MONITORING OF IMPACTS ON NAGLE CREEK WETLAND FROM MICA UNITS 5 AND 6

Reference: Project Number (CLBMON 59)

Study Period: 2012

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December 11, 2013

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1 INTRODUCTION

1.1 General Background

1.1.1 Study Area

This study area was the Nagle Creek wetland, located at the mouth of Nagle Creek where it flows into Revelstoke Reservoir. The Revelstoke Reservoir is located downstream of the Mica Dam and is part of the Columbia River system. The reservoir is within the Columbia Shuswap Regional District, located approximately 137 kilometres (km) north of Revelstoke, BC (Figure 1). The Columbia River flows southwards from Mica Dam through Revelstoke Reservoir to Revelstoke Dam, Arrow Lakes and Keenleyside Dam until merging with the Kootenay River at Castlegar and flowing south to the USA border.

The Nagle Creek wetland is potentially affected by BC Hydro's proposed flow regime changes for Mica Dam. The Mica 5/6 Environmental Assessment (EA) (KCB, 2009) defined this wetland as a valued ecosystem component (VEC). BC Hydro defined the purpose and direction of this study to evaluate the residual effects related to the Mica 5/6 project on the wetland as a commitment by BC Hydro in the Environmental Assessment Certificate (EAC). The Nagle Creek wetland monitoring study (CLBMON-59) was also incorporated into the Columbia River Water Use Plan (BC Hydro, 2007).

The Nagle Creek wetland is part of a riparian area (Figure 2). Riparian habitats are those located in the interface between land and a watercourse or water body, and they tend to support an ecologically diverse range of wildlife. Riparian areas are a unique type of habitat that possess a diverse array of environmental processes and structural characteristics that meet these requirements for a wide range of animals (Bunnell & Dupuis, 1993; Knutson & Naef, 1997), including one of the original dam building species, beavers (Andersen and Cooper, 2000; Collen and Gibson, 2001). Riparian habitats also have other important ecological functions including erosion protection (Schlosser and Karr 1981; Hupp and Osterkamp 1996; Tabacci and Collinson 2002; Webb and Erskine 2003) maintaining favourable water temperature through shading for aquatic species such as fish (Hawkins et al 1983; Davies and Nelson 1994; Pusey 2003) and the transfer of nutrients among aquatic and terrestrial habitat zones. (Naiman et al, 1997; Martinsen et al, 1998; Reimchen et al, 2003)

Riparian communities include a structurally diverse assemblage of herbaceous vegetation, shrubs and trees such as black cottonwood (*Populus trichocarpa*), and are, therefore, particularly valuable for the associated wildlife communities. Riparian area vegetation changes over time, in response to a variety of factors including

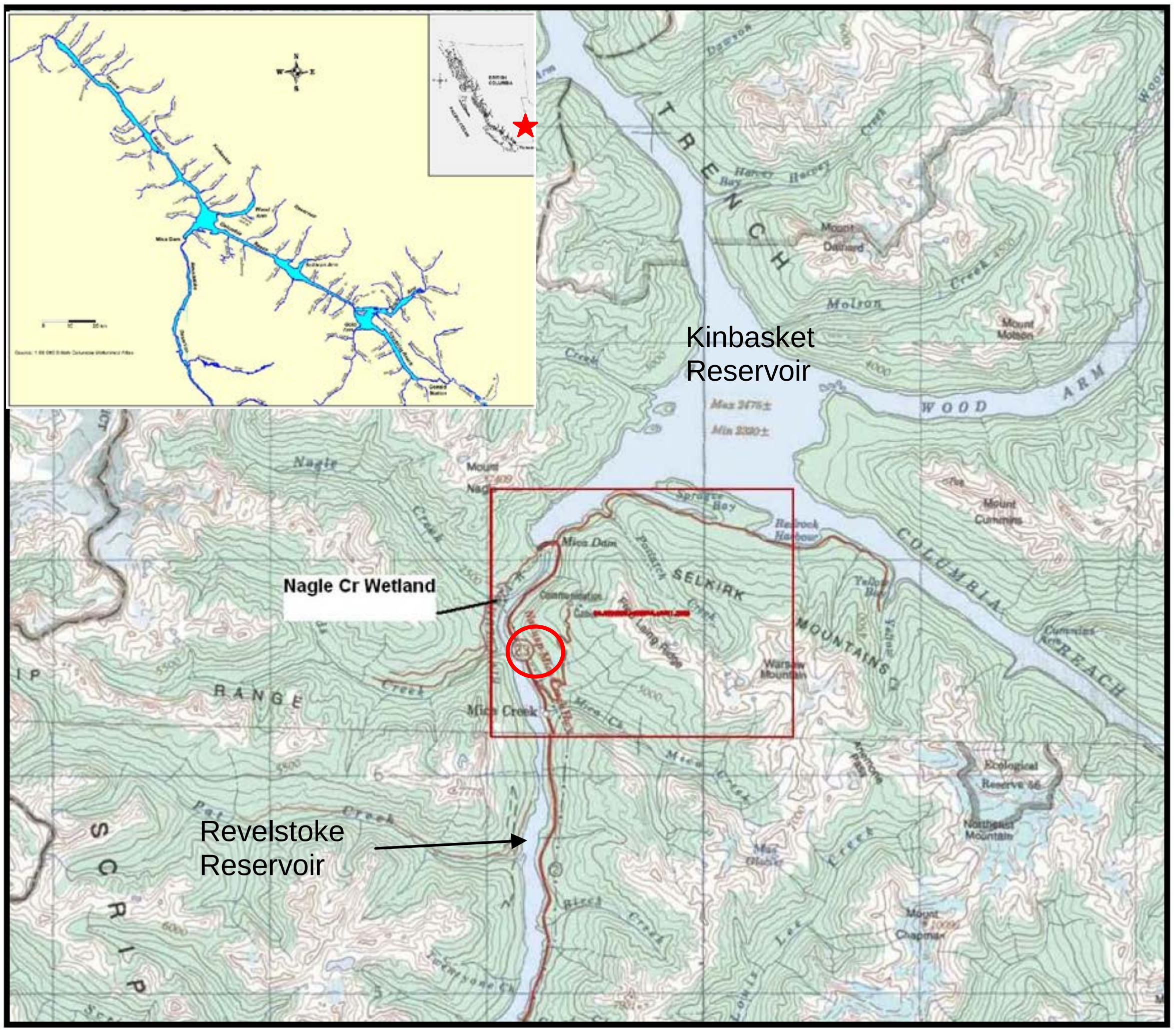

Figure 1 Overview of CLBMON 59 (Nagle Creek Wetland) study area, 137 km north of Revelstoke, within the Columbia River watershed.

plant-herbivore interactions (Bell et al, 1992; Breck et al, 2002), predator-herbivore interactions (Beschta, 2003) and flood frequency (Scott et al, 1997). These areas are adapted to regularly fluctuating water levels that occur along rivers and streams in response to the melt of the annual snowpack and to variation in precipitation. In addition to this natural heterogeneity, anthropogenic influences such as hydroelectric activities can influence water levels of riparian habitats (Rosenberg et al., 1997).

Variations in the hydrological regime can cause a number of physical and biological effects both upstream and downstream of hydroelectric activities (Baxter, 1977; Bunn and Arthington 2002). For example, water level variations can impose constraints that affect the success of the

Figure 2 Wetland at the confluence of the Nagle Creek delta with Revelstoke Reservoir (BC Hydro, 2011).

associated vegetation communities by influencing ecological processes such as seed bank recruitment (Seabloom et al., 2000) and shoreline vegetation diversity (Hill et al,. 1998). Natural and anthropogenic re-vegetation by riparian tree species can result in increased wildlife diversity (Wesley et al, 1981) through processes such as reestablishment of nest cavities in old growth cottonwood forests (Twedt and Henne-Kerr, 2001). Hydroelectric activity can directly affect riparian wetland and wet forest communities (and indirectly affect associated wildlife communities), through the temporary and potentially permanent loss of these riparian habitats, which may lead to potential declines in species abundance and diversity (Nilsson and Dynesius, 1994; Crivelli et al., 1995).

1.2 Project Background

The Revelstoke Reservoir is a water storage facility located in the Columbia Shuswap Regional District, storing water upstream of the Revelstoke Dam. The current project addresses potential impacts to the Nagle Creek wetland, located three kilometres downstream of Mica Dam. Construction of Mica Dam was completed in 1973, and it consists of an earthfill dam, outlet works and a chute spillway. The generation station was built in an underground powerhouse and contains four generator units, which were installed and operational in 1977. Both the Mica Dam and the generation station were built to accommodate two additional generator units (Units 5 and 6). Below the Mica Dam is Revelstoke Reservoir, which was created by the Revelstoke Dam after completion in 1984. The Nagle Creek wetland is influenced by water management actions at both the Mica Dam and the Revelstoke Dam. Mica Dam is currently undergoing modifications to add the two additional generating units, which will increase downstream water flow rates that may potentially impact the Nagle Creek wetland through changes in the water regime.

In accordance with the BC Environmental Assessment Act (BCEAA), an environmental assessment (EA) was completed in 2010 relating to installation of Mica Units 5 and 6 (KCB 2009).

The results of the project EA included an effects assessment of identified, valuable ecosystem components (VECs). Nagle Creek is a Revelstoke Reservoir tributary in the Mica tailrace area, located approximately 500 m north of the Blue Bridge. The small wetland near the Nagle Creek estuary was one VEC evaluated during the EA. Water level changes resulting from the project operations phase were identified as having potential positive or negative effects on the Nagle Creek wetland boundaries and function. A monitoring study to evaluate the residual effects related to the project on the wetland became one of the commitments (BC Hydro) in the Environmental Assessment Certificate (EAC). The Nagle Creek wetland monitoring study (CLBMON-59) was also incorporated into the Columbia River Water Use Plan (BC Hydro, 2007). (KCB, 2009)

This recommendation for monitoring was based on the EA flow models and estimated hydrology in the Mica Dam tailrace under the Unit 5/6 conditions.

Two key periods of the annual hydrograph were thought to have potential project effects on the Nagle Creek wetland (KCB, 2009). The first period spans March 15 - April 29 (Session 1) when water surface elevations are expected to increase, resulting in a change to the wetted area of the wetland. The second period is June 20 - July 31 (Session 2) when water surface elevations are expected to decline, resulting in less wetted area.” (KCB, 2009)

BC Hydro’s current operational regime maintains Revelstoke Reservoir at a consistent water level (571.5 m to 573.02 metres above sea level - MASL). The Mica 5/6 EA notes that the Revelstoke Reservoir operational regime will be modified after installation of the two new generators, whereby the Revelstoke Reservoir will still vary between a high full pool elevation of 573.02 MASL and a low end draft limit elevation of 571.5 MASL each year (KCB 2009, and 2013), but there will be increased flow-through of water volumes from the Revelstoke as to allow the increased flow from Mica 5/6 to pass downstream in a run-of-river manner. As such, the increased water flow from Mica Dam will result in changes to water flow volumes and water depths that may affect riparian wetland and wet forest vegetation, which in turn could affect wildlife abundance, diversity and habitat use along the Revelstoke Reservoir.

Because of the new flow management regime relating to the addition of Mica 5/6, it is important to fully understand the relationship among water level management, the establishment and success of riparian vegetation communities and cottonwood forests, and how these are ultimately linked to wildlife communities (Kushlan, 1986; Sedgwick and Knopf, 1992; Bell et al., 1992; Chow-Fraser et al. 1998).

The challenge of this current study (CLBMON 59) is to summarize the extent of the Mica 5/6 project-related water level change on the wetland boundaries at Nagle Creek through field sampling and desktop analyses, to determine if there is a significant risk to the wetland habitat. The results of this study will determine the need to conduct future biological inventory assessments in the Nagle Creek wetland area of Revelstoke Reservoir. (BC Hydro, 2011)

1.3 Management Questions

The management questions to be addressed by this monitoring program relating to the impacts of the operations Mica Units 5 and 6 are:

1. What is the estimated change in wetland boundary resulting from the Mica 5 and 6 proposed operations?
2. If a wetland boundary change is anticipated, is a significant residual impact to the wetland habitat function expected?

This study is considered a preliminary, scoping study that does not include baseline species inventory or a complete wetland functional assessment. The Consultant will be asked to estimate potential residual impacts by cross referencing the identified wetland community with its published wetland community habitat requirements and the predicted physical environment changes. Information gaps related to the management questions will also be reported by the consultant at the end of the study. (BC Hydro, 2011)

1.3.1 Management Hypothesis

The management hypotheses to be tested under this monitoring program are:

H1: Annual and seasonal variation in Mica tailrace water levels resulting from proposed operation of the Mica generation Units 5 and 6 ("Mica operations") do not directly or indirectly impact the small Nagle Creek wetland area near its estuary.

H1A: Mica Units 5 & 6 operations are not expected to result in a decreased wetland wetted area.

H1B: Mica Units 5 & 6 operations are not expected to result in changes to wetland water temperature. (BC Hydro, 2011)

1.3.2 Key Water Use Decision Affects

The key operating decisions affected by this monitoring program are the operating regimes for generation Units 5 and 6 of the Mica Dam. Results of this monitoring program will determine the need for further study of the potential for operational influence to create a residual environmental effect for the Nagle Creek wetland habitat and its boundaries near the estuary. (BC Hydro, 2011)

1.4 Monitoring Program

1.4.1 Objectives and Scope

This monitoring study consisted of one (1) year of monitoring at the Nagle wetland under Mica 1-4 conditions (pre-Mica 5/6), commencing in 2012. The results of this baseline monitoring are expected to provide insight regarding whether a significant risk to wetland habitat is expected to result from the proposed Mica Units 5 & 6 operations. The key objectives of this monitoring program are to:

1. Delineate the Nagle Creek wetland habitat boundaries and describe any changes for periods of potential flow change related to Mica Units 5 & 6 operations.

2. Describe the wetland water surface elevation and temperature relationship with changing Mica generation flows. A key part of this objective will be to determine the relative influence of the Nagle Creek discharge and the changing levels in Revelstoke Reservoir on the wetland water surface elevation and temperature.

3. Estimate the water surface elevation in the wetland under the proposed flows for the Mica Units 5 & 6 project and determine how this differs from operations of units 1-4. (BC Hydro, 2011)

2 METHODS

This study examines the impact of water additions to the Revelstoke Reservoir that may result from the addition of two new generators at the Mica Dam (the Assessment Case).

A variety of methods were used to meet these objectives, including review of related documents and records, desktop analyses, hydraulic modelling with calibration and a variety of field observations relating to water elevation data, wetland classification and definition of an elevation profile at the wetland site.

The initial phase, prior to field sampling, involved a review of the proposed Mica 5/6 operations, the related Mica 5/6 Environmental Assessment hydraulic modeling, and calibration work completed during the Environmental Assessment (EA). The periods of greatest risk to the wetland were identified by a review of historical water elevation records. Field methods were developed to delineate the wetland and to define an elevation profile at the wetland with sufficient precision to reliably determine the effect of anticipated water elevation changes.

2.1 Locations of Field Sampling Plots

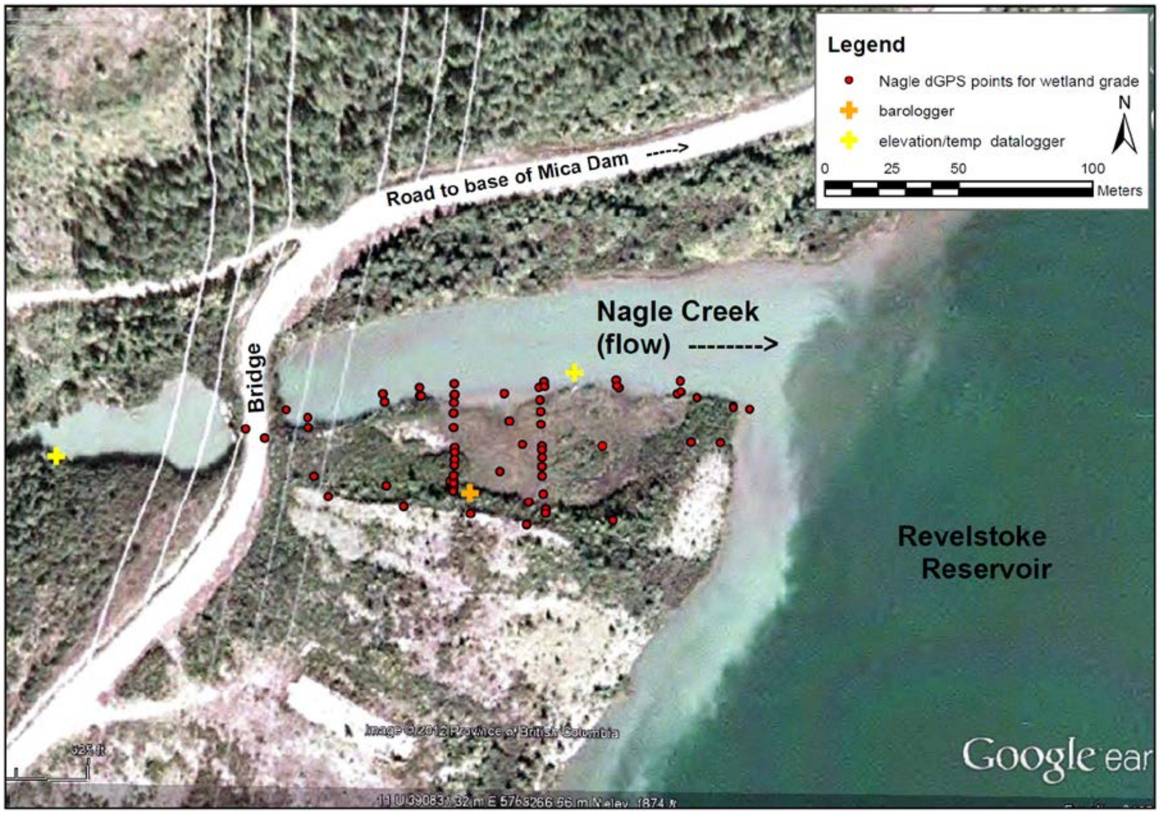

Figure 3 Overview of the 2012 CLBMON 59 sampling site, situated at Nagle Creek. Background data from digitized Google Earth air photos

2.2 Field Data Collection

Field surveys to collect data occurred on May 8-9, June 18-19, September 11-12 and September 24, 2012

2.2.1 Wetland Classification

Wetland type was assessed via the system of BC Ministry Forests, Lands, and Natural Resource Operations (Mackenzie and Moran, 2004). Plant identification was conducted to properly determine the wetland classification.

Differential GPS (Trimble dGPS) elevation/position points were recorded while in the field for a variety of positions, including dataloggers, barologger, wetland category/type boundaries, and additional points to provide dGPS data for the creation of a *micro-topographic profile* of the Nagle Creek wetland surface. Points recorded with dGPS are shown in Figure 3.

Subsequently the dGPS data were uploaded and processed using ArcGIS 9.3 to allow creation of an elevation profile using interpolation from the dGPS points.

2.2.2 Water Elevation Measurements

Two Solinst Level Loggers (Model 3001l) water pressure transducer elevation/temperature dataloggers were installed on May 8, 2012. Data were collected from May 8 to September 24, 2012. Dataloggers were placed inside a protective stilling pipe. An atmospheric barologger was also installed at the Nagle Creek site to provide local air pressure readings to enable calibration of the water elevation records. Positions of the dataloggers were recorded to allow the records to be matched to an elevation (MASL). Locations of the dataloggers and the barologger are also shown in Figure 3. Further details about the hydrological data and modelling are available in the attached hydrological report from Klohn Crippen Berger (KCB) (KCB, 2013), found in Appendix A.

2.2.3 Flow Rates of Nagle Creek

Stream flows were recorded on a cross-section of Nagle Creek using a handheld Marsh-McBirney Flo-Mate meter, and the data were subsequently converted to discharge volume following BC hydrometric standards (MoE, 2009). Further details about the hydrological data and modelling are available in the attached hydrological report from KCB (KCB, 2013), in Appendix A.

2.3 Desktop

2.3.1 Water Elevation Data and Modelling

Data from multiple sources were examined for this project, in accordance with the project Terms of Reference. Nupqu Development Corporation hired Klohn Crippen Berger (KCB) to complete this segment of the project, due to Klohn Crippen Berger's experience with hydrological modelling in the same area for the Mica 5/6 Environmental Assessment. Hydrological data examined included the following:

- BC Hydro operational water elevation data for Mica Dam, Revelstoke Forebay;
- Water elevation records for representative wet, dry and average years, as supplied by BC Hydro;
- BC Hydro Generalized Optimization Models (GOM) for M4R5 and M6R5.

Table 1: Description of BC Hydro Dam Discharge Condition Models

Model	Dam Discharge Condition Description	Assessment Condition
M4R5	Mica Generating Station – 4 units operating. Revelstoke Generating Station – 5 units operating.	Baseline Case
M6R5	Mica Generating Station – 6 units operating Revelstoke Generating Station – 5 units operating	Assessment Case

In addition, Klohn Crippen Berger ran a number of models covering flow simulations (HEC-RAS models), and calibrated those models using water elevations data, flows data and cross-sections from both this study's field program and from BC Hydro water elevations monitoring stations at Mica Dam, through Revelstoke Reservoir and at Revelstoke Forebay. Modelling included:

- HEC-RAS model calibration;
- HEC-RAS simulation of water elevations at Nagle Creek under comparative management scenarios;
- Examination of water temperature records for Nagle Creek wetland location;
- Validation of the model outputs against observed site data.

Details of the Klohn Crippen Berger hydrological analyses are contained in Appendix A.

2.4 Wetland Impacts Modelling

2.4.1 Nagle-General Optimisation Model (GOM)

After receipt of the KCB hydrology report data and model outputs, Nupqu Development Corporation utilized this data for further modelling related to water elevations at the Nagle wetland. The HEC-RAS simulation results were combined with the BC Hydro Rev5 GOM models to create a modified General Optimisation Model that projected water elevations at

Nagle Creek throughout a full year. The Nagle-GOM model results were then used to produce Exceedence (flooding) data regarding the effects of proposed management changes on the duration and depth of inundation at the Nagle Creek wetland. The Exceedence data were also used to relate water elevation management to elevations at the wetland from the GIS interpolation results.

2.4.2 Exceedences and Comparison of Inundation Scenarios

The Exceedence data and the GIS interpolated wetland surface elevations data were plotted together in order to gauge the area of impacts due to higher water levels during M6R5 (Assessment Case) inundation, in comparison to the M4R5 Baseline scenario. This allowed assessment of impacts from changes in water depth, inundation duration, and inundation timing that are likely to have on vegetation at the Nagle Creek wetland.

3 RESULTS

3.1 Wetland Delineation

Three sections of wetland were identified, each of which had a different wetland type characteristics (Figure 4).

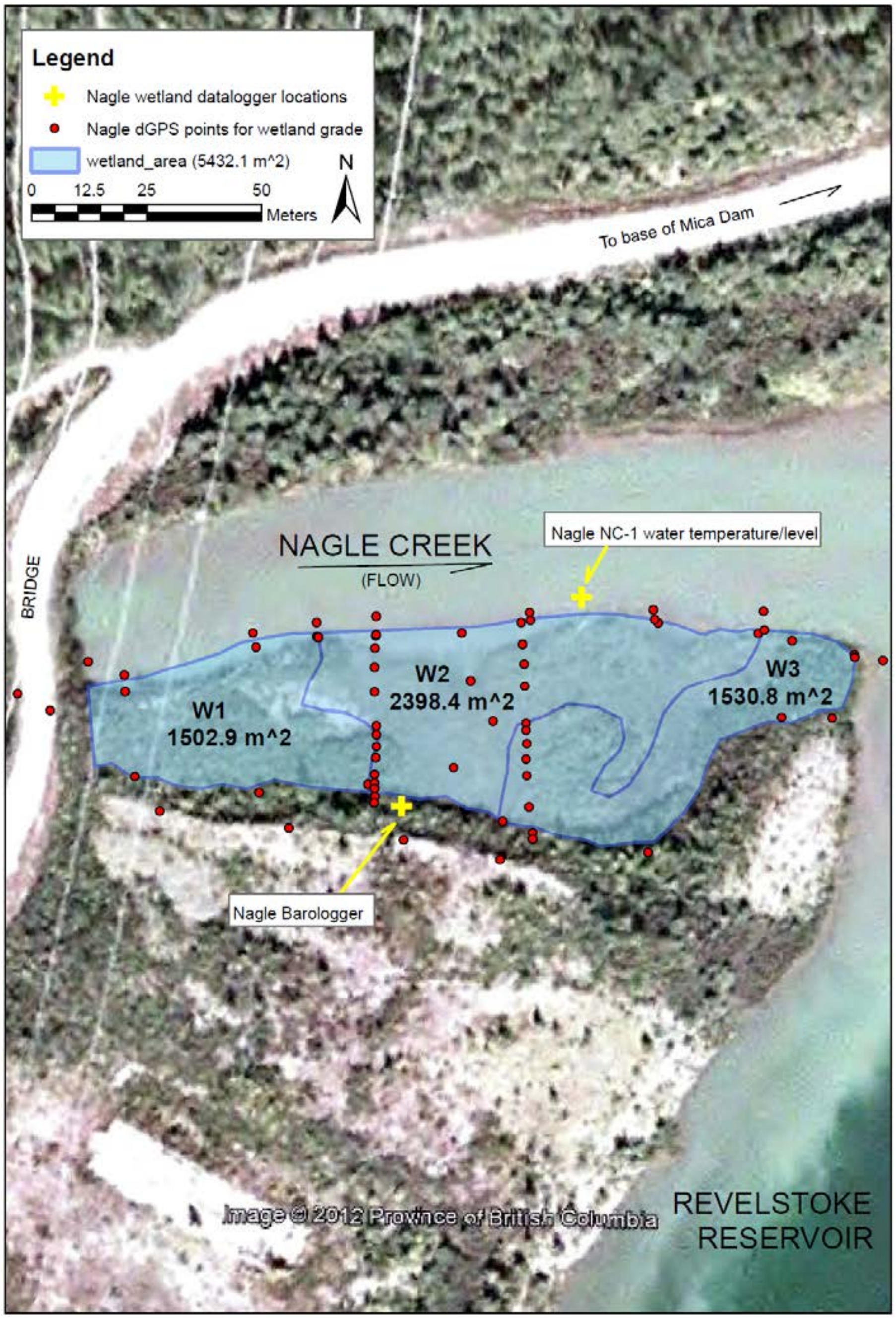

Figure 4 Three sections of wetland showing three different types, area of wetland types, location of dGPS points and location of NC-PT1-1 datalogger and Barologger.

3.2 Wetland Type Classification

In many cases wetlands may be subdivided based on visible characteristics, of which plant physiognomy is a major indicator along with species present. Often a wetland will also contain a progression of multiple wetland types based on microsite details. This was the case with the study site, and it was determined that three wetland types were present (Figure 5, Figure 6, and Figure 7).

The site is located in the Interior Cedar-Hemlock (ICH) bio geo-climatic zone. Based on the poor drainage wet/very wet hydric to subhydric mineral soils, lacustrine topographic site position and plant physiognomy, it was determined that the majority of the Nagle Creek wetland is a willow swamp. As mentioned earlier, many wetlands are composites of several different wetland types due to the variety of conditions present. Stratifying the Nagle Creek wetland site into three components is worthwhile since the central portion is very wet with a mobile hydrodynamic index, and does not support tall shrubs or trees; instead having primary cover of low-growing graminoid (grasses) and forb species. Subdivision into components yields three wetland zones shown in Figure 4:

- W1 – *Ws02 (Alder-Spirea-Sedge) / Ws04 (Willow-Sedge);*
- W2 – *Wm01 (Beaked Sedge – Water Sedge);*
- W3 – *Ws04 (Willow-Sedge).*

Figure 5 Photo of the site May 9th, 2012, showing the tall shrubs and small trees located in segment W1. Larger shrubs and small trees also grow on the steeper slopes around the wetland margin.

Figure 6 Photo of the site May 9th, 2012, showing the thin peat over mineral soil nature of the wetland, as well as low graminoids and herbs with interspersed small shrubs located in segment W2. Larger shrubs and small trees grow on the steeper slopes visible behind the surveyor, around the wetland margin.

Figure 7 Photo of the site May 9th, 2012, showing small shrubs located in segment W3. Larger shrubs and small trees grow on the steeper slopes visible at the back, around the wetland margin. Some of the lowest areas in the wetland are next to the large rock in the foreground, and as such those areas are often inundated for long periods of time which appears to have resulted in vegetation dieback. See Figure 14 for reference regarding water inundation levels at this exact location, summer 2012.

The Mica 5/6 EA (KCB, 2009) noted the site as a willow swamp, with Drummond's willow (*Salix drummondiana*), tapered rush (*Juncus acuminatus*) and small flowered bulrush (*Scirpus microcarpus*) present, which favors the classification more towards Ws04 (Willow-Sedge). During this study alder (*Alnus spp*.) and *Spiraea* were present as well, thus the listing of composite types. Drummond's willow is listed provincially as S5 and secure on the yellow list, and is listed as G4G5 globally. The remaining species common to these specific wetland types are beaked sedge (*Carex utriculata), water sedge (Carex aquatilis),* Sitka sedge *(Carex sitchensis),* marsh reedgrass *(Calamagrostis canadensis),* marsh cinquefoil *(Comarum palustre),* black twinberry *(Lonicera involucrata)* and pink spirea (*Spiraea douglasii)*, none of which are listed as species of concern in BC. Additional site observations were made of round-leaved sundew (*Drosera rotundifolia)* and white bog-orchid (*Platanthera dilatata*), which are both yellow-listed species.

MacKenzie and Moran (2004) describe marshes as shallowly flooded mineral wetlands with a dynamic hydrological regime, characterized by emergent grass-like vegetation, and often having low floristic diversity and strong dominance by one or few species. Usually marshes have >10% cover by emergent graminoids, or occasionally forbs and horsetails, with sparse or absent tree, shrub and bryophyte cover. Flooding in early season is up to 3 meters in water depth, and some marshes remain flooded at lesser depths throughout the year while others experience summer drawdown and associated substrate exposure and drying. In cool climates, marshes are often found at sites with a relatively high degree of disturbance such as wave-exposed lakeshores, floodplains and levees where water flow prevents deep peat accumulation.

3.3 Wetland Surface Elevation Profile

Differential GPS (Trimble dGPS) elevation/position points recorded in the field provided data for creation of a micro-topographic profile of the Nagle Creek wetland surface. Points recorded with the dGPS are shown in Figure 4. Subsequently, the dGPS data were uploaded and processed using ArcGIS 9.3 to allow creation of an elevation profile using interpolation from the dGPS points. (Figure 8)

Based on the interpolated wetland surface elevation, the wetland extends from a low of approximately 573.1 MASL, at a dip along the shoreline of wetland segment W2, to a high of 576.9 MASL at the far westernmost edge of wetland segment W1. Some of this area is seasonally inundated when the reservoir levels rise. Inundation of the wetland due to high water levels deriving from Nagle Creek runoff was not observed during the spring site visit despite the large high-elevation snowpack of upper Nagle Creek in Spring 2012 (Figure 12). The lowest terrestrial dGPS points was 573.44 MASL and the highest was 575.82 MASL, and while not every point of the wetland was measured with the dGPS the interpolated wetland surface elevation is considered to be accurate.

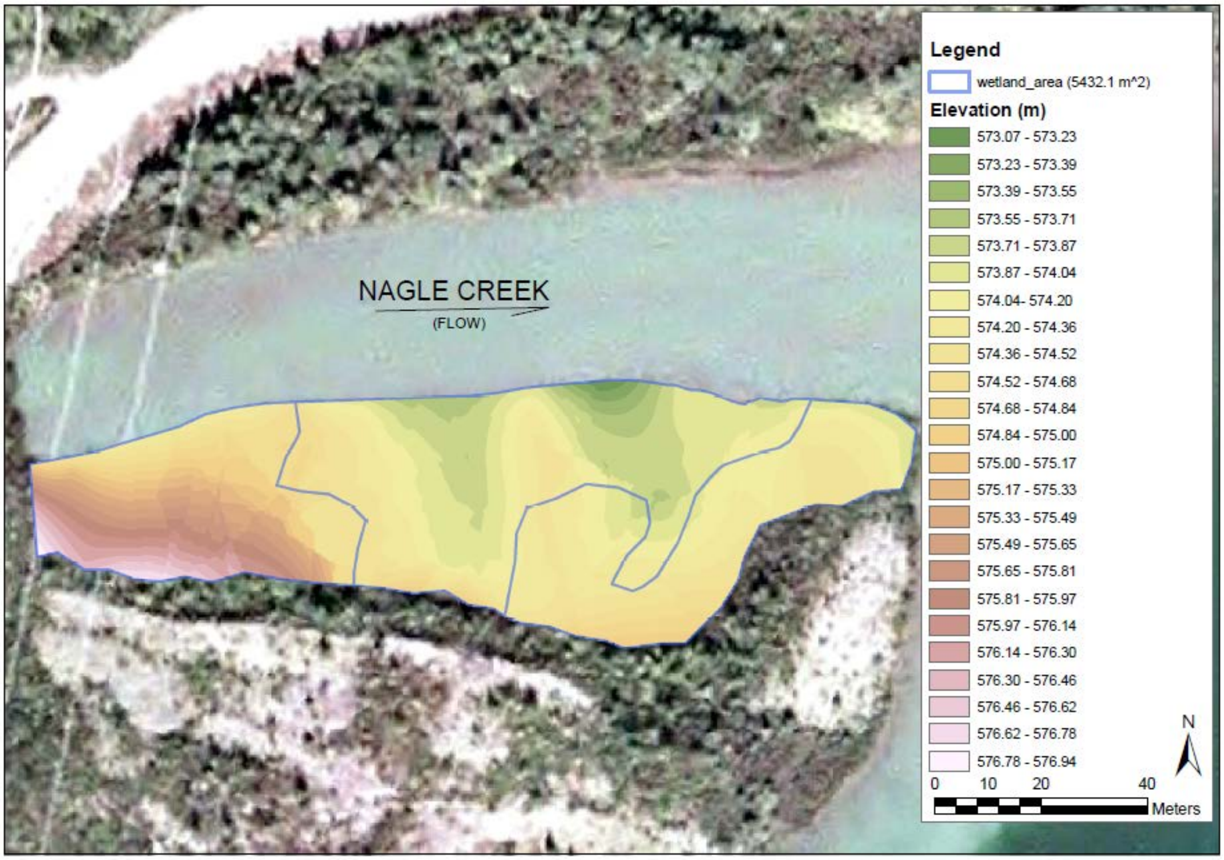

Figure 8 Interpolated elevations profile of the Nagle Creek wetland based on high-accuracy differential GPS.

3.4 Water Elevation Measurements

3.4.1 Natural versus Managed Hydroperiods

Natural hydroperiods often have more ‘uptrend’ and ‘downtrend’ at their ends due to higher spring runoff and lower summer droughts, but because the Revelstoke Reservoir is a dam-controlled system those uneven parts of the hydroperiod no longer occur. In order to examine the variability of the hydroperiod data, full water elevation cycle was plotted for each of the M4R5 scenarios (wet, dry and average years).

While there is some variability in the exact dates of the spring melt, the overall pattern of water elevation in Revelstoke Reservoir remains highly consistent across years with different snowpack and precipitation characteristics (Figure 9 and Figure 10). BC Hydro manages the water levels of the Kinbasket Reservoir to maximize use of the water storage capacity of Mica Dam by releasing substantial volumes of water in early spring, before the large part of the spring melt cycle begins (Hawkes et al, 2013). Data from 1966, 1968 and 1972 show that the highest water elevation levels at Revelstoke Reservoir occur in the summer and through the winter, not during these spring runoff cycles.

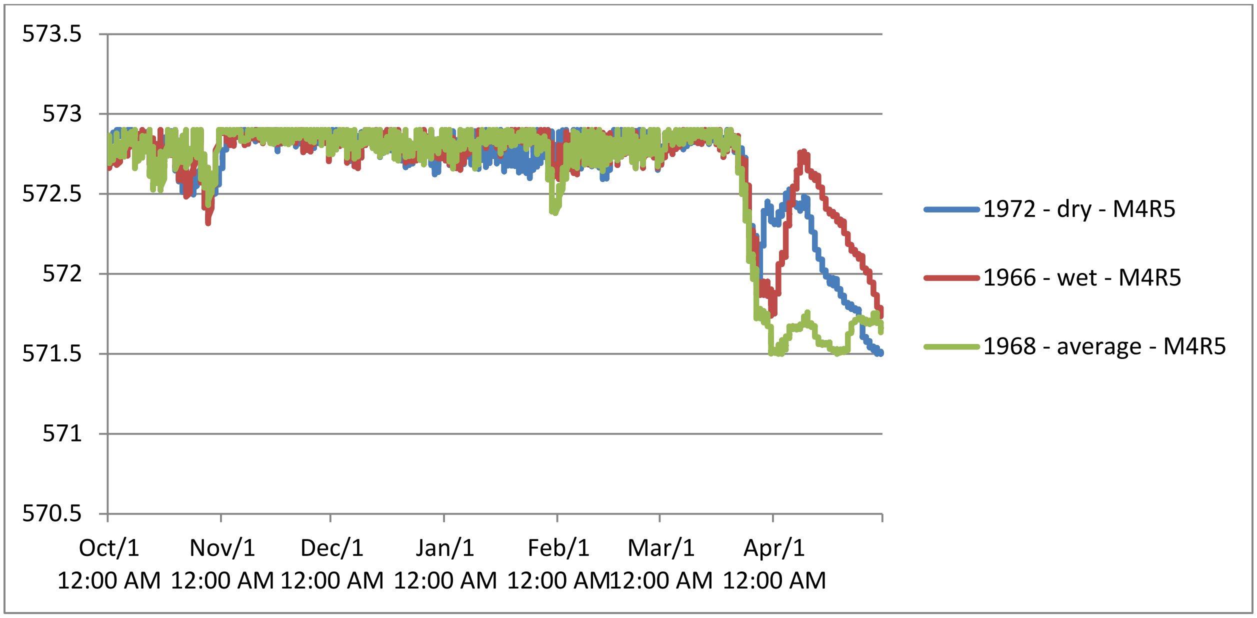

Figure 9 Water elevations in MASL for M4R5 in wet, dry and average years (1968, 1966 and 1972 respectively), showing the period October 1st to April 30th. Note the highly consistent winter water levels followed by lower spring elevations as water is drawn down in preparation for spring freshet.

Water levels in Revelstoke Reservoir are low and variable in the spring, but are highly constant the rest of the year, substantially more so than was the case before construction of the dam. Figure 11 - A clearly shows how much more variable the water flow cycles and elevations were by comparing before and after dam construction. This figure also shows how BC Hydro Water Use Planning has 'shifted' the spring freshet from a peak in June/July (Figure 11 - B), to a substantially smaller peak in August (Figure 11 - C). The shift no doubt has some impact on the composition of shoreline plant communities as some species will be better adapted to the natural cycle of spring submergence followed by gradual lowering of the water levels over the late summer, fall and winter, as opposed to the managed regime.

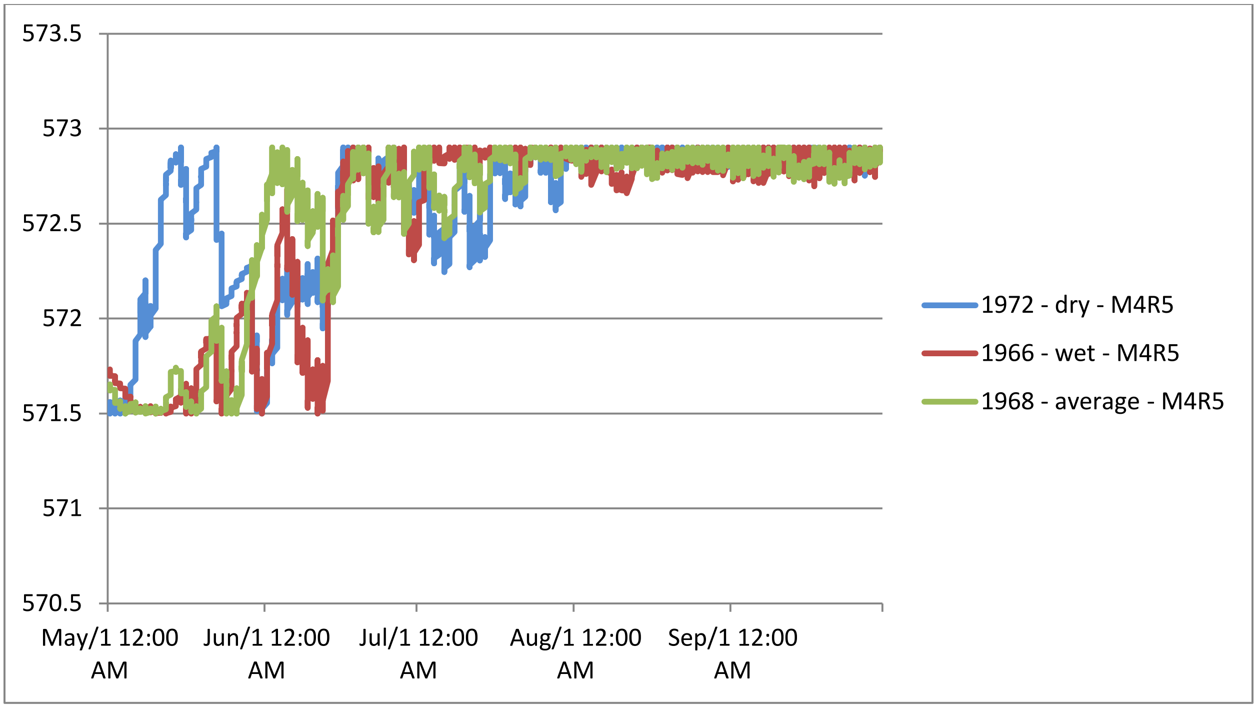

Figure 10 Water elevations in MASL for M4R5 in wet, dry and average years (1968, 1966 and 1972 respectively), showing the period May 1st to September 30th. Note the variable water levels during spring freshet, and the highly consistent water levels for the remainder.

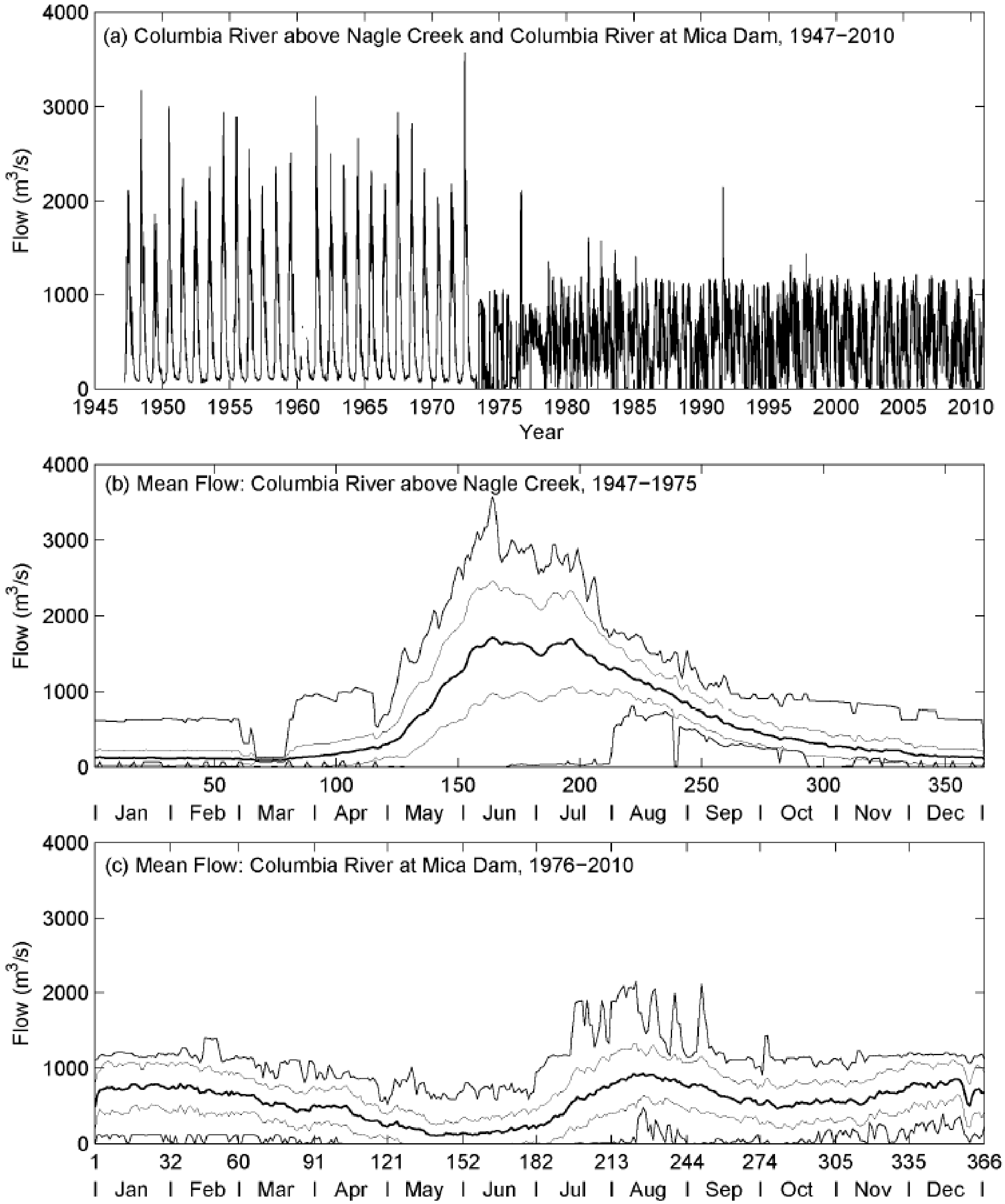

Figure 11 (A) WSC station 08ND007, “Columbia River above Nagle Creek”, 1947-1975 and BC Hydro station “Columbia River at Mica Dam Outflow”, 1976-2010. (B) Mean pre-impoundment flow for the years indicated. (C) Mean post-impoundment flow for the years indicated. Mean (heavy line), maximum and minimum (medium lines) and mean +/- one standard deviation (light lines). (From Bray, 2012)

3.4.1 High Spring Runoff

The winter of 2011/2012 had one of the deepest snowpacks documented in the region, and thus resulted in high volumes of spring runoff. Dataloggers were installed at the Nagle Creek site on May 8, 2012, just before the spring runoff began in that year.

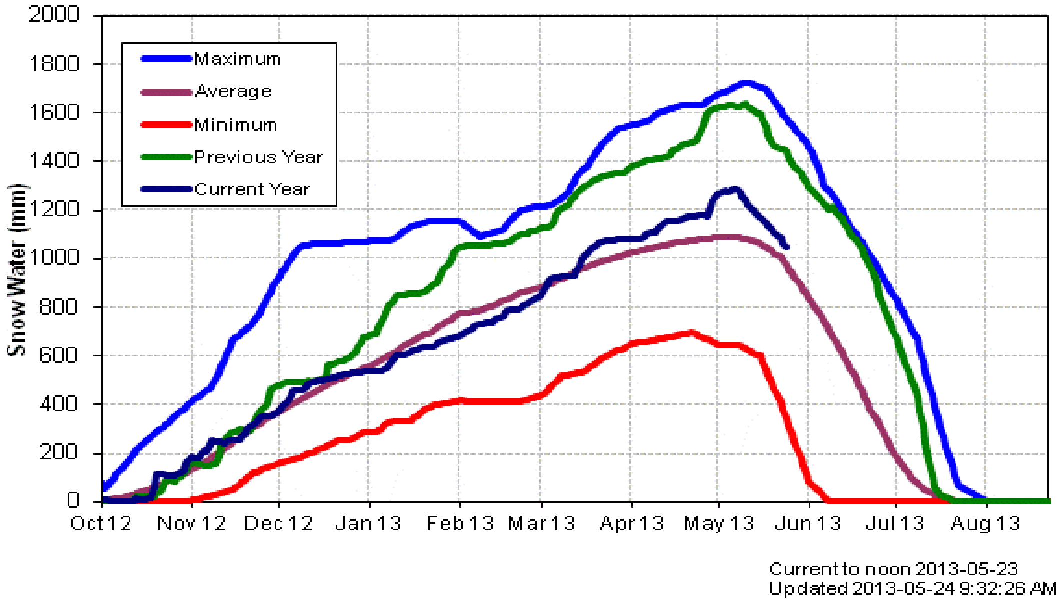

Figure 12 BC Hydro snow monitoring records for the Molson Creek snow pillow plot (records air temperature, precipitation, and snow water), located near the study location in the Upper Columbia region at Zone 11 416881 E / 5785835 N at 1930 m elevation. The green line shows 2012.

The deep snowpack resulted in a high level of snow water equivalent (Figure 12), which in spring and summer translated into high water levels in creeks and lakes that transport and store the associated runoff. Interestingly, despite the near-record snowpack in Spring 2012, both visual site observations and pressure transducer records (15 minute intervals) showed that Nagle Creek runoff water levels did not rise over the existing banks to flood the wetland (Figure 13 and Figure 14). The lack of flooding by the creek could be due to variations in the rate of warming and spring precipitation, which affect rate of spring snowmelt. It appears that flooding of the wetland is either very infrequent or rare, but this cannot be determined without long-term monitoring data.

3.4.2 Water Elevation Field Data and Modelling

A combination of data from BC Hydro (water elevations and flow records), KCB (profiles) and field data water from the Nagle Creek site were used to produce a calibrated model of water flows at Nagle Creek. Those results are presented in detail in Appendix A – Hydrology Report by Klohn Crippen Berger. A brief summary is provided here.

Reservoir cross-section data and both current and projects flows data from BC Hydro were used to develop and calibrate a HEC-RAS hydraulic model of the Revelstoke Reservoir. That model predicts water elevations that will occur at Nagle Creek when a given flow volume is released from Mica Dam, considering backwater effects from the reservoir. When the HEC-RAS assessment data were combined with the GOM-Rev5 models from BC Hydro and KCB a predicted GOM model for water elevations at Nagle Creek was produced.

Revelstoke Forebay M4R5 Full Pool Elevation (FPE) is 573.02 MASL, while at Nagle Creek, the modified Nagle-GOM simulations for Mica 1-4 show that the FPE is expected to be higher at 573.6 MASL. The Nagle-GOM M4R5 FPE water depth of 573.6 MASL predicts a small amount of flooding in the central W2 portion of the Nagle Creek wetland. As expected, a small amount of flooding was observed at the site during summer 2012 (Figure 13 and Figure 14).

The adjusted Nagle-GOM models also included the other scenario of interest, the water elevations during operation of the Assessment Case at the high FPE and low Draft Limit Elevation (DLE).

3.4.2.1 Wetland Impacts Modelling

After receipt of the KCB hydrology report data and model outputs, Nupqu Development Corporation utilized this data for further modelling related to water elevations at Nagle Creek wetland.

Nagle GOM Modelling

The BC Hydro GOM-Rev5 and KCB HEC-RAS models were combined to create modified Nagle-GOM models for projected water elevations at Nagle Creek throughout a full year. HEC-RAS modelling showed that the Revelstoke Reservoir elevation will be approximately 0.6 m greater FPE at Nagle Creek due to the increased flows from M6R5-FPE compared to M4R5-FPE. These differences were used to adjust the GOM-Rev5 model for Revelstoke Forebay to account for water elevations at Nagle Creek, creating the Nagle-GOM model predictions. Adjusted Nagle-GOM models included the full range of management scenarios of interest, including the water elevations during operation at M4R5 FPE and DLE and at M6R5 FPE and DLE.

Figure 13 Photo of the primary Nagle Creek wetland site as taken on May 8th, 2012. Note the exposed rocky shoreline on the right-hand bank of Nagle Creek, and the buildings visible on the other side of the Revelstoke Reservoir.

Figure 14 Photo of the primary Nagle Creek wetland site September 13, 2012. (Note the much higher water level as compared to May 8, since the rocky bank is no longer visible. The stilling pipe was substantially above water when installed in May 2012, but it is fully underwater in this photo.

Nagle-GOM water elevations were then compared to the wetland elevations profile from the dGPS wetland elevations interpolation. Differentially-corrected GPS (dGPS) locations collected at the site show that the minimum area of the Nagle Creek wetland is approximately 5432.1 m^2, and that the sub-sections of the wetland are W1=1502.9 m^2, W2=2398.4 m^2 and W3=1530.8 m^2 (Table 2). Based on the interpolated wetland surface elevation, the wetland extends from a low of approximately 573.1 MASL at a dip along the shoreline of wetland segment W2, to a high of 576.9 MASL at the far westernmost edge of wetland segment W1.

Table 2: Nagle Creek Wetland Sub-section Areas

Sub-Segments	Description	Baseline Case Minimum Area (m^2)
W1	Ws02 (Alder-Spirea-Sedge)/Ws04 (Willow-Sedge)	1502.9
W2	Wm01 (Beaked Sedge-Water Sedge)	2398.4
W3	Ws04 (Willow-Sedge)	1530.8
Totals		5432.1

The Nagle-GOM model results show that under Assessment Case, the DLE (i.e., lowest water elevation expected) will be 573.4 MASL, approximately the same height (+0.3 m) as the low end of the wetland elevation, and close to the highest elevations under the current Baseline Case. This is expected to result in higher groundwater in the wetland, and potentially a small amount of flooding of the toe of the wetland at this DLE level, which is the lowest of the Assessment Case water elevations planned. If the wetland toe remains flooded year-round it will have impacts on the wetland vegetation at the site, potentially pushing some of the plant species upslope. Few tall emergents were seen at the site (only small-flowered bulrush), so it may be some time before these types of plants colonize this habitat unless seeds or shoots are transplanted.

The Nagle-GOM model predicts Assessment Case FPE (i.e., highest management water elevation expected) to be 574.2 MASL, approximately 0.9 m above the wetland minimum elevation of 573.1 MASL, and thus is predicted to result in flooding of a relatively large portion of the W2 segment of the wetland. If this flooding is extensive during the growing season it may lead to disappearance of the majority of the species currently present and alter the balance between remaining species in favour of flood-tolerant species (Banach et al 2009). Most wetland plants can withstand some minor periodic flooding by means of physiological adaptations and energy budgeting (Manzur et al, 2009).

Exceedences and Comparison of Baseline and Assessment Case Scenarios

DURATION OF INUNDATION

Exceedences are a way of calculating the probability that water levels will exceed a given elevation based on statistical analysis of historical values. From these calculations, the amount of time that a certain water level may occur can be extrapolated. For example, if a measured water elevation under the Assessment Case is 573.56 MASL, comparing this with the related table (Table 3) shows that this water elevation will be exceeded 80% of the time.

Table 3: Exceedences for M4R5 (Baseline Case) and M6R5 (Assessment Case) scenarios, and difference in water elevations between the two cases.

% Exceedence	**Nagle Creek Location**		
	M4R5 water elevation (m)	**M6R5 water elevation (m)**	**M6R5 - M4R5 elevation difference (m)**
Minimum (low water, DLE)	572.50	573.40	0.90
100	572.50	573.40	0.90
95	572.55	573.43	0.88
90	572.60	573.47	0.87
85	572.65	573.51	0.86
80	572.70	*573.56*	0.86
75	572.75	*573.59*	0.84
70	572.80	*573.62*	0.82
65	572.85	*573.66*	0.81
60	572.91	*573.70*	0.79
55	572.95	*573.74*	0.78
50	573.00	***573.77***	0.77
45	573.05	*573.81*	0.76
40	573.10	*573.84*	0.74
35	573.15	*573.87*	0.72
30	573.20	*573.91*	0.71
25	573.25	*573.95*	0.70
20	573.31	*573.99*	0.68
15	573.36	*574.03*	0.67
10	573.40	*574.07*	0.67
5	573.46	*574.10*	0.64
0	**573.52**	*574.13*	0.61
Maximum (high water, FPE)	573.60	574.20	0.60

Note that M6R5 water elevation is predicted to be greater than M4R5 water level at 0% Exceedence.

Data presented in Table 3 allows for comparison of both management scenarios: the M4R5 (Baseline Case) versus M6R5 (Assessment Case). The data indicate that 50% M6R5 Exceedence is higher than FPE at M4R5 Base Case Exceedence (Table 3, also bold and underlined item). Also, the M6R5 scenario shows that the Nagle Creek wetland will be inundated with deeper water and for a greater duration of time than M4R5, since 80% Exceedence for M6R5 is higher than 0% Exceedence for M4R5 (Table 3).

AREA OF INUNDATION

Comparison of the Baseline Case and the Assessment Case was also made in terms of the area of inundation that occurs in each case. Table 4 shows that the Assessment Case results in substantially more flooded area within the Nagle Creek wetland than currently occurs under the Baseline Case. The W2 wetland segment, which has the lowest elevations, is the most strongly affected with over half its area inundated during the higher water levels (50% Exceedence level or higher). While the current Baseline Case indicates only 2.7% areal flooding, and only at the highest water levels, the Assessment Case is predicted to have increases in inundation of up to 61% of W2, 19.6% of W3 and 1.3% of W1 wetland sub-segments. This is presented in Figure 15 and Figure 16, which show the inundated areas for both M4R5 and M6R5, as well as the Exceedence limits as they relate to inundation of the wetland areas.

Table 4: Area of flooding at different percentages of Exceedence levels within the Nagle Creek wetland, comparing both the M4R5 and M6R5 scenarios. Total area of inundation summed amounts to 0.2197 hectares (ha), 40.4% of total wetland area (0.5732 ha).

Scenario	water depth (m) at given Exceedence level	W1-dry (ha)	W1-wet (ha)	W2-dry (ha)	W2-wet (ha)	W3-dry (ha)	W3-wet (ha)
M4R5 - Exceedence 0%	573.52	0.1503	0	0.2334	0.0064	0.1531	0
M4R5 - Exceedence 50%	573.00	0.1503	0	0.2398	0	0.1531	0
M4R5 - Exceedence 100%	572.55	0.1503	0	0.2398	0	0.1531	0
M6R5 - Exceedence 0%	574.13	0.1501	0.0002	0.0868	0.1530	0.1231	0.03
M6R5 - Exceedence 50%	573.78	0.1503	0	0.2007	0.0391	0.1527	0.0004
M6R5 - Exceedence 100%	573.40	0.1503	0	0.2364	0.0034	0.1531	0
M6R5 to M4R5 difference - Exceedence 0%	0.61	-0.0002	0.0002 (+1.3%)	-0.1466	0.1466 (+61%)	0.0300	0.0300 (+19.6%)
M6R5 to M4R5 difference - Exceedence 50%	0.78	0	0	-0.0391	0.0391 (+16.3%)	0.0004	0.0004 (+0.3%)
M6R5 to M4R5 difference - Exceedence 100%	0.85	0	0	-0.0034	0.0034 (+1.4%)	0	0

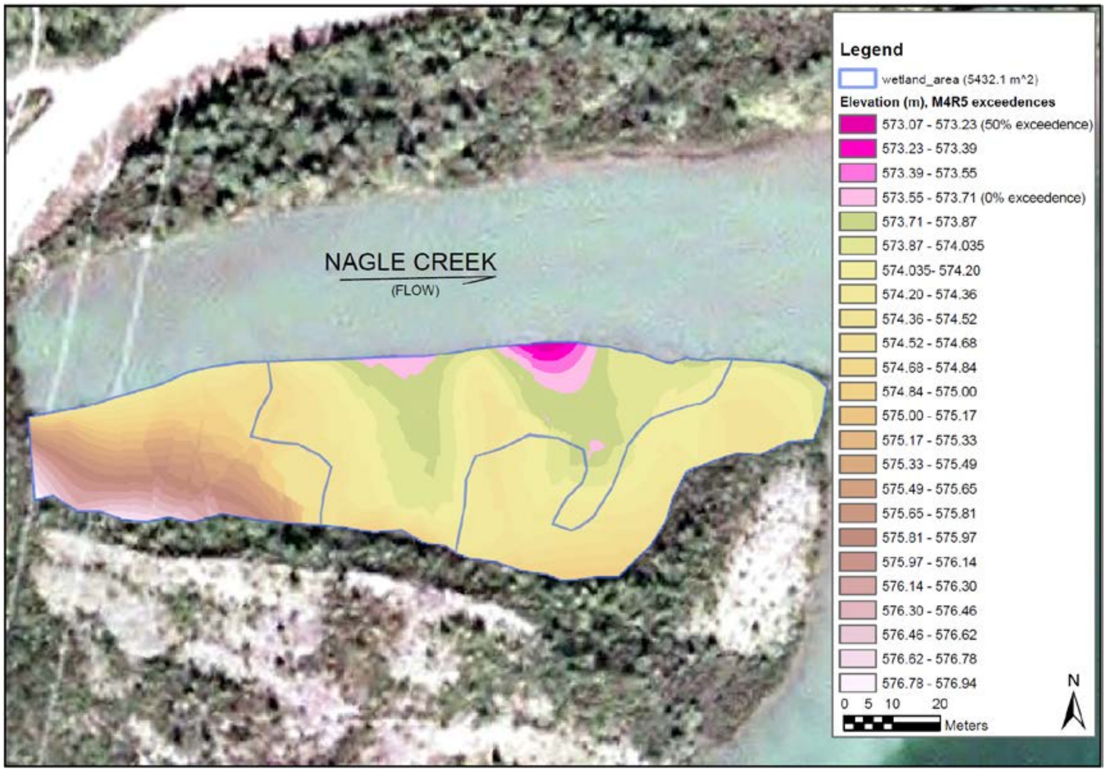

Figure 15 M4R5 Impact areas under current water elevation management scenario, 50% to 0% Exceedence.

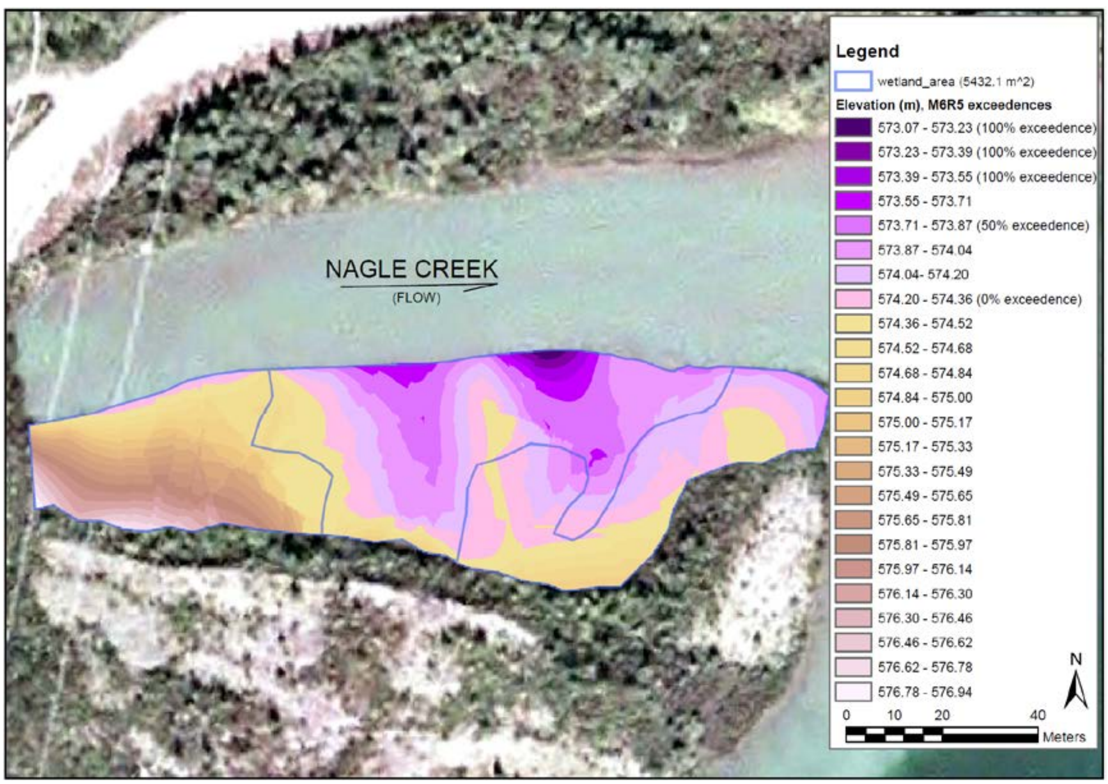

Figure 16 M6R5 Impact areas under current water elevation management scenario, 100%, 50% to 0% Exceedence.

FREQUENCY OF INUNDATION

After implementation of the assessment case water regime, inundation of the Nagle Creek wetland is predicted to be more frequent at the deeper end of the range (lower % Exceedence; Table 5). Differences between average cumulative inundations show that the Assessment Case has more frequent inundations at 55% - 65% Exceedence or above, and substantially more days at 35% Exceedence inundation level or deeper than the Baseline Case. This means the Assessment Case water management regime will tend towards the deep end of the management range, and thus the Nagle Creek wetland will be inundated for substantially more days per year under the Assessment Case scenario than under the current Baseline Case.

The overall theme for the Assessment Case is that of more lengthy durations of inundation, more frequent inundation, a greater area of inundation, and deeper inundation of the Nagle Creek wetland relative to the Baseline Case. Overall it is predicted that 89 more days at 5% Exceedence inundation level (plus 42 @ 10%, and 67 at 0%) will occur, for a total of 198 more days at these highest inundation levels relative to the Baseline Case. This scenario would be a major shift from the current operating regime that results in little or no inundation of the wetland.

Table 5: Area of flooding at different % Exceedence levels within the Nagle Creek wetland, comparing both the M4R5 and M6R5 scenarios.

% Exceedence	M4R5 M4R5 - water elevation	M4R5 M4R5 - # days inundated	M4R5 M4R5 - # days inundated this depth or deeper, per year	M6R4 M6R5 - water elevation	M6R5 M6R5 - # days inundated	M6R5 M6R5 - Number days inundated this depth or deeper, per year	M6R5 - M4R4 M6R5 - M4R5 elevation difference (m)	M6R5 - M4R5 M6R5 - M4R5 Difference in number inundated days	M6R5 - M4R5 M6R5 - M4R5 Differences between days inundated this depth or deeper per year
Minimum (100) = low water	572.5	0.95		573.40	2.05		0.90	1.11	
95.01 - 100.00	572.50	15.22	365.04	573.40	13.61	364.99	0.90	-1.61	-0.05
90.01 - 95.00	572.55	6.33	349.82	573.43	8.44	351.38	0.88	2.11	1.57
85.01 - 90.00	572.60	7.08	343.48	573.47	5.81	342.94	0.87	-1.28	-0.54
80.01 - 85.00	572.65	5.72	336.40	573.51	5.19	337.13	0.86	-0.53	0.73
75.01 - 80.00	572.70	3.14	330.68	573.56	4.61	331.94	0.86	1.47	1.26
70.00 - 75.00	572.75	3.89	327.54	573.59	3.00	327.33	0.84	-0.89	-0.21
65.01 - 70.00	572.81	3.33	323.65	573.62	1.97	324.33	0.82	-1.36	0.68
60.01 - 65.00	572.85	3.17	320.31	573.66	2.33	322.36	0.81	-0.83	2.04
55.01 - 60.00	572.91	4.36	317.15	573.70	2.89	320.02	0.79	-1.47	2.88
50.01 - 55.00	572.96	4.36	312.79	573.74	4.47	317.13	0.78	0.11	4.35
45.01 - 50.00	573.01	4.06	308.42	573.77	3.64	312.66	0.77	-0.42	4.24
40.00 - 45.00	573.06	3.72	304.37	573.81	2.56	309.02	0.76	-1.17	4.66
35.01 - 40.00	573.12	4.89	300.64	573.84	2.92	306.47	0.74	-1.97	5.82
30.01 - 35.00	573.16	6.56	295.75	573.87	4.22	303.55	0.72	-2.33	7.80
25.01 - 30.00	573.21	7.06	289.20	573.91	6.00	299.33	0.71	-1.06	10.13
20.01 - 25.00	573.26	8.58	282.14	573.95	6.64	293.33	0.70	-1.94	11.19
15.01 - 20.00	573.31	14.97	273.56	573.99	8.36	286.69	0.68	-6.61	13.13
10.01 - 15.00	573.36	35.44	258.59	574.03	12.89	278.33	0.67	-22.56	19.74
5.01 - 10.00	573.41	73.95	223.14	574.07	27.39	265.44	0.67	-46.56	42.30
0.01 - 5.00	573.46	125.00	149.20	574.10	147.03	238.05	0.64	22.03	88.86
0	573.51	24.20	24.20	574.13	91.03	91.03	0.61	66.83	66.83
Maximum (0) = high water	573.51	24.20		574.20	91.03		0.6		

3.5 Wetland Water Temperature

The project Terms of Reference requests that the effect of the change in water regime in Revelstoke Reservoir on water temperatures in the wetland be examined. The dataloggers installed at the site recorded temperature as well as pressure. The KCB 2013 report (Appendix A) states: "Over the duration of the observation period (May 8^{th} to September 24^{th} 2012), mixing and backwatering effects from the Revelstoke Reservoir have an effect on water temperature at the NC_1-1 site, but have a limited impact on water temperature recorded at the NC_2-1 site". This means that Revelstoke Reservoir is very likely to influence water temperatures of the wetland as long as the site remains contiguous with the reservoir and is exposed to flooding when the reservoir water elevation rises. If the water in the Nagle Creek wetland remains protected and the reservoir calm, there may be some effect of 'ponding' in the flooded wetland (after M6R5 it will be inundated to a greater extent) whereby the water is semi-trapped and thus warms to a temperature greater than the Revelstoke Reservoir in general, but the data are not yet available to predict what this higher temperature in the wetland may be.

4 DISCUSSION

4.1 Wetland Impacts

4.1.1 Wetland Types

The Nagle Creek wetland site can be divided into three different types of wetlands. Each of these wetland types occupies a different elevation zone and they exhibit variation in the tolerance of their member plants to inundation. The wetland subsection W2 (Wm01 - Beaked Sedge-Water Sedge) is most susceptible to be impacted since it occupies the lowest elevation band and plants there will need to struggle the most to adapt to the anticipated water levels.

4.1.2 Duration, Frequency, Depth and Area of Inundation Impacts under the Assessment Case

The overall theme in the Assessment Case is that of more lengthy durations of inundation, more frequent inundation, a greater area of inundation, and deeper inundation relative to the Baseline Case. Overall there are 89 more days at 5% Exceedence inundation level (plus 42 @ 10%, and 67 at 0%) for a total of 198 more days at these highest inundation levels relative to the current regime, a major shift from the current situation which results in little or no inundation of the wetland. Greater depths of +0.9 m (DLE) to +0.6 m (FPE) are predicted to result from the rise in water levels.

4.1.3 Area of Impacts

The Assessment Case predicts substantially more flooded area within the Nagle Creek wetland than currently occurs under the Baseline Case. The W2 wetland segment, which has the lowest elevations, is the most strongly affected with over half the area inundated during the higher water levels (50% Exceedence level or higher). While the current Baseline Case model predicts only limited flooding, and only at the highest water level, the Assessment Case model predicts increases in inundation of up to 61% of W2, 19.6% of W3 and 1.3% of W1 wetland segments (Figure 15 and Figure 16).

4.1.4 Overall impacts

Given the impacts to wetland area, frequency and duration of inundation and depth of flooding, we expect that there will be some shift in the plant species composition and distribution. As was noted during the field visits in 2012, the area of deepest inundation is relatively devoid of plants already. If water levels rise further, a greater area of the wetland will be exposed to similar circumstances. In studies of adaptations by plants to inundation, Sorrel et al. (2012) found that the dominance of helophytes when standing water is present is due in large part to their morphological adaptations that allow them taller stature in the water, and minute physiological adaptations that allow them to withstand greater levels of oxygen deprivation despite being continually inundated. Most other species, such as small forbs, do not have these adaptations, and those species will die if they are submerged for long periods with no respite. Certain intermediary species such as some tall species of *Carex* (e.g., *C. utriculata* and *C. aquatilis)*, both of which were present at the site) are capable of changing their growth pattern to reduce low growth and focus on tall stems in order to adapt to higher water levels; however, the degree to which they would be successful in the Assessment Case is not known. Manzur et al. (2009) noted similar growth activity by partially submerged plants that extended shoots, but remained quiescent when fully submerged, a strategy doomed to fail if the water levels remain consistently deep rather than periodically rising and falling as is more typical in nature. This is one of the reasons for the decline of net primary productivity noted by Utzig and Holt (2008) in their analysis of impacts from dams over the Columbia Basin region, and a similar result may occur in the Nagle Creek wetland.

There are a two suggested options to deal with this situation. First, the do nothing approach. The plants may adapt and the wetland may become a haven for tall morphologies of *Carex* and see a bloom of other emergents such as bulrushes and cattails (*Typha spp*.). Second, plant some seeds or individuals of emergent species better adapted to deeper water. This would speed transition from the current wetland plant community to a new one that contains a greater diversity of deep-marsh type plants. This study did not include providing detailed vegetation composition analyses, but a list of potential candidate species could be derived from the species lists of the Arrow and Kinbasket vegetation inventory for example (Enns et al.; Hawkes et al 2013).

The Assessment Case predicts that the Nagle Creek wetland will be inundated at deeper water depths than it is currently, since 80% Exceedence for the assessment case is greater than 0% Exceedence for the Baseline Case (Table 4). This 80% Exceedence is also predicted to result in relatively large areas of the wetland being inundated for the majority of the year (i.e., 331.94 days) at depths approximately equal to the maximum depths at Baseline Case, versus only 24 days at those same maximum depths in the Baseline Case. Water depth at 50% M6R5 is higher than FPE at M4R5, and the area will be inundated 238-278 days at depths of 0.6 m deeper than current FPE for M4R5, which is virtually guaranteed to cause impacts to the vegetation, especially to smaller plants such as sedges and forbs that will no longer be above water for more than a few days a year (Figure 17). It is predicted that this will also cause impacts to small shrubs and possibly large shrubs and trees since they are not adapted to that water depth profile and in general cannot tolerate prolonged submergence. Additional impact may be caused by ice scouring at a higher and different level than what occurs at present. This assessment predicts that the vegetation communities will be 'pushed' upslope by the raised water levels. Species adapted to deeper water may replace the species currently present (e.g., emergents such as bulrush that favour growing in flooded areas), once they have colonized the site. Given the lesser amount of flat terrain upslope (the wetland is bounded by steep banks), this will cause a reduction in area of seasonally inundated wet meadow marsh wetland area by a substantial margin, replacing it with a marsh that is consistently flooded.

Tall *Carex* species are normally adaptable to about 0.3 m of inundation/submergence, after which the ability of the plant to ‘outgrow’ the impact is not sufficient and vegetative cover will decline (Sorrell et al, 2012). *Scirpus* spp (*S. lacustris, S microcarpus*) are also capable of morphologically greater heights, and together with *Typha* species (adaptable up to 2 m of depth), usually dominate the 0.5-2.0 m deep marsh habitat type.

4.1.5 Recommended further studies

Although the TOR document mentioned two seasons of interest (March-April, and May-September), the March-April runoff period was not examined when the CLBMON-59 project was allocated too late in the spring for that to be a feasible option. Our examination of the records (Figure 9 and Figure 10) implies that it is not strictly necessary to examine the current elevations data in the field during March-April runoff, because the water levels are generally lower at that time than they are during the remainder of the year.

Wetland plant species have varying susceptibility to inundation duration and depth of submergence. It is recommended that further investigation occur of species-specific and community composition response in relation to inundation, to better define preferences and tolerance range of the local species that are found in the drawdown water level management zone.

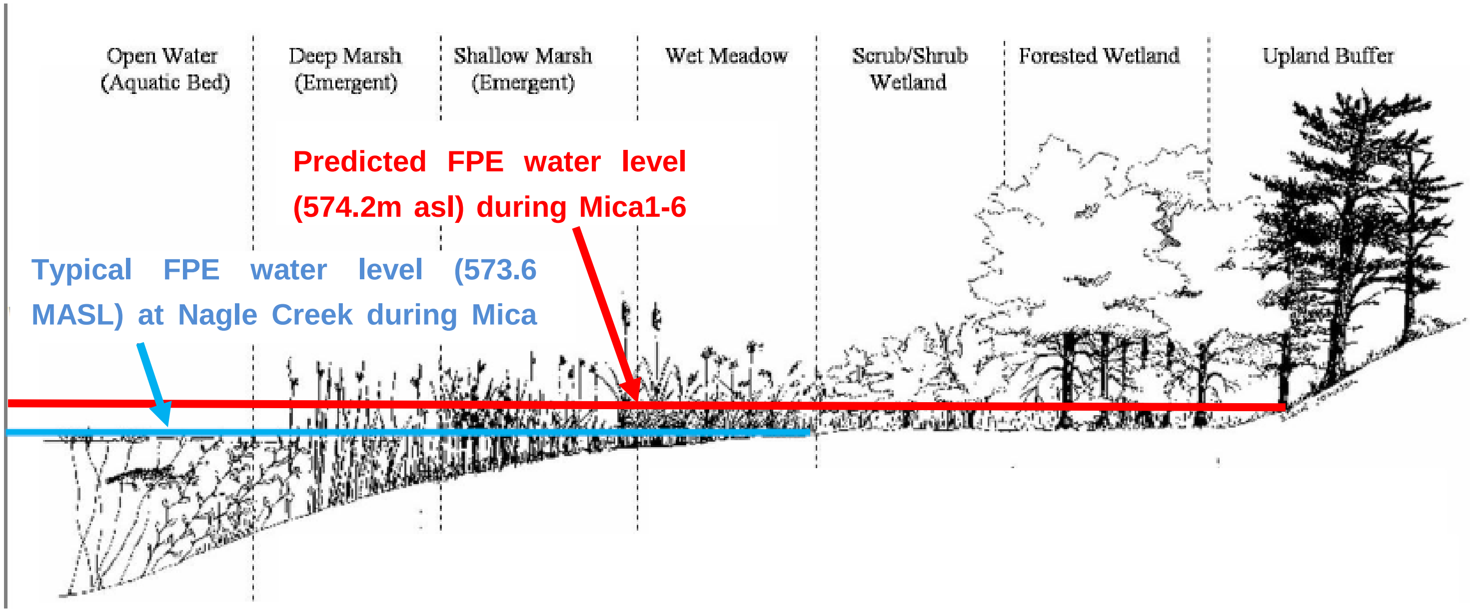

Figure 17 Hypothetical drawing demonstrating typical current Full Pool Elevation (FPE) water level at the Nagle Creek wetland during M4R5 (Mica 1-4; blue), and potential impact due to predicted 0.9m rise to FPE water level when the Mica 5/6 generators come online (Mica 1-6 GOM prediction results; red). (Original base figure from Fox and Keenan, 2011; water levels and descriptions added by Nupqu Development Corporation.)

4.1.6 Western Toad and Wetland Water Temperatures

The project Terms of Reference requests that the effect of the reservoir on water temperatures at the wetland be examined relative to potential impacts to western toads (Anaxyrus boreas). The COSEWIC Assessment and Status report is one of the best resources for this species (COSEWIC report - Wind and Dupuis, 2002), and in regard to toad breeding sites it states:

> *Western toads breed in a variety of natural and artificial aquatic habitats, with or without tree or shrub canopy cover, coarse woody debris, or emergent vegetation (COSEWIC 2003). They breed in ponds, stream edges, or the shallow margins of lakes (Olson 1992, Reimchen 1992, Corkran and Thoms 1996), as well as in ditches and road ruts (Gyug 1996, E. Wind and L. Dupuis, pers. obs.). Recorded oviposition depths range from 5 cm to 2 m, but depths greater than one metre are rare (Corn 1998). Livo (1999) found that toad breeding sites in Colorado had significantly fewer predators such as beetles and salamanders, than sites without and that site selection was a balance between water temperature and the presence of predators. In support of this, toad larvae aggregate in the warm, shallow margins of lakes during the day to accelerate their developmental rate (Poll et al. 1984) and seek cover among emergent vegetation (Olson 1992). They disperse to deeper waters at night (Livo 1999).*
>
> *Adult Western Toads congregate at breeding sites in the spring. In south-central British Columbia they breed in May (Poll et al. 1984, Gyug 1996), while in the Okanogan Highlands, Gyug (1996) found toad breeding to coincide with the time when average daily minimum and maximum temperatures rose above freezing and 10°C respectively.*
>
> *Egg embryos develop and hatch at approximately ten mm in total length (Nussbaum et al. 1983) within three to twelve days, depending on water temperatures (Leonard et al. 1993, Hengeveld 2000). Tadpoles of this species are often found at high elevation and latitude in early fall, where little time remains before the onset of winter snows (Kinsey and Law 1998, E. Wind, pers. obs.). Their transformation into ten to 12-mm long toadlets takes roughly six to eight weeks (Green and Campbell 1984). Metamorphosis is usually complete within 3 months of egg laying (Stebbins 1951).*
>
> *Like all amphibians, Western Toads are ectothermic, relying on movement between habitat types to thermoregulate. Unlike other smooth-skinned amphibians, toads and newts depend largely on their lungs for thermoregulation (Noble 1954). The range of voluntary thermal minima (3.0°C) and maxima (29.5°C) of Western Toads from southern latitudes is relatively wide compared to other amphibian species (Brattstrom 1963). Davis (2000) fitted toads on Vancouver Island with data loggers and found that their*

temperatures fell exactly within this range, even though surface temperatures fluctuated more extensively.

Based on this information, it is understood that western toad egg deposition occurs after snowmelt when breeding ponds are water-filled, but that the species is highly tolerant of quite a wide range of temperature conditions. Like most amphibian species, predation of eggs and young is a key limiter, and their life history strategy at this stage is to produce large numbers of eggs to improve the likelihood that some individuals will survive into sexually mature adults.

Given the wide range of temperature variability that the species is amenable to, it is capable of breeding in relatively cold conditions. The northerly aspect of the Nagle Creek wetland (which held snow into June in 2012), and the exposure of the site to open water of the Revelstoke Reservoir where fish may be present and preying on eggs and larvae (assuming it becomes flooded upon implementation of Assessment Case) means that the Nagle Creek wetland does not appear to be an ideal toad breeding site. If the intention is to create toad breeding habitat, then berms placed in strategic locations may result in better breeding sites, as parts of the wetland may then be isolated from the main body of the lake and thus reduce potential for predation.

4.1.7 Interpretation of Results

A listing interpretation of results on residual effects is given in Table 6. The format follows EA certificate methodology.

Table 6: List of potential impacts to the Nagle Creek wetland resulting from Assessment Case Implementation.

Impact type	Residual Effects	Confidence	Probability of Occurrence	Significance	Uncertainty
Area of wetland inundated	Increased area of inundation by 40.4%	high	high	Low	Low
Duration of inundation	Increased duration of inundation – for example, 332 cumulative days at 573.5m elevation under M6R5, versus 24 days at same depth under M4R5	high	high	Low	Low
Frequency of inundation	Exceedences – 88 more days at 5% Exceedence under M6R5 versus M4R5	high	high	Low	Low
To vegetation composition	Change in hydrological regime may result in a change to the vegetation that can survive at the site	High	High	Low	Low
To rare wetland ecosystems	Change in hydrological regime may result in a change to the vegetation that can survive at the site	high	Low to nil Site ecosystems not listed as rare in BC	Low	low
Effect on toad habitat potential	Flooding of Nagle Creek wetland will potentially reduce toad habitat quality by exposing the wetland pool areas to fish which may eat eggs.	moderate	Low to nil, because no toads breeding at the site in 2012 or 2009	Low	High, toad breeding sites could change

4.1.8 Management Hypotheses

The management hypotheses to be tested under this monitoring program were:

H1: *Annual and seasonal variation in Mica tailrace water levels resulting from proposed operation of the Mica generation Units 5 and 6 ("Mica operations") do not directly or indirectly impact the small Nagle Creek wetland area near its estuary.*

H1A: *Mica Units 5 & 6 operations are not expected to result in a decreased wetland wetted area.*

H1B: *Mica Units 5 & 6 operations are not expected to result in changes to wetland water temperature.*

Our results reject hypothesis H1. Specifically, there will be a number of changes with regard to duration, frequency, depth and area of inundation. Some of these are likely to result in changes to the vegetative composition of the site.

Hypothesis H1A is accepted. It is predicted that substantial increases in the flooded area will occur at the Nagle Creek wetland *under the Assessment Case* in comparison to the Baseline Case. While there is a predicted increase in flooded area, the nature of the flooding is predicted to change. Whether that newly flooded area continues to provide similar level of functional habitat is debatable - it will likely have different characteristics as a deep marsh relative to a seasonally flooded marsh.

Hypothesis H1B is rejected. The Assessment Case is predicted to produce cooler conditions at the site than currently exist in the Baseline Case, because the area will be flooded to a greater degree.

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6 APPENDIX A

Please refer to:

6.1 Nagle Creek Wetland Hydrological Assessment

6.1.1 Incremental Impact of Proposed Mica Units 5 and 6 on Nagle Creek Wetland.

Prepared by Klohn, Crippen Berger, May 22, 2013, submitted to Nupqu Development Corporation.