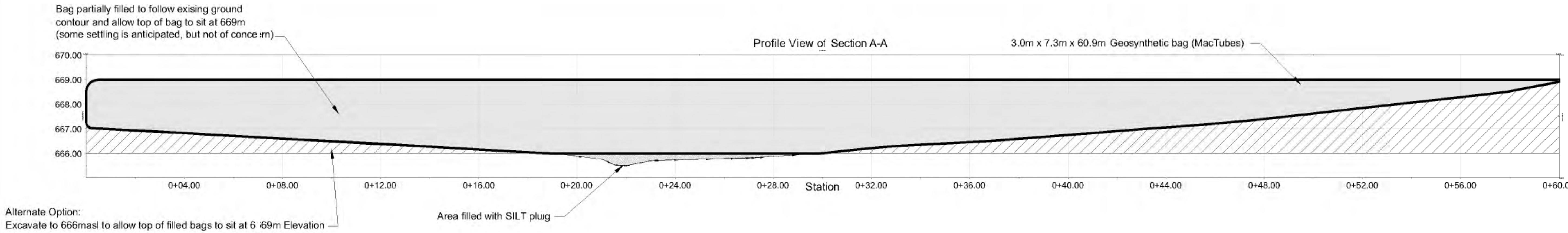
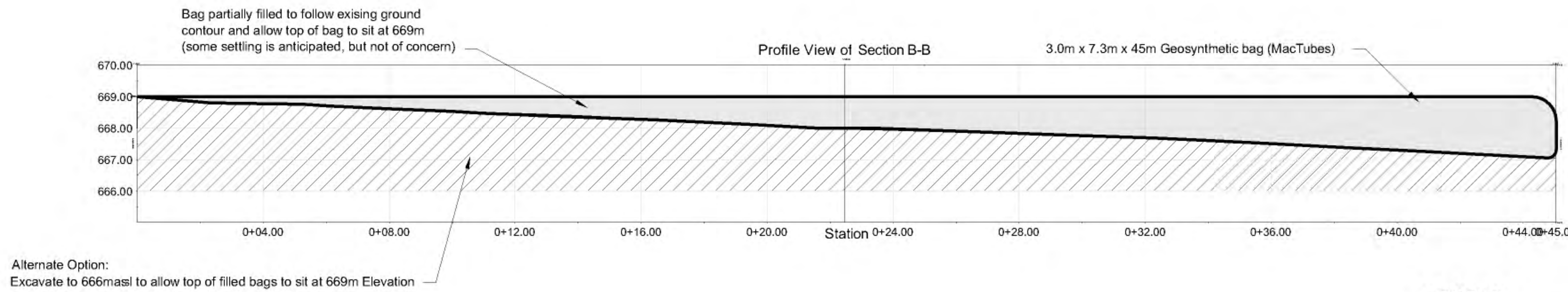
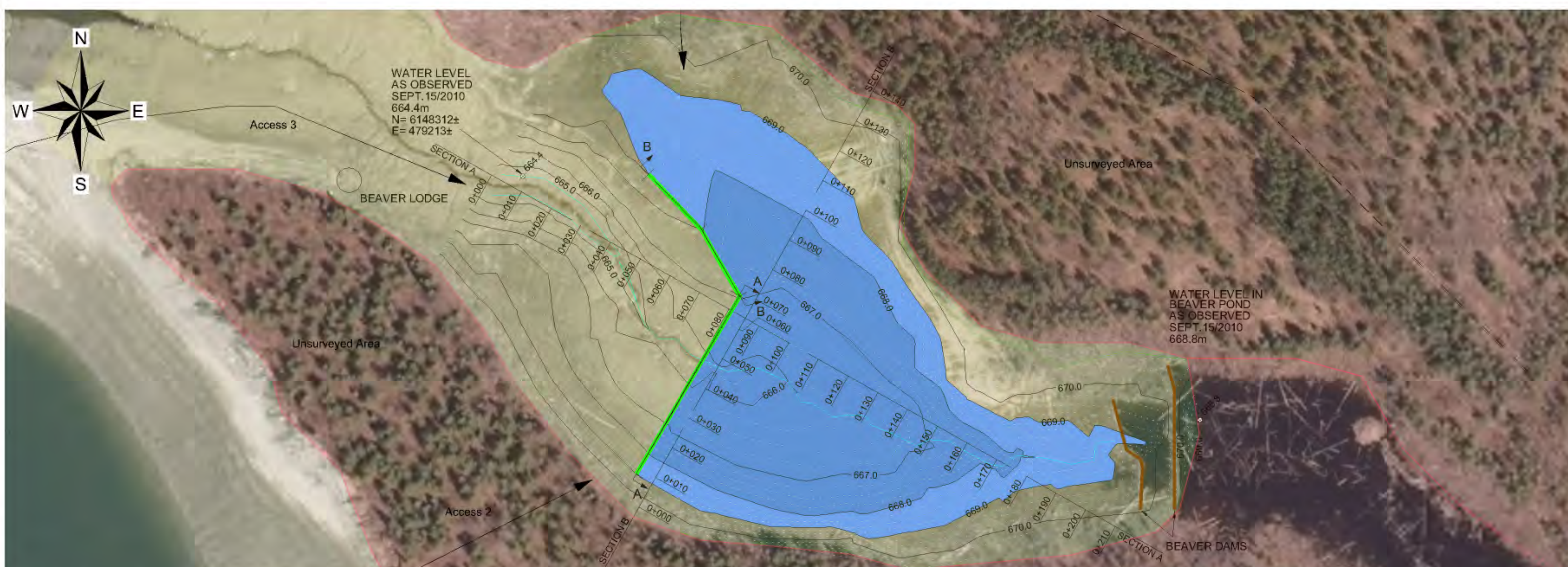
CHECK	MG	13-DEC-10		
REVIEW	CM	16-MAR-11		







LEGEND

- Major Contour (1m Interval):
- Minor Contour (0.25m Interval):
- Bushline:
- Creek/ Edge of Water:
- Spot Elevation:
- Proposed Structure:
- Low Archaeological Potential
- Unsurveyed Area
- High Archaeological Potential
- Flood Area of Basin with depth less than 1m (0.365ha)
- Flood Area of Basin with depth greater than 1m (0.558ha)

REFERENCES

1.) **COORDINATE REFERENCE: UTM ZONE 11n, NAD83**
MAP REFERENCE: Base mapping provided by Vector Geomatics Land Surveying Ltd
IMAGERY: Base imagery provided by BCHydro.

0 15 30 45 60 75
METRES

PROJECT
GMSWORKS 17
WILLISTON RESERVOIR WETLAND DEMONSTRATION SITES
STAGE II - DETAILED DESIGN AND COST ESTIMATE

TITLE
WDS 34 BEAVER POND SECTIONS AND LOCATION PLAN

Golder Associates
Kamloops, BC

PROJECT No.		10-1492-0076	FILE No.	1014920076_site6-2
DESIGN	MG	26-NOV-10	SCALE AS SHOWN	REV. 0
CADD	BKL	13-DEC-10		
CHECK	MG	13-DEC-10		
REVIEW	CM	16-MAR-11		

DESIGN DRAWING 3

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APPENDIX C

Laboratory Test Results

Laboratory Determination of Water Content of Soil and Rock

ASTM D 2216-05

Project #:	10-1492-0076
Short Title:	GMSWORKS17
Client	BC Hydro
Location	MacKenzie, BC
Lab ID	1460

Borehole	TP10-01	TP10-01	TP10-01	TP10-01	TP10-01	TP10-01
Sample Number	1	2	3	4	5	6
Depth (m)	0.1 to 0.3	0.6 to 0.7	0.9 to 1	1.1 to 1.2	1.4 to 1.5	2.6 to 2.8
Mass of Dry Soil (g)	483.8	685.3	308.1	75.3	559.1	369.8
Water Content W (%)	**17.9**	**22.3**	**74.1**	**393.8**	**29.5**	**36.7**

Borehole	TP10-02	TP10-02	TP10-02			
Sample Number	1	2	4			
Depth (m)	0 - 0.2	0.7 to 0.8	2.6 to 2.8			
Mass of Dry Soil (g)	471.7	205.6	142.3			
Water Content W (%)	**14.6**	**28.2**	**33.2**			

Borehole						
Sample Number						
Depth (m)						
Mass of Dry Soil (g)						
Water Content W (%)						

Borehole						
Sample Number						
Depth (m)						
Mass of Dry Soil (g)						
Water Content W (%)						

Borehole						
Sample Number						
Depth (m)						
Mass of Dry Soil (g)						
Water Content W (%)						

RJ	December 2, 2010	RJ	December 7, 2010
TESTED BY	DATE TESTED	CHECKED BY	DATE CHECKED

Golder Associates Ltd.
10628 Peck Lane, Fort St. John, British Columbia, Canada V1J 4M7
Tel: +1 (250) 785 9281 Fax: +1 (250) 785 7287 www.golder.com

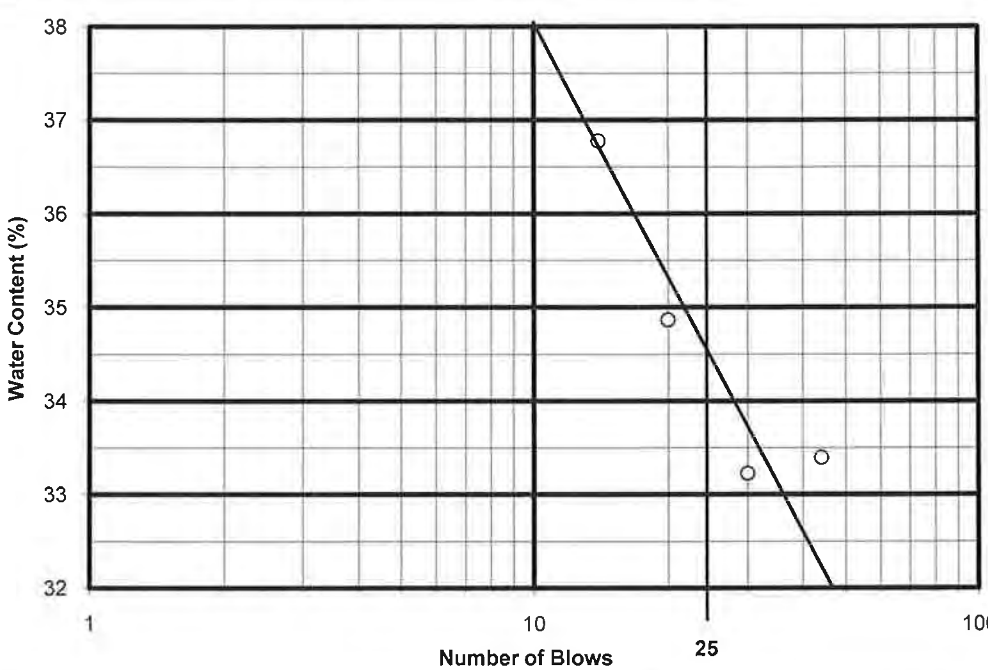
* The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

Project # 10-1492-0076 Tech : RNS

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

TYPE OF TEST	LL	LL	LL	LL		W% Nat.
CONTAINER NUMBER						
NUMBER OF BLOWS	30	20	14	44		
MASS WET SOIL + TARE	69.26	72.60	74.47	79.40		272.00
MASS DRY SOIL + TARE	58.70	60.87	61.63	66.27		214.00
MASS OF WATER	10.56	11.73	12.84	13.13		58.00
MASS OF CONTAINER	26.92	27.23	26.72	26.96		8.40
MASS OF DRY SOIL	31.78	33.64	34.91	39.31		205.60
WATER CONTENT W (%)	33.2	34.9	36.8	33.4		28.2

TYPE OF TEST	PL	PL	Test Pit No.	10-2
CONTAINER NUMBER			SAMPLE	2
MASS WET SOIL + TARE	32.53	29.25	DEPTH	0.7 to 0.8 m
MASS DRY SOIL + TARE	28.46	26.10	LIQUID LIMIT (%)	34.5
MASS OF WATER	4.07	3.15	PLASTIC LIMIT (%)	25.8
MASS OF CONTAINER	12.83	13.75	PLASTICITY INDEX (%)	8.7
MASS OF DRY SOIL	15.63	12.35	W% Natural (%)	28.2
WATER CONTENT W (%)	26.0	25.5	LIQUIDITY INDEX	0.28



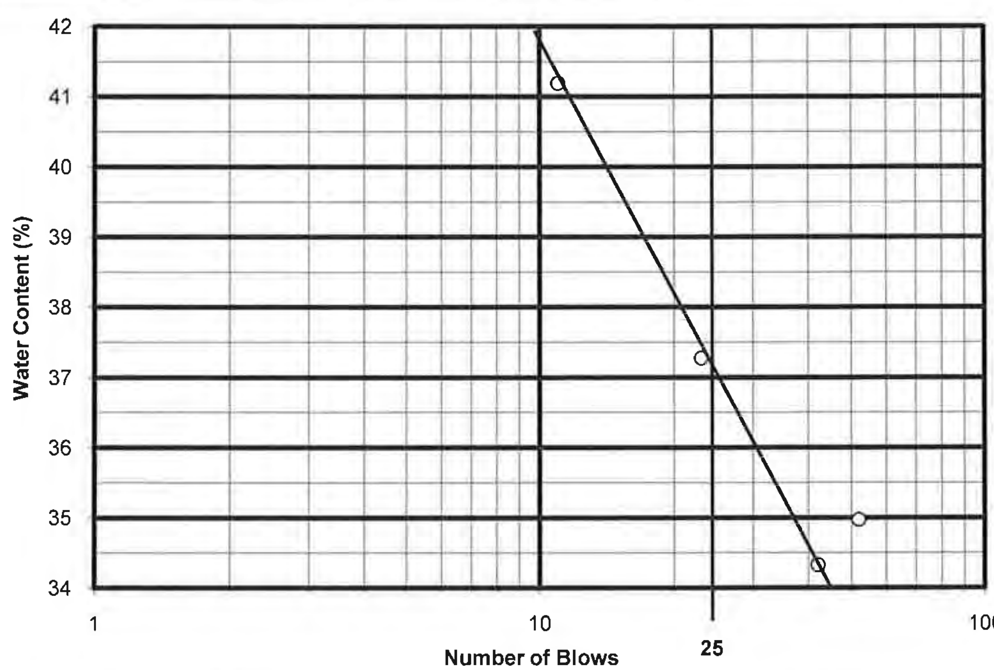
SAMPLE DESCRIPTION : ML
SILT, trace sand and clay, Slight plasticity

Project # 10-1492-0076 Tech : RNS

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

TYPE OF TEST	LL	LL	LL	LL		W% Nat.
CONTAINER NUMBER						
NUMBER OF BLOWS	52	23	11	42		
MASS WET SOIL + TARE	69.48	67.91	70.77	73.70		
MASS DRY SOIL + TARE	58.67	56.95	58.09	61.84		
MASS OF WATER	10.81	10.96	12.68	11.86		
MASS OF CONTAINER	27.76	27.55	27.31	27.29		
MASS OF DRY SOIL	30.91	29.40	30.78	34.55		
WATER CONTENT W (%)	35.0	37.3	41.2	34.3		

TYPE OF TEST	PL	PL	Test Pit No.	10-2
CONTAINER NUMBER			SAMPLE	4
MASS WET SOIL + TARE	29.64	28.02	DEPTH	2.6 to 2.8 m
MASS DRY SOIL + TARE	26.06	24.98	LIQUID LIMIT (%)	37.1
MASS OF WATER	3.58	3.04	PLASTIC LIMIT (%)	28.4
MASS OF CONTAINER	13.54	14.24	PLASTICITY INDEX (%)	8.7
MASS OF DRY SOIL	12.52	10.74	W% Natural (%)	
WATER CONTENT W (%)	28.6	28.3	LIQUIDITY INDEX	#VALUE!



SAMPLE DESCRIPTION : ML

SILT, trace sand and clay, Slight plasticity

Golder Associates

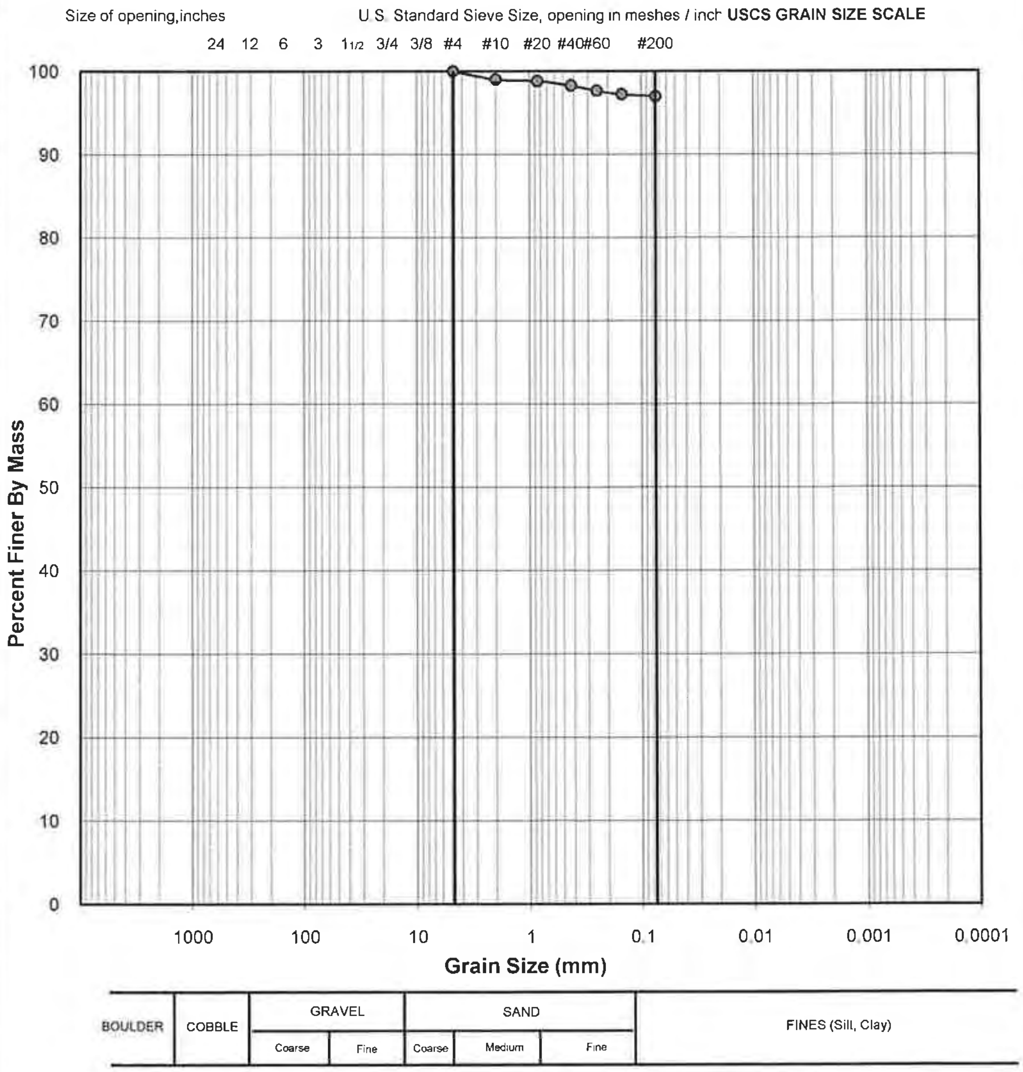
Golder Associates Ltd. - Fort St. John Laboratory
10628 Peck Lane
Fort St. John, BC

PARTICLE SIZE ANALYSIS OF SOILS

Reference
ASTM C136-06 & C117-04

Project No.:	10-1492-0076	**Borehole:**	**TP10-02**
Client:	BC Hydro	**Sample No.:**	2
Project:	Williston Lake Wetlands	**Depth (m):**	0.7 to 0.8
Location:	Airport Site	**Lab ID No:**	1460
Remarks:		**Other:**	-
		Material Specification:	NONE
		Method:	SPLIT, WASHED
		Date Tested:	2-Dec-10

Sieve Size (USS)	Sieve Size (mm)	Passing %
3.5"	87.5	100.0
3"	75.0	100.0
2"	50.0	100.0
1.5"	37.5	100.0
1"	25.0	100.0
3/4"	19.0	100.0
1/2"	12.5	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2.00	99.0
#20	0.850	98.8
#40	0.425	98.3
#60	0.250	97.7
#100	0.150	97.2
#200	0.075	97.0



** The test data given herein pertain to the sample provided only. This report constitutes a testing service only. Interpretation of the data can be provided upon request.*

RJ	December 2, 2010	Ravi Jassal	Secember 8, 2010
TESTED BY	DATE	CHECKED BY	DATE

APPENDIX D

Record of Test Pit Sheets

Test Pit No.	Depth (m)	Description	Sample/Depth
TP10-01	0 m	Loose, moist, brown, medium grained SAND.	Sa 1 (0.1 to 0.3 m) MC = 17.9 %
	0.5 m	Loose, moist, grey, medium to coarse grained SAND.	Sa 2 (0.6 to 0.7 m) MC = 22.3 %
	0.9 m	Soft, moist to wet, grey, silty CLAY, trace sand.	Sa 3 (0.9 to 0.1 m) MC = 74.1 %
	1.1 m	Soft, moist, dark brown to black, fibrous PEAT	Sa 4 (1.1 to 1.2 m) MC = 393.8 %
	1.4 m	Loose, moist, blue grey, silty fine SAND, contains organics (wood fragments).	Sa 5 (1.4 to 1.5 m) MC = 29.5 %
	2.0 m	Loose, wet, blue grey, coarse grained SAND, trace to some silt.	Sa 4 (2.6 to 2.8 m) MC = 33.2 %
	2.8 m	Termination of Test Pit. Seepage at 2 m depth. Water level within test pit at 2.6 m upon completion of test pit. Sloughing of test pit walls observed.	

Note: MC = Moisture Content; PL = Plastic Limit; LL = Liquid Limit; PI = Plasticity Index; and, LI = Liquidity Index. Gradation analysis results are percentages by weight. PP = Pocket Penetrometer (UCS Estimate). Shear Strength, S_u, is one-half of the UCS.

TP10-02	0 m	Compact, moist, brown SAND, trace gravel, contains clayey silt clumps. [FILL]	Sa 1 (0 to 0.2 m) MC = 14.6 %
	0.7	Firm, moist, light brown, clayey SILT, trace sand. [FILL]	Sa 2 (0.7 to 0.8 m) MC = 28.2 % LL = 34.5 % PL = 25.8 % PI = 8.7 % LI = 0.28 3% Sand 97 % Fines
	0.8 m	Loose to compact, moist, brown, medium to coarse grained SAND. [FILL]	Sa 3 (1.5 to 1.8 m)
	2.5 m	Firm, moist, blue grey, clayey SILT, trace sand. [FILL]	Sa 4 (2.6 to 2.8 m) MC = 33.2 % LL = 37.1 % PL = 28.4 % PI = 8.7 % LI = 0.55
	2.8 m	Termination of Test Pit. No seepage was observed. Sloughing of test pit walls observed.	

Test Pit No.	Depth (m)	Description	Sample/Depth
TP10-03	0 m	Compact, moist, brown, medium to coarse grained SAND, trace silt. [FILL]	Sa 1 (0 to 0.2 m)
	2.0	Compact, moist, blue grey, fine sandy SILT, trace clay, grades to firm to stiff, moist, blue grey, clayey SILT, trace sand. [FILL]	Sa 2 (2.5 to 2.6 m)
	2.8 m	Termination of Test Pit. No seepage was observed. Minor sloughing of test pit walls observed.	

Note: TP10-03 consisted of a vertical cut within the embankment slope. Depths indicated in logs are from top of cut and do not necessarily indicate thickness of the encountered materials.

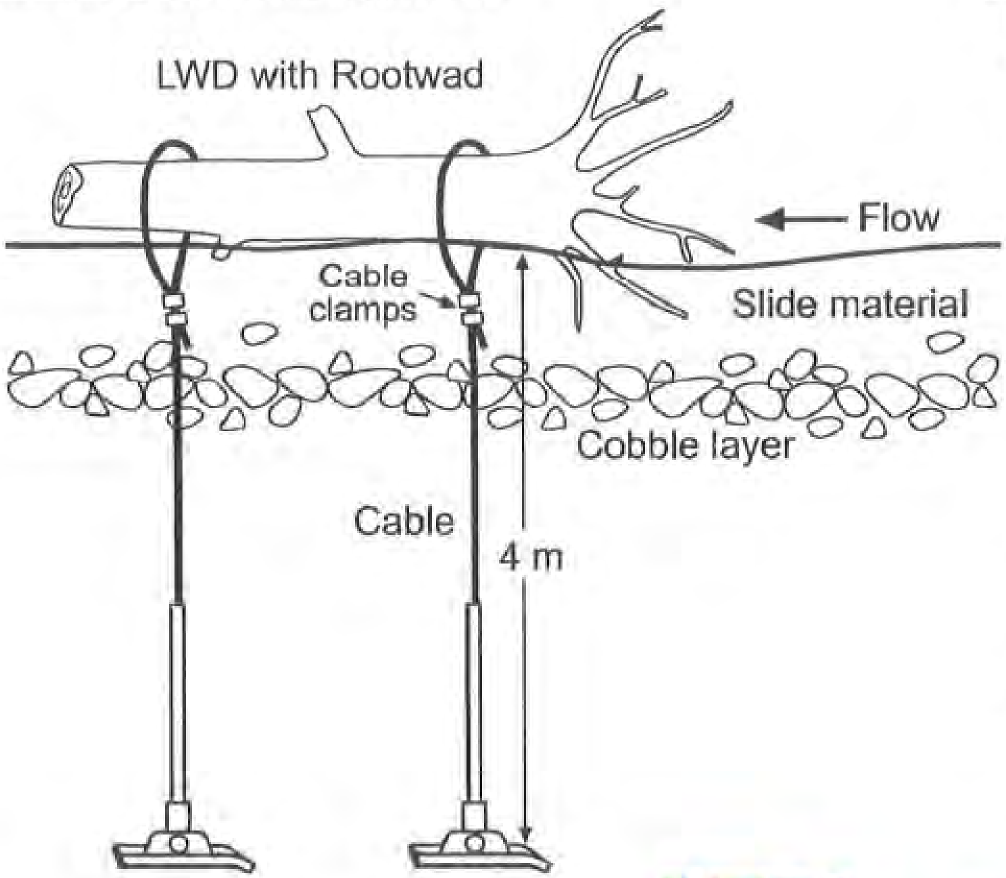
APPENDIX E

Ancillary Habitat Works Anchoring Systems LWD/CWD

Appendix E: Ancillary Habitat Works Anchoring Systems LWD/CWD

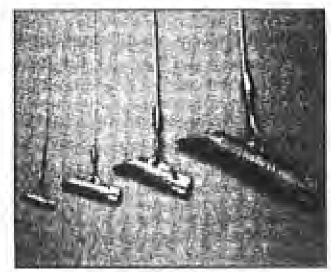
- Duckbill Anchors
- Manta Ray ®
- Loamy and gravely substrate

Rodman 2000. BC Watershed Restoration Technical Circular

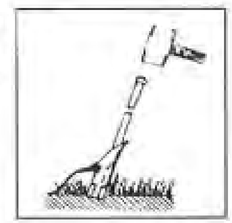


WRP 1997 – Technical Circular No. 9

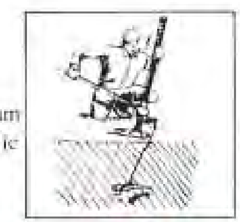
The duckbill anchor. Effective in loamy and gravely substrate.



DRIVE ANCHOR TO DESIRED DEPTH: DUCKBILL anchors are driven into the soil using a hammer and drive steel. As the anchor is being driven, it is actually compacting the soil around the anchor head. Once the anchor is at the proper depth, the drive steel is removed.



LARGER DUCKBILL ANCHORS:
To set larger anchors, use the fulcrum (lever) principle, manual or hydraulic jack, winch or post puller.

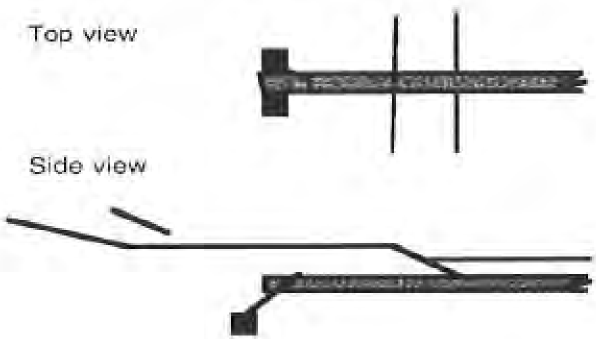


Appendix E: Ancillary Habitat Works Anchoring Systems LWD/CWD

- Deadmen
- Cable attachment to log/concrete/rock in bank
- Loamy and gravely substrate

WRP 1997 – Technical Circular No. 9

Use of wood or concrete deadman for soft or gravely soil. Excavate perpendicular trench 0.5 to 1.5 meters below elevation of log bottom. Fasten 5/8" cable, or wrap cable to deadman. Add large rock for weighing down if loamy soil. Thoroughly compact fill with heavy equipment.



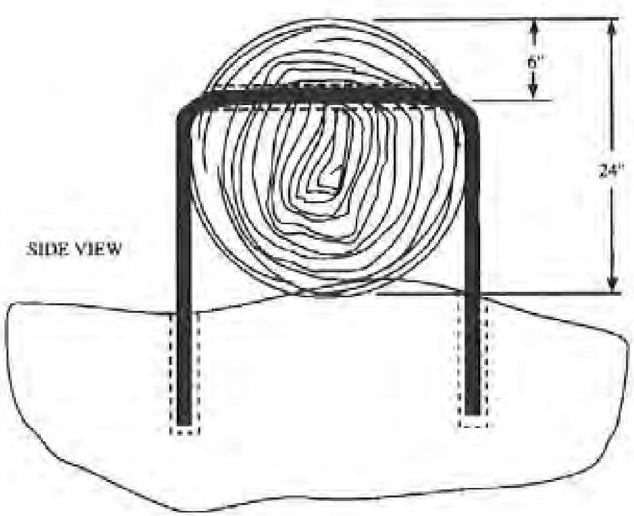
King County Dept. of Natural Resources, Washington St.

Appendix E: Ancillary Habitat Works Anchoring Systems LWD/CWD

- Cable attachment to log/concrete/rock in bank ®
- Loamy and gravely substrate

WRP 1997 – Technical Circular No. 9

For medium to large streams: 5/8" cable (galvanized or stainless).
3/4" diamond-tipped drill (very tight fit)
Hilti c-10 epoxy cartridges
Drill 8-10" hole in boulder with Hilti gas-powered drill. Clean hole thoroughly of dust by rinsing. Insert epoxy followed by cable. In small streams, 1/2" cable with 5/8" hole is acceptable.

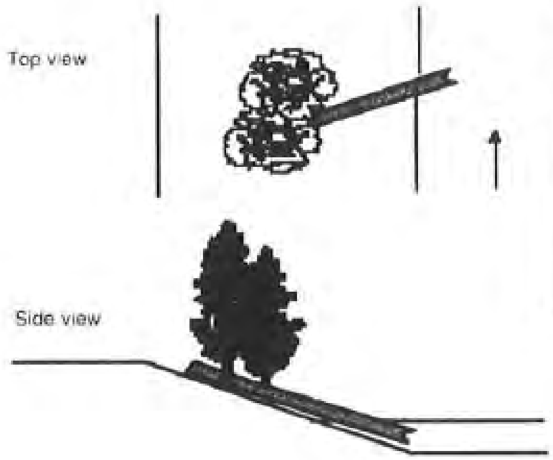


Appendix E: Ancillary Habitat Works Anchoring Systems LWD/CWD

- Cabling to trees

WRP 1997 – Technical Circular No. 9

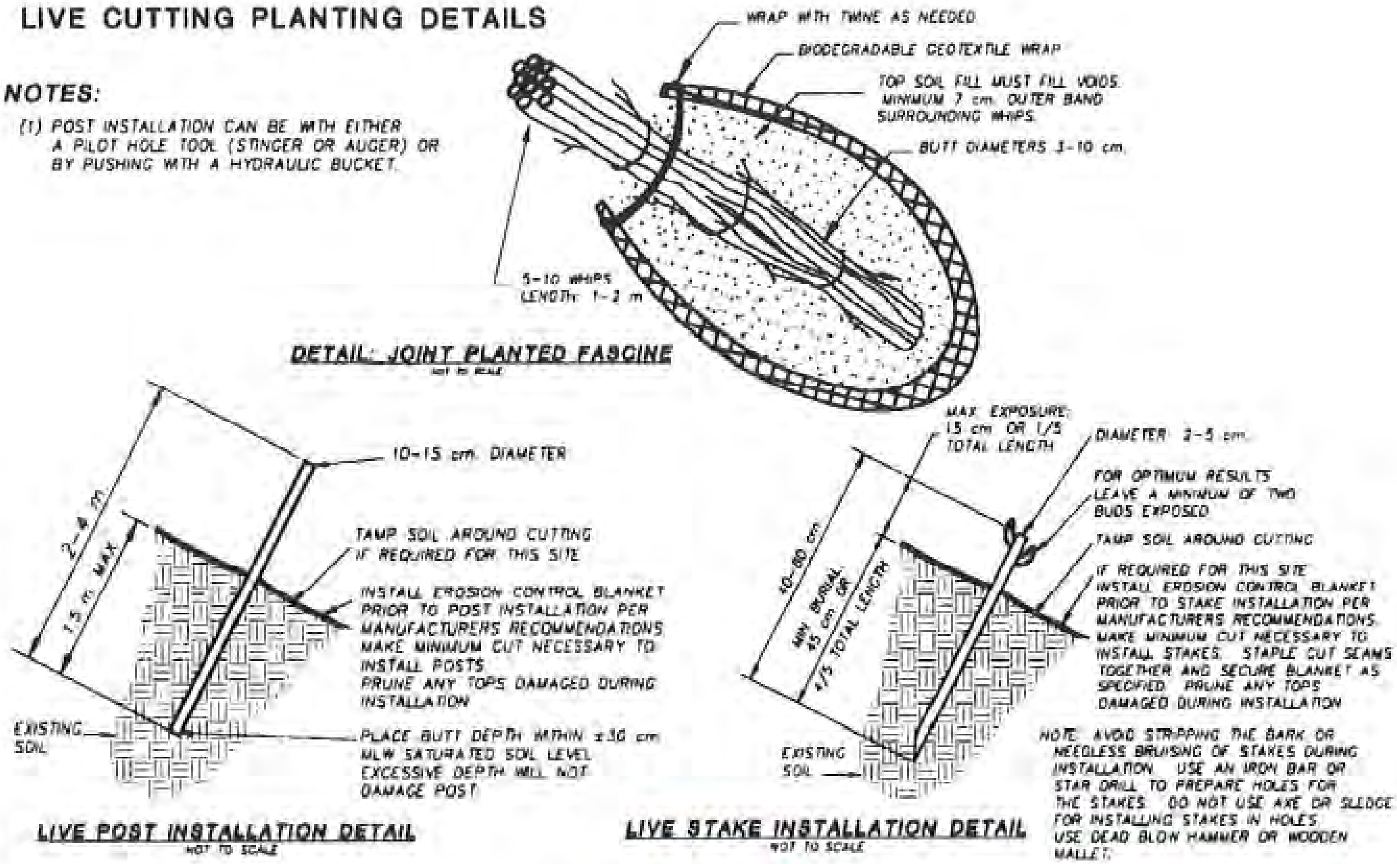
Standing tree wedge technique. Applicable when riparian area has large stable trees. Sweeper logs can be placed between two trees and cabled. Fasten end into streambed with rebar or cable onto existing boulders.



Appendix E: Ancillary Habitat Works - Revegetation

- Live cuttings
- Simplest of techniques to promote shrub growth
- *Salix sp.* (willow) and *Cornus stolonifera* (red osier dogwood) work well

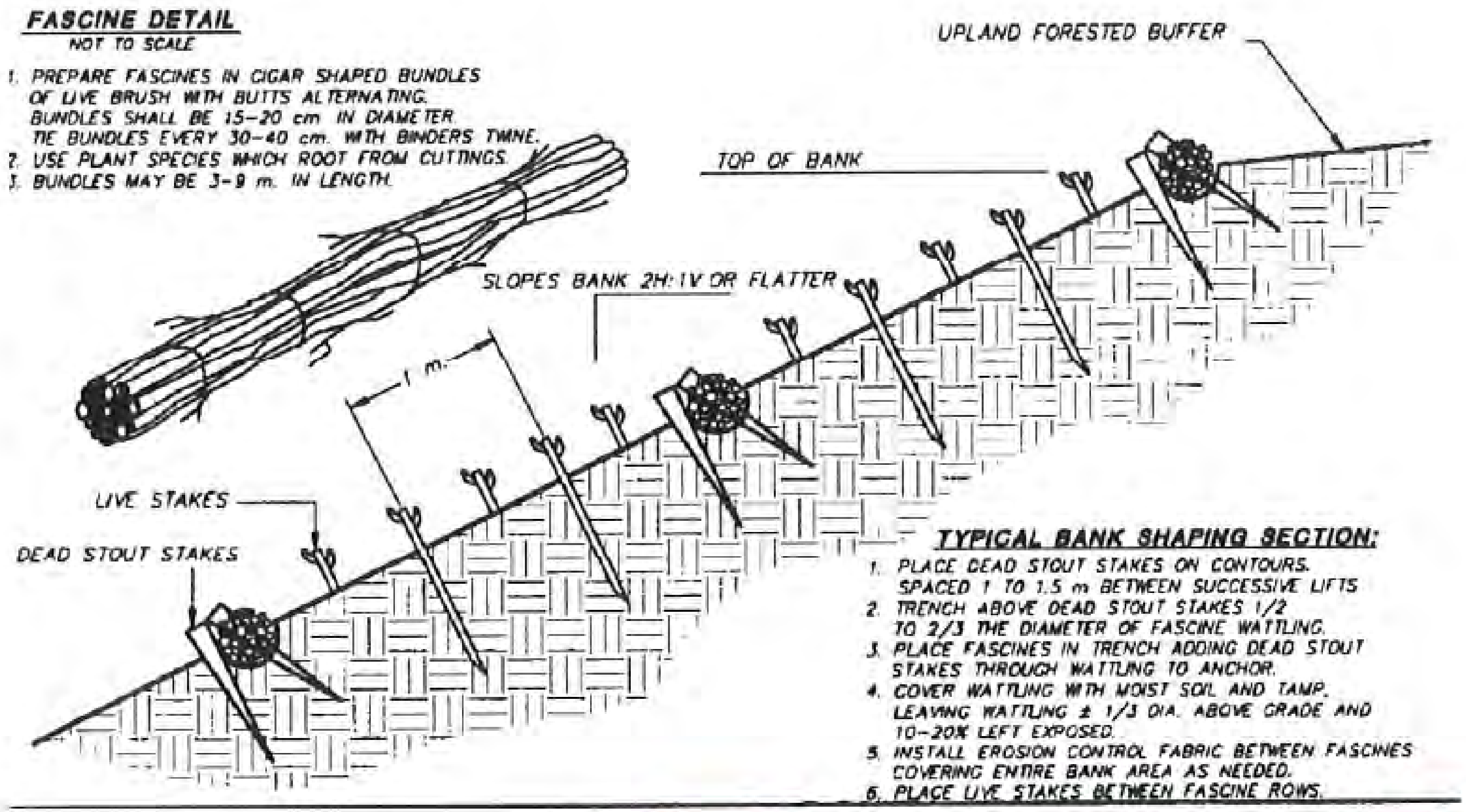
WRP 1997 – Technical Circular No. 9



Appendix E: Ancillary Habitat Works - Revegetation

- Wattles/Facine
- Protect bank from erosion (such as wave wash)
- Promote shrub growth

WRP 1997 – Technical Circular No. 9

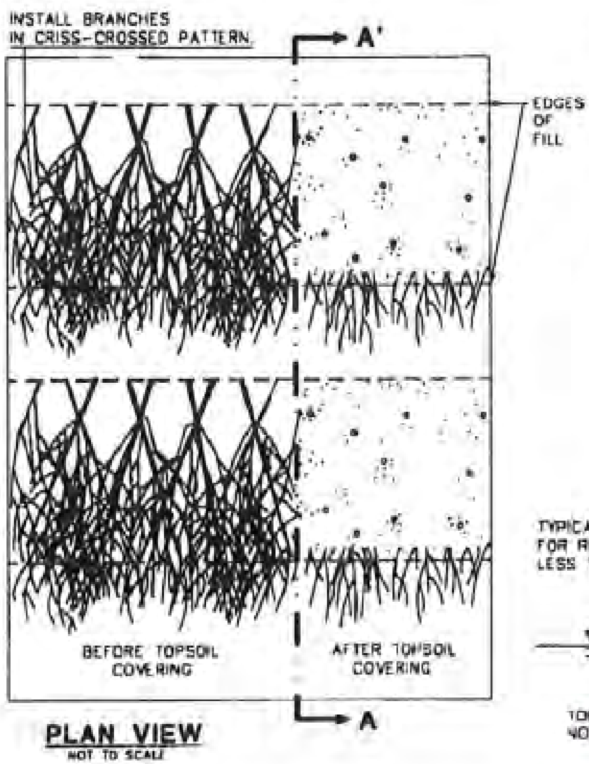


Appendix E: Ancillary Habitat Works - Revegetation

- Brush Layering
- Protect banks from erosion (such as wave wash)
- Promote shrub growth

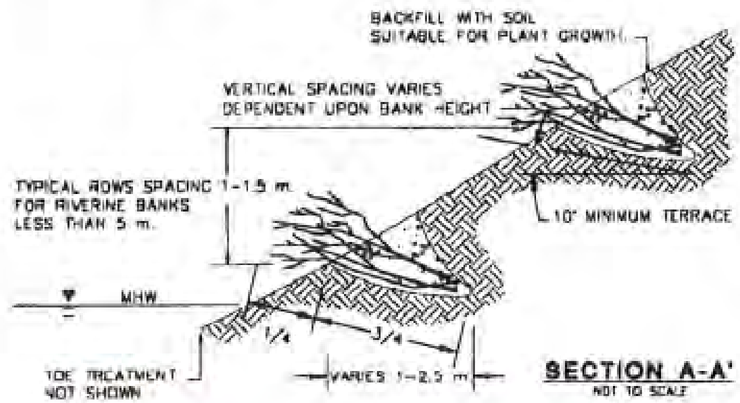
WRP 1997 – Technical Circular No. 9

TYPICAL INSTALLATION OF BRUSH LAYER (FILL SLOPES)



NOTES:

(1) SLOPE TERRACES TO 10 MINIMUM AS SHOWN
(2) INSTALL BRANCH LAYER FOUR TO SIX INCHES THICK WITH BRANCHES IN A CRISS-CROSSED PATTERN. BUTTS SHALL BE PLACED INTO BANK.
(3) FILL SOIL USED BETWEEN BRANCH LAYERS MUST BE SUITABLE FOR PLANT GROWTH
(4) LIVE BRANCHES SHALL BE A MIX OF DIFFERENT SPECIES AND AGE AND HAVE A MINIMUM DIAMETER OF ONE INCH AT BUTT
(5) GENERAL APPLICATION: THIS TREATMENT TYPICALLY INSTALLED ABOVE 10-YEAR FLOOD LEVEL AND/OR A VEGETATED GEOGRID. HARDENED TOE TREATMENTS ARE GENERALLY ESSENTIAL. THIS TREATMENT IS RELATIVELY COST EFFECTIVE AND CAN BE LESS LABOR INTENSIVE.
(6) STEM DENSITY: GENERALLY 6 STEMS (WHIPS) PER RUNNING FOOT OF BRUSH LAYER. (ADJUST UPWARD IF LOWER MORTALITY IS EXPECTED)
(7) NATIVE WILLOW AND DOGWOOD SPECIES MAY BE USED. TREAT DOGWOOD WITH ROOTING HORMONE.

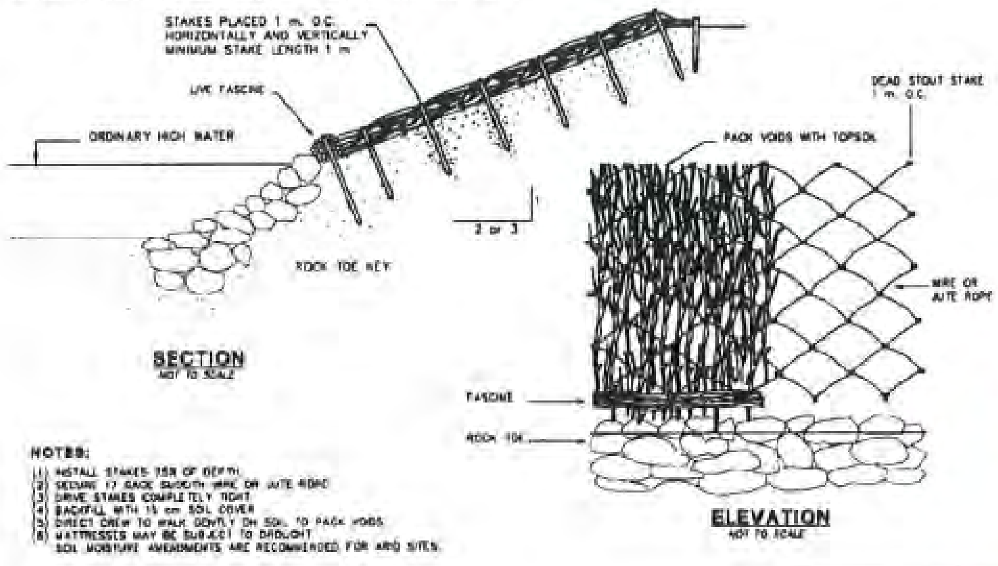


Appendix E: Ancillary Habitat Works - Revegetation

- Brush Mattress
- Protect banks from erosion (such as wave wash)
- Promote shrub growth

WRP 1997 – Technical Circular No. 9

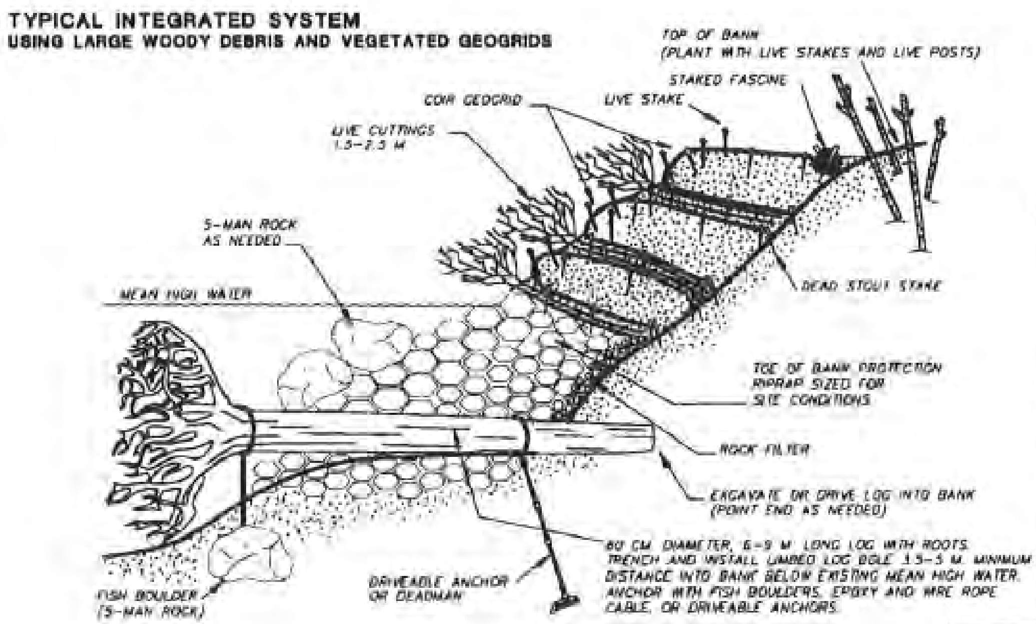
BRUSH MATTRESS (SHOWN WITH ROCK TOE)



Appendix E: Ancillary Habitat Works – Integrated works

- Mix and match techniques
- Adds habitat complexity
- Test effectiveness of methods (adaptive management)

WRP 1997 – Technical Circular No. 9



APPENDIX F

Vegetation Photographs

Photograph 1: Epilobium angustifolium (Onagraceae), also known as fireweed, is native to the area but generally prefers open habitats and will grow in dry or wet areas but will generally disappear from frequently wet sites.

Photograph 2: Immature development prevented confirmation of a positive ID of this species.

Photograph 3: Rorippa palustris (Brassicaceae), yellow cress, is a native species common to marshy ground and would be an appropriate species to consider for revegetation purposes.

Photograph 4: Typha latifolia (Typhaceae), cattail, is the only species of cattail identified in the Williston Reservoir area.

Photograph 5: Persicaria lapathifolia (Polygonaceae), willow herb, is considered a weed spceis, but is still native to the area.

Photograph 6: Bidens cernua (Asteraceae),nodding beggar ticks, is native to the area and commonly found in marshy ground, ponds and ditches and can be considered an appropriate species for the site.

Photograph 7: Hieracium umbellatum (Asteraceae), narrow leaved hawkweed is a native species which tends to prefer fairly dry, open meadows and clearings and may disappear if site gets wetter.

n:\active\2010\1492 biosciences\10-1492-0076 bch williston wetland demo sites\reporting\final\appendices\appendix f vegetation photographs cmedits dec14 (2).docx

APPENDIX G

Cost Estimates

APPENDIX G-1

Budget for Placement of Two 1200 mm culverts at WDS 6-2 Airport Lagoon

Table 1: Common to Either Alternative (A or B).

DESCRIPTION	Unit	Quantity	Unit Price	Amount
Mobilization & Demobilization	LS	1	$13,000	$13,000
Traffic Management				
The contractor to prepare traffic management plans	LS	1	$8,000	$8,000
Survey & Project Record Drawings				
Contractor to provide survey layout and to provide as-constructed survey pick-up	LS	1	$3,000	$3,000
Controlled Density Fill				
Controlled density Fill - Plugging existing culverts	m^3	127	$250	$31,750
Concrete Cut-off Walls				
Existing Culverts	m^3	6	$300	$1,800
Imported Backfill				
Well graded sand & gravel for the embankment fill ear existing culvert outlets	m^3	50	$20	$1,000
Gabion Mat - Supply & Install				
Gabion Mat (8 m x 15 m x 0.5 m thick) includes 3" - 8" round cobble stones	m^2	120	$115	$13,800
Geosynthetics				
Geosynthetics - Nilex 4551	m^2	184	$3	$552
Log Boom - Supply & Install				
Log Boom, c/w cables & fittings & deadman anchors, transport logs to site.	LS	1	$10,000	$10,000
Hydraulic Seeding:	m^2	1	$560	$560
Environmental (1)				
Permitting (Environmental only)	Day	3	$1,125	$3,375
Environmental Monitoring (accommodation/truck/labour)	Day	7	$1,300	$9,100
Archaeology (2)	Day	1	$1,300	$1,300
Sub Total				**$102,557**

(1) Assumes approximate ½ presences over 14 day period, with full days during works in stream (such as plugging culverts with concrete). Also assumes extended travel requirements to and from MacKenzie are not required.

(2) Archaeological permitting and monitoring requirements not included since such work is only required if the successful contractor proposes alternative approaches that call for ground disturbance in areas of high potential or outside of assessed areas.

Table 2: Horizontal Auguring (Pipe Jacking)

Alternative A - Pipe Jacking	Unit	Quantity	Unit Price	Amount
Pipe Jacking	LM	69.8	$3,575	$249,535
Sub Total				**$249,535**

Table 3: Open Excavation.

Alternative B - Open Excavation	Unit	Quantity	Unit Price	Amount
Excavation, Trenching & Backfilling (for underground Utility)				
Supply & Install Sheet Pile Wall (9 m x 21 m)	m^2	189	$430	$81,270
Common Excavation, on-site re-use	m^3	2640	$25	$66,000
Imported backfill - (well graded sand & gravel) for embankment fill near culvert outlets	m^3	50	$20	$1,000
Subgrade prep	m^2	245	$2	$490
Granular Base				
Granular Base - 150 mm thick, 19 mm minus crushed sand & gravel (20 m x 13 m)	m^2	260	$40	$10,400
Granular Sub-Base				
Granular Sub-base - 550 mm thick - 40 mm minus crushed gravel (15 m x 20 m)	m^2	300	$30	$9,000
Pipe Culvert: Supply & Install				
Pipe - 1200 mm diameter Galvanized CSP (5.5 m excavation) c/w Galv bolt type universal dimple couplers with 9" wide x 3/8" thick neoprene strip gaskets.	LM	70	$400	$28,000
Galvanized CSP Anti-Seepage Collars	ea	4	$500	$2,000
Environmental Monitoring (Includes Labour/Accommodation/Vehicle)	day	7	$1,300	$9,100
Sub Total				**$198,160**

Table 4: Summary costs by alternative.

Alternative A - Pipe Jacking			Alternative B - Open Excavation	
Description	**Amount**		**Description**	**Amount**
Common	$102,557		Common	$102,557
Pipe Jacking	$249,535		Open Excavation	$198,160
Sub- Total	**$352,092**		**Sub- Total**	**$300,717**
25% Contingency	$88,023		25% Contingency	$75,179
Total	**$440,115**		**Total**	**$375,896**

APPENDIX G-2

(A) Budget for Placement of Geosynthetic Bags WDS 34 Beaver Pond

150 mm Dragflow Dredge Pump into Mactubes						
Description	**Hrs/Items**	**Equipment**	**Labour**	**Trucking**	**Other**	**Total**
Burnaby Mob & Prep Equip Out	10	$200.00	$300.00			$5,000.00
Burnaby Mob & Prep Equip In	10	$200.00	$300.00			$5,000.00
Site Rigging In	10	$240.00	$350.00			$5,900.00
Purchase/Delivery Geotubes (1)	2				$50,000.00	$100,000.00
Production Dredging (8 x 10)	80	$240.00	$350.00			$47,200.00
Truck Dredge to Mackenzie	1			$3,500.00		$3,500.00
Crew Mobilization	10		$350.00			$3,500.00
Crew Demobilization	10		$350.00			$3,500.00
Truck Dredge to Burnaby	1			$3,500.00		$3,500.00
Flights (6 men)	6				$1,300.00	$7,800.00
Environmental						
Permitting (day)	3		1125			$3,375.00
Monitoring (day)	7		1300			$9,100.00
Archaeology (day)	1		1300			$1,300.00
15% Contingency						$29,801
TOTAL						**$229,476**

(1) Geotubes are MacTubes™ purchased from Maccaferi of Canada.

APPENDIX G-2

(B) Labour and Equipment Rates for Placement of Geosynthetic Bags WDS 34 Beaver Pond

Equipment	**Size**	**Quantity**	**Hourly**
Dragflow 6"	6" Diameter	1	$75
Genset	125 kW	1	$50
HDPE dr 11 Discharge Pipe c/w Header & Valves	6" Diameter x 50'	20	$25
Excavator	20t	1	$75
Container & Spares	20' connex	1	$15
Average Hourly Rate			**$240**
Labour	**Base Rate/hr**		
Project Supervisor	$45.00		
Project Engineer	$45.00		
Dredge Operator	$50.00		
Excavator Operator	$50.00		
Levy Labour	$35.00		
Environmental Monitor	$100.00		
Archaeological Monitor	$100,00		
Permitting (Archaelogy/Environmental)	$150.00		
Summary Crew Rate per Hour (5 man Crew)	$225.00		
SUMMARY COSTS			
Working 6 day week 10 hrs per day	**Rate**	**Hours/Quantity**	**Total**
Crew Rate first 40 hrs straight time	$225.00	40	$9,000
Crew Rate next 20 hrs 1.5x	$337.50	20	$6,750
Out of Town	$300.00	5	$1,500
Room & Board (5 men x $ 150.00)	$750.00	5	$3,750
Average cost of Labour per hour	**Avg / Hr**	**$350.00**	

APPENDIX H

Geo-tube Information

APPENDIX H-1

Flintex Technical Fabrics™

Flintex™ 2 Ply OS500pp (used in construction of the MacTube™ GeoTube®) is composed of 2 layers of high-tenacity polypropylene fabric. The yarns of which are woven into a network in such a manner that they retain relative position to each other for the high demands required for geosynthetic bags. **Flintex 2 Ply OS500pp** is inert to biological degradation and resistant to most naturally encountered chemicals, alkalis and acids.

Table 1: Material Specifications for Flintex™ 2 Ply OS500pp.

Physical Property	Tst Method	Units	Value
Operating Strength (OS)	ASTM D4595	kN.m (lbs/in)	158 (900)
After seaming	ASTM D4884	kN.m (lbs/in)	158 (900)
Wide Width ULT Elongation	ASTM D4595	%	20
Apparent Opening Size (AOS)	ASTM D4751	mm (US sieve) microns	0.300 (50) 300
Flow Rate	ASTM D4491	$l/min/m^2$	817 (20)
UV Resistance (at 500 hrs)	ASTM D4255	%	95
Mass/Unit Area	ASTM D5261	g/m2 (oz/sy)	1200 (35)
Weave Style	n/a	n/a	rip-resistant
Pressure Relief Band	n/a	inch	4
Port Design	n/a	n/a	radial shirt-sleeve
Colour	n/a	n/a	sand

APPENDIX H-2

See attached documentation associated with article "Eco Friendly Defence Against Erosion in Arctic Regions", accessed from: http://www.sciencedaily.com/releases/2009/10/091007081532.htm?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+sciencedaily+(ScienceDaily%3A+Latest+Science+News)&action=print

APPENDIX I

In Stream Work Windows

Appendix I **Work windows for various fish species inhabiting Williston Reservor relative to construction and developmen in and around a stream.**

Site	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Arctic grayling				1			15					
Bull trout						15		15				
Burbot	15					15						
Kokanee	15				31				1			
Lake trout						15			1			
Lake whitefish						15			1			
Northern pike					1	30						
Mountain whitefish					31				15			
Rainbow trout				1 15			15					
Walleye					1	30						
Yellow Perch				15			15					

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

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