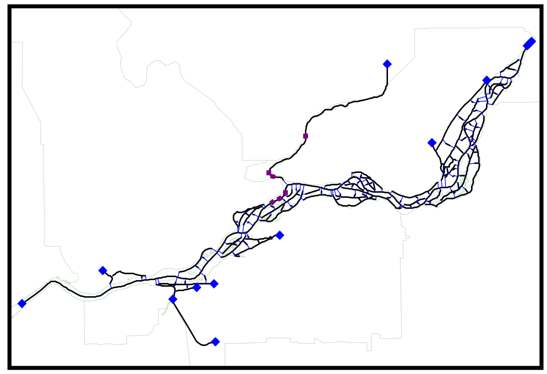
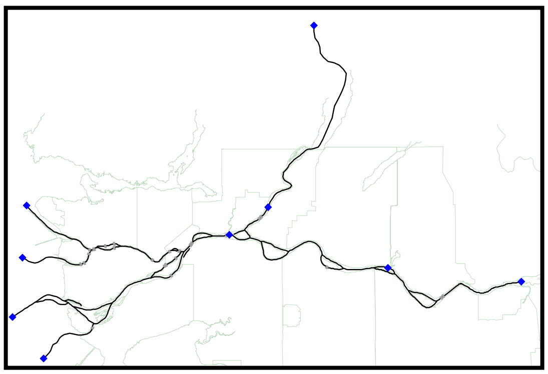
BC MINISTRY OF ENVIRONMENT





FRASER RIVER HYDRAULIC MODEL UPDATE

FINAL REPORT

MARCH 2008

nhc northwest hydraulic consultants

Leaders in water resource technology

Fraser River Hydraulic Model Update
Final Report

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EXECUTIVE SUMMARY

In 2006, **northwest hydraulic consultants** (**nhc**) developed a MIKE11 hydraulic model for the Fraser River, covering the reach from just upstream of Mission to the Strait of Georgia. Using the model, a new design profile was computed and found to be up to 1 m higher than the previous design profile developed in 1969. The results affected the profile for the upstream reach from Laidlaw to Mission developed in 2001 by UMA Engineering Ltd. The two models were merged into a single model and a design profile computed, corresponding to a reoccurrence of the 1894 flood.

The 2007 snow-pack was well above normal and considering the increase in the design profile there was concern of potential flooding in the Fraser Valley. The British Columbia Ministry of Environment (MOE) retained **nhc** to run the new hydraulic model in real-time to forecast flood levels between Laidlaw and the Strait of Georgia. An intensive program of water level and flow data collection was carried out by Water Survey Canada (WSC), MOE, Fraser Valley municipalities and others to monitor river conditions and assess model performance during the daily forecasting as well as collect additional information for model fine-tuning. The model performed well but it became evident that there were problems with previously reported discharge data published by WSC. Also, that the Laidlaw – Mission (upper) model was not entirely compatible with the Mission – Georgia Strait (lower) model.

An unprecedented amount of water level and flow data was collected during the 2007 flood and following the freshet the project described in this report was undertaken to resolve the discharge data issues, update the two models as necessary, merge them and refine the previously developed design profile.

Both the Hope and Mission stage-discharge curves were revised by WSC in 2007. Using corrected discharges the lower model was calibrated to the 2007 flood and validated to the 2002 flood. A slight reduction in roughness coefficients was warranted for flows under 14,500 m^3/s. However, roughness coefficients for the design profile were unaltered in the Mission-Douglas Island reach since they were previously derived using a historic model and the 1948 flood, to ensure proper representation of channel conditions at very high flows. No network changes were required to the fully hydro-dynamic lower model. The design profile was essentially unaltered, with a maximum flood level reduction of 0.16m in the Coquitlam area.

The upper model was recalibrated to the 1999 flood and validated to the 2007 flood. Significant changes were made to the model network. These modifications were undertaken to allow operating the model hydro-dynamically rather than using the diffusive wave algorithm. Roughness coefficients were revised, Harrison Lake was added to the model and several other changes were made. The changes resulted in increases and decreases in the design profile of up to 0.28 m.

A number of dikes were raised prior to the 2007 freshet. The dike crest elevation assessment completed in 2006 was repeated using the updated design profile and available as-built dike survey information.

The two models were combined and provide an excellent tool for forecasting flood levels for the Lower Fraser River. The model needs to be kept up-to-date and particularly during floods with return periods exceeding about 10-15 years it should be revalidated. The model is highly sensitive to flow and it is imperative that WSC carry out additional flow measurements during peak flows to keep the stage-discharge curves current for key gauges on the river.

CREDITS AND ACKNOWLEDGEMENTS

This project was conducted under the guidance of Ron Henry, P.Eng. of the BC Ministry of Environment, who throughout the project provided information, direction and advice. Russell White, M.Sc. and Bruno Tassone, P.Eng. of Water Survey Canada assisted with reviewing flow records and obtaining flow measurements during the 2007 freshet. Dan Couture and Mick Mills of Public Works and Government Services Canada provided flow split measurements at various locations. The cooperation of all the gauge operators during the 2007 freshet measurement program was greatly appreciated.

Key **nhc** staff involved in this project was Tamsin Lyle, P.Eng. who completed the hydraulic modelling updates; Sarah North, who managed the GIS component of the project; and Charlene Menezes, GIT, who completed the dike assessment and prepared the dike drawings. Project management and flow reviews were carried out by Monica Mannerström, P.Eng. The report was prepared by Tamsin Lyle and Monica Mannerström, with independent review by Dr. David McLean, P.Eng.

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1 INTRODUCTION

In 2006, **northwest hydraulic consultants** (**nhc**) developed a MIKE11 hydraulic model for the Fraser River, covering the reach from just upstream of Mission to the Strait of Georgia. This model was merged with a model developed by UMA Engineering Ltd. (UMA) in 2001 for the reach from Laidlaw, just downstream of Hope, to Mission. Using these models, a new design flood profile was computed that replaced the previous profile developed in 1969. The new profile was found to be up to 1 m higher than the old profile in some locations.

Due to the increase in the design profile and the high snow-pack in 2007 there was concern that the freshet would be large enough to potentially trigger flooding in the Fraser Valley. To aid with flood response during the freshet, the British Columbia Ministry of Environment (MOE) retained **nhc** to run the hydraulic model in real-time to forecast flood levels between Laidlaw and the Strait of Georgia. An intensive program of water level and flow data collection was carried out by Water Survey Canada (WSC), MOE, Fraser Valley municipalities, Public Works and Government Services Canada (PWGSC) and some private agencies to monitor river conditions, improve the accuracy of model input data and assess the model performance.

During the forecasting project, it became apparent that there were inconsistencies in reported WSC flows affecting the model results. Also, the need was identified to extend and fine-tune the Laidlaw-Mission model to make it more compatible with the Mission-Strait of Georgia model. The data collected in 2007, provided an excellent basis for undertaking this model update work.

1.1 SCOPE OF WORK

MOE’s original scope of work for the Fraser River hydraulic model update study specified the following tasks:

1. Review river flow measurements and river cross section surveys carried out by Water Survey of Canada (WSC) staff and others, in relation to the flows estimated using the present rating curves. Flow measurements were done at the Fraser River at Mission, Fraser River at Hope and the Harrison River at the Lake outlet. Liaise with WSC staff to discuss the flow estimates and possible revisions to rating curves at these flow gauge sites.
2. During the freshet, flow split data was collected at Douglas Island and other sites, by Public Works and Government Services Canada (PWGSC). The measured flow split data are to be compared with the computed flows generated with the model and adjustments made as required.
3. Review the accuracy of water level gauge data collected during the freshet by local municipalities, diking districts and other agencies. In some instances there may be datum problems or local hydraulic effects, where the actual water level varies greatly from the modelled level.

4. Recalibrate and verify the Mission to Georgia Strait model using observed water levels and Mission flows based upon a new rating curve, taking into account recent flow measurements.
5. Re-run the design flood profile for the Fraser River below Mission using the recalibrated model and compare it to the previous design flood profile, as shown in the 2006 **nhc** report.
6. Carry out a detailed review of the Mission to Laidlaw model and revise the model as required. The revisions are to also include extending the model to include Harrison Lake.
7. Re-run the upstream model for the design event and compare it to the design profile prepared in the 2006 **nhc** and the 2001 UMA Engineering reports.
8. Prepare revised dike profile drawings to illustrate the design profile and to incorporate the new dike crest elevations where revised under the 2007 Urgent Flood Mitigation Works Program. The dike profile drawings for dikes in Dewdney, Abbotsford, Pitt Meadows, Maple Ridge, Surrey, Port Coquitlam and Mission need to be revised to illustrate the new dike crests.
9. Prepare additional dike profile drawings to illustrate the water surface profile for various flows (estimated return periods 1:100, 1:50 and 1:25 yr) and the new dike crest elevations.
10. Merge the upstream and downstream models into one seamless model that can be used in future for water level forecasting during the freshet.
11. Prepare a report summarising the results of the model recalibration. Update the relevant tables and figures from the 2006 **nhc** report to illustrate the new flood profile.

As a result of preliminary findings and at the request of MOE and other stakeholders, the original scope was modified and expanded to include:

12. Review a letter prepared by WSC regarding stream-gauge information and obtain additional discharge measurements and other information, not initially available.
13. Prepare water level reference tables for all the gauge sites in the study reach corresponding to Mission water levels of between 6.0 m and 8.5 m in 0.5 m increments.
14. Present preliminary study results to MOE and municipal representatives. Provide follow-up information and answer questions subsequent to the meeting.
15. Compare 2007 bathymetric surveys at bridge crossings and 2005 model cross-sections to assess recent river changes. Also, assess historic cross-section changes at Mission and Hope. Review WSC files for relevant information such as the original Colonel Whyte memo from 1934 regarding the 1894 high water marks at Hope.
16. Review ADCP flow measurement data for Mission collected by WSC and **nhc** and calculate channel roughness coefficients based on velocity vector data.

1.2 REPORT OUTLINE

This report describes the hydraulic model updates and presents the latest design profile for the Lower Fraser River based on the flow and water level data collected during the 2007 freshet. Section 2 provides modelling background information, Section 3 reviews flow measurements at key locations, summarizes rating curve revisions and observed channel changes, Section 4 describes the updates to and recalibration of the upper and lower Fraser River models and Section 5 describes the updated design profile. Section 6 gives guidance on the use of the models for flood forecasting. Section 7 provides the dike assessment methodology and results. A new tool developed over the course of the project, a set of municipal reference tables, is described in Section 8. Conclusions and recommendations are provided in Section 9, and a full reference list is found in Section 10.

2 BACKGROUND

2.1 EARLY FLOOD INVESTIGATIONS

The flood of 1894 has been adopted as the design flood condition for the Fraser River. No reliable flow measurements were taken during the flood, but based on an approximate high water mark at Hope established forty years after the flood (Appendix A), a flow estimate of 17,000 m^3/s was previously derived (Fraser River Board, 1958). Prior to the 1999-2008 Fraser River numerical modelling work, the design standard for dikes and other structures along the river was an estimated 1894 profile, developed in 1969. The profile was derived mainly from historic high water marks from 1894, 1948 and the 1960's. Some adjustments were made to account for the effects of dikes built after the high water mark observations.

In 1894, during the flood of record, a maximum water level of 7.92 m was observed at Mission. During this flood the entire floodplain, including the vast Sumas Prairie was inundated and the Fraser River flowed into Harrison Lake across Agassiz. The floodplain provided substantial flow storage, which would have significantly reduced the peak flow at Mission compared to the flow at Hope. No dikes confined the flow in 1894 and the channel capacity would have been considerably greater than in 1969. In spite of these flow and channel variations, the 1969 profile work set the Mission design level at an elevation of 7.92 m, equal to the level observed in 1894.

A relatively large flood occurred in 1997, with a return period exceeding 10 years. During the flood, MOE collected water level data at a series of gauges, mostly located in the Mission to Agassiz reach. MOE plotted this data against the design profile and showed that the two profiles were far from parallel. In some reaches, particularly at Harrison Mills/Chilliwack, the 1997 flood profile was surprisingly close to the estimated 1894 profile, indicating that the profile developed in 1969 may not be an appropriate design standard.

2.2 LAIDLAW - MISSION (UPPER) MODEL

As a result of the 1997 findings, the City of Chilliwack, with the assistance of MOE, retained UMA Engineering Ltd (UMA) to model the Fraser River and update the design profile for the 65 km long gravel bed reach between Laidlaw, just downstream of Hope, and Mission. A MIKE 11 model was developed using 1999 bathymetry and LiDAR data. The river reach is complex, containing multiple channels and a number of gravel bars. The model included Harrison River to Harrison Lake outlet and the lower Vedder River (UMA, 2000).

MIKE11 provides three methods for computing water levels; the fully dynamic method; the diffusive wave approximation and the kinematic wave approximation (**nhc**, 2006). UMA encountered some instability problems when using the fully dynamic method and chose to use the diffusive wave approximation.

The model was calibrated to WSC flows for the 1999 flood and validated to the flood of 1997. The design profile was based on an upstream inflow of 17,000 m^3/s, corresponding to the estimated 1894 flood. A Harrison River discharge of 2,230 m^3/s was assumed and other inflows were estimated based on flow ratios. The model downstream boundary condition was set equal to the observed 1894 water level at Mission of 7.92 m. The computed design profile was found to be up to 0.85 m higher than the 1969 profile.

In 2001, UMA undertook further hydrologic analyses and were able to fine-tune the Harrison River design flow to 1,300 m^3/s, which lowered the Fraser design profile near the Harrison confluence. However, the revised profile was still a maximum of 0.8 m higher than the 1969 design profile (UMA, 2001). The model results raised questions regarding the accuracy of the design profile downstream of Mission.

2.3 MISSION - STRAIT OF GEORGIA (LOWER) MODEL

In 2005, the Fraser Basin Council (FBC) and MOE in collaboration with municipal and federal stakeholders retained **nhc** to build a MIKE11 model for the roughly 90 km long reach from Mission to Strait of Georgia. This work was completed in December 2006, and was documented in two progress reports and a final report (**nhc**, 2006).

The model was built using 2005 bathymetry for the channels and LiDAR data for the floodplain topography. It covered the Fraser River sand-bed reach, from just upstream of Mission to Georgia Strait and encompassed the North, Middle and South Arms of the Fraser, including Canoe Pass as well as Pitt River and Pitt Lake. The river reach is tidal and it was essential that the fully hydrodynamic method of MIKE 11 be used. The model was calibrated to hourly flows provided by WSC for the 2002 flood and validated to reported flows for 1999 and 1997. Within the study reach, recorded water levels were available at 13 locations in 2002, 6 locations in 1999 and 6 locations in 1997.

The calibration/validation floods had return periods in the order of 10-years. In sand-bed rivers, such as the lower Fraser, sand dunes begin to form in certain flow ranges and may subsequently wash-out as flows increase, affecting the channel roughness. To verify if the roughness coefficients developed for flows in the 10-year flood range would be applicable at the design discharge, a separate historic model was developed for the Mission to Douglas Island reach. It used bathymetry from the 1950's and was calibrated to the floods of 1948 and 1950, with reported flows at Hope of respectively 15,200 m^3/s and 12,600 m^3/s. The calibrated roughness coefficients for these high flows were found to be somewhat lower than in the 10-year flood range (flow at Hope around 11,000 m^3/s) and were subsequently used for the design profile computations. The development of the historic model and the flow-roughness relationship is more fully described in the **nhc (**2006) report.

To model the freshet design profile, an upstream inflow of 18,900 m^3/s was adopted at Mission, corresponding to the 1894 flood estimate at Hope of 17,000 m^3/s plus local inflows between Hope and Mission. Additional flows for the Stave, Pitt, Alouette and Coquitlam Rivers were incorporated. The updated design profile, which assumed that flow is confined by dikes, was found to be 1 m higher at Mission than the 1969 profile. This result showed that the previous starting level for the upper model was incorrect and that the UMA design profile needed to be revised.

2.4 INITIAL COMBINED MODELS

Following the development of the lower model, it was merged with the upper model to provide a flood level forecasting tool for the entire river between Laidlaw and the Strait of Georgia (**nhc**, 2006). During the preparatory phase of the 2007 freshet flood level forecasting project, a careful review was made on the input data and the operation of the combined model. During this phase, some discrepancies were identified with the published flow data. Some limitations were also found with the combined model's operations (**nhc**, 2007). These issues were as follows:

- The sum of discharges published by WSC for Fraser River at Hope, Harrison River at Harrison Lake Outlet and other smaller tributaries between Hope and Mission was consistently higher than reported discharges at Mission. Since the lower model had been calibrated to reported Mission flows, using the sum of upstream flows as input, resulted in water levels downstream of Mission that were too high.
- The reach between Mission and Harrison Lake in the upper model was tidally influenced and the diffusive wave approximation used in the model did not provide accurate results. When the fully hydrodynamic method was used, instabilities occurred.
- Harrison Lake was not included in the model. Since the hydrologic model used by MOE's River Forecast Centre (RFC) predicted lake inflows, lake outflows required for modelling could not accurately be determined.
- The upper model used unusually high roughness coefficients to account for energy losses other than those associated with channel friction. It was suspected that these coefficients would not be representative for flows outside the calibration range. Other roughness concerns were associated with the overly jagged bed topography of the upper model.

As a result, the upper and lower models had to be run separately during the 2007 freshet and some flow adjustments made to ensure accurate water level predictions. The work described in this report was chiefly undertaken to:

- Together with WSC, investigate and resolve discharge discrepancies.
- Improve the compatibility of the upper model with the lower model to simplify flood level forecasting procedures in the future.
- With the extensive flow and water level data collected in 2007, fine-tune the calibration of the upper and lower models and refine the design profile.

3 2007 Freshet Data Collection and Analysis

The Fraser River flood level forecasting project highlighted the need for extensive and accurate flow and water level data, particularly at high flows. Considering the high snow-pack in the spring of 2007 and the potential for a significant flood, an unprecedented data collection program was undertaken by WSC, MOE, municipalities, PWGSC and private organizations. This included collecting water level information at over 70 gauges, obtaining flow measurements at WSC key gauge sites and channel splits, as well as bathymetric surveys at some bridge crossings.

3.1 Water Level Gauges

WSC operates five continuous water level gauges along the Fraser Main Arm; at Hope, Mission, Whonnock, Port Mann and Steveston, plus one on the North Arm (Vancouver South), one on Pitt River (near Port Coquitlam), one on the Harrison River (at Harrison Hot Springs), and one on the Chilliwack River at Vedder Crossing. Of these gauges, only Pitt River and North Arm gauges did not report in real-time during the 2007 freshet. The Harrison and Chilliwack stations reported daily flows, all others hourly data.

Compared to the 2002 flood, used for calibrating the lower model, a number of additional continuous recording gauges were installed prior to the 2007 freshet. In total, 21 continuous gauges were in operation within the lower model reach, compared to only 13 in 2002. In the upper model reach there were five continuous gauges.

MOE maintains 30 staff gauges between New Westminster and Hope, with an additional 16 staff gauges run by the municipalities of New Westminster, Coquitlam, Kent and Chilliwack. These gauges are manually read, typically once a day during the freshet, when water levels at Mission approach or exceed 6 m. The condition of staff gauges was checked prior to the freshet and any required repairs carried out.

Over the freshet period, data was collected from a total of 70 gauges between Hope and the Ocean. Map 1 shows the gauge network. This was the most extensive water level data ever collected on the river.

3.2 Discharge Measurements

3.2.1 Measurement Program

Accurate flow data is essential for model calibration and flood level computations. The 2007 forecasting preparatory work showed that summing the Fraser River flow at Hope and the local inflows between Hope and Mission (from Harrison River, Chilliwack River, and other smaller tributaries) consistently resulted in higher flows than those reported at Mission. WSC was informed of this apparent discrepancy and subsequently provided excellent cooperation and technical support to assess this issue. WSC also collected a large number of flow measurements at the Hope, Harrison and Mission gauge sites to update their rating curves. A preliminary analysis of this information was summarized by **nhc** in a memorandum (September 20, 2007). In a letter dated November 16, WSC responded to the memorandum and provided further clarification on measurement techniques and procedures for developing stage-discharge curves.

Typically, flows published and reported in real-time by WSC are based on observed water levels and stage-discharge curves established for each gauge. Periodically, WSC measures flows to confirm that the stage-discharge curve in use is still representative. Any net changes to the channel cross-section, such as aggradation or degradation, give rise to shifts in the stage-discharge relationship and typically, a new curve is developed if measured flows consistently deviate by more than 5%. The number of measurements obtained per year has reduced in the past decade.

3.2.2 FRASER RIVER AT HOPE

WSC gauge *Fraser River at Hope, 08MF005* is located on the right bank, 15 m downstream of the Highway/Old Kettle Valley Railroad Bridge. To convert to geodetic datum, 27.926 m must be added to the gauge height. Flow measurements were previously obtained from the bridge using a Price Meter but are now taken by boat using an Acoustic Doppler Current Profiler (ADCP). The ADCP measurements are considered more accurate but channel changes cannot be evaluated based on these metering notes since the measurement cross-section varies each time, as a result of the boat drifting downstream.

Water level and flow records begin in 1912 and since then 35 different stage-discharge curves have been in use, suggesting a fairly active channel cross-section. A specific gauge curve based on the stage-discharge curves is plotted in Figure 3.1. The data shows aggradation from about 1920 to the 1940's, followed by degradation from the early 1950's to the 1980's. This trend seems to have reversed and the channel section has now aggraded. On November 12, 2007, WSC introduced a new stage-discharge curve, replacing the previous curve from 1987. The new curve was made effective from January 1, 2006. In recent years relatively few flow measurements have been obtained at discharges exceeding 5,000 m^3/s, relevant for flood conditions. In the 1990's nine such measurements were obtained and during the period from 2000 to 2006 there were only four. This is a significant reduction from the number of 5,000+ m^3/s measurements in the 1960's (28), 1970's (36) and 1980's (23). Since flows are a direct function of the stage-discharge curve, it is imperative that the curve be kept up-to-date. The channel section is active and future shifts in the stage-discharge relation are expected. Accurate reported flows are essential for both hydrologic and hydraulic modelling of the river.

The highest measurement ever obtained was 12,290 m^3/s (in 1972) and the stage-discharge relationship above this flow should be considered approximate. In the future, when higher flows occur extensive measurements should be obtained. The 1894 high water mark was estimated based on anecdotal evidence forty years after the flood (Appendix A). The high water level was then applied to an approximate rating curve extension to estimate the design flow. The shifts in rating curves over time add further uncertainty to the estimate. It is conceivable that the actual 1894 peak flow may have been quite different from 17,000 m^3/s. Extending the Fraser model to Hope gauge is recommended to verify the upper end of the present stage-discharge curve. Extending the model further to Alexandra Bridge, where a photograph was taken of the 1894 flood, could provide some verification of the flood magnitude.

Figure 3.2 demonstrates the value of the flow measurements WSC obtained in 2007. Based on the five measurements collected during the past freshet and other relatively recent measurements, WSC was able to revise the previous rating curve from 1987. The 1987 curve can be seen to plot on the far right of Figure 3.2, representing the historic maximum capacity (highest flow for a particular water level or maximum channel degradation). Also shown is the curve from 1948 which represents the historic minimum capacity curve (least flow for a particular water level or maximum channel aggradation). These two curves form upper and lower bounds of all rating curves. The new relationship developed in 2007 plots roughly in the middle and closely matches the curve in effect from 1964 to 1967.

The 2007 flow measurements are listed in Table 3.1, along with reported flows based on the 1987 curve and corrected flows based on the revised curve. The percentage error is tabulated for each set. Using the revised curve, a flow time-series was developed for the freshet period (Table 3.2).

During the 2007 freshet, the River Forecast Centre of MOE prepared flow forecasts for Fraser River at Hope based on Environment Canada weather forecasts and hydrologic modelling. The predicted flows at Hope formed the main input to the flood level forecasting.

3.2.3 HARRISON RIVER AT HARRISON LAKE

WSC *Station 08MG013, Harrison River near Harrison Hot Springs* has been in operation since 1933. Water levels are measured at the lake but the flow measurement site is located several kilometres downstream of the lake outlet. During high Fraser River water levels, the flow in Harrison River is affected by backwater and under such conditions WSC estimates the flows based on water levels at Harrison Lake and at a secondary gauge, *Station 08MG022, Harrison River below Morris Creek*. However, real-time flows reported during the 2007 freshet were based directly on the 08MG013 rating curve and did not incorporate the backwater correction. In the future, WSC intends to include the correction in real-time, which will be very helpful for both flow and water level forecasting. The backwater correction is approximate but according to WSC, adjusted flows are within the specified 5% tolerance.

For Harrison River, five measurements were obtained during 2007 as shown in Table 3.1. Backwater adjusted flows agreed reasonably well with measured values, except on June 11, 2007. During the Fraser freshet, Harrison River flows typically correspond to only about 10% of Fraser flows and adjustments were not made to the rating curve or the correction method. The 2007 time-series flows are listed in Table 3.2.

In addition to predicted flows at Hope, RFC provided Harrison Lake outflows. However, attempts were maid to match predicted flows to the real-time unadjusted Harrison River flows, resulting in flows that were too high. By including Harrison Lake in the MIKE11 model, RFC can predict lake inflows rather than outflows, simplifying hydrologic modelling for Harrison River.

3.2.4 FRASER RIVER AT MISSION

Water levels at *Station 08MG024, Fraser River at Mission* are tidally influenced at most flows. Water level records date back to the 1870's but flow records commence in 1965. Because of the strong tidal influence at low river discharges, flow records are typically not available for stage levels less than 3 m (flows less than about 6,000 m^3/s). Even in the 3 m to 6+ m range there is a tidal effect and for a particular water level the flow may vary. WSC is considering installing an acoustic velocity meter at this site (Appendix A).

The stream-gauge is located on the right bank, 16 m downstream of the CPR Bridge. The measurement section is 320 m upstream of the gauge. To convert to geodetic datum, 0.043 m must be added to the gauge height (0.073 m, prior to 1988). The measurement section at Mission has degraded by about 0.5 m since 1965 as shown in the specific gauge plot in Figure 3.3. In recent years, relatively few flow measurements were obtained for flows exceeding 6,000 m^3/s, relevant to flood conditions. During the 1990's a total of 10 such measurements were collected, dropping to 3 for the period 2000 to 2006.

The data collected in 2007, along with other recent measurements were invaluable for updating the rating curve. The 10 flow measurements (Table 3.1) collected in 2007 consistently deviated by 5% or more from the previous stage-discharge curve and following the freshet, WSC provided a new curve. All rating curves used for the gauge are plotted in Figure 3.4. The 2007 time-series flows, developed based on the latest curve, are listed in Table 3.2.

The gauge section is likely to continue to degrade and obtaining regular flow measurements to keep the stage-discharge rating curve up to date is essential. The maximum flow recorded at Mission was 13,650 m^3/s (in 1972). The upper end of the rating curve agrees with model results and assumes flow is confined by dikes. Additional flow measurements along the upper end of the curve would be very useful.

3.3 FLOW SPLIT DATA

Flow split measurements were obtained to validate the lower model's ability to correctly distribute flows at major islands. The measurements, conducted by PWGSC, are summarized in Table 3.3 and were collected at:

- Douglas Island (6 locations)
- Trifurcation (4 locations)

- Ladner (3 locations)
- Steveston (4 locations)
- North Arm (3 locations)

Several transects were obtained at each location. The ADCP measurements in the lower reaches of the river are very sensitive to tidal levels; the river flow near the ocean is rapidly varying as the tide rises and falls. Based on model runs, measurements were timed for periods when the least flow variation was expected for a particular location. Generally, repeat measurements gave similar answers, implying good accuracy.

3.4 ADOPTED FRESHET DISCHARGES

Time series flows for the 2007 freshet were developed based on the revised rating curves for Hope and Mission. Figure 3.5 compares unadjusted and adjusted hydrographs. With the adjusted hydrographs, the sum of flows upstream of Mission more closely equal flows at Mission. There are still some deviations, particularly peak flows at Mission appear to be truncated compared to the sum of upstream flows. This may be due to physical changes, such as flow going into storage or inaccurately estimated local inflows. The flow measurements are included in Figure 3.5 and deviate slightly from the hydrographs. During future flood forecasting projects, when the upper and lower models are operated as a single model, it will be necessary to compare reported and modelled flows at Mission. For accurate flood level predictions it may be necessary to adjust model flows at Mission.

The sparse flow data collected from 1999 to 2006 at Hope and Mission make it difficult to determine when the revised rating curves should be applied. Hydrographs for the 2002 and 1999 floods were also plotted based on the unadjusted and adjusted rating curves (Figures 3.6 and 3.7). The fit was considerably better with the adjusted curves and the decision was made to use the revised rating curves to determine flows for the 2002 and 1999 floods. Table 3.4 summarizes peak model inflows for 1999, 2002, 2007 and design conditions.

3.5 BATHYMETRIC SURVEYS

The specific gauge analyses showed that the channel at Mission has continuously degraded since 1965 and that the channel at Hope has aggraded in recent years. Channel surveys were reviewed to see if channel cross-sections would confirm these changes.

Current metering notes were reviewed for Hope from 1917 to 1982 as shown in Figure 3.8. Portions of the section has scoured or built up by over 3 m but systematic trends were not detected. Even during a single freshet, significant changes take place. A separate plot was produced using BC Ministry of Transport (MOT) bridge soundings from 1983 to 2001 at a section 30 m upstream of the bridge as shown in Figure 3.9. Again, large fluctuations occurred in the bed, but aggradation/degradation trends were not detected.

Systematic bed lowering over the last 40 years has been documented in the reach between Mission and New Westminster (**nhc**, 2006). Large bed level variations occur at the Mission gauge during the freshet, with the channel scouring by up to 5 m and then rapidly infilling. This is not surprising considering the large sand-dunes that move through the reach. The irregular bed shifts make it difficult to detect longterm changes at this site. Also an extensive riprap apron has been placed under the Mission Bridge to arrest scour.

BC Ministry of Transportation conducted surveys at several major Fraser River bridge crossings in the summer of 2007. The bathymetric data was compared to the 2005 cross-sections used in the MIKE11 model. Cross-sections were extracted from the survey data as close to the MIKE11 sections as possible, however, there was not suitable data available for comparison in all cases. Plots of the crossing sites are shown in Figures 3.10 through 3.14. For the most part, there is little change observed between the 2007 and 2005 sections. River depths and areas are very similar for the Oak Street, Knight Street, Queensborough and Port Mann bridges. The Mission Road bridge comparison shows a slight aggradation upstream and degradation downstream of the structure. It was not possible to locate the cross-section lines at the same location for the 2007 and 2005 data as the surveys were taken on slightly different lines, and some of the observed bed level shift may not be due to actual changes in bed level. Similarly, the exact location of the original MIKE11 cross-section at the Agassiz-Rosedale bridge site is not known and a direct comparison of bed levels could not be made.

4 MODEL RECALIBRATION AND UPDATES

Model calibration involves adjusting channel/overbank roughness coefficients until modelled and observed water levels agree for a particular flood event with a known flow. If an incorrect flow is used for calibration the model will not be representative. If the flow used for calibration is less than the actual flow, as was shown to be the case at Mission, model roughness coefficients will be too high. On the other hand, if the flow used for calibration is higher than the actual flow, as was seen at Hope, the coefficients will be too low. The coefficients in turn affect the computed profiles, if coefficients are too high the profile will also be too high and vice versa.

The WSC flow revisions meant that both the lower and the upper models had to be recalibrated. The extensive water level and flow data collected in 2007 allowed for much more detailed calibrations than those performed previously. Undertaking this work also offered an opportunity to make the upper model more compatible with the lower model.

For recalibration, the lower and upper models were initially worked on separately and were then combined into a single model. During future flood forecasting, runs can be made using the single model, simplifying the forecasting procedure. Using the recalibrated model, a revised design profile was calculated for the reach from Laidlaw to Strait of Georgia as described in Section 5.

4.1 LOWER MODEL

As outlined by **nhc** (2006), separate freshet and winter models were developed for the lower model reach. The winter model was insensitive to river flows and a recalibration of the winter model was not necessary.

4.1.1 MODEL UPDATES

The lower model was initially calibrated and validated to flows reported by WSC for the Mission gauge using data from 2002, 1999 and 1997. Model recalibration was performed using the 2007 data and the re-validation using 2002 data. The new Mission rating curve increased the 2007 peak flow from 11,000 m^3/s to 11,800 m^3/s or by 7% (Table 3.4). The 2002 flow was increased from 11,000 m^3/s to 11,900 m^3/s or by 8%. Tributary inflows at the Stave, Alouette and Coquitlam Rivers were based on recorded values. The tributary inflow to Pitt Lake was estimated based on regional hydrology and remain unchanged from the original calibration.

Tide levels form the downstream boundary condition for the model. For 2007, tide levels were based on observed values at Point Atkinson as recorded by the Canadian Hydrographic Service. The 2002 tide levels were previously provided by Triton Consultants as described in **nhc** (2006).

Unlike the upper model, no physical modifications to the model network were necessary. However, to remove any tidal influence on the inflow boundary, the network was extended upstream to the Vedder Canal confluence. A schematic of the model is shown in Map 2.

4.1.2 MODEL CALIBRATION (2007)

Results for the calibration of the 2007 freshet are listed in Table 4.1. The agreement with the recorded peak levels is generally within the target accuracy of ± 0.10 m, with an average absolute error of 0.05 m. Plots of observed and modelled water levels are provided in Appendix B.

Not all gauges were used in the calibration as some data was suspect. Data from the Matsqui gauge consistently showed a water level greater than the Mission gauge even though it is downstream of Mission, and was therefore not included in the analysis. The City of Abbotsford is investigating this anomaly. The Nelson Road gauge data did not show complete troughs over the tidal cycle as the gauge was unable to read below a particular water level. However, the gauge reported good data for peak water levels and was included in the calibration.

Tidal trough values were not as well matched as tidal peaks but since the main purpose of the model was to simulate peak levels, the calibration was considered sufficiently accurate. The average absolute trough error was 0.11 m.

Original and revised Manning's roughness coefficients at key cross-sections are compared in Table 4.2. Within the ocean, where river flow is partly over salt water, n-values of 0.015 were used. Roughness coefficients downstream of New Westminster did not require adjustment. Side-channel coefficients were generally unchanged. Between New Westminster and Mission, roughness coefficients were reduced from the 0.030 to 0.033 range to 0.028 as a result of additional water level information collected in 2007 and the adjustments to inflow at Mission. Final coefficients ranged from 0.028 to 0.033 in the mainstem and were higher in the side channels, up to 0.035. MIKE11 interpolates linearly between upstream and downstream roughness coefficients for intervening cross-sections.

For cross-sections downstream of Port Mann, the relative roughness coefficient was varied from 1.0 at peak tide to 0.75 at low tide to better match the water levels during the tidal troughs. Overbank roughness coefficients estimated from air-photography ranged from about 0.08 to 0.10.

Modelled and measured flow splits were also compared (Table 4.3). In general, there is excellent agreement between the observed and modelled flows. Exceptions are the split between the North and Middle Arms and Canoe Pass. Both locations are within the tidal reach and strongly influenced by ocean conditions. Water levels and flows are rapidly varying in this area, and ADCP flow measurements are very sensitive to the time they are taken. Based on channel cross-section areas and flow conveyance, modelled flows seem more representative than the observed splits.

4.1.3 MODEL VALIDATION (2002)

The model was validated using water levels recorded during the 2002 freshet. Good agreement was found between the observed and modelled values as shown in Table 4.1 and Appendix B. The average absolute error for peak water levels in 2002 is 0.07 m, and most values fall well within the target range of ±0.10 m. The agreement was slightly better than what was achieved in 2006. Some gauge results had to be discounted from the analysis. These included Manson and Bath Slough, which in 2007 was found to have sunk up to 0.17 m from the previously surveyed datum; the actual height of the gauges in 2002 is not known.

The 2002 flow split comparison was repeated and found to give very similar results to those reported in 2006 (Table 4.3).

4.1.4 ASSESSMENT OF RESULTS

The model calibration and validation results show that the accuracy of the water level predictions are well within target values and that the model meets or exceeds the standards set for floodplain mapping studies. However, the calibration and validation flows are much lower than the design flood condition and the model should be reassessed and refined if higher flows are experienced.

nhc (2006) presented a graph relating roughness coefficients to discharge. Based on the historic model calibration of the 1950 and 1948 floods, the Douglas Island to Mission reach had a roughness coefficient of 0.028 at an estimated Mission flow of 14,530 m^3/s and a coefficient of 0.027 at an estimated flow of 15,840 m^3/s. This diagram was updated as shown in Figure 4.1 to include the revised roughness coefficients. A constant coefficient of 0.028 is valid for flows up to 14,530 m^3/s and only a slight reduction occurs at higher flows. The design flow is 20% higher than the 1948 flood and it is not known if roughness values will reduce further at flows exceeding the 1948 flood of 15,840 m^3/s. There is no basis for assuming a further reduction and the coefficient previously used for the design flood (0.027) was maintained.

Recent research has been carried out for estimating channel roughness coefficients based on ADCP velocity measurements. During the 2007 freshet **nhc** carried out a number of field measurements of current velocity and discharge with an ADCP at the Mission gauge. Surveys of dune geometry were also made to assess the relation between bedform characteristics and channel roughness. The analysis is described in Appendix C. WSC's ADCP discharge measurements from 2007 were also reviewed to see if the information could be used for estimating roughness. However, it was found that the instrument settings varied between the WSC and **nhc** equipment and the WSC results are not directly comparable. The Manning's roughness coefficient at the Mission gauge site determined from the ADCP data (based on **nhc** data) was 0.031. The model calibration results indicated the average channel roughness in the Mission reach was slightly lower (0.028). The direct model calibration results are considered to be more accurate and more representative of reach-average conditions. The results of the ADCP analysis however are promising and suggest that it may be possible to use this approach to supplement other calibration techniques.

4.2 UPPER MODEL

4.2.1 ORIGINAL MODEL LIMITATIONS AND MODEL UPDATES

During the flood forecasting project it was found that the 2001 upper model was not entirely compatible with the lower model. It was also found to have some limitations that affected its use for real-time forecasting. The changes made to the model are outlined below and summarised in Figure 4.2. Map No. 3 shows the model extents, cross-section locations and significant structures.

1. The original upper model was designed to run using the "diffusive wave" algorithm, where as the lower model uses the "high order fully dynamic" algorithm. As described by **nhc** (2006) the dynamic method is more accurate and is essential for tidally affected and backwatered reaches. When the upper model was first run in fully dynamic mode minor instabilities occurred. By reducing the time step and introducing some of the other modifications described below, the instabilities were minimized and the model can now be run in fully dynamic mode.
2. The original upper model used very high roughness coefficients to account for losses other than friction, such as bend and contraction losses, which may not be representative at flows outside the calibration range. To rectify this, specific hydraulic energy losses were introduced in the model at significant contractions, expansions and bends in the Harrison River and in the Fraser mainstem near the mouth of the Harrison River. These losses were input as a coefficient, *k*, in the network file and were then applied to the energy equation: $\Delta h = kV^2/2g$. The loss coefficients were originally calculated based on standard losses for given bend, contraction and expansion angles and then adjusted based on model calibration. Energy losses applied in this fashion provide valid losses throughout the modelled flow range.
3. The bed topography in the original cross-section geometry had a highly irregular jagged surface, likely a result of the digital elevation model used to develop the cross-sections. This lead to exaggeration of the wetted perimeter, affecting calibrated roughness coefficients and energy loss calculations. All of the cross-sections in the mainstem and many of the cross-sections in the major side-channels were smoothed such that the flow area remained the same while the perimeter was reduced. This was accomplished using a simple smoothing algorithm coded in visual basic.
4. The upper model uses a complex branched network to describe flow over braided gravel bars, and therefore there are numerous junctions. In some reaches the network was simplified to reduce the number of junctions, which have higher hydraulic losses in the model than would likely be observed. Given the one dimensional nature of the

model, it is necessary to treat the gravel reach as a series of connected channels. By limiting the number of junctions, unrealistic hydraulic losses were reduced.

5. The original model boundary was at the outlet of Harrison Lake, which is affected by backwater at high Fraser River flows. Outflows from the lake are difficult to establish, especially in real-time for flood level forecasting, and the model was extended to the upstream end of Harrison Lake. The addition of the lake means that the model will route flows through the lake based on available storage and backwater from the Fraser River. However, the model used for calibration, validation and to establish design water levels does not include the lake as there are no reliable lake inflow estimates available. It would be advisable to run the RFC Harrison River hydrologic model and the MIKE11 model in tandem to ensure that the models are mutually compatible and jointly correctly calibrated.
6. In the spring of 2007, **nhc** conducted a field assessment of the gauges to be read during the freshet. Some gauge location links were refined in the model.
7. Water levels at the downstream boundary condition were adjusted to reflect the changes to the Mission rating curve. For the design profile and associated sensitivity runs, the updated lower model water levels formed the downstream boundary condition.
8. Inflows at the upstream boundary were updated to reflect the adjustments to the rating curve at Hope.

The upper model was initially developed, calibrated and validated to flows reported by WSC for the Mission gauge using data from 1999 and 1997. As a result of the changes listed above, The upper model was recalibrated to the 1999 flood as this was the closest high flow year to when the bathymetric data was collected. Model revalidation was performed using the 2007 data. The new Hope rating curve only marginally reduced the 1999 or 2007 peak flows, where as lesser flows were more significantly affected. Complete inflows for the calibration run are presented in Table 3.1.

Tributary inflows for both 1999 and 2007 are based on a combination of reported flows (Chilliwack River, Chehalis River), estimated flows (Silverhope Creek, Ruby and Wahleach Creeks, Norrish Creek and Sumas River), and backwater adjusted flows (Harrison River). Reported flows are from WSC, estimated flows are based on reported flows and relative drainage areas of the tributaries. The adjusted Harrison River inflow estimates are based on WSC's spreadsheet that account for the backwater from the Fraser River. All tributary flows were daily flow averages and spanned a six week period around the peak Fraser River flow.

The roughness values for most reaches changed significantly. The upper model calibration and validation were more involved than for the lower model. This was due in part to the calibration of the hydraulic loss coefficients in addition to the calibration of roughness coefficients. The model was calibrated and validated using a network that did not include Harrison Lake, as flow input to the upstream end of the Lake for 1999 and 2007 are not known. Harrison Lake was added to the model once calibration of roughness and energy losses was complete.

While completing network mapping in GIS, it became clear that the MIKE11 network file created by UMA did not exactly match the cross-section locations shown in the CAD drawings and reporting for the 2001 model. The reasons for these adjusted locations are not known, and therefore for the current model the cross-sections are assumed to be where they are shown in the MIKE11 network file.

4.2.2 MODEL CALIBRATION(1999)

Results for the recalibration for the 1999 freshet are listed in Table 4.4. The agreement with the recorded peak levels is generally within the target accuracy of ± 0.10 m, with an average absolute error of 0.05 m. Plots of observed and modelled water levels are provided in Appendix D. For the most part, observed and modelled water levels are in good agreement over the five days around the freshet peak. The exceptions include the gauges near the Agassiz-Rosedale Bridge, where there are three gauges in close proximity (Agassiz Bridge South, Agassiz Bridge North and Chip Intake) that have significantly different recorded water levels. This may be due to two dimensional hydraulic conditions such as super-elevation at the bend upstream of Agassiz Bridge, or possibly to errors in the gauge readings. The model was calibrated to minimise the average absolute error at all three sites; the model under-predicts water levels at the Chip Intake gauge by 0.13 m, over-predicts water levels at the Agassiz-Rosedale Bridge North gauge by 0.14 m and is within 0.01 m of the Agassiz-Rosedale Bridge South gauge.

Estimated Manning's roughness coefficients are presented in Table 4.5. MIKE11 interpolates linearly between upstream and downstream roughness coefficients for intervening cross-sections. Roughness values for the gravel reach were based on theoretical values before being slightly modified during the calibration process; main channel sections were assigned a Manning's roughness value of 0.030, side-channels a value of 0.035, unvegetated gravel bars a value of 0.035, agricultural floodplain areas a value of 0.040 and well vegetated overbank areas a value of 0.060. Calibrated Manning's roughness coefficients lie within the original theoretical bounds of 0.030 to 0.060 as shown in Table 4.5.

Hydraulic loss coefficients in the Harrison River and at Harrison bend were adjusted during the calibration process. Initial loss coefficients were based on theoretical values; the final coefficients were based on slight adjustments to the theoretical values as a result of calibration.

4.2.3 MODEL VALIDATION (2007)

Following calibration, the model was validated using water levels recorded during the 2007 freshet. Good agreement was found between the observed and modelled values as shown in Table 4.4 and Appendix D. The average absolute error for peak water levels in 2007 is 0.08 m, and most values fall well within the target range of ±0.10 m. Some gauges (Bell Dam, Seabird Island and Wahleach Powerhouse) were not included in the validation due to irregularities and suspect data. The validation shows generally good results, though water levels on the Fraser River mainstem between Harrison River and Agassiz-Rosedale Bridge show over-prediction of water levels. This may in part be due to changes to the river morphology in this complex reach since the river was surveyed in 1999 or to inflow estimates.

4.2.4 Assessment of Results

The results from the calibration and validation show that the upper model is an excellent tool for computing water levels. The accuracy of the water level predictions are well within target values and the model meets typical standards set for floodplain mapping. However, the calibration and validation flows are much lower than the design flood condition. Also, the bathymetry used to build the upper model is almost ten years old. The gravel reach is subject to significant changes, especially during high flow years. The model should be reassessed and refined if higher flows are experienced or if significant bathymetric changes are identified. Extending the model to Hope would provide valuable information for fine-tuning the upper end of the Hope rating curve.

4.3 Merged Model

The upper and lower Fraser River models were joined together to provide a single model of the entire reach of the river from Hope to the Strait of Georgia. This simplifies running the model, particularly for flood forecasting. Also, for flood level forecasting, Harrison Lake was included in the model so that RFC predicted lake inflows can directly be used as model input rather than lake outflows.

4.3.1 Inclusion of Harrison Lake

Harrison Lake, with a surface area of 255 km^2, provides a significant storage volume. In the first instance, Harrison Lake was added to the upper model only. This allowed for verification of the lake routing. Once the upper model was shown to accurately route flows through the Lake, Harrison Lake was added to the merged model.

Lake geometry was digitised from 1951 charts (International Pacific Salmon Fisheries Commission), the most recent readily available data, at 3 km intervals. The lake bathymetry is not expected to have changed greatly over the 60 years since this data was collected. The data was included as additional cross-sections in the XNS11 file. The network file was also edited to include the lake.

The lake routing was validated using 2007 data. Recorded lake inflow data was not available and a simple hydrologic model was applied to the observed data on the Lillooet River near Pemberton (08MG005) to estimate inflows. The boundary file was edited to input flow at the top end of the lake, and the model was run for the two weeks surrounding the 2007 freshet peak. Water levels on the lake were compared to observed levels, and the single observed flow measurement was compared to modelled flows. Figure 4.3 shows a comparison of observed and modelled data for Harrison River and Lake. The validation for the lake is not nearly as good as for the remainder of the model. This is primarily due to the limited observed data, in particular the estimated flows upstream of the lake. When the model is used for forecasting, the RFC is able to provide estimates at the lake inlet using a WARNS hydrologic model.

The lake outlet has a relatively small outlet capacity, especially when the Harrison River is backwatered by the Fraser and it takes time for the model to adjust if the initial conditions are incorrect. It is important that consideration of the initial lake elevation is taken, especially when running the model in real-time.

4.3.2 MODEL MERGING METHODOLOGY

The DOS tool "pfs.MERGE" was used to join the upper and lower models but some editing of the combined network and hydrodynamic parameter files was required. Where the two models overlap between Vedder Canal and Mission, the upstream model was used, as this model was calibrated in detail to observed water levels in this reach.

4.3.3 MODEL VALIDATION (2007)

To ensure that the merged model functions correctly, it was validated to the 2007 event. The model input was the same as that used for the lower and upper models, except that input to the Harrison system was based on flow estimates at the inlet of Harrison Lake rather than reported flows on the Harrison River. The Lillooet River flow estimation method is described above.

Good agreement was found between the observed and modelled values as shown in Table 4.6. As expected, the values are near identical to the water levels calculated with the two individual models. The average absolute error for peak water levels in 2007 is 0.08 m, and most values fall well within the target range of ±0.10 m. As before, some gauges were not included in the validation due to irregularities and suspect data collection.

5 DESIGN FLOOD PROFILE

5.1 LOWER MODEL

5.1.1 MODEL CONDITIONS

Following successful model calibration and validation, the model boundary conditions were set to design values. As specified in the original terms of reference, and as per the 2006 model development, a design inflow of 18,900 m^3/s was used at the upstream end of the model, corresponding to a discharge of 17,000 m^3/s at Hope (estimated to have occurred in 1894), plus local inflows between Hope and Mission. A summary of inflows for the design flood is presented in Table 3.1.

During the Fraser River freshet, high tide levels are common (since large tides occur in June around the time of the peak freshet) but storm surges are minimal. At the four outlet arms, the 2002 calibration tide levels were used as the downstream boundary condition (maximum tide at Point Atkinson of 1.84 m GSC). The levels roughly correspond to a two-year return period summer high tide (no surge). Since winter flood conditions exceed freshet levels for the lower 28 km, an in-depth analysis of summer tides was not carried out.

For the Douglas Island–Mission reach, the roughness value derived from calibration of the historic high-flow model was used. Some adjustments had to be made to the calibrated model to accommodate the design flow. All standard, non-standard and other types of dikes including railroad and highway embankments were extended vertically in the model to stop flow spillage onto the floodplain. This was based on the assumption that dikes presently not high enough will be raised to prevent flooding in the future and is in keeping with MOE guidelines for floodplain mapping studies. However, unprotected floodplain areas, as covered by cross-section lines on Map No. 2, were included as actively conveying flow.

5.1.2 SIMULATION RESULTS

The water level at Mission was found to be 8.9 m GSC or 1.0 m higher than the design water level computed in 1969, which was equal to the observed 1894 level. The design profile is plotted in Drawing No. 1 and tabulated in Table 5.1. Also listed in the table are the design level increases compared to the 1894 profile calculated in 1969, and compared to the design level calculated in 2006 using the original MIKE11 model. Explanations for the difference in flood profiles between the 1969 and 2007 profiles are found in the 2006 report, and include changes to the river geometry, the introduction of dikes into the model and the loss of floodplain storage.

The updated design profile remains virtually unchanged from the profile developed by **nhc** in 2006 as shown in Table 5.1 and Figure 5.1. There has been a minor lowering of the profile from just below the trifurcation to Douglas Island. This is a result of the fine-tuning of the calibration using the very comprehensive 2007 data set. Water surface profiles are shown in plan on Map 4.

Flow levels at the bridges were reviewed and only one bridge, Jacob-Haldi at McMillan Island was subject to pressure flow, with water touching the bridge deck but not overflowing it. Computed flow split percentages at the design flow were nearly the same as for the calibration/validation flows.

5.1.3 Sensitivity Runs

In order to assess the sensitivity of the model to changes in inflows, ocean levels and roughness a series of sensitivity analyses were undertaken for the original model (**nhc**, 2006). For completeness these analyses were repeated for the updated model as summarised in Appendix E.

5.2 Upper Model

5.2.1 Model Conditions

Following successful model calibration and validation, the model boundary conditions were set to design values. A design inflow of 17,000 m^3/s at Hope was used with a flow of 1,300 m^3/s at Harrison Lake outlet. Tributary design inflows from several tributaries were based on peak flow ratios as summarized in Table 3.1. The downstream boundary condition at Mission was based on modelled water levels for the lower model with a peak water level of 8.9 m GSC.

Roughness coefficients in gravel-bed rivers do not typically vary with flow and the coefficients derived from the 1999 model calibration were used for the design profile. During the design flood, large gravel bar shifts are likely to occur, resulting in some profile variations. It is not possible to predict these variations and instead careful consideration should be given to specifying an adequate freeboard allowance.

Similar adjustments were made to the upper model as to the lower model to convey the design flow.

5.2.2 Simulation Results

The design profile is plotted in Drawing No. 2 and tabulated in Table 5.2. A comparison is provided with the design profiles derived in 2006 in Figure 5.2. The water surface profile is shown in plan on Map 5.

A comparison of the updated profile and the profile prepared by **nhc** in 2006 shows relatively minor changes considering the extensive modifications made to the model. Results are generally within $\pm$ 0.2 m and the maximum difference is an increase 0.32 m at Maria Slough.

There is a significant difference between the UMA 2001 profiles and the updated profiles in the reach between Mission and the Harrison River confluence. This is due to the backwater effects from further downstream. The updated downstream boundary level at Mission is 0.9 m higher than the value used by UMA in 2001. The change in the water level at Mission affects the design profile for a significant distance upstream due to the relatively gradual slope of the channel which creates a significant backwater effect. This change is apparent to just upstream of the confluence of the Harrison and Fraser Rivers.

There is very little difference between the updated flood profiles, the UMA 2001 profile and the original 1969 design flood profile upstream of the Agassiz-Rosedale Bridge.

5.2.3 Sensitivity Runs

The upper model was tested for sensitivity to inflows, the Mission water level and roughness. Tabular and graphical results of the sensitivity modelling are presented in Appendix F.

5.3 Model Limitations

The accuracy of the predicted flood levels is limited by several factors including:

- The reliability and accuracy of flow data for calibrating and verifying the models.
- The range of flow conditions the model has been calibrated to. When the design discharge is significantly higher than the calibration flows, assumptions must be made on the hydraulic roughness. In the case of the Fraser River, the design flood is about 60% greater than the calibration flows used in 2007.
- Topographic changes that occur in the channel and on the floodplain over time in response to degradation/aggradation, new infrastructure such as bridges or dikes etc.
- Changes in flow confinement due to breaching of dikes or overbank spills. It should be recognized that the model assumes all existing dikes have been raised so that the flow is fully confined. If a breach occurs, the actual water level could be different from the water level predicted in the model.

6 FLOOD LEVEL FORECASTING MODEL

In order to provide stakeholders with accurate real-time water levels during a freshet event, the model has been set-up to allow for flood level forecasting. The forecasting model is intended to be a "dynamic" model that is maintained by regular updates. The lower model was previously found to be relatively insensitive to bed changes unlike the upper model. The upper reach should be updated with new bathymetry at least every ten years, as previously recommended by UMA.

DHI is continuously updating and expanding the MIKE11 software. Older versions are not necessarily compatible with newer versions and the model should be kept up to date with newer software versions as they become available.

6.1 INPUT REQUIREMENTS

For present river conditions the model is directly useable and only the boundary conditions need to be edited when applying the model in flood forecasting mode. The model boundary conditions include inflow at Hope, numerous tributary inflows and ocean tide levels. Inflows at Hope and Harrison Lake can be based on predicted freshet flood hydrographs provided by the RFC. Design and calibration/validation flows (Table 3.1) as well as real-time reported flows can be used as a guideline to estimate tributary inflows for flood forecasting.

Predicted tide levels are available for Point Atkinson from published tide tables or from the web at: www.waterlevels.gc.ca. This data does not include water level increases due to local or surge conditions. Triton Consultants used a harmonic model to adjust Point Atkinson data to the four outlet arms. The adjustments were found to be quite minor, roughly 0.1 m or less, and therefore the Point Atkinson data can be directly applied to the four arms without significant loss in accuracy.

6.2 USER INSTRUCTIONS

Detailed user instructions are found in Appendix H of the 2006 **nhc** report, overview instructions are presented here.

The MIKE11 model is formed of four distinct input files, which are combined in a simulation file. The four input files contain information on the river network, cross-sections, boundary conditions and hydraulic parameters. When running the model in flood forecast mode, typically only the boundary condition file and associated time series file need to be revised. This editing can be accomplished through the simulation file. The simulation file also specifies the time period which needs to be adjusted for forecasting.

The boundary condition data should ideally be hourly, and the model run with a 2 second time-step. The period of modelling can span the entire freshet period or only a few days. The computational time for a two week period is roughly four hours. Generally the model needs a run-up time of at least 6 hours (real-time) before computations are stabilised and the results reliable.

In the Douglas Island to Mission reach, channel roughness decreases from 0.028 to 0.027 in the 14,530 m^3/s to 15,840 m^3/s flow range. When forecasting flows in this range, the hydraulic parameter file must be altered. An input file, where roughness is automatically adjusted within the model based on average cross-section velocity, was prepared but is not supported by the current version of MIKE11. According to DHI, this file may be useable with future versions of the software.

6.3 SIMULATION RESULTS

Once the model has successfully run, the output can be viewed in MIKEView. MIKEView provides a number of options for viewing the output either as plotted profiles, or as tabulated water levels. Discharge and other hydraulic parameters can also be viewed. Peak flood levels, the timing of peaks, the length of time water levels exceed a certain value and other important information can be directly extracted from MIKEView.

Ideally, the model should be run in forecast mode for each freshet flood and the simulated profile compared with observed data following the flood. This would provide direct feed-back on the accuracy of the model and the need for new bathymetry. During high flows, exceeding the current calibration/validation flows of approximately 12,000 m^3/s at Mission such comparisons are essential. To ensure that future comparisons are feasible, flow and water level gauges must remain operational.

The model is straightforward to run and operate. However, if given un-representative input, it will provide erroneous results. It is imperative that the model be operated by technically qualified persons only.

Considering the potential discrepancies between flows at Mission and the sum of upstream flows caused by future rating curve shifts, it is necessary to compare the modelled and reported flows at Mission. If modelled and reported flows show a consistent divergence, it may be necessary to adjust model flows.

6.4 LIMITATIONS

The limitations outlined in the model predictions in Section 5.3 also apply to the model when it is used as a flood forecasting tool. In addition, the model forecast predictions will be limited by the actual accuracy of the discharge forecasts issued by RFC. The accuracy of forecasted flows during the 2007 freshet was discussed in **nhc** (2007). According to RFC 12-24 hour forecasts are within $\pm$200 m^3/s, 24-48 hour forecasts are within $\pm$300 m^3/s and 48-96 hour forecasts within $\pm$5 to 7% for flows greater than 10,000 m^3/s at Hope.

7 DIKE ASSESSMENT

A comparison of dike crest elevations and the design profile was provided by **nhc** (2006). A set of 12 drawings were prepared based on information from MOE, municipalities and LiDAR surveys. In preparation of the 2007 freshet, a number of dikes were raised, including the dikes at Mission/Silverdale, Dewdney, Abbotsford, Chilliwack, Kent (D), Maple Ridge, Surrey, Pitt Meadows and Port Coquitlam. To reflect the updated design profile and raised dike crest profiles, the 2006 dike assessment was repeated. Dike information sources are summarized in Table 7.1.

In addition to the design profile, with and without a freeboard allowance of 0.6 m, the water surface profiles corresponding to Mission water levels of 6.0 m, 7.0 m and 8.0 m were added to the drawings. These three additional profiles assume a reoccurrence of the recorded maximum June tide, which occurred in 1982 and had a peak water level of 1.95 m GSC at Point Atkinson.

To facilitate future easy updating of the dike information, the dike and river station information was combined in a GIS database. The dike assessment methodology and a qualitative discussion of the dikes is included in this section.

7.1 METHODOLOGY

The GIS data base included the following information:

- Dike locations and station features supplied by MOE.
- Model reach centrelines exported from the MIKE11 upper and lower models, including reach names.
- Model cross-section information exported from the MIKE11 upper and lower models, including reach names, river stationing, and water levels.
- Model cross-section lines derived from input data that was used to build the MIKE11 models.

Model cross-section information was converted to point data along the model reach centrelines based on river stationing. A spatial join was then used to attribute the cross-section lines with model data. In order to determine water levels along the dikes, cross-sections were extended to intersect the dikes. A GIS technique called "linear referencing" was used to interpolate dike station values for model cross-section points along each dike. The result was a series of model water level values tied to station values along each dike. Dike station adjustments were necessary in some locations and dike elevations associated with a given dike station should be considered approximate. Updated dike drawings are shown in Drawings 3 to 18. Detailed crest surveys should be undertaken prior to any upgrade work.

7.2 ASSESSMENT RESULTS

A qualitative overview assessment of each dike was completed by comparing dike crest elevations with the design flood profile, with and without freeboard. In general, the dikes were found to have inadequate freeboard or to be at risk of overtopping during the design flood. Of the dikes reviewed, about 14% were found to have adequate freeboard over most of their length. By comparison, 49% had inadequate freeboard but crest elevations that generally exceeded the design flood level, where as 37% were found to be below the design flood level. Table 7.2 summarises the assessment.

When dikes are breached, water levels on the land side of the dikes may exceed those predicted by the model. UMA(2000) described modelling undertaken assuming a breach of the railway embankment at Seabird Island. This work along with other previous studies was reviewed as summarised in the memorandum included in Appendix G. Under certain conditions, water levels just upstream of the railway bridge across Maria Slough could conceivably be higher than those on the river side of the railway. The same situation may arise at other locations, where dikes trap flood waters, increasing water levels beyond those indicated by the design profile.

8 WATER LEVEL REFERENCE TABLES

At the request of MOE and participating municipalities, water level reference tables were generated relating local water levels to the water level at Mission gauge. The tables show expected water levels at key locations along the river given Mission gauge readings of between 6 and 9 m, in 0.5 m increments. The tables are presented in Appendix H. The development of the tables involved numerous runs of both the lower and upper models. The initial request was for flood profiles corresponding to the 100, 50 and 25-year floods. However, since a frequency analysis of Fraser River flows has not been completed, MOE advised using the range of water levels at Mission.

8.1 LOWER MODEL

For the lower model the process began by estimating inflows at Mission that would correspond to gauge readings of 6.0, 6.5, 7.0, 7.5, 8.0, 8.5 and 9.0 m at Mission using the updated rating curve. The historic highest tide for May-June, with a complete hourly dataset at Point Atkinson, was 1.95 m GSC recorded on June 24^{th}, 1982. The model was then run using this dataset as the downstream boundary condition and the tributary inflows from the 2002 validation model. An iterative process was followed, where the inflow at Mission was adjusted slightly until the maximum recorded water level was found to match the required level. Once this was achieved, minimum and maximum water levels were reported in tabular form for municipal boundaries and gauge sites.

The reference tables generated do not replace real-time flood level forecasting. Water levels in the sand-bed reach are strongly influenced by ocean levels. The reference tables were generated for the historic highest tide condition, and do not represent typical freshet conditions. Actual water levels may be lower or may exceed those tabulated. **The reference tables should be used for guidance only and do not replace real-time forecasting**.

8.2 UPPER MODEL

The development of the reference tables for the upper model reach was simpler than for the lower reach. The downstream boundary condition at Mission was set to the desired water level, and inflows at Hope, Harrison and tributaries were calculated as a function of total flow at Mission (from the lower model) and flow contributions for the calibration/validation and design runs. Table 8.1 shows tributary inflows for each Mission water level scenario. Maximum water levels at municipal boundaries and gauge locations are presented in the reference tables in Appendix H. As for the lower model tables, actual water levels may vary. Computations are based on assumed tributary inflows that will vary with each freshet. **The reference tables should be used for guidance only and do not replace real-time forecasting.**

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

1. Extensive hydrometric data was collected in 2007 in comparison to previous years. The data provided an excellent opportunity to validate the overall accuracy of the Fraser River model. The results from the 2007 freshet and the model recalibration confirm the key findings of the 2006 flood profile report. The design profile is virtually unchanged, and the key recommendations of the original report remain valid.
2. Models are only as good as the data available for model development, calibration and validation. At the outset of the recalibration project it was found that the discharge at Mission was systematically under-estimated over the last decade because of a shift in the WSC rating curve. Using the new corrected data required minor adjustments to model roughness for flows in the 5,000 m^3/s to 14,500 m^3/s range.
3. A number of modifications were made to the upper model to improve its accuracy and compatibility with the lower model. The new approach eliminated the need for unrealistic roughness values. The revised model can be run in the high order fully dynamic mode of MIKE11.
4. The two models (upper and lower) were successfully merged into a single model. The merged model was also extended to include Harrison Lake to better model the flow contribution from the Harrison system during freshet events. The new merged model provides a simple tool for flood forecasting along the whole length of the Lower Fraser River.

9.2 RECOMMENDATIONS

1. The updated flood profile should be adopted by MOE and local governments for upgrading dikes and land use planning purposes.
2. The merged model that includes Harrison Lake should be adopted for future flood forecasting operations. The RFC should be advised that for future flood level forecasting, Harrison Lake inflows rather than outflows are required. A joint test run of the RFC Harrison River WARNS model and the MIKE11 model should be undertaken to confirm that the models are mutually compatible.
3. The intensive, real-time water level data collection program that was launched in 2007 should be repeated during all future large flood events, with return periods of ten years or more.
4. The WSC needs resources to continue regular measurements of flow at Hope, Harrison Lake outlet and Mission during the freshet season to ensure that rating curves at these key sites are kept up to date. The focus needs to be on flows exceeding

5,000 m^3/s at Hope and 6,000 m^3/s at Mission. Real-time reported Harrison flows adjusted for Fraser River backwater would be very useful for both hydrologic and hydraulic forecast modelling. A $\pm$ 5% error in the Mission flow at 12,000 m^3/s translates to a discrepancy of $\pm$ 0.2 m in computed water levels. For flood level forecasting it is very important that reported and predicted flows are as accurate as possible.

5. The model performance needs to regularly be assessed, particularly during floods that are appreciably larger than the calibration and validation flows. Over time, the model may need further updating as a result of changes to the river geometry or because the model is working beyond the flow range it was developed for.
6. The model should be extended to Hope gauge to provide confirmation of the upper end of the rating curve. Further extension to Alexandra Bridge may offer some confirmation of the 1894 flood magnitude, based on 1894 photography at the bridge.
7. Freeboard requirements, particularly in the gravel bed reach should be reviewed.
8. Higher flood levels than those modelled may occur during the design flood as a result of dike breaches and water ponding on the land side of the diking.

10 REFERENCES

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TABLES

Table 3.1: WSC 2007 Flow Measurements

Measurements at Mission (Fraser River):

Date - Time	Gauge Height (m)	Measured Flow (m^3/s)	Reported Flow (m^3/s)	Error %	Corrected Flow (m^3/s)	Error %
5/24/2007 17:50	3.750	7450	6810	-8.6	7175	-3.7
6/5/2007 10:57	5.461	10500	9880	-5.9	10522	0.2
6/5/2007 15:00	5.465	10548	9890	-6.2	10530	-0.2
6/5/2007 16:00	5.452	10600	9860	-7.0	10504	-0.9
6/6/2007 15:10	5.682	11200	10397	-7.2	11110	-0.8
6/11/2007 10:30	5.935	12100	11004	-9.1	11818	-2.3
6/12/2007 9:00	5.820	11500	10728	-6.7	11496	0.0
6/18/2007 12:20	4.705	8760	8369	-4.5	9010	2.9
6/26/2007 11:00	4.410	8751	7857	-10.2	8429	-3.7
6/26/2007 13:34	4.384	8755	7813	-10.8	8380	-4.3

Measurements at Hope (Fraser River):

Date - Time	Gauge Height (m)	Measured Flow (m^3/s)	Reported Flow (m^3/s)	Error %	Corrected Flow (m^3/s)	Error %
5/25/2007 12:30	7.160	6240	6550	5.0	6155	-1.4
6/6/2007 8:30	8.850	9830	9870	0.4	9733	-1.0
6/11/2007 15:50	9.151	10300	10493	1.9	10460	1.6
6/18/2007 17:07	7.838	7400	7846	6.0	7454	0.7
6/25/2007 14:40	7.715	7123	7598	6.7	7198	1.1

Measurements at Harrison Hot Springs (Harrison River):

Date - Time	Gauge Height (m)	Measured Flow (m^3/s)	Reported Flow (m^3/s)	Error %	Adjusted Flow (m^3/s)	Error %
5/25/2007 8:50	10.000	627	784	25.0	661	5.4
6/6/2007 11:00	11.962	1140	1630	43.0	1201	5.4
6/11/2007 12:40	12.085	1030	1700	65.0	1144	11.1
6/18/2007 14:52	11.295	1090	1250	14.7	1095	0.5
6/25/2007 18:32	11.192	988	1180	19.4	1027	3.9

Measurements at Agassiz (Fraser River):

Date - Time	Gauge Height (m)	Measured Flow (m^3/s)
6/11/2007 18:30	-	10200

Table 3.2: 2007 Freshet Flow Time Series

Date	Hope			Silverhope	Harrison	Chilliwack	Chehalis	Ruby+W	Norrish	Sumas	Sum of	Mission			Diff. of	Diff. of
	Reported (m^3/s)	Corrected (m^3/s)	Measured (m^3/s)	Estimated (m^3/s)	Adjusted (m^3/s)	Reported (m^3/s)	Reported (m^3/s)	Estimated (m^3/s)	Estimated (m^3/s)	Estimated (m^3/s)	Cor.Inflows (m^3/s)	Reported (m^3/s)	Corrected (m^3/s)	Measured (m^3/s)	Reported Q's (m^3/s)	Corrected Q's (m^3/s)
15-May	6080	5715		26	473	102	49	6	14	2	6387	6348	6544		404	-158
16-May	6111	5744		31	513	122	49	6	14	3	6482	6399	6616		450	-133
17-May	6126	5758		33	560	129	49	6	14	3	6553	6556	6830		365	-277
18-May	6143	5774		30	599	119	49	6	14	3	6594	6571	6851		393	-256
19-May	6369	5983		32	622	124	49	6	14	3	6832	6752	7096		467	-264
20-May	6531	6131		30	637	117	49	6	14	3	6987	7013	7439		373	-452
21-May	6593	6188		29	645	112	49	6	14	3	7045	7036	7467		414	-422
22-May	6627	6220		27	637	104	49	6	14	2	7059	7003	7426		462	-367
23-May	6703	6290		27	622	105	49	6	14	2	7116	6984	7402		544	-286
24-May	6625	6219		27	631	106	49	6	14	2	7054	6976	7391	7450	484	-337
25-May	6496	6100	6240	28	661	111	49	6	14	3	6973	6700	7026		669	-53
26-May	6414	6023		30	695	117	49	6	14	3	6936	6550	6822		777	114
27-May	6384	5996		32	706	126	49	6	14	3	6932	6487	6737		832	195
28-May	6319	5936		31	738	120	49	6	14	3	6897	6428	6656		852	241
29-May	6400	6011		29	748	113	49	6	14	3	6973	6431	6660		931	313
30-May	6737	6322		33	742	130	49	6	14	3	7299	6690	7013		1024	286
31-May	7102	6659		41	750	159	49	6	14	4	7681	7117	7570		1007	111
1-Jun	7343	6901		36	817	177	40	7	11	2	7992	7445	7965		988	27
2-Jun	7677	7267		39	890	191	40	7	11	3	8446	7829	8398		1028	49
3-Jun	8197	7824		42	965	207	40	7	11	3	9100	8287	8919		1185	181
4-Jun	8883	8587		54	1054	267	40	7	11	4	10024	8930	9610		1390	414
5-Jun	9448	9224		53	1133	263	40	7	11	4	10736	9777	10433	10550	1182	303
6-Jun	9909	9756	9830	45	1201	223	40	7	11	3	11287	10263	10954	11200	1176	333
7-Jun	10333	10222		36	1273	177	40	7	11	2	11768	10617	11367		1262	401
8-Jun	10646	10576		30	1236	149	40	7	11	2	12050	10739	11509		1382	541
9-Jun	10840	10790		28	1171	140	40	7	11	2	12189	10885	11679		1354	510
10-Jun	10891	10847		28	1121	139	40	7	11	2	12195	10981	11791		1259	404
11-Jun	10659	10589	10300	28	1144	139	40	7	11	2	11960	11011	11826	12100	1019	134
12-Jun	10118	9978		25	1179	123	40	7	11	2	11365	10624	11375	11500	881	-10
13-Jun	9637	9450		23	1207	115	40	7	11	2	10855	10194	10873		848	-18
14-Jun	9330	9085		23	1166	114	40	7	11	2	10448	9864	10507		830	-59
15-Jun	8926	8635		23	1134	112	40	7	11	2	9962	9476	10148		778	-186
16-Jun	8498	8158		24	1116	117	40	7	11	2	9474	9035	9715		779	-240
17-Jun	8159	7770		27	1101	132	40	7	11	2	9090	8660	9326		819	-237
18-Jun	7904	7506	7400	26	1095	127	40	7	11	2	8813	8357	8997	8760	855	-184
19-Jun	7794	7395		24	1052	118	40	7	11	2	8649	8162	8779		886	-130
20-Jun	7913	7523		26	1047	128	40	7	11	2	8783	8152	8767		1022	17
21-Jun	8065	7676		28	1035	139	40	7	11	2	8938	8395	9039		931	-101
22-Jun	8040	7676		27	1026	134	40	7	11	2	8924	8545	9206		742	-282
23-Jun	7825	7428		25	1087	125	40	7	11	2	8725	8334	8972		787	-247
24-Jun	7653	7242		24	1083	116	40	7	11	2	8525	8081	8684		855	-159
25-Jun	7643	7229	7123	23	1027	113	40	7	11	2	8452	7992	8579		874	-128
26-Jun	7624	7210		21	931	105	40	7	11	1	8326	7966	8551	8753	774	-225
27-Jun	7508	7084		22	1066	106	40	7	11	1	8337	7908	8486		853	-149
28-Jun	7276	6830		23	895	112	40	7	11	2	7919	7713	8269		652	-349
29-Jun	7072	6632		24	987	117	40	7	11	2	7819	7588	8128		672	-309
30-Jun	6966	6534		25	1032	125	40	7	11	2	7776	7460	7982		748	-207

Notes:

1. Corrected Hope flows are based on rating curve developed from complete set of WSC measurements provided in December 2007. Modelling and Table 3.4 based on data provided to nhc in summer 2007.

Table 3.2 Cont: 2002 Freshet Flow Time Series

Date	Hope			Silverhope	Harrison	Chilliwack	Chehalis	Ruby+W	Norrish	Sumas	Sum of	Mission			Diff. of	Diff. of
	Reported (m^3/s)	Corrected (m^3/s)	Measured (m^3/s)	Estimated (m^3/s)	Adjusted (m^3/s)	Reported (m^3/s)	Reported (m^3/s)	Estimated (m^3/s)	Estimated (m^3/s)	Estimated (m^3/s)	Cor.Inflows (m^3/s)	Reported (m^3/s)	Corrected (m^3/s)	Measured (m^3/s)	Reported Q's (m^3/s)	Corrected Q's (m^3/s)
1-Jun	8530	8200		38	801	188	78	7	11	3	9326	8850	9526		806	-200
2-Jun	8790	8484		38	780	187	75.5	7	11	3	9586	9080	9756		811	-170
3-Jun	8720	8416		38	819	187	75	7	11	3	9555	9230	9906		630	-351
4-Jun	8440	8098		38	892	187	80	7	11	3	9315	9210	9894		448	-579
5-Jun	8260	7898		41	947	203	87	7	11	3	9197	9110	9792		449	-595
6-Jun	8290	7931		43	1020	213	73	7	11	3	9301	9020	#N/A		640	#N/A
7-Jun	8290	7936		36	1060	178	64	7	11	2	9294	8920	9594		729	-300
8-Jun	8660	8344		30	995	149	66	7	11	2	9605	8900	9576		1020	29
9-Jun	9090	8818		28	884	136	64.5	7	11	2	9950	9140	9820		1082	130
10-Jun	8980	8700		30	870	147	70.3	7	11	2	9837	9350	10028		767	-191
11-Jun	8510	8178		35	976	170	75.4	7	11	2	9454	9140	9816	9469	646	-362
12-Jun	8220	7856		41	1040	200	84.9	7	11	3	9242	8900	9572		706	-330
13-Jun	8360	8007		48	1070	238	94.9	7	11	3	9479	8990	9670		843	-191
14-Jun	8760	8451		53	1100	262	97.4	7	11	4	9985	9390	10066		904	-81
15-Jun	9140	8878		56	1160	276	91	7	11	4	10483	9870	10516		875	-33
16-Jun	9440	9219		51	1230	253	79.2	7	11	3	10854	10200	10894		875	-40
17-Jun	9660	9479		44	1250	215	67.2	7	11	3	11075	10400	11146		857	-71
18-Jun	10000	9912		48	1220	237	75	7	11	3	11513	10800	11616		802	-103
19-Jun	10200	10164		41	1190	203	69.6	7	11	3	11689	11000	11849		725	-160
20-Jun	10400	10371		37	1150	183	58	7	11	3	11820	11000	11804		849	16
21-Jun	10600	10552		39	1100	192	62.1	7	11	3	11966	11000	11860		1014	106
22-Jun	10400	10300		43	1100	210	61.3	7	11	3	11735	11000	11863		835	-128
23-Jun	9870	9729		42	1190	206	57.3	7	11	3	11245	10800	11527		586	-282
24-Jun	9440	9217		39	1250	192	52.6	7	11	3	10771	10400	11093	11183	594	-322
25-Jun	9580	9383		39	1260	192	50.1	7	11	3	10945	10100	10782		1042	163
26-Jun	9860	9726		43	1220	210	52.1	7	11	3	11272	10100	10790		1306	482
27-Jun	10100	9948		44	1200	215	57.1	7	11	3	11484	10400	11070		1237	414
28-Jun	10200	10088		44	1260	216	74.6	7	11	3	11704	10600	11311		1216	392
29-Jun	10100	9995		58	1340	283	82	7	11	4	11780	10900	11647		984	133
30-Jun	10200	10157		46	1380	225	76.8	7	11	3	11906	10800	11619		1149	287
1-Jul	10100	9940		34	1340	193	65.8	4	5	3	11585	10600	11392		1144	192
2-Jul	9840	9695		28	1270	163	49.8	4	5	2	11218	10300	11051		1062	167
3-Jul	9620	9438		26	1190	147	40.2	4	5	2	10852	10100	10740		934	112
4-Jul	9100	8831		23	1170	134	35.7	4	5	2	10205	9640	10304		834	-99
5-Jul	8490	8160		22	1150	124	33.3	4	5	2	9500	9020	9696		810	-196
6-Jul	7890	7500		20	1120	118	30.3	4	5	2	8799	8330	8968		859	-169
7-Jul	7330	6894		22	1080	126	31.2	4	5	2	8164	7820	8383		780	-220
8-Jul	7030	6602		27	1020	155	39	4	5	2	7854	7540	8068		742	-214
9-Jul	6670	6263		25	991	142	34.5	4	5	2	7466	7260	7739		613	-273
10-Jul	6540	6147		25	982	146	34.9	4	5	2	7347	6940	7348		799	-1
11-Jul	6440	6053		28	979	160	35.6	4	5	2	7266	6820	7183		834	84
12-Jul	6510	6119		28	990	161	36	4	5	2	7346	6880	7264		856	81
13-Jul	6620	6218		26	1000	152	34.8	4	5	2	7442	6900	7295		944	147
14-Jul	6760	6344		25	1010	145	32.4	4	5	2	7568	6950	7356		1034	212
15-Jul	6900	6474		23	1020	131	29.8	4	5	2	7688	7150	7610		964	78

Notes:

1. Corrected Hope flows are based on rating curve developed from complete set of WSC measurements provided in December 2007. Modelling and Table 3.4 based on data provided to nhc in summer 2007.
2. No water level recorded at Mission on June 6th, 2002.

Table 3.2 Cont: 1999 Freshet Flow Time Series

Date	Hope			Silverhope	Harrison	Chilliwack	Chehalis	Ruby+W	Norrish	Sumas	Sum of	Mission			Diff. of	Diff. of
	Reported (m^3/s)	Corrected (m^3/s)	Measured (m^3/s)	Estimated (m^3/s)	Adjusted (m^3/s)	Reported (m^3/s)	Reported (m^3/s)	Estimated (m^3/s)	Estimated (m^3/s)	Estimated (m^3/s)	Cor.Inflows (m^3/s)	Reported (m^3/s)	Corrected (m^3/s)	Measured (m^3/s)	Reported Q's (m^3/s)	Corrected Q's (m^3/s)
1-Jun	7580	7165		33	839	160	82	7	11	2	8298	8047	8640		667	-342
2-Jun	7340	6906		29	873	142	72	7	11	2	8042	7897	8471		579	-429
3-Jun	7290	6850		27	884	135	77	7	11	2	7993	7844	8416		589	-423
4-Jun	7440	7010		30	832	149	82	7	11	2	8123	8045	8648		508	-525
5-Jun	7630	7225		38	758	187	131	7	11	3	8360	8427	9084		338	-724
6-Jun	7760	7360		35	816	173	98	7	11	2	8503	8637	9300		266	-797
7-Jun	7740	7346		31	954	151	66	7	11	2	8568	8467	9116		495	-548
8-Jun	7980	7594		27	937	134	61	7	11	2	8773	8554	9220		605	-447
9-Jun	8470	8133		24	831	120	56	7	11	2	9184	8921	9606		600	-422
10-Jun	8620	8300		23	806	114	66	7	11	2	9329	8977	9654		672	-325
11-Jun	8360	8009		23	841	112	70	7	11	2	9074	8703	9364		722	-290
12-Jun	8040	7656		25	849	125	88	7	11	2	8763	8469	9116		678	-353
13-Jun	7880	7490		33	857	163	106	7	11	2	8669	8465	9118		594	-449
14-Jun	7880	7485		46	895	227	124	7	11	3	8799	8643	9314		550	-515
15-Jun	8080	7698		59	969	292	142	7	11	4	9182	9044	9734		520	-552
16-Jun	8800	8496		61	1100	299	144	7	11	4	10122	9642	10316		784	-194
17-Jun	9360	9121		45	1220	223	110	7	11	3	10741	10194	10883		785	-142
18-Jun	9750	9590		42	1300	207	97	7	11	3	11257	10603	11359		814	-102
19-Jun	10200	10176		39	1290	194	85	7	11	3	11805	11004	11829		825	-24
20-Jun	10500	10510		36	1240	177	72	7	11	2	12055	11364	12252		681	-197
21-Jun	10700	10686		35	1200	174	69	7	11	2	12184	11498	12408		701	-224
22-Jun	11000	10976		38	1160	186	77	7	11	3	12458	11602	12534		880	-76
23-Jun	11000	11043		38	1140	186	76	7	11	3	12503	11700	12642		761	-139
24-Jun	10800	10821	10626	39	1160	190	76	7	11	3	12306	11641	12570	11045	644	-264
25-Jun	10300	10371		40	1210	199	77	7	11	3	11918	11402	12282		444	-364
26-Jun	9880	9852		38	1280	186	71	7	11	3	11447	11026	11832		449	-385
27-Jun	9450	9345		33	1330	164	62	7	11	2	10955	10584	11317		476	-362
28-Jun	9180	9024		32	1330	155	59	7	11	2	10619	10152	10807		624	-188
29-Jun	9110	8948		29	1290	144	62	7	11	2	10493	9801	10448		854	45
30-Jun	9090	8926		30	1230	145	63	7	11	2	10413	9704	10364		873	49
1-Jul	9090	8921		29	1170	167	71	4	5	2	10370	9733	10392		806	-22
2-Jul	9070	8905		29	1160	166	65	4	5	2	10336	9718	10376		783	-40
3-Jul	9060	8904		26	1150	149	67	4	5	2	10307	9651	10314		811	-7
4-Jul	8920	8760		23	1120	133	57	4	5	2	10104	9508	10174		756	-70
5-Jul	9010	8862		21	1050	123	53	4	5	2	10120	9371	10048		898	72
6-Jul	9090	8943		25	979	144	62	4	5	2	10164	9459	10134		852	30
7-Jul	9170	9038		32	969	185	88	4	5	3	10324	9685	10352		772	-28
8-Jul	9250	9136		31	1040	176	86	4	5	3	10480	9960	10594		633	-114
9-Jul	9410	9336		31	1070	181	81	4	5	3	10711	10110	10776		675	-65
10-Jul	9600	9560		36	1110	206	88	4	5	3	11012	10457	11188		595	-176
11-Jul	9720	9712		39	1190	226	88	4	5	3	11268	10731	11504		545	-237
12-Jul	9850	9869		41	1250	234	84	4	5	3	11490	10977	11793		494	-303
13-Jul	9770	9771		40	1340	233	80	4	5	3	11477	11106	11936		370	-458
14-Jul	9640	9619		39	1450	222	79	4	5	3	11420	11030	11846		412	-426
15-Jul	9580	9555		33	1490	189	69	4	5	3	11347	10931	11731		441	-384

Notes:
1. Corrected Hope flows are based on rating curve developed from complete set of WSC measurements provided in December 2007. Modelling and Table 3.4 based on data provided to nhc in summer 2007.

Table 3.3: 2007 Flow Split Measurements

Area	Location	Date	Time	Discharge (m^3/s)	Average (m^3/s)	Notes
Douglas Island	Fraser R d/s of Douglas Isl	12-Jun-07	12:01 PM	15,260	15,200	2.5 km d/s of Douglas Isl. under power lines
		12-Jun-07	12:05 PM	15,105		
	Douglas Isl South Channel	12-Jun-07	11:35 AM	9,853	8,990	
		12-Jun-07	11:44 AM	9,017		
	Fraser R u/s of Douglas Isl	12-Jun-07	11:13 AM	12,773	12,550	Approx 1.3 km u/s of Douglas Isl.
		12-Jun-07	11:19 AM	12,330		
	Douglas Isl East Channel	12-Jun-07	10:50 AM	3,587	3,680	
		12-Jun-07	10:54 AM	3,764		
	Douglas Isl North Channel	12-Jun-07	10:31 AM	6,319	6,240	
		12-Jun-07	10:34 AM	6,151		
	Pitt R	12-Jun-07	09:53 AM	2,208	2,280	u/s of the Pitt River bridges
		12-Jun-07	09:57 AM	2,347		
Trifurcation	Annieville Channel	11-Jun-07	08:57 AM	12,407	12,300	u/s end of Annacis island approx. 200 m
		11-Jun-07	09:15 AM	12,022		d/s from end of the island in Annieville Ch.
		11-Jun-07	09:23 AM	12,575		
		11-Jun-07	09:29 AM	12,317		
	Fraser R full flow	11-Jun-07	09:44 AM	16,408	15,750	1000m upstream of Annacis island
		11-Jun-07	09:52 AM	14,867		
		11-Jun-07	09:57 AM	16,547		
		11-Jun-07	10:03 AM	15,181		
	North Arm	11-Jun-07	10:31 AM	1,731	1,650	At entrance of the Fraser North Arm approx.
		11-Jun-07	10:33 AM	1,613		100m u/s of the Railroad bridge.
		11-Jun-07	10:37 AM	1,676		
		11-Jun-07	10:40 AM	1,595		
	Annacis Channel	11-Jun-07	10:13 AM	1,579	1,450	u/s end of Annacis Channel
		11-Jun-07	10:17 AM	1,319		Near the Pipeline Crossing.
		11-Jun-07	10:19 AM	1,561		
		11-Jun-07	10:22 AM	1,355		
Kirkland Island	Woodward	13-Jun-07	10:08 AM	13,633	13,430	
		13-Jun-07	10:13 AM	13,254		
		13-Jun-07	10:19 AM	13,430		
		13-Jun-07	10:25 AM	13,420		
	Ladner	13-Jun-07	09:47 AM	1,165	1,150	At the entrance of Ladner Reach
		13-Jun-07	09:50 AM	1,180		
		13-Jun-07	09:55 AM	1,118		
		13-Jun-07	09:57 AM	1,153		
	Canoe Pass	13-Jun-07	09:12 AM	357	346	At the entrance of Canoe Pass(u/s)
		13-Jun-07	09:14 AM	336		
Garry Point	Garry Point	13-Jun-07	07:05 AM	11,850	11,960	Fraser River main channel by Garry Point
		13-Jun-07	07:12 AM	12,070		
	Steveston Entrance	13-Jun-07	06:56 AM	302	294	At entrance of Steveston harbour (d/s)
		13-Jun-07	06:57 AM	285		
	Reifel Island	13-Jun-07	08:01 AM	13,837	14,180	d/s of entrance of Sea Reach
		13-Jun-07	08:10 AM	14,521		
	Albion Wall	13-Jun-07	07:33 AM	2,128	1,960	Parallel to Albion wall
		13-Jun-07	07:42 AM	1,801		
Sea Island	Middle Arm	14-Jun-07	07:52 AM	1,013	1,030	
		14-Jun-07	07:55 AM	1,037		
	North Arm d/s	14-Jun-07	08:06 AM	1,101	1,090	
		14-Jun-07	08:08 AM	1,084		
	North Arm u/s	14-Jun-07	08:21 AM	2,003	2,040	
		14-Jun-07	08:24 AM	2,126		
		14-Jun-07	08:29 AM	1,983		
		14-Jun-07	08:32 AM	2,035		

Table 3.4: Peak Inflows to Models

Location	Peak flow (m^3/s)			
	1999	2002	2007	Design
Fraser at Hope	11030	10530	10830	17000
Silverhope Creek	61	58	55	85
Harrison River	1490	1380	1275	1300
Chilliwack River	299	283	267	390
Chehalis River	144	97	49	120
Ruby and Wahleach Creeks	7	7	7	168
Norrish Creek	11	11	14	112
Sumas River	4	4	4	30
Fraser at Mission	12650	11865	11825	18900
Stave River	270	330	131	365
Pitt River	100	100	107	368
Alouette River	7	5	3	4
Coquitlam River	19	20	4	10

Notes:

1. Tabulated flows at Hope based on preliminary updated rating curve, equivalent to WSC curve in effect from 1964 to 1967. Final adopted curve slightly different giving peak flows of 11,043 m^3/s for 1999, 10,552 m^3/s for 2002; and 10,847 m^3/s for 2007. (Negligible effect on calibration validation)
2. Flows upstream of Mission do not necessarily equal flows at Mission but correspond to best estimates

Table 4.1: Freshet Calibration/Validation of Water Levels for Lower Model

2007 Calibration of Water Levels for Lower Model (Continuous Gauges)

Gauge Name (Downstream to Upstream)	**Peak Comparison**			**Trough Comparison**		
	Modelled (m GSC)	Observed (m GSC)	Modelled less Observed Diff. (m)	Modelled (m GSC)	Observed (m GSC)	Modelled less Observed Diff. (m)
North Arm						
Fraser R. (North Arm) at Vancouver - 08MH032	1.87	1.83	0.04	-0.11	-0.55	0.44
Bathslough	1.90	1.91	-0.01	-0.05	-0.12	0.07
Fraser River at Byrne Creek	2.05	1.99	0.06	0.25	0.05	0.20
Queensborough	2.13	1.95	0.18	0.49	0.45	0.04
Main Arm						
Fraser R. at Steveston - 08MH028	1.67	1.75	-0.08	-0.85	-0.79	-0.06
3395 River Road	1.71	1.73	-0.02	-0.51	-0.62	0.11
Elliot & River Road	1.83	1.88	-0.05	-0.28	-0.37	0.09
62B & River Road	1.85	1.92	-0.07	-0.17	-0.16	-0.01
No. 6 Road	1.90	1.80	0.10	-0.03	-0.32	0.29
Nelson Road	2.02	1.89	0.13	0.24	*0.00*	*0.24*
9600 River Road	2.13	2.13	0.00	0.53	0.56	-0.03
New Westminster	2.37	2.37	0.00	1.33	1.10	0.23
Manson	2.33	2.29	0.04	1.20	0.96	0.24
Fraser R. at Port Mann PS - 08MH126	2.56	2.59	-0.03	1.76	1.77	-0.01
Pitt River at Argue St	2.70	2.66	0.04	2.07	n/a	n/a
Pitt R. near Port Coquitlam - 08MH035	2.70	2.68	0.02	2.16	2.27	-0.11
Baynes Road	3.17	3.16	0.01	2.73	2.77	-0.04
192nd Street	3.38	3.39	-0.01	3.00	3.05	-0.05
Salmon River Confluence	4.17	*4.05*	*0.12*	3.91	n/a	n/a
Fraser R. at Whonnock - 08MH044	4.79	4.77	0.02	4.57	4.60	-0.03
Matsqui Slough Discharge	5.81	*6.07*	*-0.26*	5.63	*5.97*	*-0.34*
Fraser R. at Mission - 08MH024	6.08	6.02	0.06	5.96	5.92	0.04
	Avg. Abs Error:		**0.05**	**Avg. Abs Error:**		**0.12**

Notes:
1. Suspect observed data shown in *italics,* and not included in average error.
2. Observed data from June 10th, 2007. Modelled data for same period.
3. Model calibrated to peak or near peak levels in order to best represent maximum flood conditions.
4. Only peak hourly data provided for Pitt River at Argue St.
5. Observed data for Matsqui greater than at upstream gauges. Suspect datum to be verified.
6. Richmond gauges (Bathslough, Nelson Road, Queensborough and No. 6 Rd) observed data with 2007 datums.

2002 Validation of Water Levels for Lower Model (Continuous Gauges)

Gauge Name (Downstream to Upstream)	**Peak Comparison**			**Trough Comparison**		
	Modelled (m GSC)	Observed (m GSC)	Modelled less Observed Diff. (m)	Modelled (m GSC)	Observed (m GSC)	Modelled less Observed Diff. (m)
North Arm						
Fraser R. (North Arm) at Vancouver - 08MH032	1.69	1.63	0.06	-0.52	-0.96	0.44
Bathslough	1.74	*1.82*	*-0.08*	0.45	*-0.35*	*0.80*
Queensborough	2.00	*1.61*	*0.39*	0.18	*-0.44*	*0.62*
Main Arm						
Fraser R. at Steveston - 08MH028	1.44	1.63	-0.19	-1.31	-1.44	0.12
No. 6 Road	1.71	1.72	-0.01	-0.38	-0.70	0.31
Nelson Road	1.86	1.81	0.05	-0.08	-0.24	0.16
New Westminster	2.29	2.27	0.02	0.95	0.69	0.26
Manson	2.34	*2.16*	*0.18*	1.08	*0.51*	*0.58*
Fraser R. at Port Mann PS - 08MH126	2.54	2.50	0.03	1.57	1.40	0.16
Pitt R. near Port Coquitlam - 08MH035	2.71	2.68	0.04	1.98	2.04	-0.06
192nd St.	3.41	n/a	n/a	2.88	2.95	-0.07
Salmon River Confluence	4.21	*4.07*	*0.14*	3.84	*3.86*	*-0.02*
Fraser R. at Whonnock - 08MH044	4.83	4.85	-0.02	4.56	4.55	0.01
Fraser R. at Mission - 08MH024	6.13	6.09	0.04	5.94	5.89	0.05
	Avg. Abs Error:		**#VALUE!**	**Avg. Abs Error:**		**0.15**

Notes:
1. Suspect observed data shown in *italics,* and not included in average error.
2. Peak and trough levels recorded as maximum and minimum water levels respectively on June 22nd, 2002.
3. Manson gauge at near same location on river as New Westminster gauge but with different recorded water levels.
4. Bathslough gauge, No.6 Road and Nelson Road datums updated in 2007 due to dike settlement. Unknown datum for 2002.
5. Salmon River gauge data suspect and inconsistent.
6. Suspect data for 192nd St. on 10th June.

Table 4.2: Freshet Calibration Roughness Summary for Lower Model

River	Station	Calibration Run		Design Run	
		Original (2006) Calibration Values	Final Calibration Roughness Values	Original (2006) Calibration Values	Final Calibration Roughness Values
Global		*0.031*	*0.031*	*0.031*	*0.031*
'ANNACIS'	0	0.033	0.033	0.033	0.033
'ANNACIS'	7091	0.033	0.033	0.033	0.033
'BARNSTON'	0	0.030	0.032	0.030	0.032
'BARNSTON'	7446	0.030	0.032	0.030	0.032
'CANNERY'	0	0.035	0.035	0.035	0.035
'CANNERY'	3155	0.035	0.035	0.035	0.035
'CANOE'	0	0.015	0.015	0.015	0.015
'CANOE'	7579	0.015	0.015	0.015	0.015
'CANOE'	8560	0.033	0.033	0.033	0.033
'CANOE'	11783	0.033	0.033	0.033	0.033
'CRESCENT'	0	0.030	0.030	0.030	0.030
'CRESCENT'	3724	0.030	0.030	0.030	0.030
'DOUGLAS'	1159	0.029	0.033	0.029	0.033
'DOUGLAS'	4646	0.029	0.033	0.029	0.033
'FRASER'	-1545	0.015	0.015	0.015	0.015
'FRASER'	7944	0.015	0.015	0.015	0.015
'FRASER'	9394	0.033	0.033	0.033	0.033
'FRASER'	10578	0.033	0.033	0.033	0.033
'FRASER'	35451	0.033	0.031	0.033	0.031
'FRASER'	35451	0.033	0.028	0.033	0.028
'FRASER'	46984	0.030	0.028	0.030	0.028
'FRASER'	46984	0.031	0.028	**0.027**	**0.027**
'FRASER'	85416	0.030	0.028	**0.027**	**0.027**
Fraser_R	85567.1	0.030	0.030	n/a	n/a
Fraser_R	100331.5	0.030	0.030	n/a	n/a
'LADNER'	0	0.033	0.033	0.033	0.033
'LADNER'	9654	0.033	0.033	0.033	0.033
'MATSQUI'	0	0.030	0.030	0.030	0.030
'MATSQUI'	6480	0.030	0.030	0.030	0.030
'MCMILLAN'	0	0.030	0.028	0.030	0.028
'MCMILLAN'	5493	0.030	0.028	0.030	0.028
'MIDDLE ARM'	0	0.015	0.015	0.015	0.015
'MIDDLE ARM'	7325	0.015	0.015	0.015	0.015
'MIDDLE ARM'	7325	0.032	0.032	0.032	0.032
'MIDDLE ARM'	14066	0.032	0.032	0.032	0.032
'MITCHELL'	0	0.035	0.035	0.035	0.035
'MITCHELL'	4377	0.035	0.035	0.035	0.035
'NORTH ARM'	0	0.035	0.035	0.035	0.035
'NORTH ARM'	19345	0.035	0.035	0.035	0.035
'NORTH ARM'	19345	0.032	0.032	0.032	0.032
'NORTH ARM'	31804	0.032	0.032	0.032	0.032
'PITT'	0	0.030	0.030	0.030	0.030
'PITT'	46483	0.029	0.029	0.029	0.029
'POPLAR'	0	0.032	0.032	0.032	0.032
'POPLAR'	1356	0.032	0.032	0.032	0.032
'SAPPERTON'	0	0.032	0.032	0.032	0.032
'SAPPERTON'	4780	0.032	0.032	0.032	0.032
'STURGEON'	0	0.015	0.015	0.015	0.015
'STURGEON'	6036	0.015	0.015	0.015	0.015
'TRIF PHASE 3'	0	0.033	0.033	0.033	0.033
'TRIF PHASE 3'	1752	0.033	0.033	0.033	0.033

Notes:
1. Roughness values presented as a Manning's n number.
2. Presented values are base values, in some reaches roughnesses vary with depth. Particularly in tidal lower reaches.
3. MIKE11 linearly interpolates roughness values for each cross-section based on bounding rougnhnesses presented in table.
4. Global roughness values are used when no specific roughness is used.

Table 4.3: Freshet Calibration/Validation of Flows for Lower Model

2007 Validation of Flow Splits

Split #	Channels			Observed Split			Modelled Split		
				June 11-14th			At measured time		
	1	2	3	1	2	3	1	2	3
5	Fraser	Douglas		72%	29%		67%	34%	
6	Fraser	North Arm	Annacis	78%	10%	9%	83%	9%	6%
7	Fraser	Ladner		92%	8%		94%	6%	
8	Ladner	Canoe		77%	23%		97%	3%	
9	Fraser	Cannery	Sturgeon	84%	2%	14%	91%	2%	7%
10	North Arm	Mid Arm		53%	50%		91%	11%	

Notes:
1. Flows measured by PWGSC between June 11th and 14th, 2007.
2. Modelled results at same time/date as observed data.
3. All percentages refer to split at each junction, not total Fraser flow.
4. Flow splits in lower reaches of mainstem are very sensitive to time of measurement relative to tidal cycle.
5. Where data available, percentages are based on split flows relative to measured flow above split
and therefore do not necessarily add up to exactly 100%.

2002 Validation of Flow Splits

Split #	Channels			Observed Split			Modelled Split								
				Approx. 6000 cms			Average over time			At High Tide (June			At Low Tide (June		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	Fraser	Matsqui		71%	29%		74%	26%		73%	27%		74%	26%	
2	Fraser	Crescent		90%	10%		90%	10%		90%	10%		90%	10%	
3	Fraser	McMillan		94%	6%		94%	6%		94%	6%		94%	6%	
4	Fraser	Barnston		70%	30%		75%	25%		75%	25%		75%	25%	
5	Fraser	Douglas		70%	30%		64%	36%		62%	38%		66%	34%	
6	Fraser	North Arm	Annacis	80%	10%	10%	82%	11%	8%	78%	12%	9%	85%	9%	6%
7	Fraser	Ladner		90%	10%		89%	11%		89%	11%		93%	7%	
8	Ladner	Canoe		41%	59%		82%	18%		72%	28%		98%	2%	
9	Fraser	Cannery	Sturgeon	84%	2%	14%	89%	2%	9%	77%	4%	19%	97%	0%	3%
10	North Arm	Mid Arm		44%	56%		81%	16%		70%	29%		98%	2%	

Notes:
1. Flows measured by PWGSC in May/June 2002.
2. Splits #7 and #10 were measured during winter low flow conditions and are approximate only
3. Downstream of trifurcation, percentages refer to split at each junction, not total Fraser flow
4. Flow splits in lower reaches of mainstem are very sensitive to time of measurement relative to tidal cycle.

Table 4.4: Freshet Calibration/Validation of Water Levels Summary for Upper Model

1999 Calibration of Water Levels for Upper Model

Gauge Name (Downstream to Upstream)	Observed Time (23rd June)	Modelled (m GSC)	Observed (m GSC)	Modelled less Observed Diff. (m)
Dewdney PS	8:55	6.72	6.75	-0.03
Robson PS	10:20	7.17	7.22	-0.05
McGillivray Slough PS	11:00	7.67	7.61	0.06
Collinson PS	10:45	7.64	7.60	0.04
Quaamitch Slough	10:40	8.06	8.03	0.03
Chilliwack Creek PS (Wolfe Road)	11:30	8.76	8.76	0.00
Hope Slough at Young St.	n/a	9.24	9.14	0.10
Bell Dam	11:20	9.38	9.37	0.01
Minto Landing Area (Bell Slough)	10:30	11.01	10.97	0.04
Harrison Mills (Kilby)	8:00	11.81	11.80	0.01
Scowlitz (Harrison Bay)	8:20	11.88	11.88	0.00
Duncan Bateson PS	8:25	11.91	11.92	-0.01
Carey Point	10:00	13.47	13.42	0.05
Hammersley PS	7:15	14.17	14.13	0.04
Chip (Camp-Hope) Intake	n/a	16.65	16.78	-0.13
Agassiz-Rosedale Bridge North	6:20	17.00	16.86	0.14
Agassiz-Rosedale Bridge South	8:50	16.99	17.00	-0.01
Maria Slough	6:05	19.24	19.31	-0.07
Herrling Island	8:25	20.63	20.55	0.08
Johnson Slough	5:55	26.89	26.87	0.02
Wahleach(Jones) Creek	8:40	27.01	27.06	-0.05
		Avg. Abs Error:		**0.05**

Notes:
1. Some gauges (Cuthbert, Seabird Island and Tranmer) have no reported data on 23rd.
2. The two Agassiz bridge gauges and the Chip intake gauge are in close proximity, though report very different values.
3. Location of data reported for Seabird Island gauge uncertain.
4. When observed time unknown, modelled data extracted at 12:00 PM.

2007 Validation of Water Levels for Upper Model

Gauge Name (Downstream to Upstream)	Observed Time (10th June)	Modelled (m GSC)	Observed (m GSC)	Modelled less Observed Diff. (m)
Dewdney PS	Continuous	6.45	6.47	-0.02
Robson PS	13:40	6.86	6.90	-0.04
McGillivray Slough PS	8:00	7.39	7.37	0.02
Collinson PS	8:00	7.41	7.33	0.08
Quaamitch Slough	14:10	7.80	7.74	0.06
Chilliwack Creek PS (Wolfe Road)	8:00	8.60	8.49	0.11
Hope Slough at Young St.	8:00	9.11	8.95	0.16
Bell Dam	14:20	8.98	*6.88*	*2.10*
Minto Landing Area (Bell Slough)	8:00	10.91	10.79	0.12
Harrison Mills (Kilby)	8:14	11.71	11.58	0.13
Duncan Bateson PS	7:53	11.80	11.68	0.12
Harrison R. below Morris Creek - 08MG022	Continuous	11.89	11.77	0.12
Carey Point	8:00	13.40	13.21	0.19
Hammersley PS	7:44	14.10	13.91	0.19
Chip (Camp-Hope) Intake	8:00	16.60	16.74	-0.14
Agassiz-Rosedale Bridge North	9:44	16.93	16.87	0.06
Agassiz-Rosedale Bridge South	10:18	16.93	16.97	-0.04
Cuthbert Road	10:08	19.13	19.08	0.05
Maria Slough	10:23	19.12	19.12	0.00
Herrling Island	10:00	20.57	20.65	-0.08
Johnson Slough	7:50	26.81	26.83	-0.02
Wahleach Powerhouse	Continuous	17.96	*17.62*	*0.34*
Wahleach (Jones) Creek	9:35	26.94	26.95	-0.01
		Avg. Abs Error:		**0.08**

Notes:
1. Suspect data shown in *italics,* and not included in average error.
2. Modelled data for staff gauges reported at observed time.
3. Modelled and observed data for continuous gauges reported as peak flow on June 10th, 2007.
4. Downstream boundary condition set to WSC reported levels at Mission.
5. Observed data at Bell Dam possibly reported for upstream side of dam.
6. No datum shift to GSC available for Wahleach Powerhouse. Observed data irregular.

Table 4.5: Calibration Roughness Summary for Upper Model

River	Station	2001 Model	2007 Model
Global			*0.032*
AGASSIZ_CHEAM	0	0.1	0.038
AGASSIZ_CHEAM	5056	0.1	0.038
DND_N	0	0.1	0.040
DND_N	5425	0.1	0.040
DND_S	0	0.1	0.040
DND_S	2000	0.1	0.040
EC_RES_76	0	0.1	0.035
EC_RES_76	2421	0.1	0.035
FP_121054R	0	0.032	0.040
FP_121054R	1451	0.032	0.040
FP_123058L	0	0.1	0.035
FP_123058L	1981	0.1	0.035
FP_124155R	0	0.1	0.040
FP_124155R	1943	0.1	0.040
FP_125294R	0	0.1	0.035
FP_125294R	1266	0.1	0.035
FP_135366R	0	0.1	0.035
FP_135366R	1574	0.1	0.035
GREYELL_I	0	0.1	0.055
GREYELL_I	2966	0.1	0.055
HERRLING_I	0	0.1	0.050
HERRLING_I	6485	0.1	0.050
HOG_I	0	0.1	0.040
HOG_I	2833	0.1	0.040
HOPE_S	0	0.1	0.030
HOPE_S	3766	0.1	0.030
ISLAND_D	0	0.1	0.060
ISLAND_D	1626	0.1	0.060
MINTO_I	0	0.1	0.060
MINTO_I	4601	0.1	0.060
PETERS_IR1	0	0.1	0.060
PETERS_IR1	1760	0.1	0.060
PETERS_IR2	0	0.1	0.060
PETERS_IR2	2480	0.1	0.060
QUEENS_I	0	0.1	0.060
QUEENS_I	3437	0.1	0.060
SEABIRD_N	0	0.1	0.040
SEABIRD_N	8413	0.1	0.040
SEABIRD_S	218.7	0.1	0.040
SEABIRD_S	7953	0.1	0.040
SKWAY_IR5	0	0.1	0.032
SKWAY_IR5	3760	0.1	0.032
SC_132593L	0	0.033	0.030
SC_132593L	9535	0.033	0.030
SC_132852L	0	0.032	0.035
SC_132852L	1793	0.032	0.035
SC_140481L	0	0.032	0.035
SC_140481L	3174	0.032	0.035
SC_146171L	0	0.032	0.035
SC_146171L	3420	0.032	0.035
SC_149184R	0	0.0325	0.030
SC_149184R	2200	0.0325	0.030
SC_MARIA_621L	0	0.034	0.045
SC_MARIA_621L	2128	0.034	0.045
MARIA_S	0	0.028	0.045
MARIA_S	3925	0.028	0.045
MINTO_C	0	0.033	0.032
MINTO_C	4507	0.033	0.032
MINTO_C	5017	0.044	0.032
MINTO_C	5502	0.044	0.032
SC_107131L	0	0.028	0.025
SC_107131L	3248	0.028	0.025

(Continued)

River	Station	2001 Model	2007 Model
VEDDER_R	0	0.028	0.035
VEDDER_R	6690	0.028	0.035
SUMAS_R	0	0.028	0.035
SUMAS_R	3050	0.028	0.035
SC_110624R	166.3	0.028	0.038
SC_110624R	2819	0.028	0.038
HARRISON_R	0	0.033	0.035
HARRISON_R	9000	0.034	0.035
HARRISON_R	11700	0.045	0.030
HARRISON_R	14800	0.06	0.030
HARRISON_R	17844.6	0.06	0.030
FRASER_R	85400	0.029	0.031
FRASER_R	100000	0.029	0.032
FRASER_R	102000	0.0275	0.032
FRASER_R	114000	0.0275	0.033
FRASER_R	115000	0.03	0.033
FRASER_R	115370	0.031	0.035
FRASER_R	115783	0.04	0.035
FRASER_R	115979	0.045	0.035
FRASER_R	116184	0.055	0.035
FRASER_R	116399	0.1	0.035
FRASER_R	116640	0.1	0.035
FRASER_R	116921	0.093	0.035
FRASER_R	117196	0.05	0.035
FRASER_R	117515	0.043	0.035
FRASER_R	117640	0.043	0.035
FRASER_R	118000	0.033	0.035
FRASER_R	124000	0.032	0.036
FRASER_R	125000	0.032	0.033
FRASER_R	127885	0.033	0.030
FRASER_R	128051	0.039	0.030
FRASER_R	128295	0.039	0.030
FRASER_R	128730	0.039	0.029
FRASER_R	129135	0.033	0.029
FRASER_R	129500	0.033	0.029
FRASER_R	131000	0.03	0.030
FRASER_R	154447	0.032	0.035
GREYELL_S	0	0.032	0.030
GREYELL_S	4200	0.032	0.030
GREYELL_S	4220	0.0512	0.033
GREYELL_S	4947	0.0512	0.033
SC_110122R	0	0.032	0.043
SC_110122R	1323	0.032	0.043
SC_110122R	1720	0.096	0.050
SC_110122R	2414	0.096	0.060
SC_110122R	3009	0.032	0.060
SC_124986R	0	0.032	0.035
SC_124986R	1664	0.032	0.035
SC_124986R	2000	0.0416	0.035
SC_124986R	2414	0.0416	0.035
SC_130239R	130	0.032	0.032
SC_130239R	1500	0.032	0.032
SC_130239R	1840	0.048	0.032
SC_130239R	2223	0.048	0.032
Strawberry			0.037
Strawberry			0.037
Nicomen	0		0.035
Nicomen	1738		0.035
HarrisonLake	0		0.020
HarrisonLake	56000		0.020
FRASER_R	122000		0.035
FRASER_R	122000		0.036
SC_122760L	0		0.040
SC_122760L	6322		0.040

Notes:
1. 2001 model refers to UMA model.
2. 2007 model refers to recalibrated model with updated inflow at Hope and Harrison.
3. Roughness values presented as a Manning's n coefficient.
4. Presented values are base values, in some reaches roughnesses vary with distance across river.
5. MIKE11 linearly interpolates roughness values for each cross-section based on bounding rougnhnesses presented in table.
6. Global roughness values are used when no specific roughness are input.
7. Some new reaches and new reach roughnesses added for 2007 model.

Table 4.6: 2007 Freshet Validation of Water Levels for Merged Model

Gauge Name (Downstream to Upstream)	Gauge Type/ Observed Time (10th June)	**Peak Comparison** Modelled (m GSC)	Observed (m GSC)	Modelled less Observed Diff. (m)
Fraser R. (North Arm) at Vancouver - 08MH032	Continuous	1.87	1.83	0.04
Bathslough	Continuous	1.91	1.91	0.00
Fraser River at Byrne Creek	Continuous	2.04	1.99	0.05
Queensborough	Continuous	2.13	1.95	0.18
Fraser R. at Steveston - 08MH028	Continuous	1.67	1.75	-0.08
3395 River Road	Continuous	1.72	1.73	-0.01
Elliot & River Road	Continuous	1.84	1.88	-0.04
62B & River Road	Continuous	1.86	1.92	-0.06
No. 6 Road	Continuous	1.92	1.80	0.12
Nelson Road	Continuous	2.03	1.89	0.14
9600 River Road	Continuous	2.14	2.13	0.01
New Westminster	Continuous	2.41	2.37	0.04
Manson	Continuous	2.37	2.29	0.08
Fraser R. at Port Mann PS - 08MH126	Continuous	2.61	2.59	0.02
Pitt River at Argue St	Continuous	2.75	2.66	0.09
Pitt R. near Port Coquitlam - 08MH035	Continuous	2.75	2.68	0.07
Baynes Road	Continuous	3.23	3.16	0.07
192nd Street	Continuous	3.45	3.39	0.06
Salmon River Confluence	Continuous	3.69	*4.05*	*-0.36*
Fraser R. at Whonnock - 08MH044	Continuous	4.86	4.77	0.09
Matsqui Slough Discharge	Continuous	5.88	*6.07*	*-0.19*
Fraser R. at Mission - 08MH024	Continuous	6.14	6.02	0.12
Dewdney PS	Continuous	6.57	6.47	0.10
Robson PS	13:40	6.94	6.90	0.04
McGillivray Slough PS	8:00	7.44	7.37	0.07
Collinson PS	8:00	7.46	7.33	0.13
Quaamitch Slough	14:10	7.80	7.74	0.06
Chilliwack Creek PS (Wolfe Road)	8:00	8.58	8.49	0.09
Hope Slough at Young St.	8:00	9.08	8.95	0.13
Bell Dam	14:20	8.94	*6.88*	*2.06*
Minto Landing Area (Bell Slough)	8:00	10.86	10.79	0.07
Harrison Mills (Kilby)	8:14	11.61	11.58	0.03
Duncan Bateson PS	7:53	11.67	11.68	-0.01
Harrison R. below Morris Creek - 08MG022	Continuous	11.75	11.77	-0.02
Carey Point	8:00	13.37	13.21	0.16
Hammersley PS	7:44	14.07	13.91	0.16
Chip (Camp-Hope) Intake	8:00	16.60	16.74	-0.14
Agassiz-Rosedale Bridge North	9:44	16.93	16.87	0.06
Agassiz-Rosedale Bridge South	10:18	16.93	16.97	-0.04
Cuthbert Road	10:08	19.15	19.08	0.07
Maria Slough	10:23	19.15	19.12	0.03
Herrling Island	10:00	20.57	20.65	-0.08
Johnson Slough	7:50	26.83	26.83	0.00
Wahleach Powerhouse	Continuous	17.96	*17.62*	*0.34*
Wahleach (Jones) Creek	9:35	26.93	26.95	-0.02
		Avg. Abs Error:		**0.08**

Notes:
1. Suspect data shown in *italics,* and not included in average error.
2. Modelled data for staff gauges reported at observed time.
3. Modelled and observed data for continuous gauge reported as peak flow on June 10th, 2007.
4. Only peak hourly data provided for Pitt River at Argue St.
5. Observed data for Matsqui greater than at upstream gauges. Suspect datum to be verified.
6. Richmond gauges (Bathslough, Nelson Road, Queensborough and No. 6 Rd) observed data with 2007 datums.
7. Observed data at Bell Dam possibly reported for upstream side of dam.
8. No datum shift to GSC available for Wahleach Powerhouse. Observed data irregular.
9. Values vary slightly from separate lower and upper models due to slight differences in inflows, particularly for Harrison system.

Table 5.1: Design Profile Comparisons for Lower Model (Historic and 2007 Updated)

Municipality/Diking District	Location	MIKE 11 Chainage		Design Flood 2007 Modelled WL (m GSC)	Design Flood 1969 Calculated WL (m GSC)	Design Flood Difference (m)
North Fraser						
City of Vancouver	West end UBC	'NORTH ARM'	1238	2.88	2.62	0.26
	Burnaby border	'NORTH ARM'	22157	3.03	2.68	0.35
City of Richmond	Sea Island: McDonald Slough	'NORTH ARM'	9913	2.88	2.62	0.26
	Sea Island: West end at Middle Arm	'MIDDLE ARM'	6788	2.88	2.62	0.26
	Middle and North Arm Confluence	'MIDDLE ARM'	14066	2.89	2.62	0.27
	Terra Nova Park at Middle Arm	'MIDDLE ARM'	7834	2.88	2.62	0.26
	New Westminster border	'NORTH ARM'	28105	3.14	3.10	0.04
City of Burnaby	Vancouver border	'NORTH ARM'	22157	3.03	2.68	0.35
	New Westminster border	'NORTH ARM'	28761	3.14	3.17	-0.03
City of New Westminst	Burnaby border	'NORTH ARM'	28761	3.14	3.17	-0.03
	Coquitlam border	'FRASER'	37528	4.22	3.95	0.27
City of Coquitlam	Burnaby border	'FRASER'	37528	4.22	3.95	0.27
	Port Coquitlam border	'FRASER'	42617	4.67	4.37	0.30
City of Port Coquitlam	Coquitlam border	'FRASER'	42617	4.67	4.37	0.30
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.92	4.50	0.42
	Pitt River at De Bouville Slough	'PITT'	7342	4.92	4.57	0.35
District of Pitt Meadows	Pitt River at Sheridan Hill	'PITT'	10817	4.92	4.57	0.35
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.92	4.50	0.42
	Maple Ridge border	'FRASER'	53954	6.00	5.11	0.89
District of Maple Ridge	Pitt Meadows border	'FRASER'	53954	6.00	5.11	0.89
	Whonnock Creek	'FRASER'	71256	7.70	6.71	0.99
	Mission border	'FRASER'	73842	7.90	7.00	0.90
District of Mission	Maple Ridge border	'FRASER'	73842	7.90	7.00	0.90
	Silverdale Creek	'FRASER'	80578	8.48	7.50	0.98
	Mission bridge	'FRASER'	85182	8.87	7.91	0.96
South Fraser						
Corporation of Delta	Roberts Bank at Canoe Pass	'CANOE'	8065	2.86	2.59	0.27
	Massey Tunnel	'FRASER'	18117	2.92	2.65	0.27
	Surrey border	'FRASER'	31926	3.54	3.60	-0.06
	Westham Island: Roberts Bank at Canoe Pass	'CANOE'	8065	2.86	2.59	0.27
	Westham Island: Reifel Island at Ladner Reach	'FRASER'	9650	2.84	2.59	0.25
	Westham Island: Upstream end	'LADNER'	4506	2.87	2.59	0.28
City of Richmond	Steveston, Garry Point Park	'FRASER'	7589	2.84	2.59	0.25
	Massey Tunnel	'FRASER'	18117	2.92	2.71	0.21
	New Westminster Border	'ANNACIS'	3136	3.31	3.50	-0.19
City of New Westminst	City of Richmond Border	'ANNACIS'	3136	3.31	3.50	-0.19
	Trifurcation	'FRASER'	34089	3.82	3.60	0.22
City of Surrey	Delta border	'FRASER'	31926	3.54	3.60	-0.06
	Township of Langley border	'BARNSTON'	6011	5.83	5.05	0.78
Barnston Diking Distric	Barnston Island: downstream end	'BARNSTON'	0	5.27	4.75	0.52
	Barnston Island: upstream end	'BARNSTON'	7446	5.96	5.11	0.85
Township of Langley	Surrey border	'BARNSTON'	6011	5.83	5.05	0.78
	Jacob-Haldi Bridge	'MCMILLAN'	2644	6.94	5.95	0.99
	Abbotsford border	'FRASER'	70804	7.66	7.00	0.66
City of Abbotsford	Langley border	'FRASER'	70804	7.66	7.00	0.66
	Mission Bridge	'FRASER'	85182	8.87	7.91	0.96

Notes:
1. Historic calculated water levels were obtained from profile drawings and MOE maps and are approximate for the locations indicated.
2. Modelled water levels are based on smoothed profile.
3. Water levels below chainage 28369 are based on winter design condition (200-year, 95% confidence tide event).
4. Water levels above chainage 28369 are based on freshet design condition (reoccurance of 1894 event).

Table 5.1 Cont: Design Profile Comparisons for Lower Model (Original and Updated)

Municipality/Diking District	Location	MIKE 11 Chainage		Design Flood 2007 Modelled WL (m GSC)	Design Flood 2006 Modelled WL (m GSC)	Design Flood Difference (m)
North Fraser						
City of Vancouver	West end UBC	'NORTH ARM'	1238	2.88	2.88	0.00
	Burnaby border	'NORTH ARM'	22157	3.03	3.03	0.00
City of Richmond	Sea Island: McDonald Slough	'NORTH ARM'	9913	2.88	2.88	0.00
	Sea Island: West end at Middle Arm	'MIDDLE ARM'	6788	2.88	2.89	-0.01
	Middle and North Arm Confluence	'MIDDLE ARM'	14066	2.89	2.89	0.00
	Terra Nova Park at Middle Arm	'MIDDLE ARM'	7834	2.88	2.89	-0.01
	New Westminster border	'NORTH ARM'	28105	3.14	3.14	0.00
City of Burnaby	Vancouver border	'NORTH ARM'	22157	3.03	3.03	0.00
	New Westminster border	'NORTH ARM'	28761	3.14	3.26	-0.12
City of New Westminst	Burnaby border	'NORTH ARM'	28761	3.14	3.26	-0.12
	Coquitlam border	'FRASER'	37528	4.22	4.24	-0.02
City of Coquitlam	Burnaby border	'FRASER'	37528	4.22	4.24	-0.02
	Port Coquitlam border	'FRASER'	42617	4.67	4.83	-0.16
City of Port Coquitlam	Coquitlam border	'FRASER'	42617	4.67	4.83	-0.16
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.92	5.08	-0.16
	Pitt River at De Bouville Slough	'PITT'	7342	4.92	4.90	0.02
District of Pitt Meadows	Pitt River at Sheridan Hill	'PITT'	10817	4.92	4.90	0.02
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.92	5.08	-0.16
	Maple Ridge border	'FRASER'	53954	6.00	6.05	-0.06
District of Maple Ridge	Pitt Meadows border	'FRASER'	53954	6.00	6.05	-0.06
	Whonnock Creek	'FRASER'	71256	7.70	7.69	0.00
	Mission border	'FRASER'	73842	7.90	7.96	-0.06
District of Mission	Maple Ridge border	'FRASER'	73842	7.90	7.96	-0.06
	Silverdale Creek	'FRASER'	80578	8.48	8.51	-0.03
	Mission bridge	'FRASER'	85182	8.87	8.88	-0.01
South Fraser						
Corporation of Delta	Roberts Bank at Canoe Pass	'CANOE'	8065	2.86	2.87	0.00
	Massey Tunnel	'FRASER'	18117	2.92	2.93	-0.01
	Surrey border	'FRASER'	31926	3.54	3.58	-0.04
	Westham Island: Roberts Bank at Canoe Pass	'CANOE'	8065	2.86	2.87	0.00
	Westham Island: Reifel Island at Ladner Reach	'FRASER'	9650	2.84	2.84	0.00
	Westham Island: Upstream end	'LADNER'	4506	2.87	2.88	0.00
City of Richmond	Steveston, Garry Point Park	'FRASER'	7589	2.84	2.84	0.00
	Massey Tunnel	'FRASER'	18117	2.92	2.93	-0.01
	New Westminster Border	'ANNACIS'	3136	3.31	3.23	0.08
City of New Westminst	City of Richmond Border	'ANNACIS'	3136	3.31	3.23	0.08
	Trifurcation	'FRASER'	34089	3.82	3.84	-0.02
City of Surrey	Delta border	'FRASER'	31926	3.54	3.58	-0.04
	Township of Langley border	'BARNSTON'	6011	5.83	5.91	-0.09
Barnston Diking Distric	Barnston Island: downstream end	'BARNSTON'	0	5.27	5.43	-0.16
	Barnston Island: upstream end	'BARNSTON'	7446	5.96	6.03	-0.07
Township of Langley	Surrey border	'BARNSTON'	6011	5.83	5.91	-0.09
	Jacob-Haldi Bridge	'MCMILLAN'	2644	6.94	6.97	-0.03
	Abbotsford border	'FRASER'	70804	7.66	7.65	0.01
City of Abbotsford	Langley border	'FRASER'	70804	7.66	7.65	0.01
	Mission Bridge	'FRASER'	85182	8.87	8.88	-0.01

Notes:
1. 2006 model as presented in Final Report of December 2006
2. Modelled water levels are based on smoothed profile.
3. 2007 water levels below chainage 28369 are based on winter design condition (200-year, 95% confidence tide event).
4. 2007 water levels above chainage 28369 are based on freshet design condition (reoccurance of 1894 event).

Table 5.2: Design Profile for Upper Model (1969, 2001 and 2007 Updated)

Municipality/Diking District	Location	MIKE 11 Chainage		Design Flood 2007 Modelled WL (m GSC)	2001 Modelled WL (m GSC)	Difference (m)	1969 Calculated WL (m GSC)	Difference (m)
North Fraser								
District of Mission	Mission Bridge	FRASER_R	85400	8.87	7.99	0.88	7.89	0.98
	FVRD Electoral Area G border	FRASER_R	89872	9.41	8.51	0.89	8.57	0.83
FVRD Electoral Area G	Mission border	FRASER_R	89872	9.41	8.51	0.89	8.57	0.83
	Downstream end Nicomen Island	FRASER_R	95540	9.99	9.13	0.87	9.06	0.93
	FVRD Electoral Area C border	FRASER_R	107234	11.10	10.46	0.64	9.96	1.14
FVRD Electoral Area C	FVRD Electoral Area G border	FRASER_R	107234	11.10	10.46	0.64	9.96	1.14
	District of Kent border (Harrison River)	FRASER_R	117387	13.70	13.52	0.17	12.84	0.85
	Harrison River at Lake	HARRISON_R	17845	13.93	13.81	0.12		
District of Kent	FVRD Electoral Area C border	FRASER_R	117387	13.70	13.52	0.17	12.84	0.85
	Hammersley Pump Station	FRASER_R	124155	15.90	15.86	0.04	15.36	0.55
	Upstream of Agassiz Bridge	FRASER_R	131184	18.78	18.90	-0.12	18.74	0.04
	Maria Slough	MARIA_S	0	20.29	20.42	-0.13		
Seabird First Nation	Maria Slough	MARIA_S	0	20.29	20.42	-0.13		
	Upstream end Seabird Island	FRASER_R	147935	26.88	27.05	-0.17	27.58	-0.70
FVRD Electoral District C	Upstream end Seabird Island	FRASER_R	147935	26.88	27.05	-0.17	27.58	-0.70
	Laidlaw	FRASER_R	154447	31.72	31.44	0.28	31.51	0.21
South Fraser								
City of Abbotsford	Mission Bridge	FRASER_R	85400	8.87	7.99	0.88	7.89	0.98
	FVRD Electoral Area H border	FRASER_R	92864	9.72	8.84	0.88	8.85	0.87
FVRD Electoral Area H	Abbotsford border	FRASER_R	92864	9.72	8.84	0.88	8.85	0.87
	Chilliwack border	FRASER_R	99944	10.47	9.61	0.86	9.43	1.04
City of Chilliwack	FVRD Electoral Area H border	FRASER_R	99944	10.47	9.61	0.86	9.43	1.04
	Minto Landing	MINTO_C	3073	13.23	12.75	0.48		
	FVRD Electoral Area D border	SC_122760L	6322	18.54	18.53	0.02		
FVRD Electoral Area D	Chilliwack border	SC_122760L	6322	18.54	18.53	0.02		
	Upstream of Agassiz Bridge	FRASER_R	131184	18.78	18.90	-0.12	18.74	0.04
	FVRD Electoral Area B border	FRASER_R	145700	25.65	25.52	0.14	26.23	-0.58
FVRD Electoral Area B	FVRD Electoral Area D border	FRASER_R	145700	25.65	25.52	0.14	26.23	-0.58
	Laidlaw	FRASER_R	154447	31.72	31.44	0.28	31.51	0.21

Notes:

1. 2001 model refers to UMA model.
2. 2007 model refers to recalibrated and smoothed model with updated inflow at Hope and Harrison.
3. 1969 model obtained from MOE profile and maps, profile extrapolated from km 135 to Hope Gauge at km 168
3. Difference is calculated as 2007 model less 2001, 1969 models.
4. Water level reported upstream of Agassiz bridge to eliminate local structure losses affecting profile.

Table 5.2 Cont: Design Profile for Upper Model (2006 and 2007 Updated)

Municipality/Diking District	Location	MIKE 11 Chainage		Design Flood 2007 Modelled WL (m GSC)	2006 Modelled WL (m GSC)	Difference (m)
North Fraser						
District of Mission	Mission Bridge	FRASER_R	85400	8.87	8.89	-0.02
	FVRD Electoral Area G border	FRASER_R	89872	9.41	9.34	0.06
FVRD Electoral Area G	Mission border	FRASER_R	89872	9.41	9.34	0.06
	Downstream end Nicomen Island	FRASER_R	95540	9.99	9.88	0.12
	FVRD Electoral Area C border	FRASER_R	107234	11.10	11.00	0.09
FVRD Electoral Area C	FVRD Electoral Area G border	FRASER_R	107234	11.10	11.00	0.09
	District of Kent border (Harrison River)	FRASER_R	117387	13.70	13.69	0.01
	Harrison Lake	HARRISON_R	17845	13.93	13.96	-0.03
District of Kent	FVRD Electoral Area C border	FRASER_R	117387	13.70	13.69	0.01
	Hammersley Pump Station	FRASER_R	124155	15.90	15.92	-0.02
	Upstream of Agassiz Bridge	FRASER_R	131184	18.78	18.92	-0.13
	Maria Slough	MARIA_S	0	20.75	20.42	0.32
Seabird First Nation	Maria Slough	MARIA_S	0	20.75	20.42	0.32
	Upstream end Seabird Island	FRASER_R	147935	26.88	27.05	-0.17
FVRD Electoral District C	Upstream end Seabird Island	FRASER_R	147935	26.88	27.05	-0.17
	Laidlaw	FRASER_R	154447	31.72	31.44	0.28
South Fraser						
City of Abbotsford	Mission Bridge	FRASER_R	85400	8.87	8.89	-0.02
	FVRD Electoral Area H border	FRASER_R	92864	9.72	9.62	0.10
FVRD Electoral Area H	Abbotsford border	FRASER_R	92864	9.72	9.62	0.10
	Chilliwack border	FRASER_R	99944	10.47	10.29	0.18
City of Chilliwack	FVRD Electoral Area H border	FRASER_R	99944	10.47	10.29	0.18
	Minto Landing	MINTO_C	3073	13.23	12.98	0.25
	FVRD Electoral Area D border	SC_122760L	6322	18.54	18.54	0.00
FVRD Electoral Area D	Chilliwack border	SC_122760L	6322	18.54	18.54	0.00
	Upstream of Agassiz Bridge	FRASER_R	131184	18.78	18.92	-0.13
	FVRD Electoral Area B border	FRASER_R	145700	25.65	25.52	0.14
FVRD Electoral Area B	FVRD Electoral Area D border	FRASER_R	145700	25.65	25.52	0.14
	Laidlaw	FRASER_R	154447	31.72	31.44	0.28

Notes:
1. 2006 model refers to original 2001 UMA model with updated downstream boundary condition at Mission of 8.9 m.
2. 2007 model refers to recalibrated and smoothed model with updated inflow at Hope and Harrison.
3. Water level reported upstream of Agassiz bridge to eliminate local structure losses affecting profile.

Table 7.1: Dike Information Sources

Dike Name	Source	Year	Drawing No.
Albion Dike	District of Maple Ridge	2007	34743-10
	LiDAR	2005	34743-10
Barnston Island Dike	LiDAR	2005	34743-13
Chilliwack Dike	City of Chilliwack	1998	34743-4
CNR Track, Glover Road to Armstrong Road	Township of Langley	2003	34743-9
Coquitlam Dike	Underhill & Underhill / MOE	2006	34743-12
Dewdney Dike	Dewdney Area Improvement District	1989, 2007	34743-8
Fort Langley Dike	LiDAR	2005	34743-9
Glen Valley East Wing Dike	FRFCP Operation & Maintenance Manual	1989	34743-9
Glen Valley West Wing Dike	FRFCP Operation & Maintenance Manual	1988	34743-9
	Township of Langley	2000	34743-9
Kent A Dike	District of Kent	1996	34743-3
Kent B Dike	District of Kent	1996	34743-3
Kent C Dike	District of Kent	1996	34743-3
Kent D Dike	Eaton Land Surveying Ltd.	2007	34743-3
Marina Gardens Dike	Corporation of Delta	1999, 2000	34743-18
Matsqui A Dike	City of Abbotsford	2007	34743-6
Matsqui B Dike	City of Abbotsford	2007	34743-6
Mission A Dike	District of Mission	2007	34743-8
Mission B Dike	District of Mission	2007	34743-8
New Westminster (Queensborough Dike)	FRFCP Operation & Maintenance Manual	1976	34743-14
Nicomen Island Dike	Nicomen Island Improvement District	1999	34743-7
Pitt Dike North of Alouette River	ISL Engineering and Land Services Ltd.	2007	34743-11
	FRFCP Operation & Maintenance Manual	1986	34743-11
Pitt Meadows Middle Dike	District of Pitt Meadows	2003	34743-11
Pitt Meadows North Dike	District of Pitt Meadows	2003	34743-11
Pitt Meadows South Dike	District of Pitt Meadows	2003	34743-10
	ISL Engineering and Land Services Ltd.	2007	34743-10
Pitt Polder Dike	LiDAR	2005	34743-11
	District of Pitt Meadows	1960	34743-11
Port Coquitlam Dike	Associated Engineering	2007	34743-12
Richmond North Dike	FRFCP Contract Drawings	1974	34743-15
Richmond South Dike	FRFCP Contract Drawings	1977	34743-16
River Road Dike	Corporation of Delta	1999, 2000	34743-17
Silverdale Dike	District of Mission	2007	34743-8
Surrey Dike	City of Surrey	2003	34743-13
Vedder River - Left Bank	City of Abbotsford	1999	34743-5
	City of Chilliwack	2007	34743-5
Vedder River - Right Bank	Township of Chilliwack	1973, 1999	34743-5
	City of Chilliwack	2007	34743-5
West Langley Dike	Township of Langley	2001	34743-9
Westham Island Dike	Corporation of Delta	1999, 2000	34743-18
Young Road Dike	City of Chilliwack	1998	34743-4
Young Road to Chilliwack Mountain Dike	City of Chilliwack	2007	34743-4

Table 7.2: Qualitative Dike Elevation Assessment

Dike Name	Dike Assessment					
	Dike Crest Above Freeboard		Dike Crest Above Design Water Level		Dike Crest Below Design Level	
	Complete Dike	In general; some lower areas	Complete Dike	In general; some lower areas	In general; some high areas	Complete Dike
Albion Dike						X
Barnston Island Dike					X	
Chilliwack Dike				X		
CNR Track, Glover Road to Armstrong Road				X		
Coquitlam Dike					X	
Dewdney Dike				X		
Fort Langley Dike					X	
Glen Valley East Wing Dike						X
Glen Valley West Wing Dike					X	
Kent A Dike				X		
Kent B Dike			X			
Kent C Dike			X			
Kent D Dike			X			
Marina Gardens Dike		X				
Matsqui A Dike		X				
Matsqui B Dike		X				
Mission A Dike			X			
Mission B Dike					X	
New Westminster (Queensborough) Dike		X				
Nicomen Island Dike						X
Pitt Dike North of Alouette River		X				
Pitt Meadows Middle Dike			X			
Pitt Meadows North Dike			X			
Pitt Meadows South Dike				X		
Pitt Polder Dike						X
Port Coquitlam Dike			X			
Richmond North Dike			X			
Richmond South Dike				X		
River Road Dike				X		
Silverdale Dike					X	
Surrey Dike				X		
Vedder River - Left Bank				X		
Vedder River - Right Bank						X
West Langley Dike					X	
Westham Island Dike				X		
Young Road Dike						X
Young Road to Chilliwack Mountain Dike					X	
Total Dikes in Category	**5**		**18**		**14**	

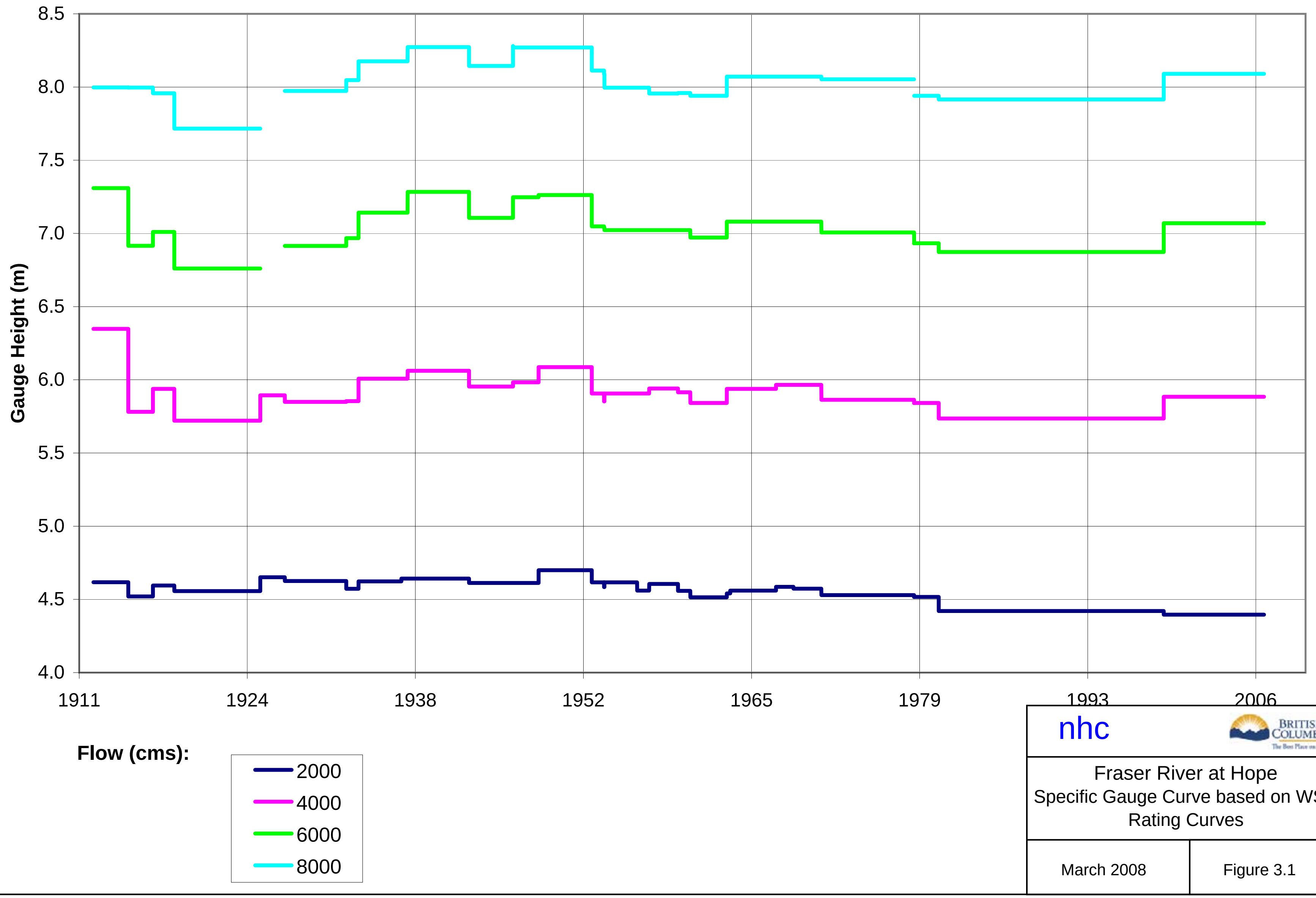
Table 8.1: Inflows to Upper Model for development of Municipal Water Level Reference Tables

Boundary		Inflow		Percentage of Flow		Percentages and Flows for Family of Inflows													
		Design Inflow m^3/s	2007 Calibration Inflow m^3/s	Design Inflow	2007 Calibration Inflow	11200 m^3/s		12350 m^3/s		13725 m^3/s		15050 m^3/s		16450 m^3/s		17800 m^3/s		19225 m^3/s	
FRASER_R	85400	8.87 m	Hydrograph	n/a	n/a		6 m		6.5 m		7 m		7.5 m		8 m		8.5 m		9 m
FRASER_R	154447	17000	10830	88.5%	86.7%	86.7%	9705	86.7%	10702	87.0%	11940	87.4%	13148	87.8%	14435	88.1%	15687	88.5%	17018
NICOMEN_S	1738	112	14	0.6%	0.1%	0.1%	13	0.1%	14	0.2%	27	0.3%	44	0.4%	64	0.5%	86	0.6%	112
DND_S	2000	0	0	0.0%	0.0%	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0
DND_N	5425	0	0	0.0%	0.0%	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0
HOPE_S	3766	0	0	0.0%	0.0%	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0
MARIA_S	3925	0	0	0.0%	0.0%	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0
VEDDER_R	6690	390	267	2.0%	2.1%	2.1%	239	2.1%	264	2.1%	291	2.1%	315	2.1%	341	2.1%	365	2.0%	390
SEABIRD_N	8413	0	0	0.0%	0.0%	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0
FRASER_R	154243	85	54	0.4%	0.4%	0.4%	48	0.4%	53	0.4%	60	0.4%	66	0.4%	72	0.4%	78	0.4%	85
SUMAS_R	2984	30	4	0.2%	0.0%	0.0%	4	0.0%	4	0.1%	8	0.1%	12	0.1%	17	0.1%	23	0.2%	30
FRASER_R	153856	168	7	0.9%	0.1%	0.1%	6	0.1%	7	0.2%	28	0.4%	55	0.5%	89	0.7%	125	0.9%	168
HarrisonLake	56000	1300	1273	6.8%	10.2%	10.2%	1141	10.2%	1258	9.6%	1312	8.9%	1337	8.2%	1344	7.5%	1332	6.8%	1301
Harrison_R	5500	120	49	0.6%	0.4%	0.4%	44	0.4%	48	0.4%	60	0.5%	72	0.5%	87	0.6%	103	0.6%	120
Sum		**19205**	**12498**	**100%**	**100%**	**100%**	**11200**	**100%**	**12350**	**100%**	**13725**	**100%**	**15050**	**100%**	**16450**	**100%**	**17800**	**100%**	**19225**

Notes:

1. Total flow at Mission based on Lower Model rating curve at Mission.
2. Inflow to all other boundaries based on relative inflow in design and 2007 calibration models and on total flow at Mission

FIGURES



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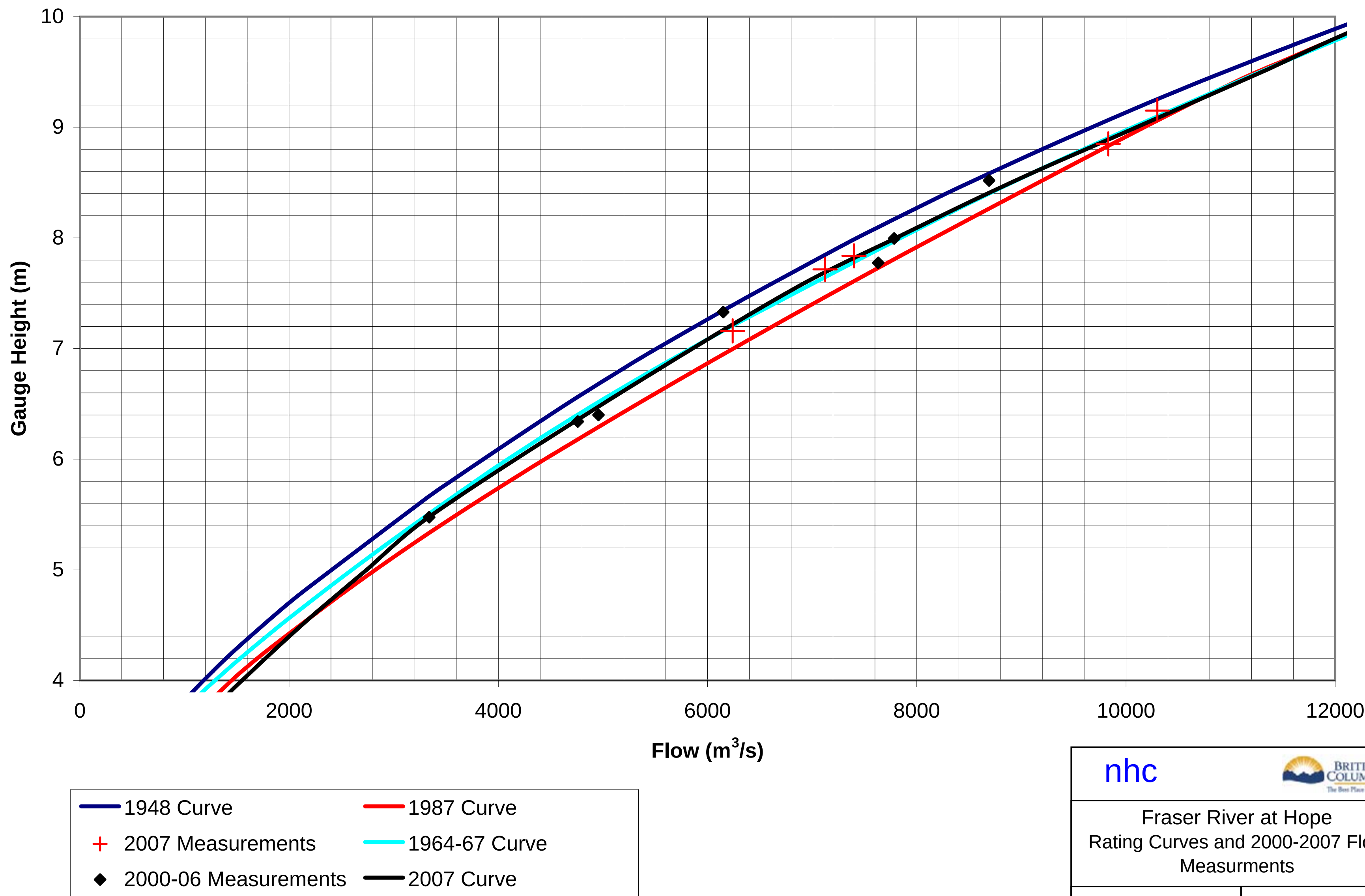
BRITISH COLUMBIA

Fraser River at Hope
Specific Gauge Curve based on WSC Rating Curves

March 2008	Figure 3.1



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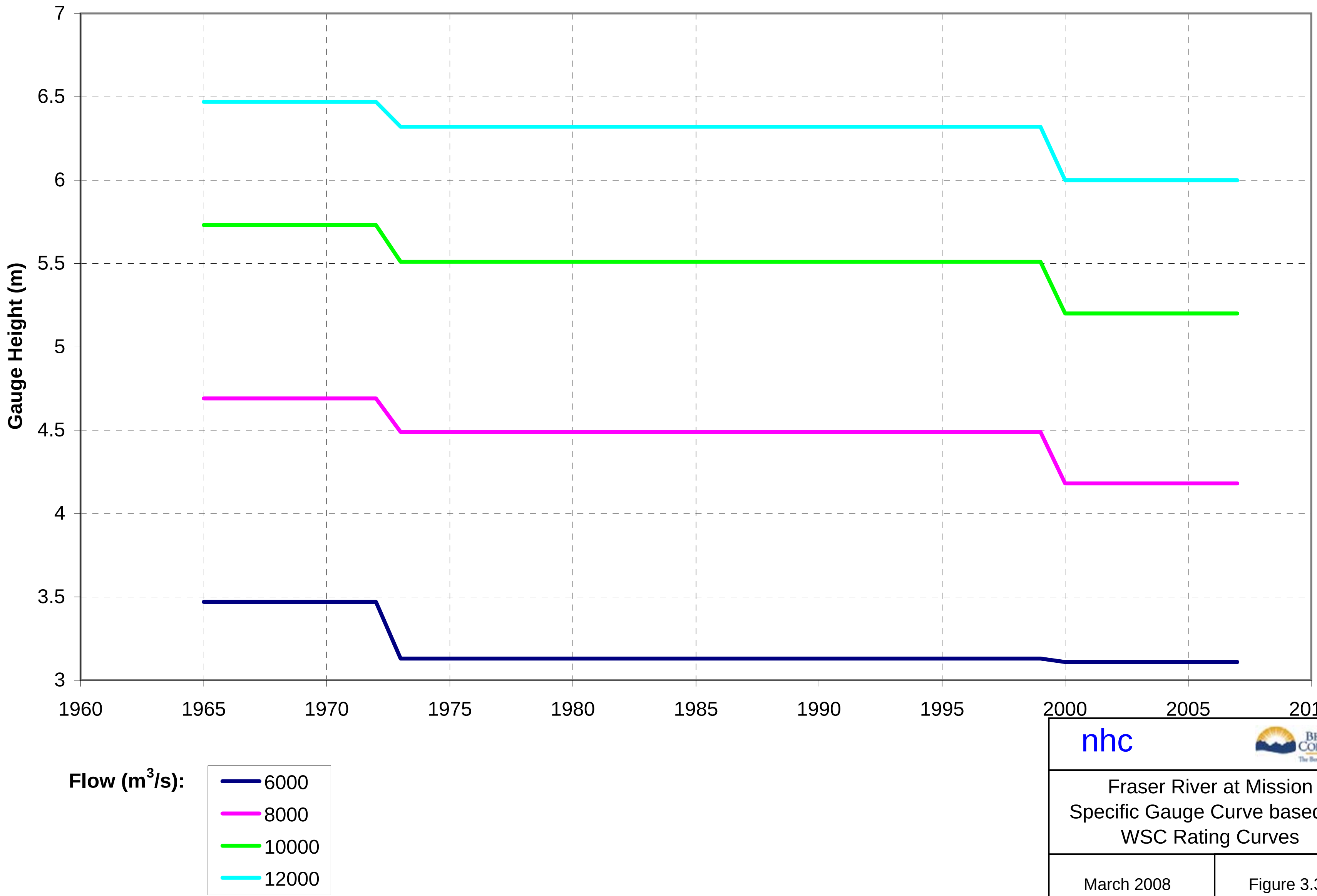
Fraser River at Hope
Rating Curves and 2000-2007 Flow Measurments

March 2008

Figure 3.2



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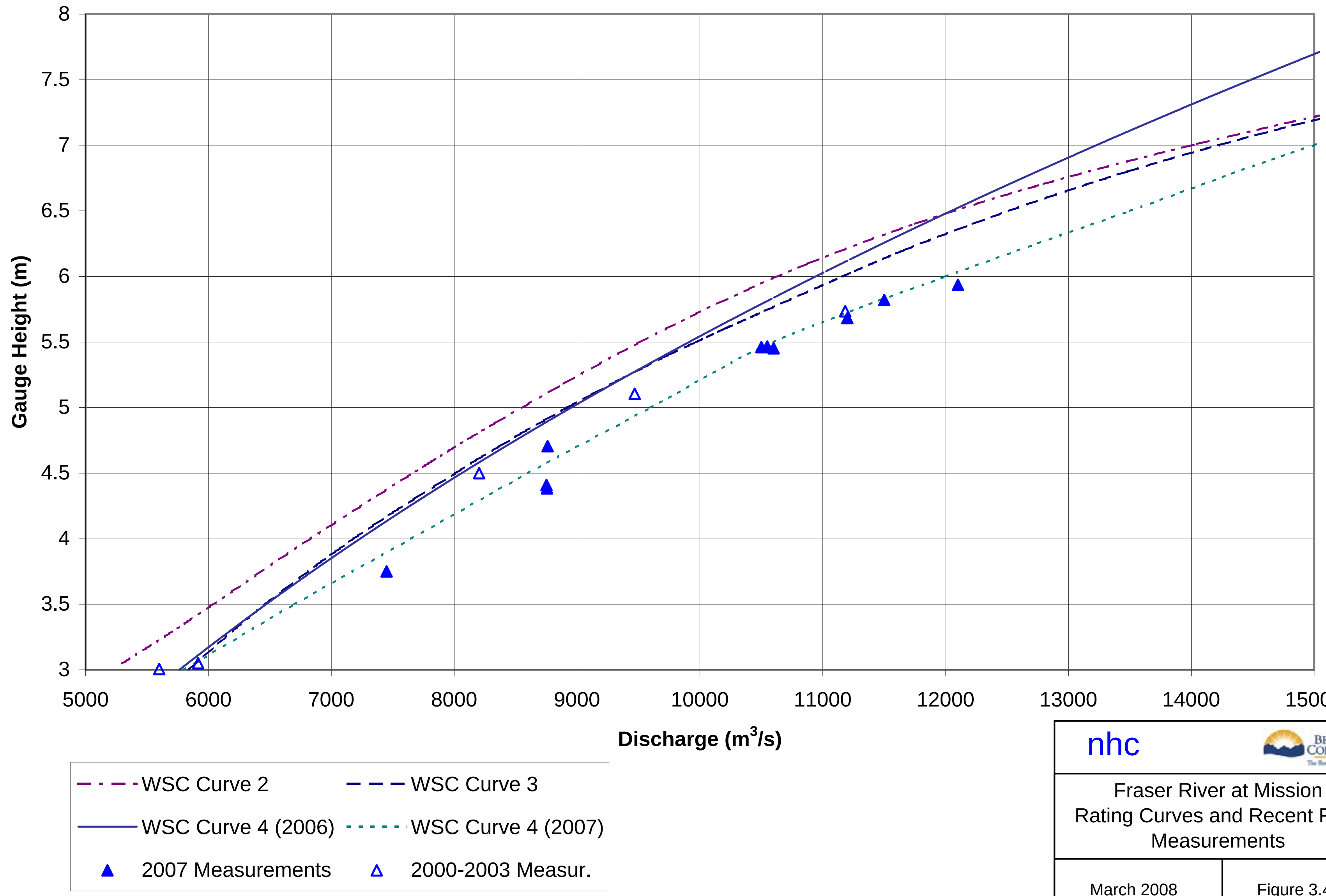
Fraser River at Mission
Specific Gauge Curve based on
WSC Rating Curves

March 2008

Figure 3.3



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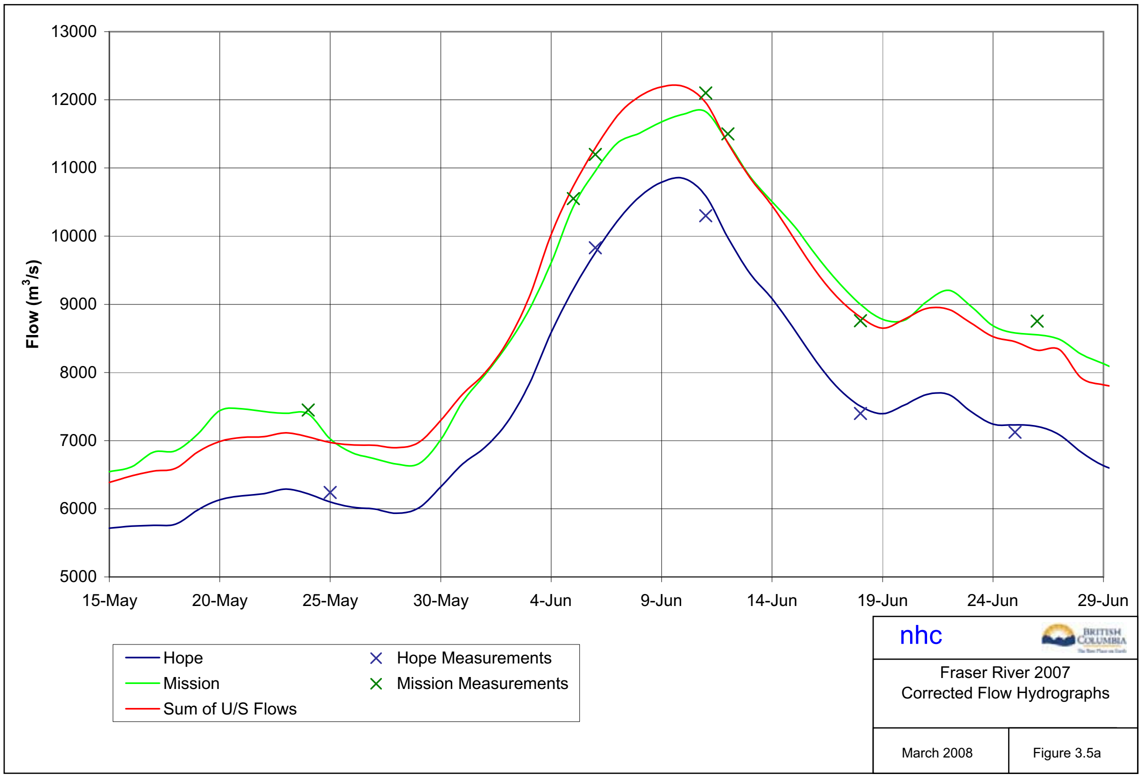
Fraser River at Mission
Rating Curves and Recent Flow Measurements

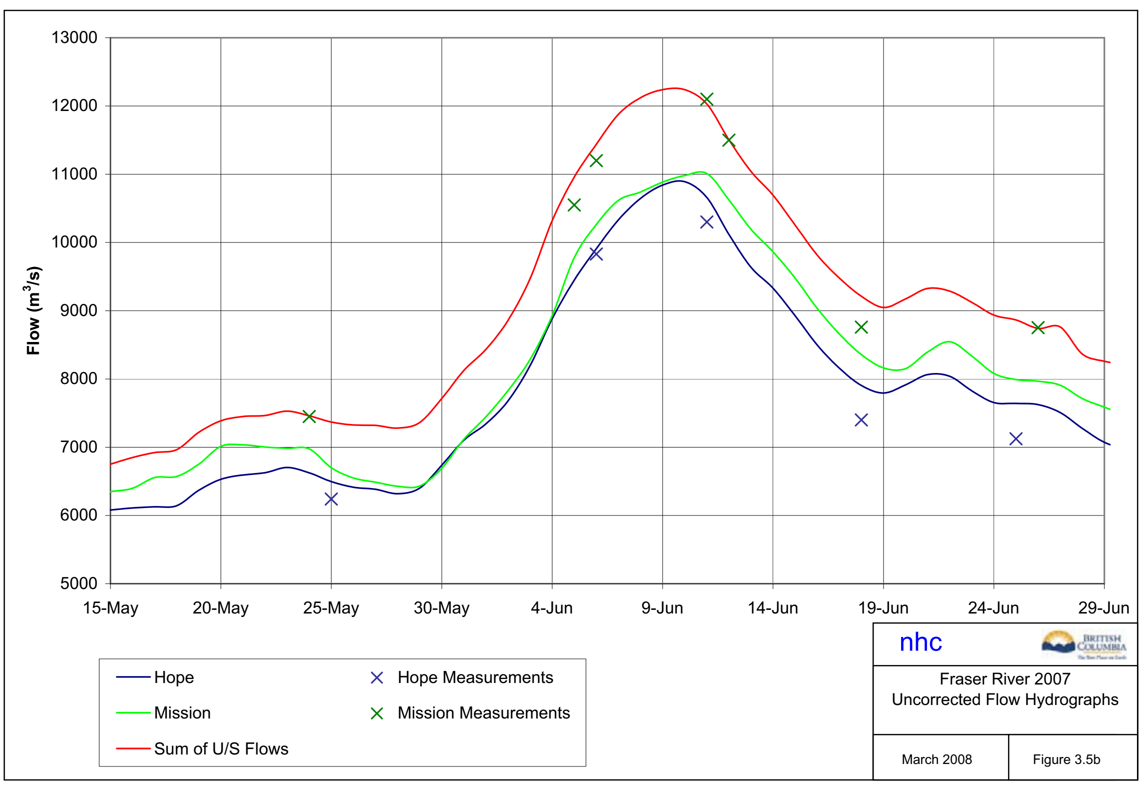
March 2008

Figure 3.4



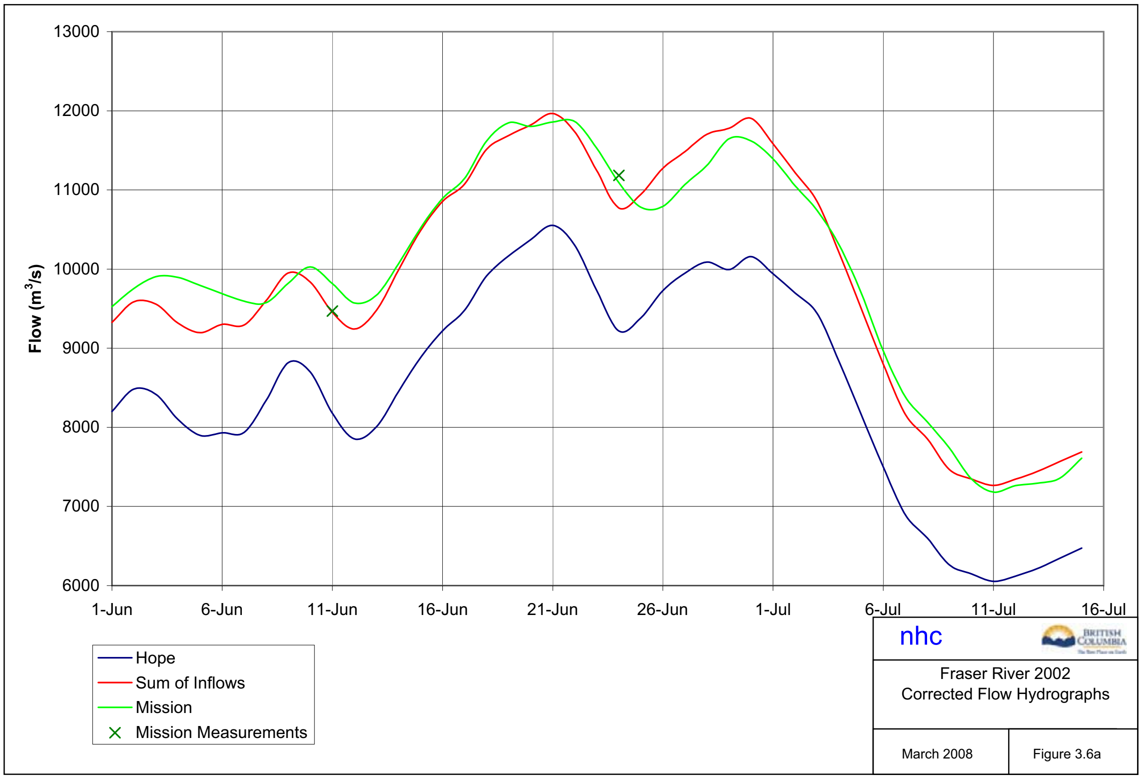
Fraser River 2007
Corrected Flow Hydrographs

March 2008 | Figure 3.5a



Fraser River 2007
Uncorrected Flow Hydrographs

March 2008 | Figure 3.5b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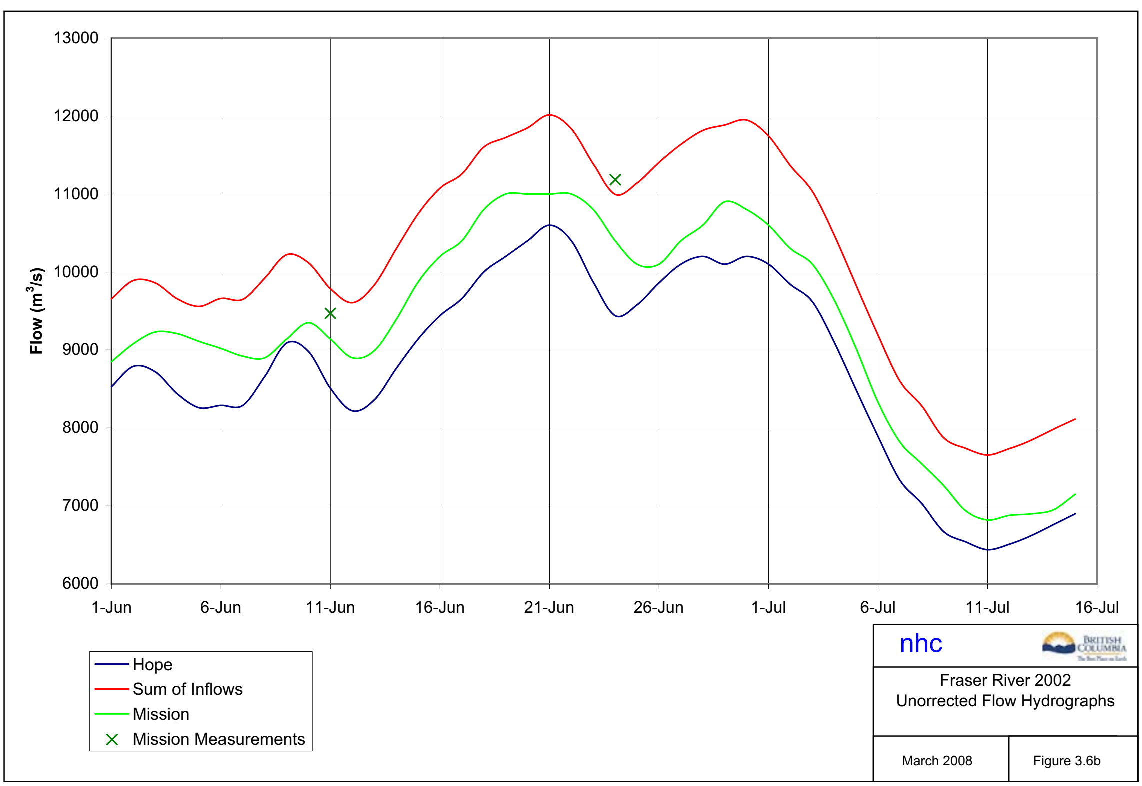
12000
11000
10000
9000
8000
7000
6000
Flow (m^3/s)
1-Jun
6-Jun
11-Jun
16-Jun
21-Jun
26-Jun
1-Jul
6-Jul
11-Jul
16-Jul
Hope
Sum of Inflows
Mission
Mission Measurements
nhc
Fraser River 2002
Corrected Flow Hydrographs
March 2008
Figure 3.6a


13000
12000
11000
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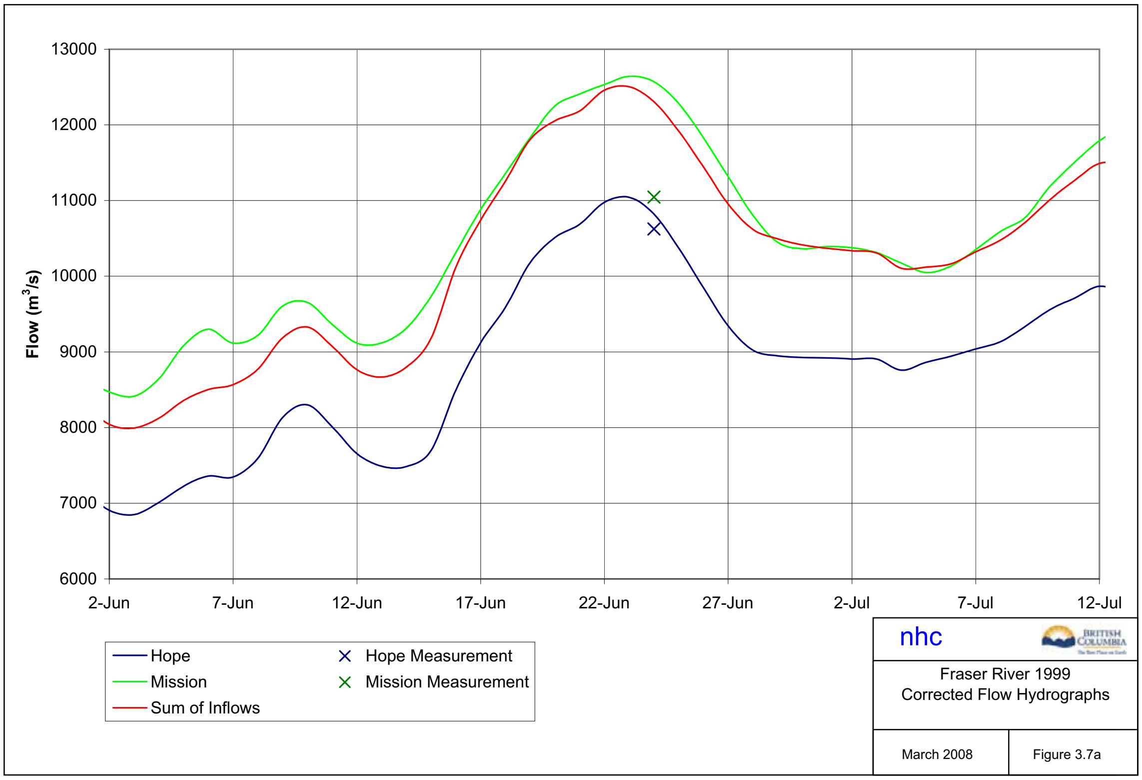
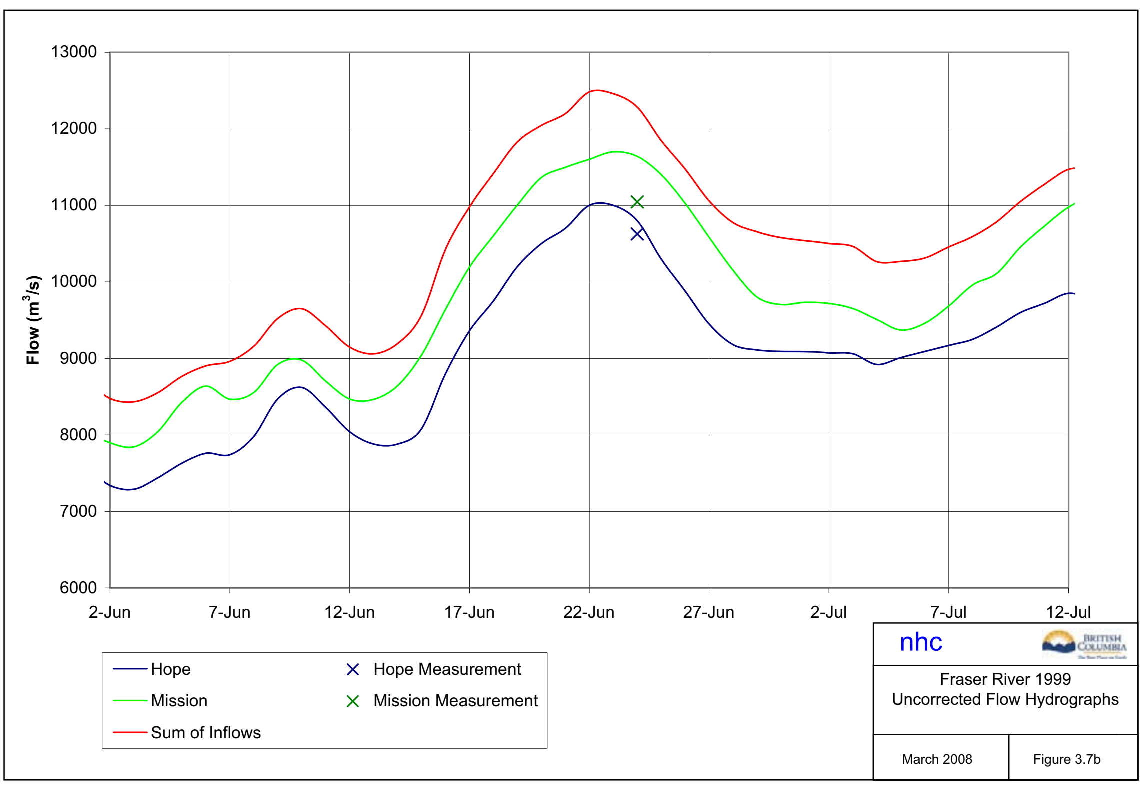
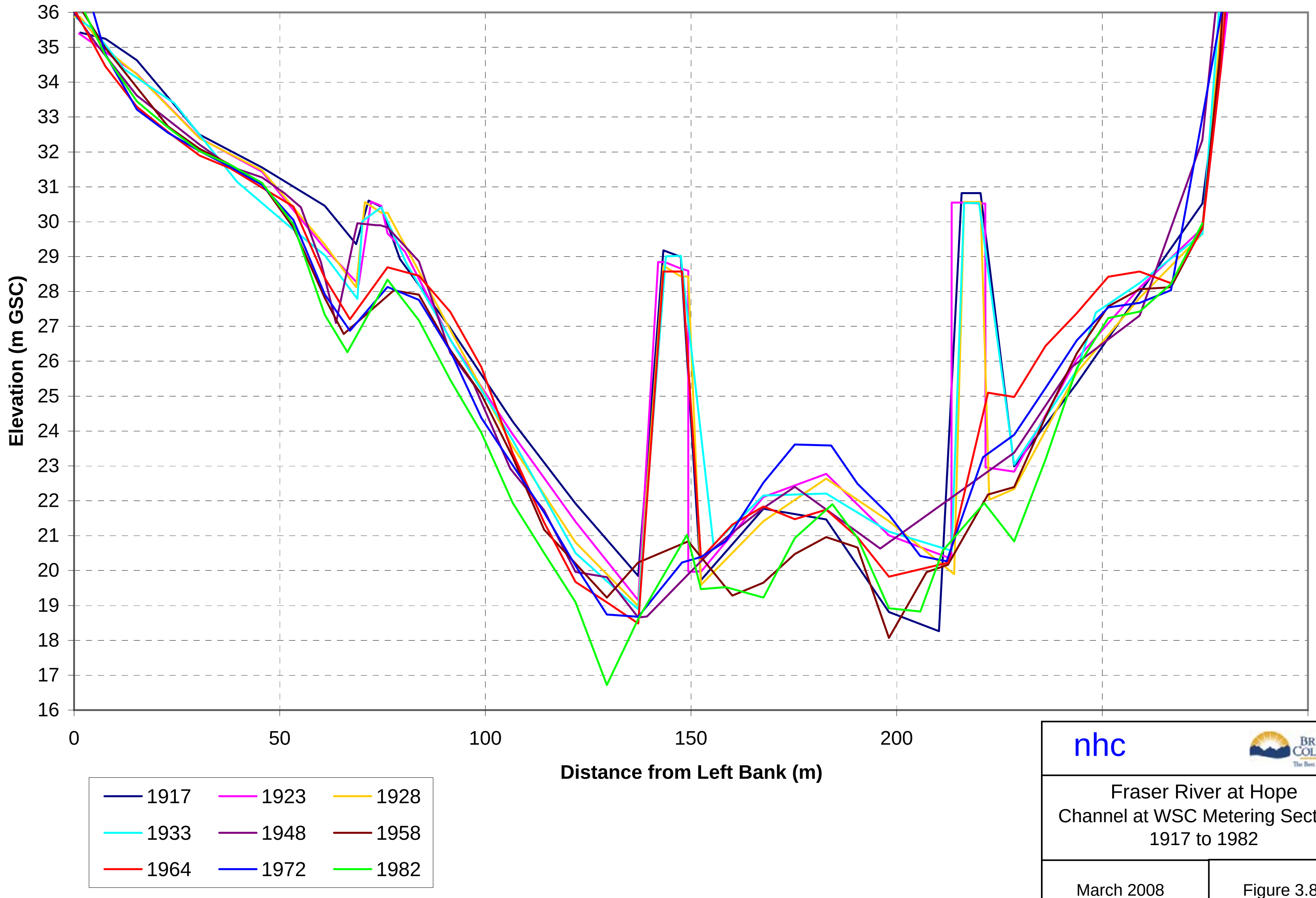
6000
Flow (m^3/s)
1-Jun
6-Jun
11-Jun
16-Jun
21-Jun
26-Jun
1-Jul
6-Jul
11-Jul
16-Jul
Hope
Sum of Inflows
Mission
Mission Measurements
nhc
Fraser River 2002
Unorrected Flow Hydrographs
March 2008
Figure 3.6b



13000
12000
11000
10000
9000
8000
7000
6000
Flow (m3/s)
2-Jun
7-Jun
12-Jun
17-Jun
22-Jun
27-Jun
2-Jul
7-Jul
12-Jul
Hope
Mission
Sum of Inflows
Hope Measurement
Mission Measurement
nhc
Fraser River 1999
Corrected Flow Hydrographs
March 2008
Figure 3.7a



13000
12000
11000
10000
9000
8000
7000
6000
Flow (m3/s)
2-Jun
7-Jun
12-Jun
17-Jun
22-Jun
27-Jun
2-Jul
7-Jul
12-Jul
Hope
Mission
Sum of Inflows
Hope Measurement
Mission Measurement
nhc
Fraser River 1999
Uncorrected Flow Hydrographs
March 2008
Figure 3.7b



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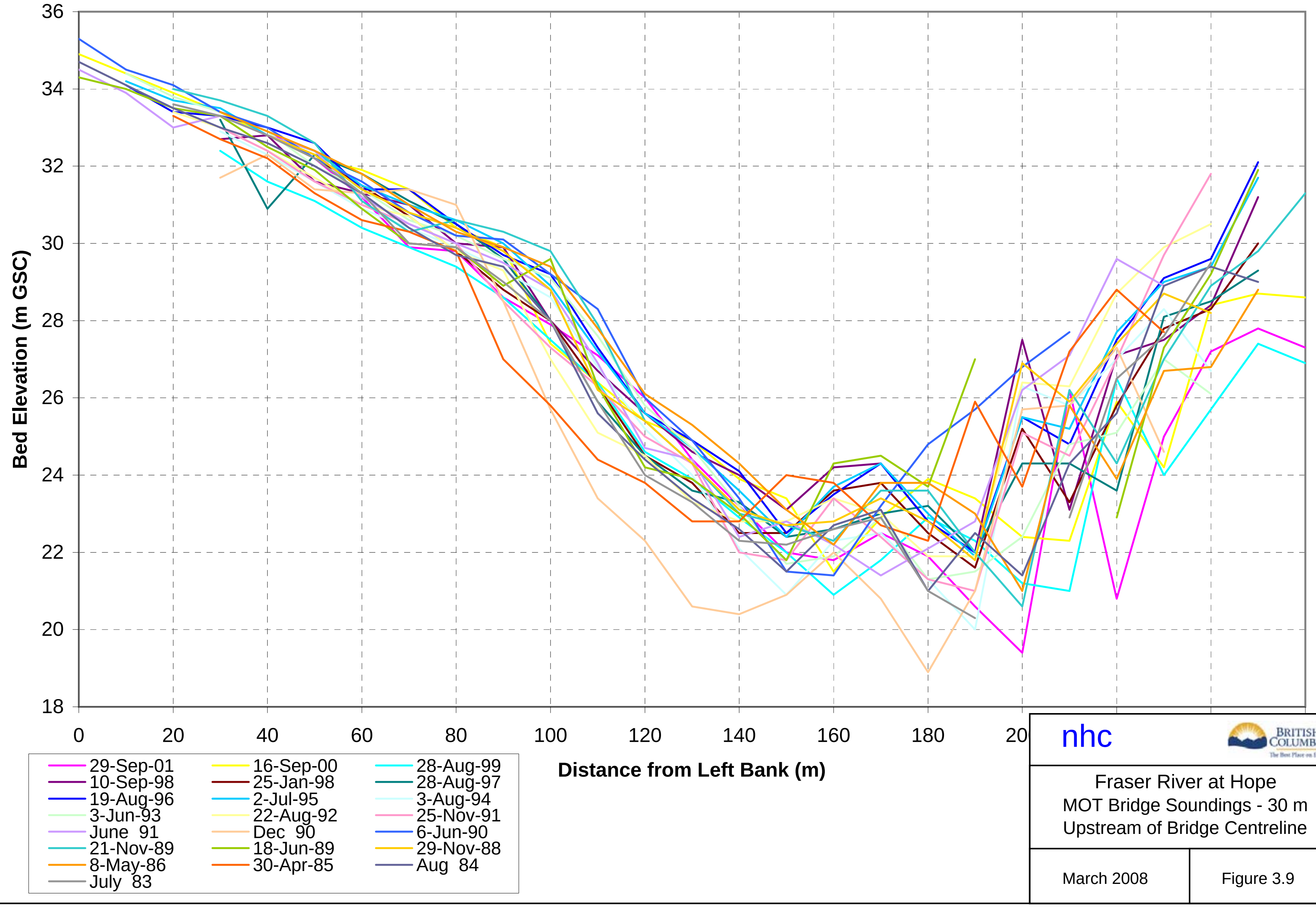
Fraser River at Hope
Channel at WSC Metering Section,
1917 to 1982

March 2008	Figure 3.8



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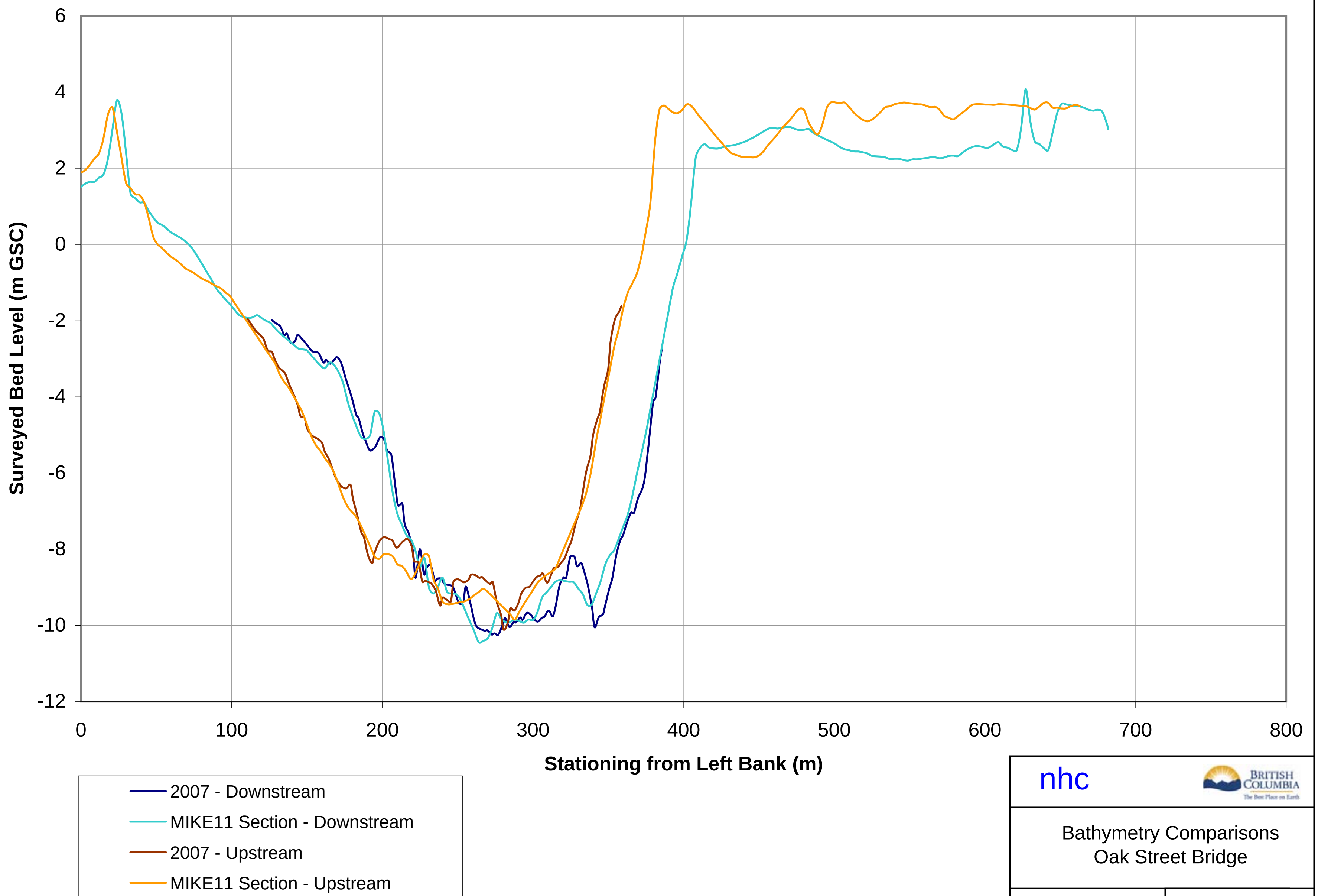
BRITISH COLUMBIA
The Best Place on Earth

Fraser River at Hope
MOT Bridge Soundings - 30 m Upstream of Bridge Centreline

March 2008

Figure 3.9



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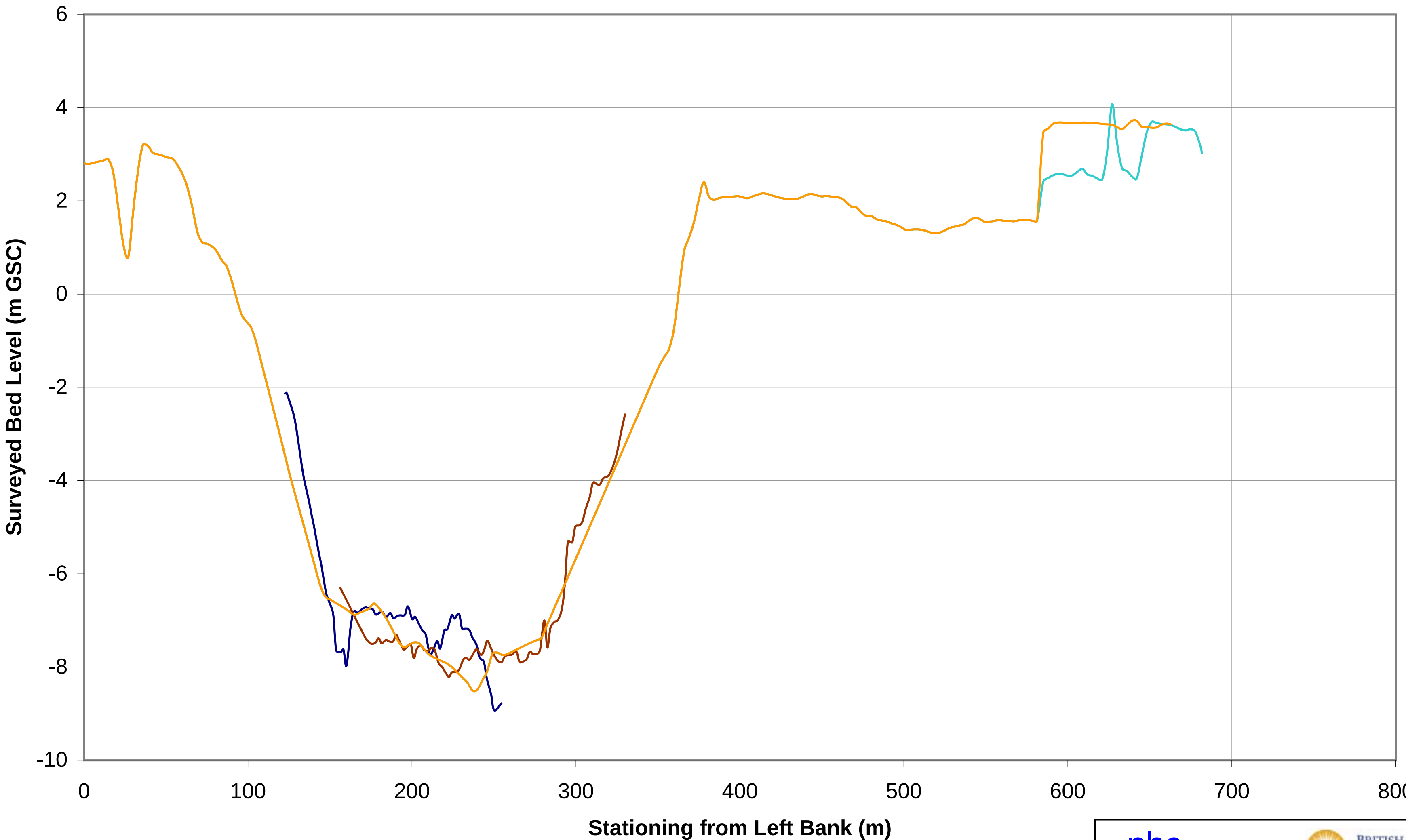
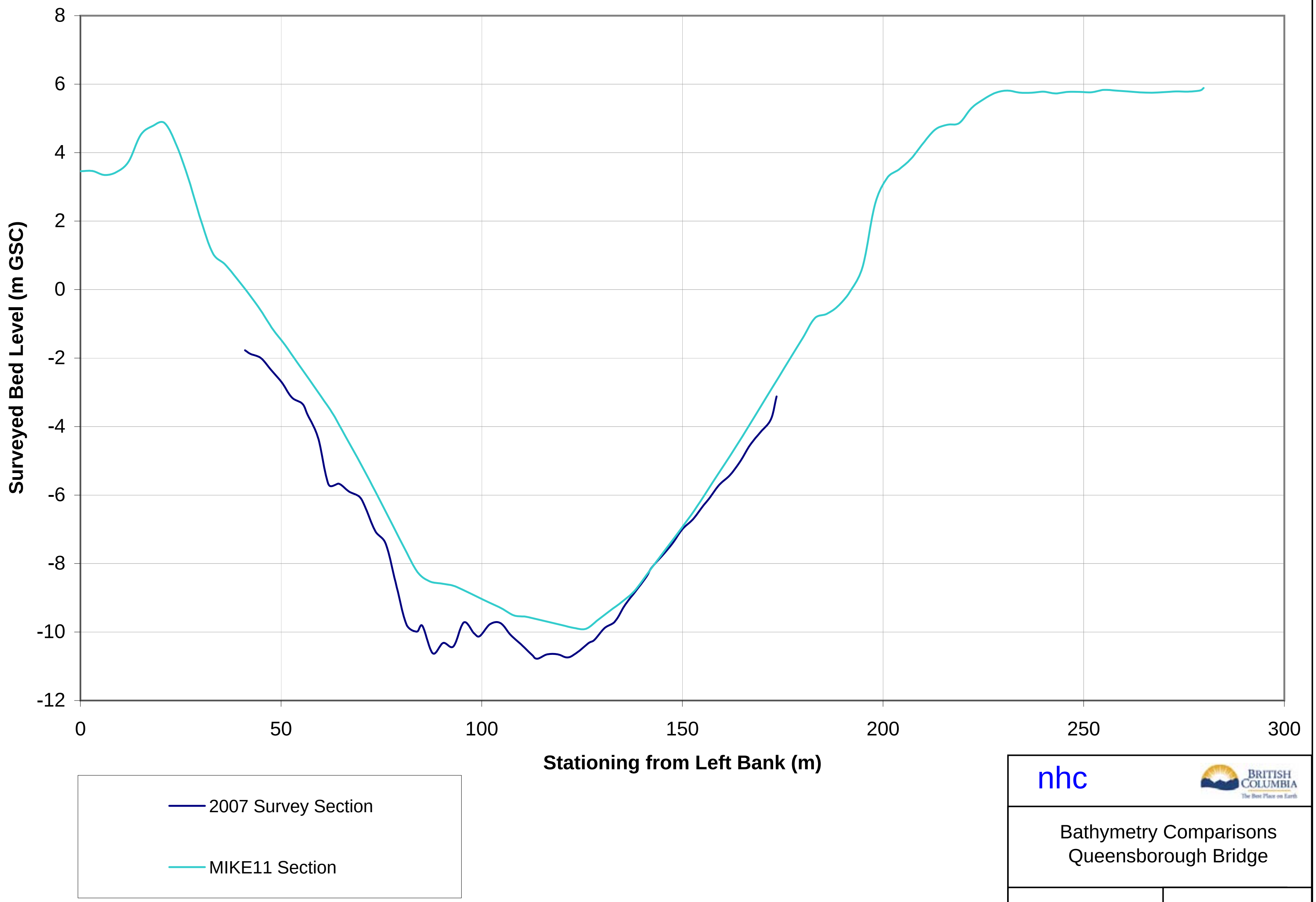
Bathymetry Comparisons
Oak Street Bridge

March 2008	Figure 3.10



Notes:
1. MIKE11 upstream and downstream sections based on same survey line.
2. 2007 downstream section located 62 m upstream of MIKE11 section. No data available at MIKE11 section.
3. 2007 upstream section located 31 m downstream of MIKE11 section. No data available at MIKE11 section.

nhc	BRITISH COLUMBIA The Best Place on Earth
Bathymetry Comparisons Knight Street Bridge	
March 2008	Figure 3.11



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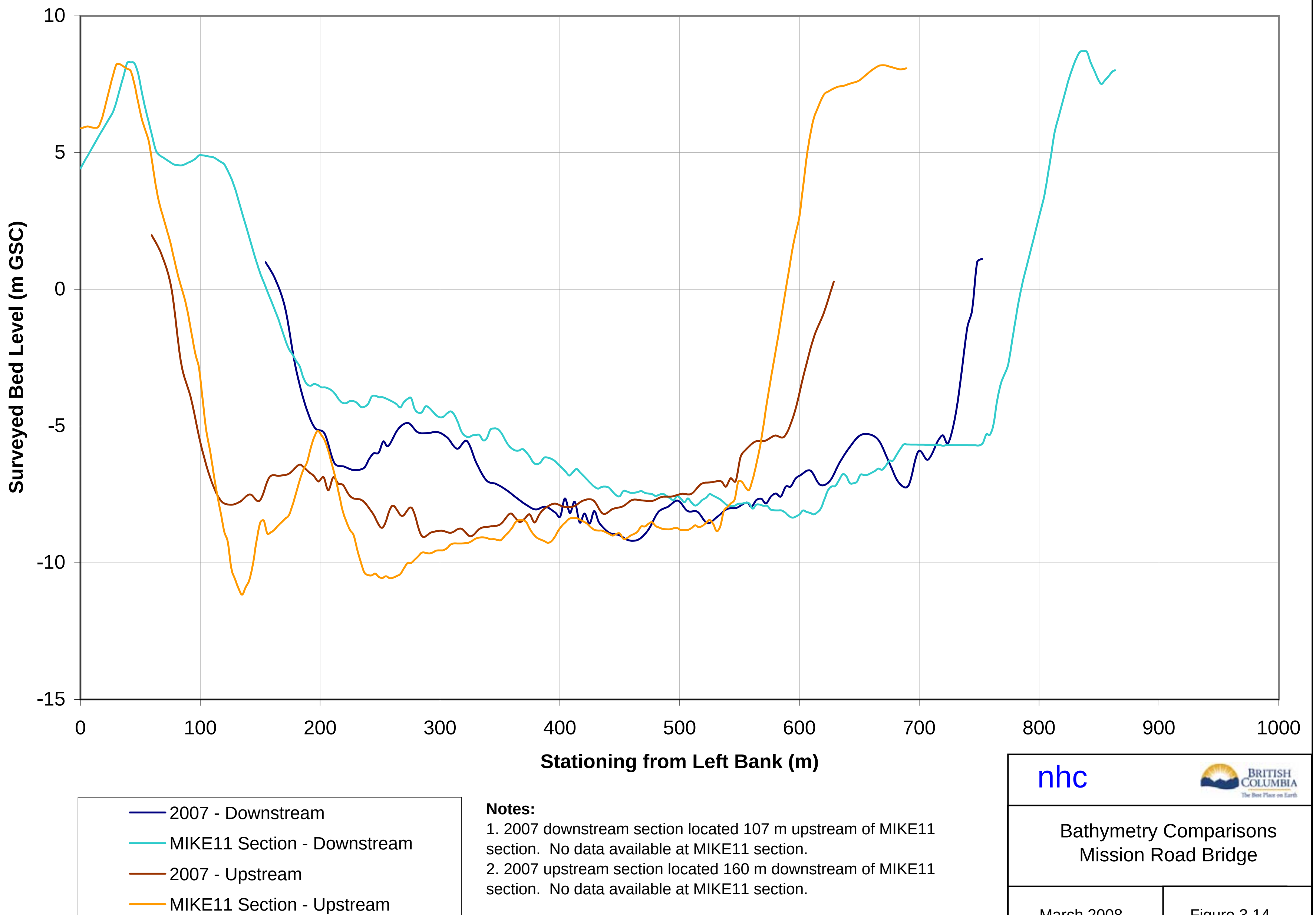
Bathymetry Comparisons
Queensborough Bridge

March 2008	Figure 3.12

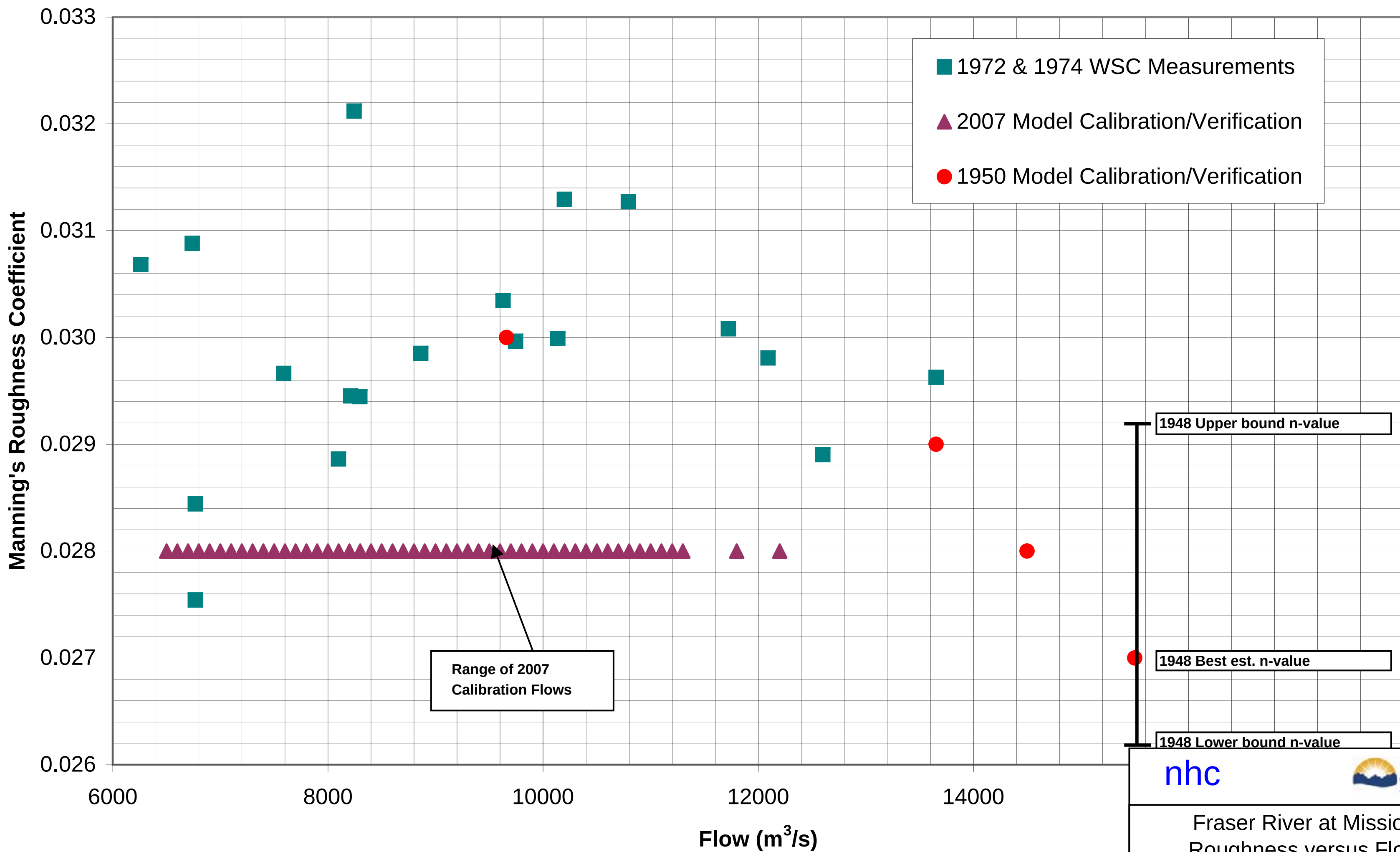
Notes:
1. 2007 section located 120 m downstream of MIKE11 section. No data available at MIKE11 section.

nhc	BRITISH COLUMBIA
Bathymetry Comparisons Port Mann Bridge	
March 2008	Figure 3.13



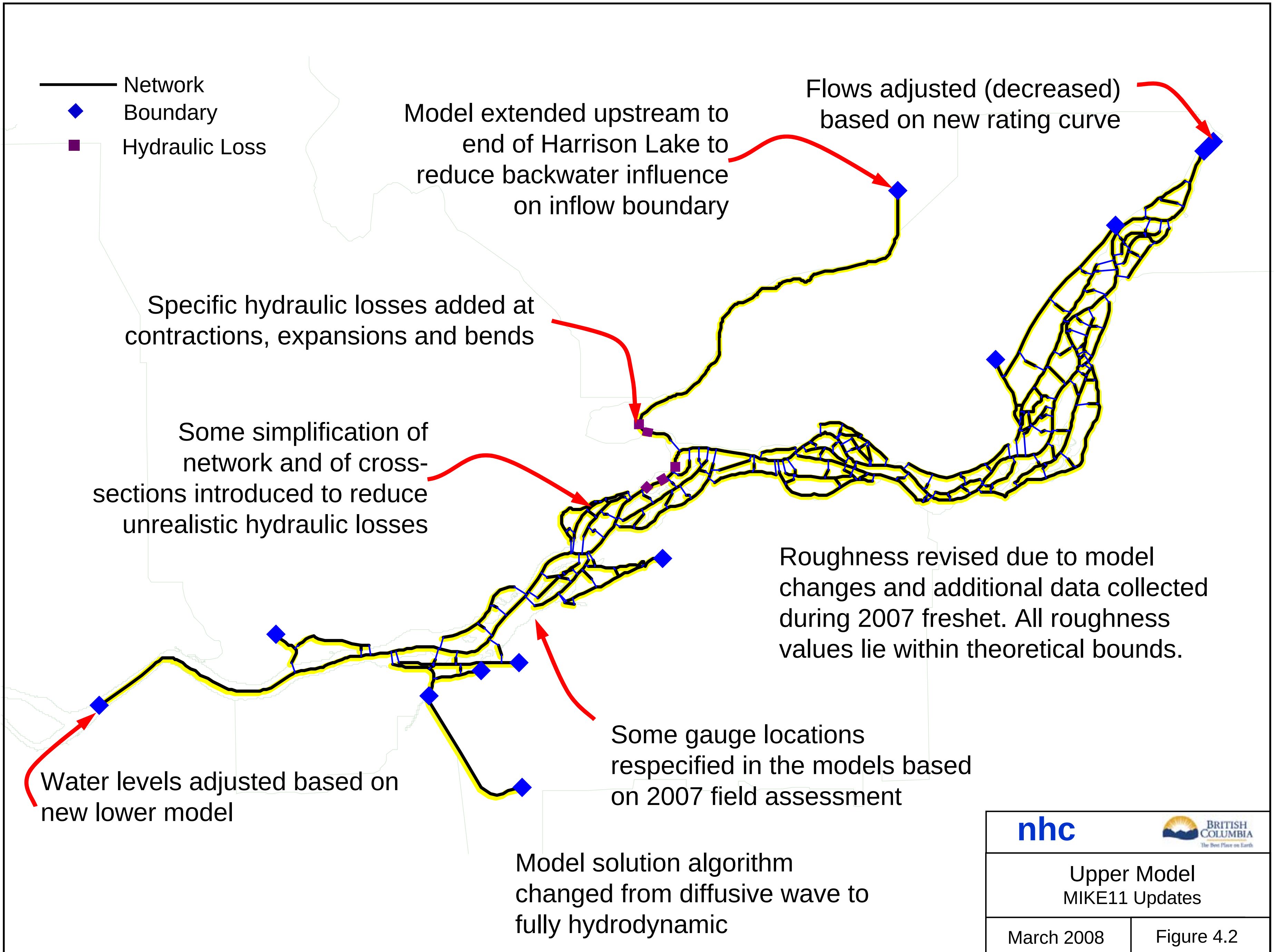
Notes:
1. 2007 downstream section located 107 m upstream of MIKE11 section. No data available at MIKE11 section.
2. 2007 upstream section located 160 m downstream of MIKE11 section. No data available at MIKE11 section.

nhc	BRITISH COLUMBIA The Best Place on Earth
Bathymetry Comparisons Mission Road Bridge	
March 2008	Figure 3.14



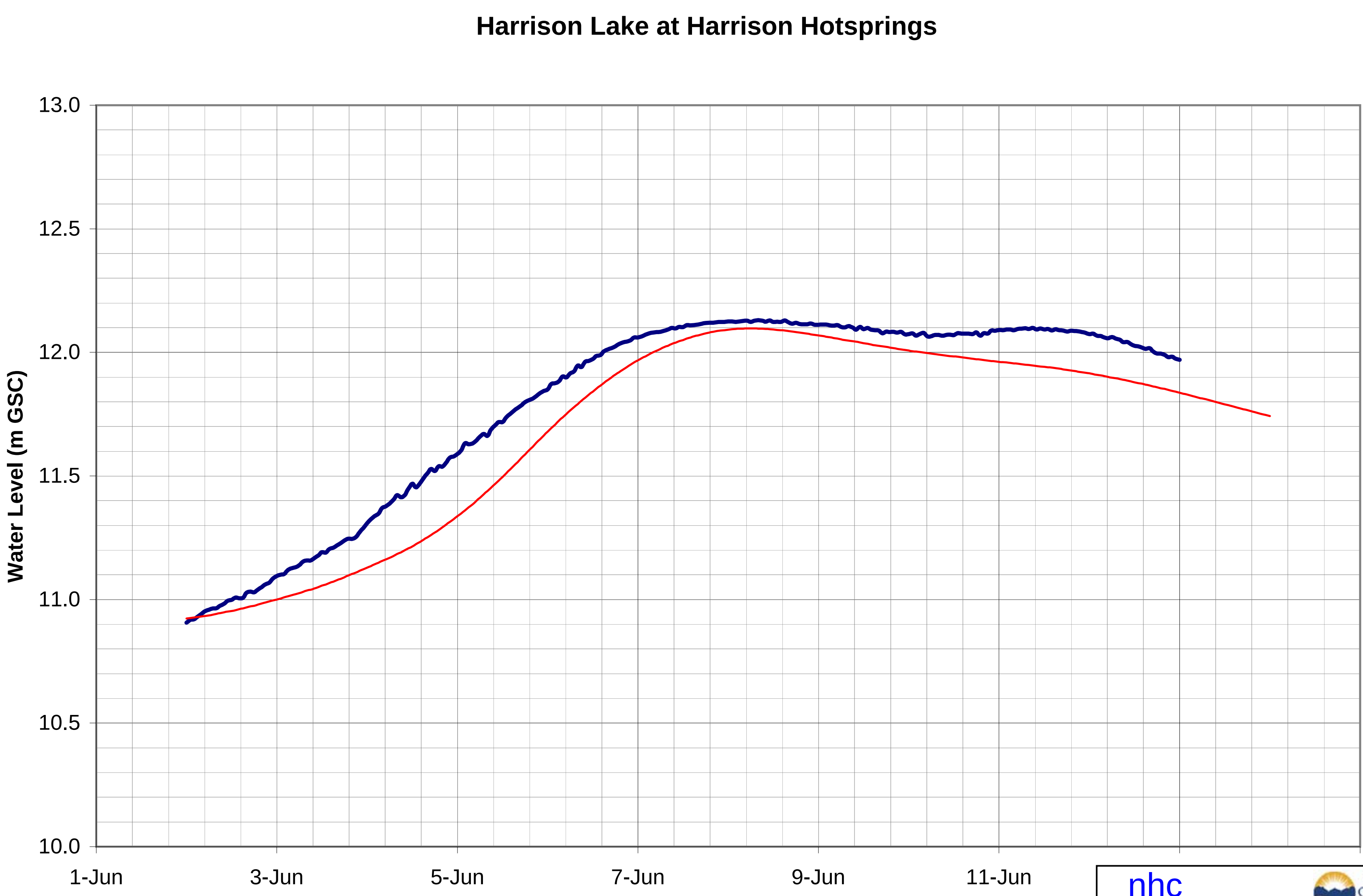
Fraser River at Mission
Roughness versus Flow

March 2008	Figure 4.1



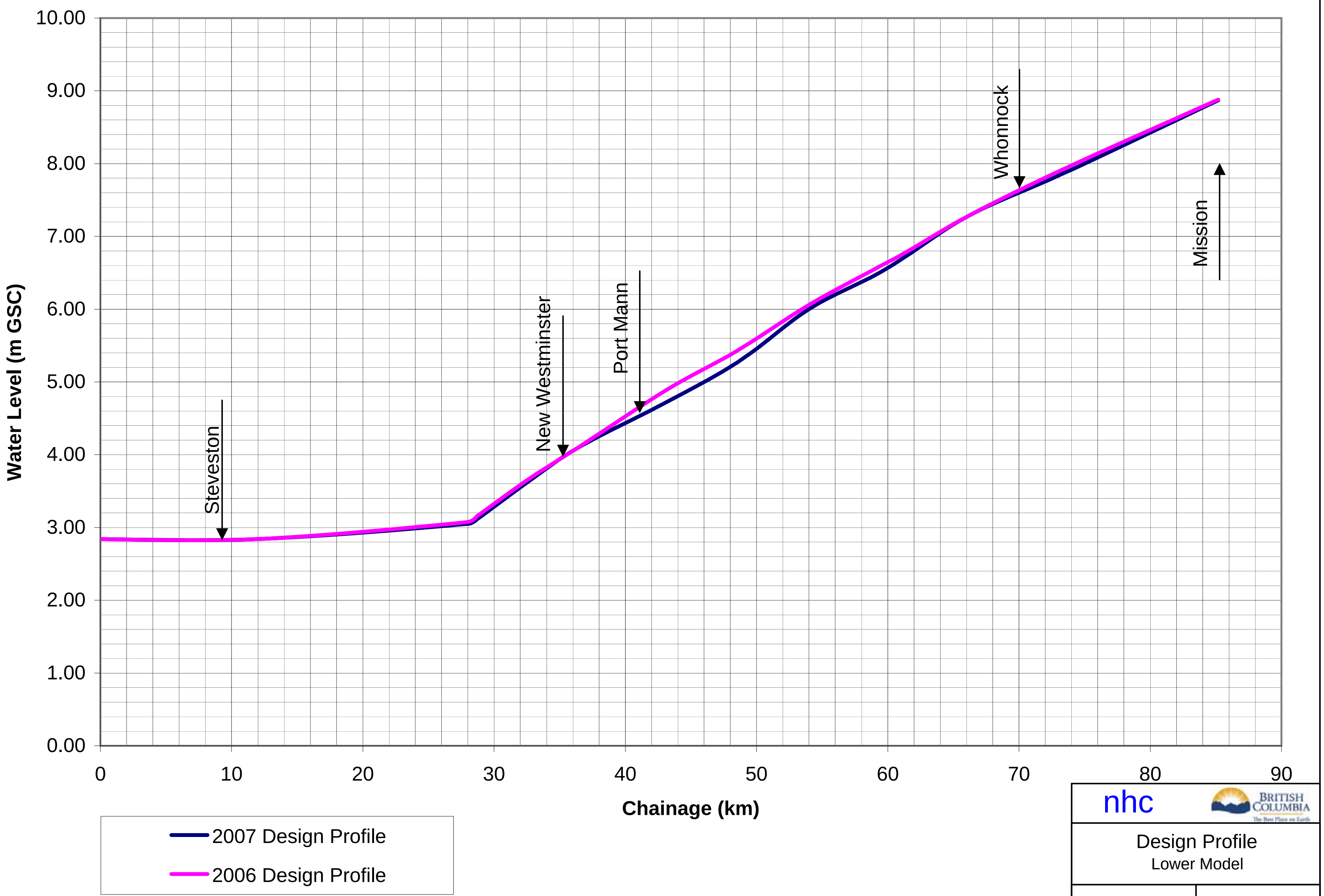
Upper Model
MIKE11 Updates

March 2008 Figure 4.2



Note: Inflows to Harrison Lake estimated

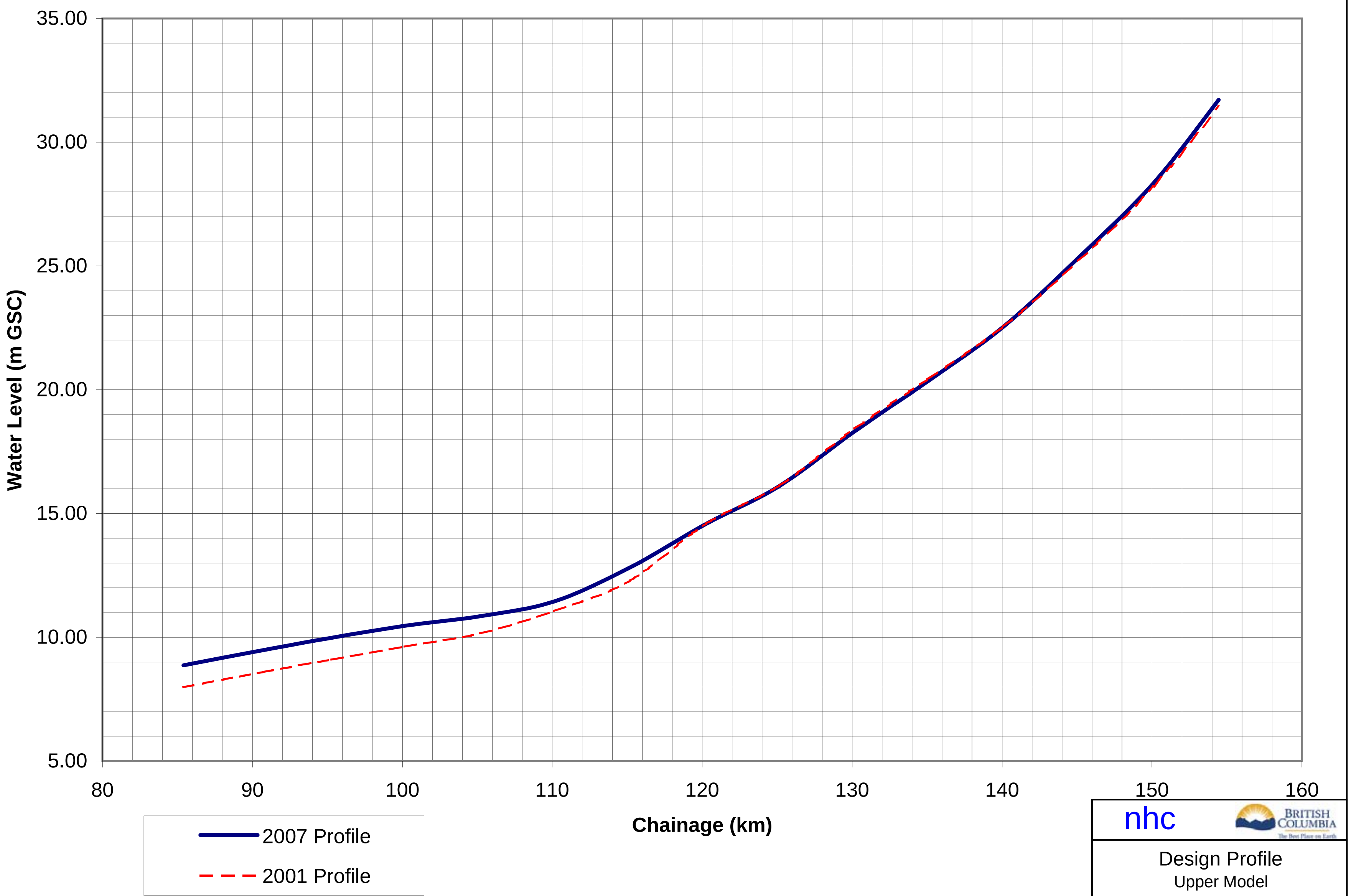
nhc	
Merged Fraser Model 2007 Calibration	
March 2008	Figure 4.3



nhc | BRITISH COLUMBIA

Design Profile
Lower Model

March 2008 | Figure 5.1

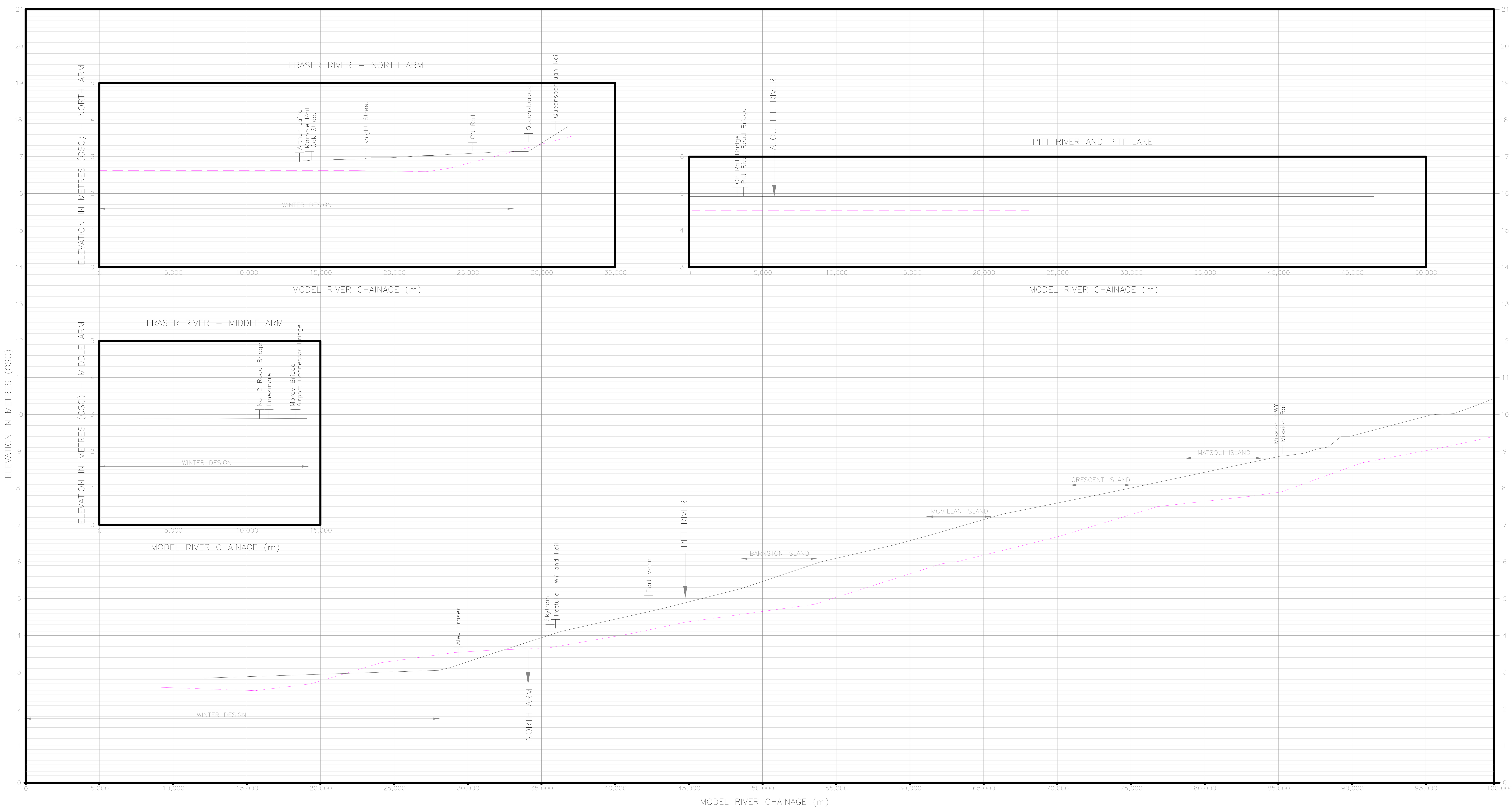


nhc

Design Profile
Upper Model

March 2008	Figure 5.2

DRAWINGS



VERTICAL DISTORTION – 1:2500

NOTES:
1) CHAINAGES ARE MIKE 11 MODEL CHAINAGES.
2) FLOWS USED IN THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
3) PROFILE GRAPHICALLY SMOOTHENED

LEGEND

- – – – 1894 Flood (1969 Calculation)
- ——— Updated Design Flood Profile (2007) (No Freeboard Allowance)

NO.	DATE	REVISION	DR.	CHK.	APPR.
A	6 Mar'08	Minor Edits	TSL	MM	MM

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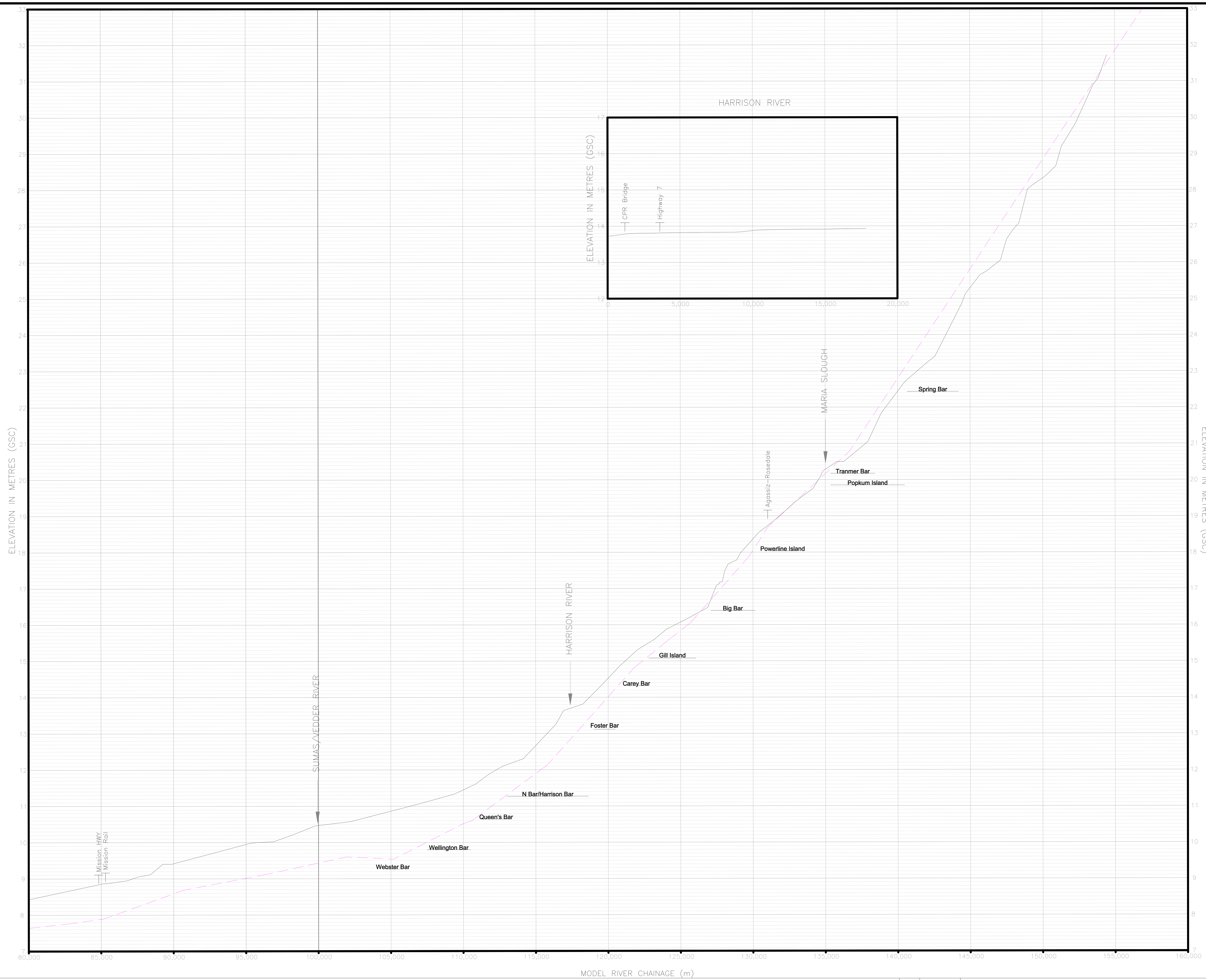
BC Ministry of Environment
Fraser River Hydraulic Model Update

Profile Comparison
2007 Modelled and 1969 Calculated Design Profiles
Downstream of Mission

SHEET SIZE D
SCALE AS NOTED
DATE 6 Mar. 2008

DRAWING NUMBER 34743–1
SHT.No. 1/1
REV. A

nhc–van: \ 4743–DwgNo1



NOTES:
1) CHAINAGES ARE MIKE 11 MODEL CHAINAGES.
2) FLOWS USED IN THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
3) PROFILE GRAPHICALLY SMOOTHENED

4) FRASER VALLEY DYKING BOARD DID NOT PRODUCE A PROFILE ABOVE MARIA SLOUGH IN 1969. LINE PRESENTED IN DRAWING IS A LINEAR INTERPOLATION BETWEEN 1969 PROFILE AT MARIA SLOUGH AND REPORTED HIGH WATER MARK AT HOPE BRIDGE.

VERTICAL DISTORTION – 1:2500

LEGEND

1894 Flood (1969 Calculation)
Updated Design Flood Profile (2007)
(No Freeboard Allowance)

NO.	DATE	REVISION	DR.	CHK.	APPR.
A	6 Mar'08	Minor Edits	TSL	MM	MM

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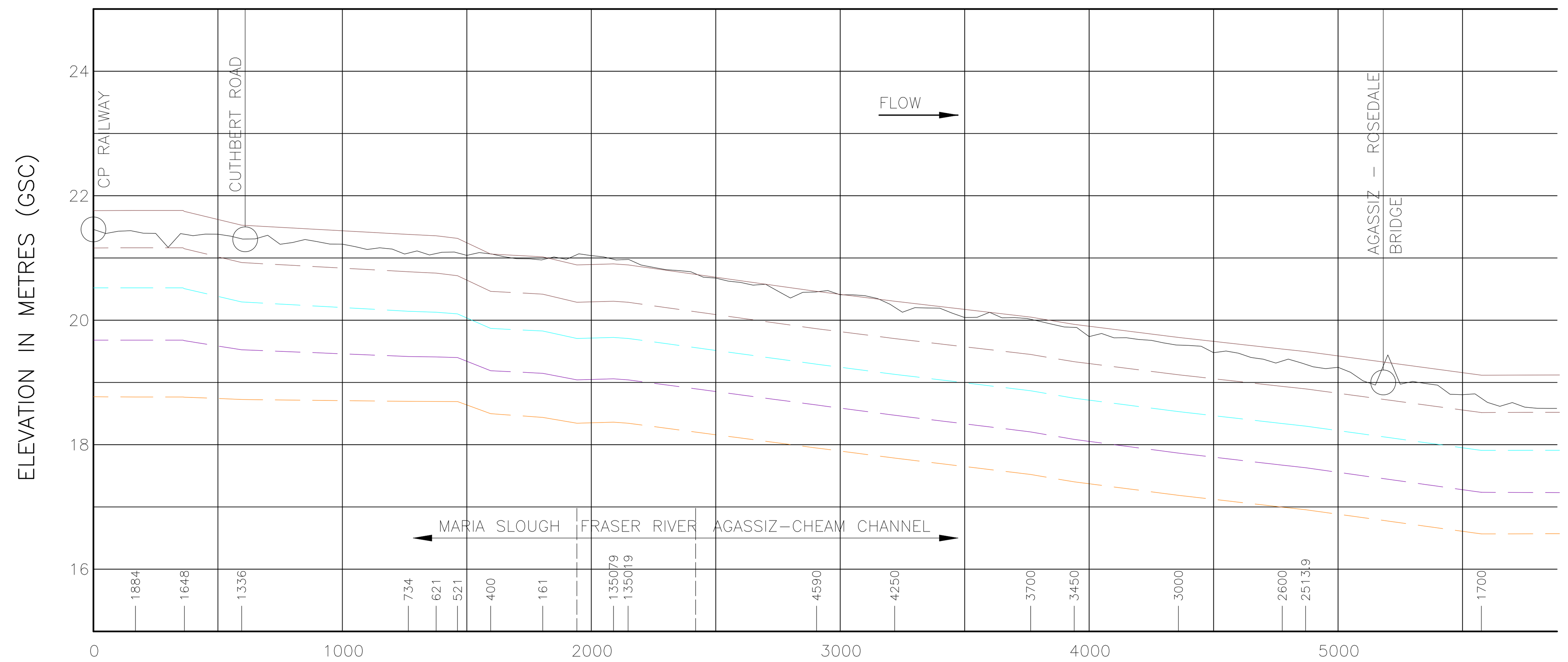
Fraser River Hydraulic Model Update

Profile Comparison
2007 Modelled and 1969 Calculated Design Profiles
Upstream of Mission

SHEET SIZE D
SCALE AS NOTED
DATE 6 Mar. 2008

DRAWING NUMBER 34743-2
SHT.No. 1/1
REV. A

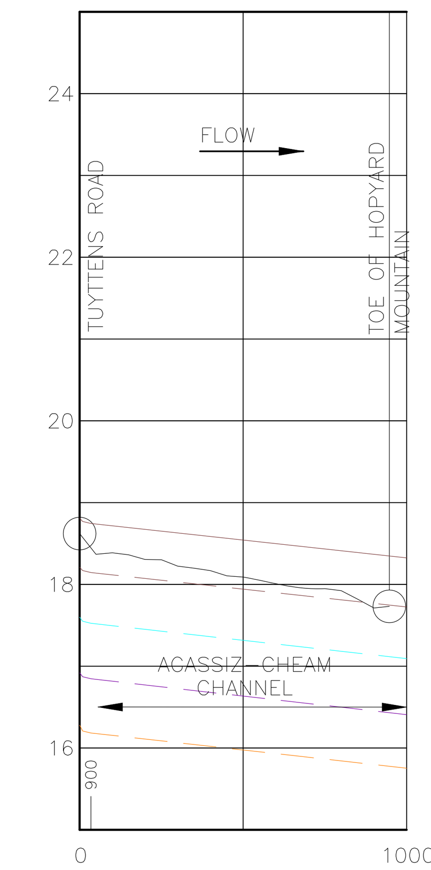
nhc–van: \ 4743–DwgNo1



DIKE CHAINAGE IN METRES

KENT – A

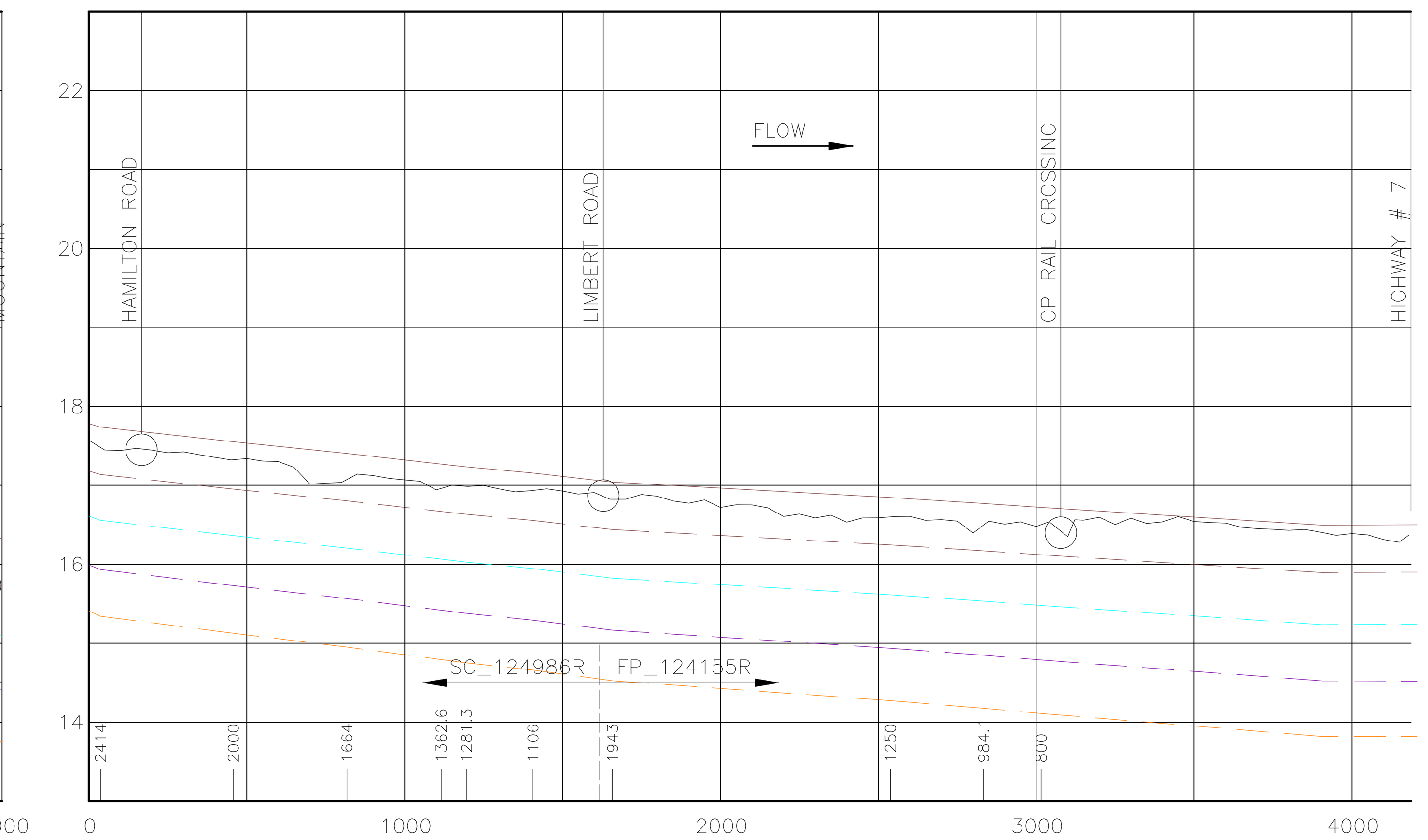
(EXISTING DIKE TAKEN FROM DISTRICT OF KENT, 1996)



DIKE CHAINAGE IN METRES

KENT – B

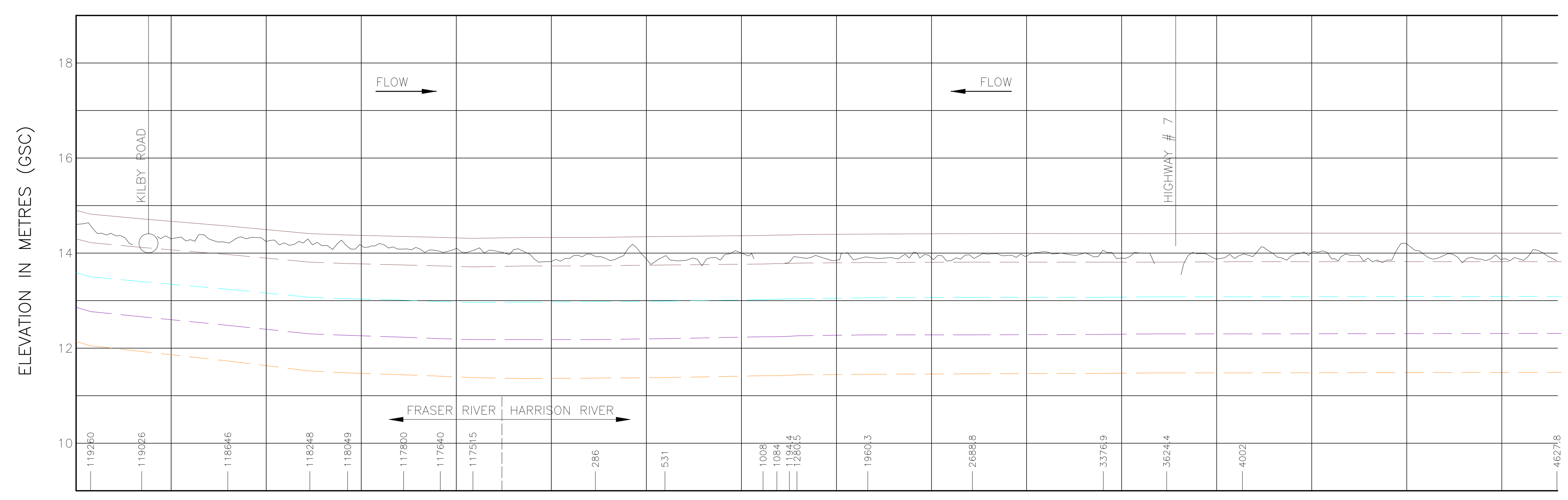
(EXISTING DIKE TAKEN FROM DISTRICT OF KENT, 1996)



DIKE CHAINAGE IN METRES

KENT – C

(EXISTING DIKE TAKEN FROM DISTRICT OF KENT, 1996)



DIKE CHAINAGE IN METRES

KENT – D

(EXISTING DIKE TAKEN FROM SURVEY BY EATON LAND SURVEYING LTD, 2007)

SCALE:

HORIZONTAL 1 : 20,000
VERTICAL 1 : 80

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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BC Ministry of Environment
Fraser River Hydraulic Model Update

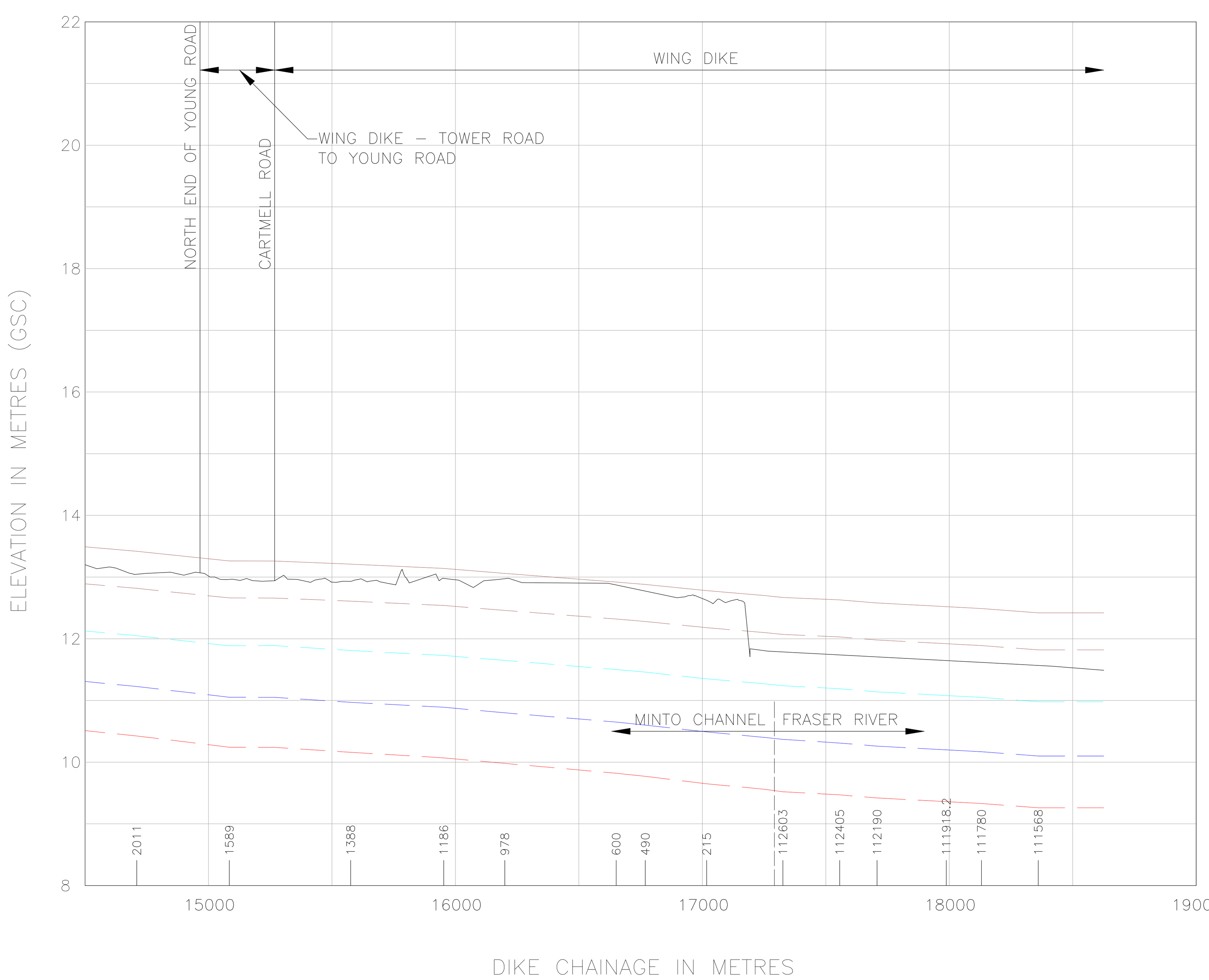
Dike Crest and Flood Profile Comparison
District of Kent

SHEET SIZE	SCALE	DATE
D	AS NOTED	12 MAR 08

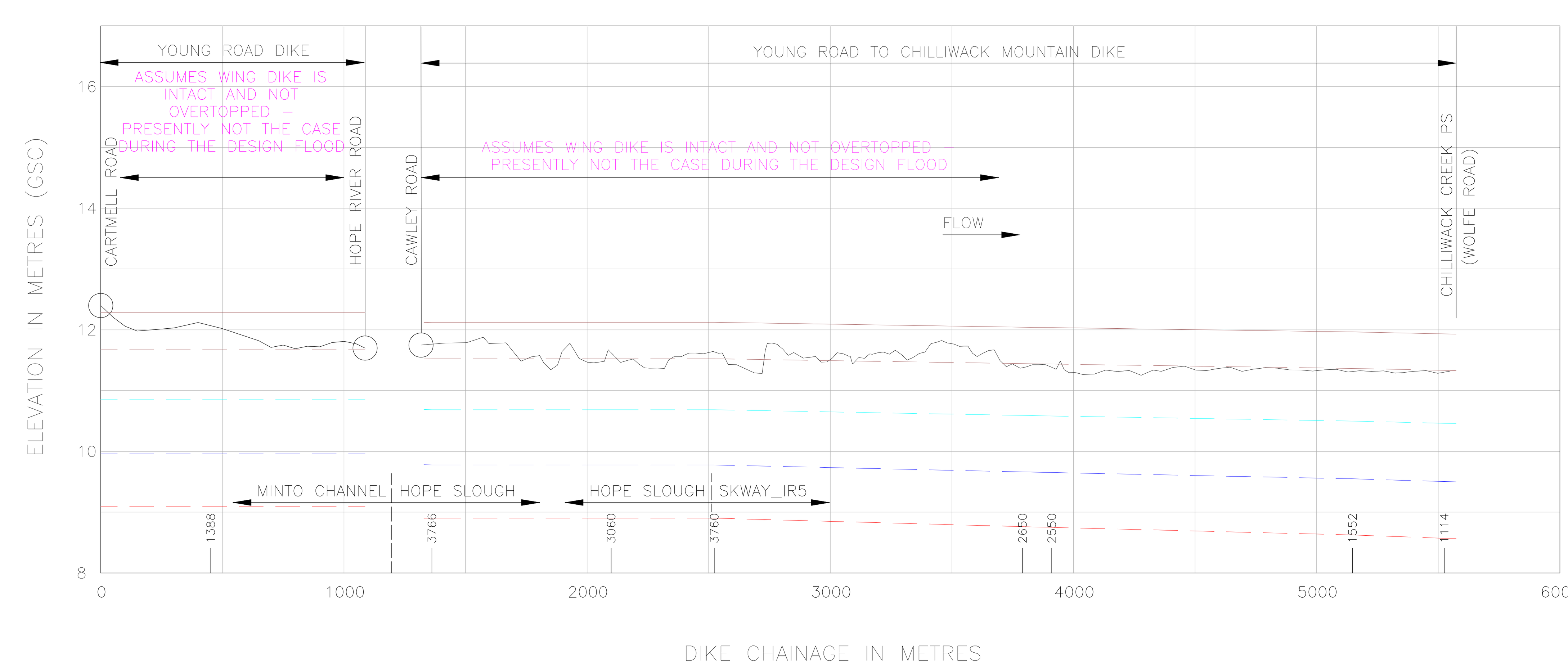
DRAWING NUMBER	SHT.No.	REV.
34743–3	1/1	0

nhc–van: \ 4743–DIKES

CHILLIWACK DIKE
(MAIN SOURCE FOR EXISTING DIKE IS CITY OF CHILLIWACK, 2007 (STA 500-1500, 3600-5000, 7400-10750, 10750-14030, 14030-15216, 15268-17193). REMAINING DATA TAKEN FROM CITY OF CHILLIWACK, 1998)



CHILLIWACK DIKE (continued)



YOUNG ROAD TO CHILLIWACK MOUNTAIN DIKE
(YOUNG ROAD DIKE TAKEN FROM CITY OF CHILLIWACK, 1998
YOUNG ROAD TO CHILLIWACK MOUNTAIN DIKE TAKEN FROM CITY OF CHILLIWACK, 2007)

SCALE:
HORIZONTAL 1 : 20,000
VERTICAL 1 : 80

NOTES:
1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
17,000 m/s AT HOPE
18,900 m/s AT MISSION
19,650 m/s AT NEW WESTMINSTER
(REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.
7. BRANCH DESIGN PROFILES ARE SUBJECT TO CHANGE AS A RESULT OF CHANNEL SHIFTING AND ISLAND OVERFLOW, PARTICULARLY NEAR HYDRAULIC STRUCTURES. USE OF MAIN CHANNEL PROFILE FOR DESIGN IS RECOMMENDED.

LEGEND
- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.
R0	11 MAR 08	ISSUED AS PRELIMINARY DRAWING			
R1	16 MAY 08	MINOR DIKE AND WATER SURFACE ADJUSTMENTS			

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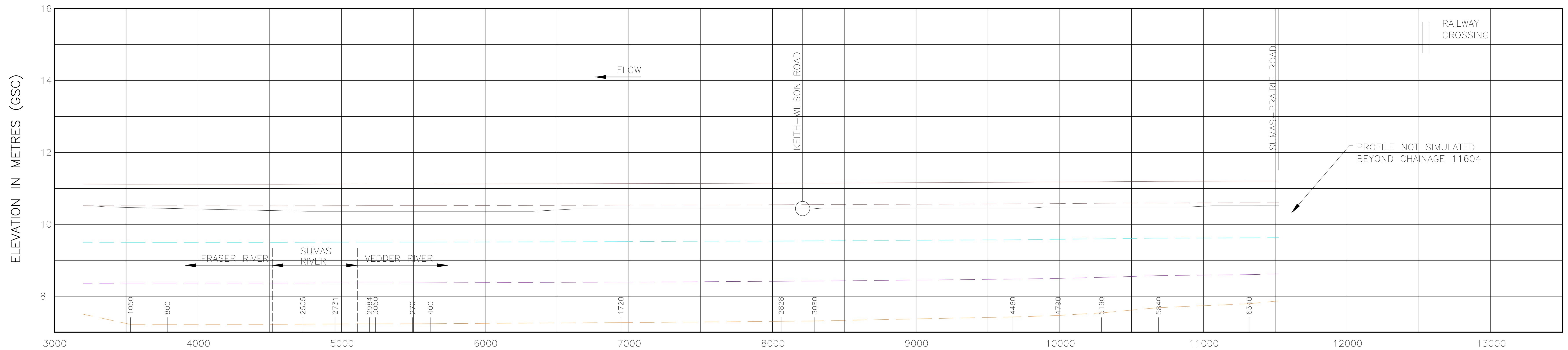
BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
City of Chilliwack

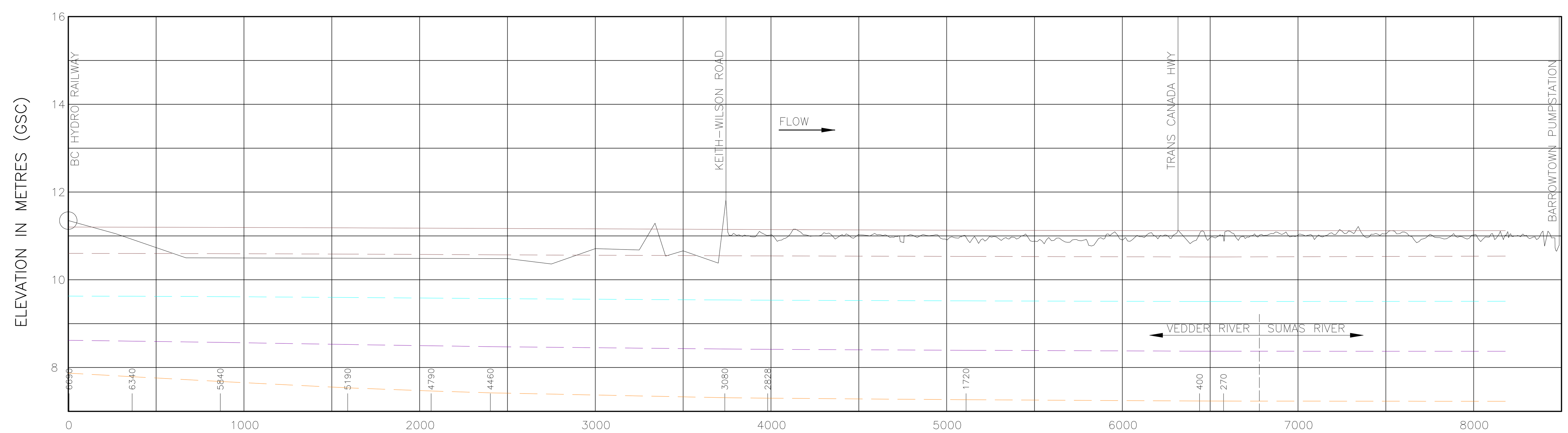
SHEET SIZE D
SCALE AS NOTED
DATE 16 MAY 08
DRAWING NUMBER 34934-4
SHT.No. 1/1
REV. 1

nhc-van: \ 4934-DIKES



DIKE CHAINAGE IN METRES

VEDDER – RIGHT BANK
(EXISTING DIKE TAKEN FROM CITY OF CHILLIWACK, 2007)



DIKE CHAINAGE IN METRES

VEDDER – LEFT BANK
(EXISTING DIKE TAKEN FROM CITY OF CHILLIWACK, 1999 (STA 0–3744)
AND CITY OF ABBOTSFORD, 2007 (STA 3745–8487)

SCALE:
HORIZONTAL 1 : 20,000
VERTICAL 1 : 80

NOTES:
1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
17,000 m^3/s AT HOPE
18,900 m^3/s AT MISSION
19,650 m^3/s AT NEW WESTMINSTER
(REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND
- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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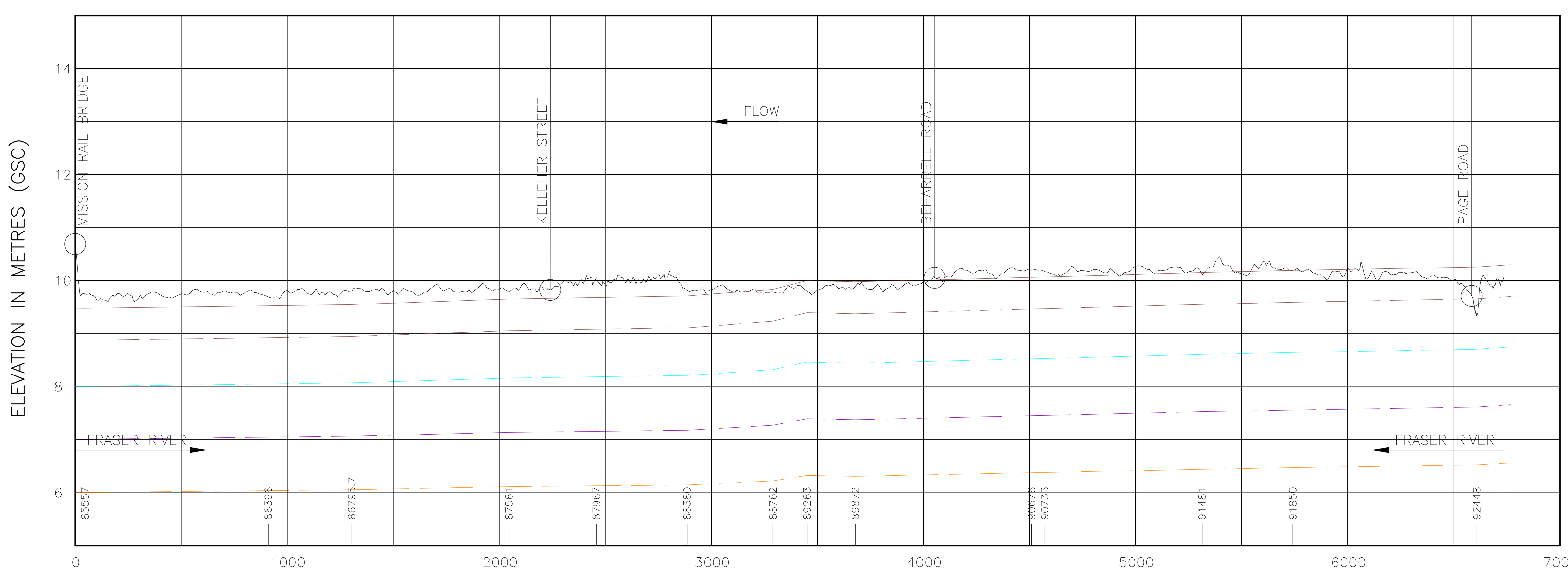
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
City of Chilliwack, City of Abbotsford

SHEET SIZE D
SCALE AS NOTED
DATE 12 MAR 08
DRAWING NUMBER 34743-5
SHT.No. 1/1
REV. 0

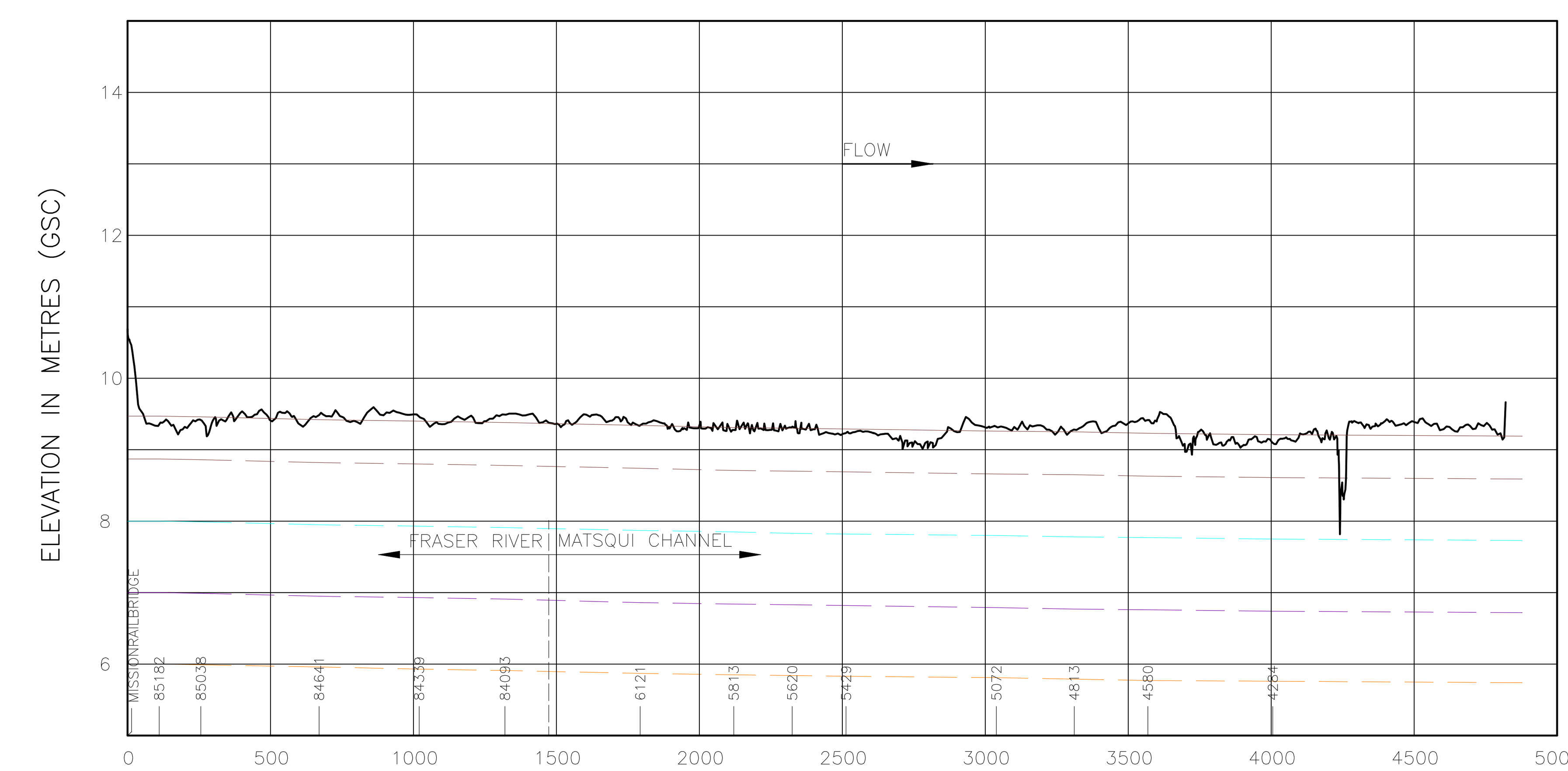
nhc-van: \ 4743-DIKES



DIKE CHAINAGE IN METRES

MATSQUI B DIKE

(EXISTING DIKE TAKEN FROM CITY OF ABBOTSFORD, 2007)



DIKE CHAINAGE IN METRES

MATSQUI A DIKE

(EXISTING DIKE TAKEN FROM CITY OF ABBOTSFORD, 2007)

SCALE:

HORIZONTAL 1 : 20,000
VERTICAL 1 : 80

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
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6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

EXISTING DIKE CREST
UPDATED DESIGN FLOOD WATER SURFACE
UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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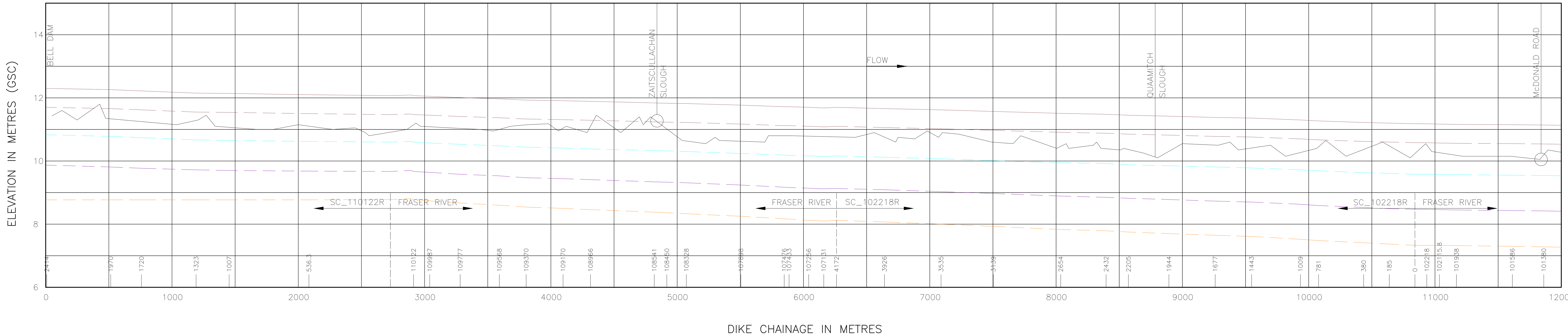
Fraser River Hydraulic Model Update

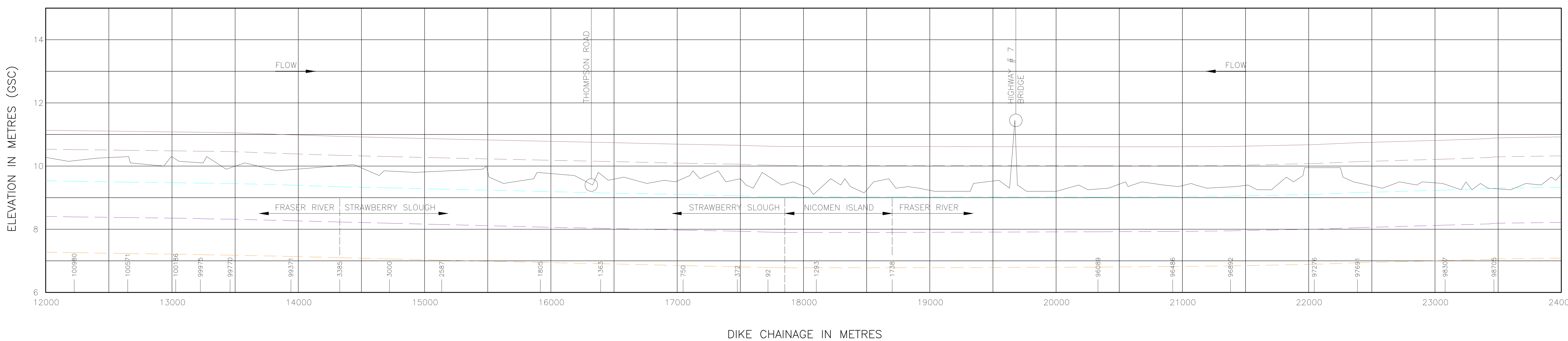
Dike Crest and Flood Profile Comparison
City of Abbotsford

SHEET SIZE	SCALE	DATE	DRAWING NUMBER	SHT.No.	REV.
D	AS NOTED	12 MAR 08	34743-6	1/1	0

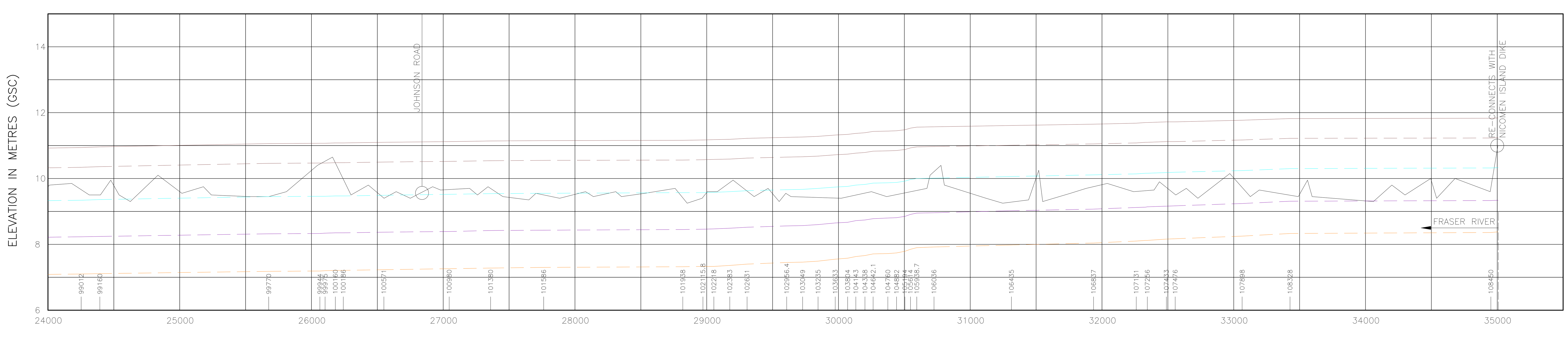
nhc-van: \ 4743-DIKES



NICOMEN ISLAND DIKE – 0 TO 12000
(EXISTING DIKE TAKEN FROM NICOMEN ISLAND IMPROVEMENT DISTRICT, 1999)



NICOMEN ISLAND DIKE – 12000 TO 24000
(EXISTING DIKE TAKEN FROM NICOMEN ISLAND IMPROVEMENT DISTRICT, 1999)



NICOMEN ISLAND DIKE – 24000 TO 35000
(EXISTING DIKE TAKEN FROM NICOMEN ISLAND IMPROVEMENT DISTRICT, 1999)

SCALE:
HORIZONTAL 1 : 20,000
VERTICAL 1 : 80

NOTES:
1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND
- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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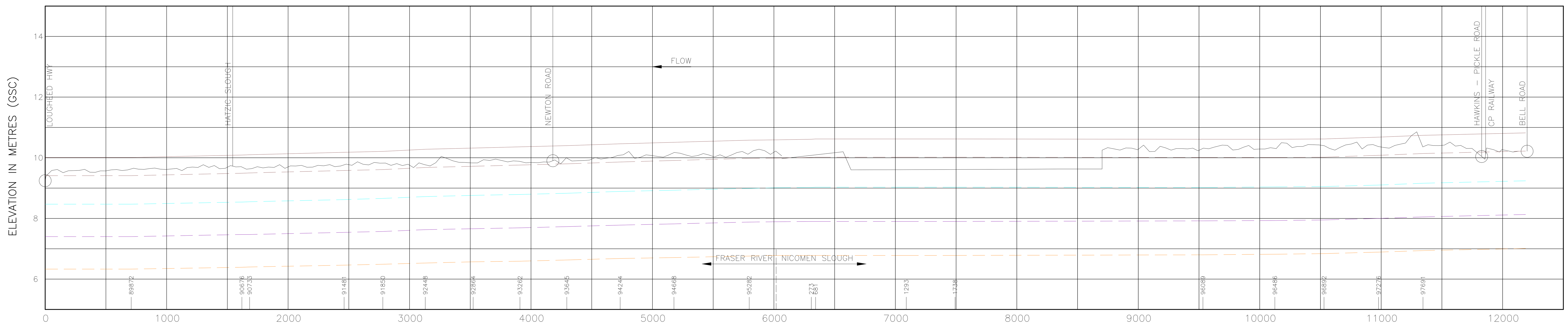
BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
Nicomen Island Improvement District

SHEET SIZE	D
SCALE	AS NOTED
DATE	12 MAR 08
DRAWING NUMBER	34743-7
SHT.No.	1/1
REV.	0

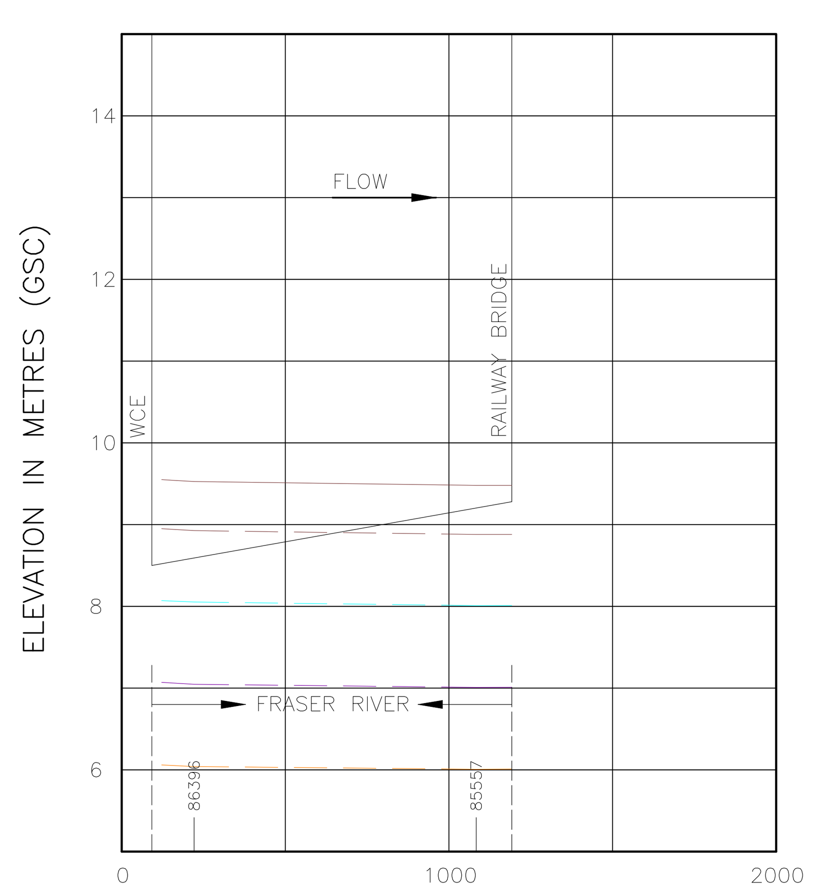
nhc–van: \ 4743–DIKES



DIKE CHAINAGE IN METRES

DEWDNEY DIKE

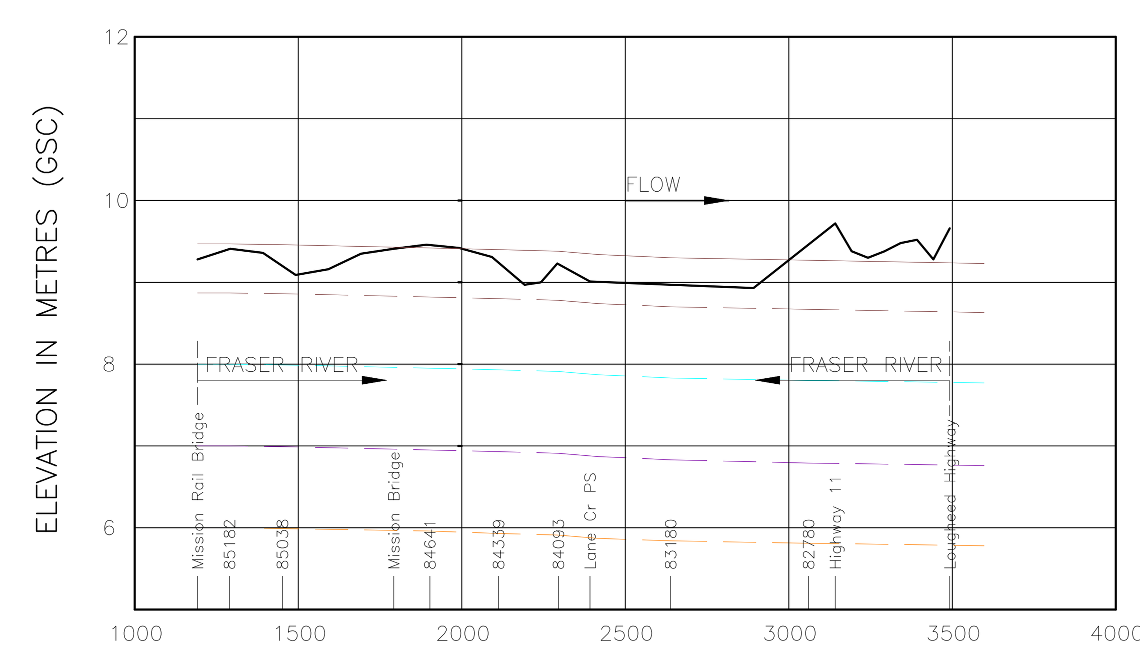
(EXISTING DIKE TAKEN FROM DEWDNEY AREA IMPROVEMENT DISTRICT, 2007 (STA 0-6064, 8702-12129) AND DEWDNEY AREA IMPROVEMENT DISTRICT, 1989 (STA 6065-8701))



DIKE CHAINAGE IN METRES

MISSION B DIKE

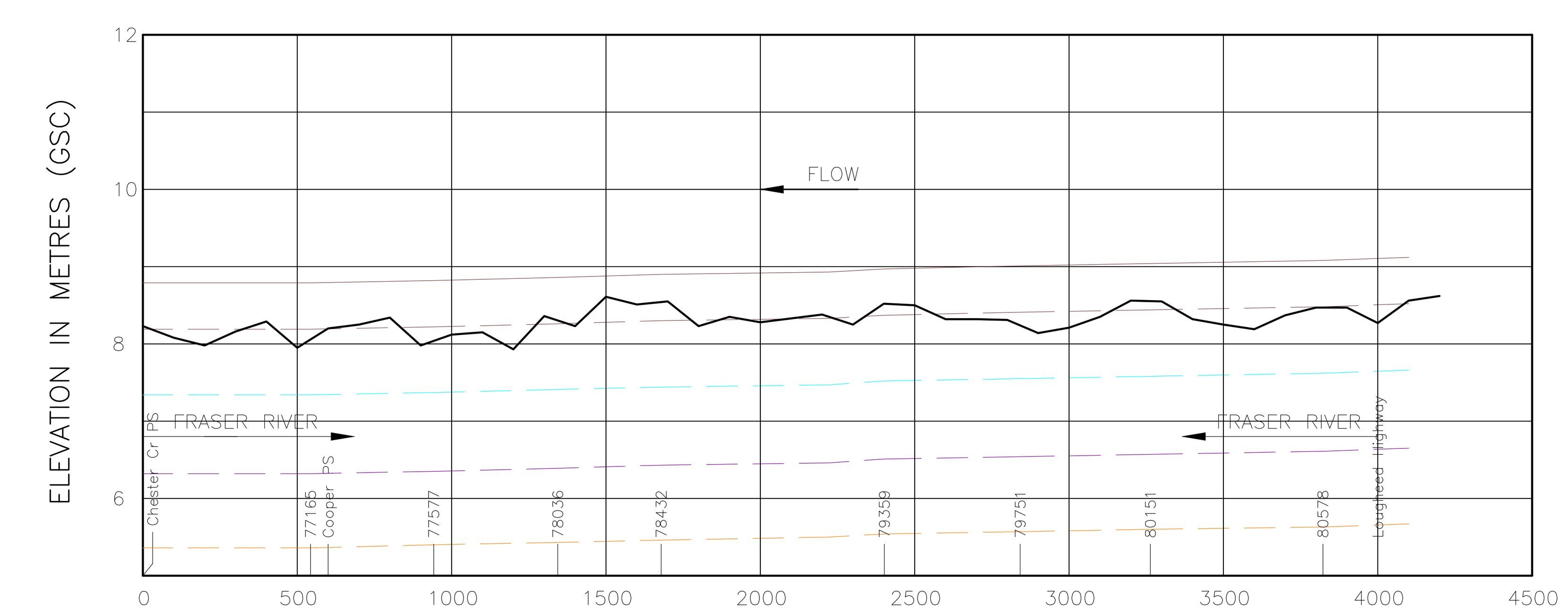
(EXISTING DIKE TAKEN FROM FROM DISTRICT OF MISSION, 2007)



DIKE CHAINAGE IN METRES

MISSION A DIKE

(EXISTING DIKE TAKEN FROM FROM DISTRICT OF MISSION, 2007)



DIKE CHAINAGE IN METRES

SILVERDALE DIKE

(EXISTING DIKE TAKEN FROM FROM DISTRICT OF MISSION, 2007)

SCALE:

HORIZONTAL 1 : 20,000
VERTICAL 1 : 80

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m³/s AT HOPE
   18,900 m³/s AT MISSION
   19,650 m³/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

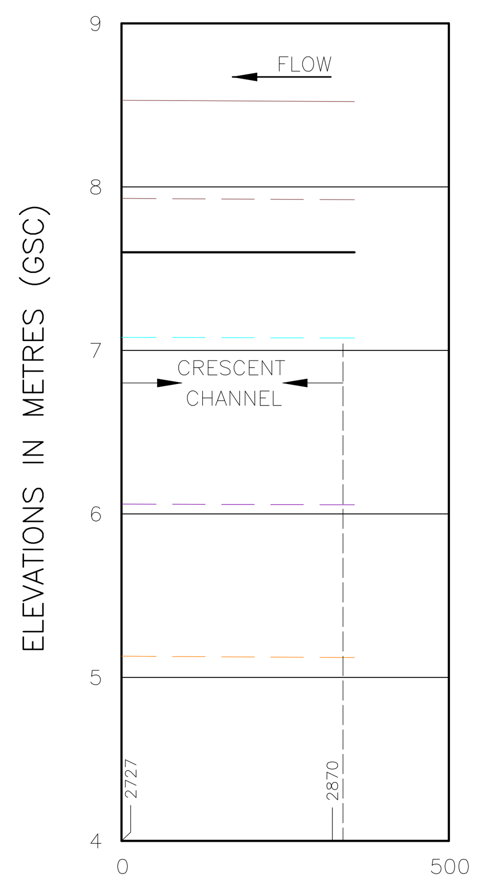
- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

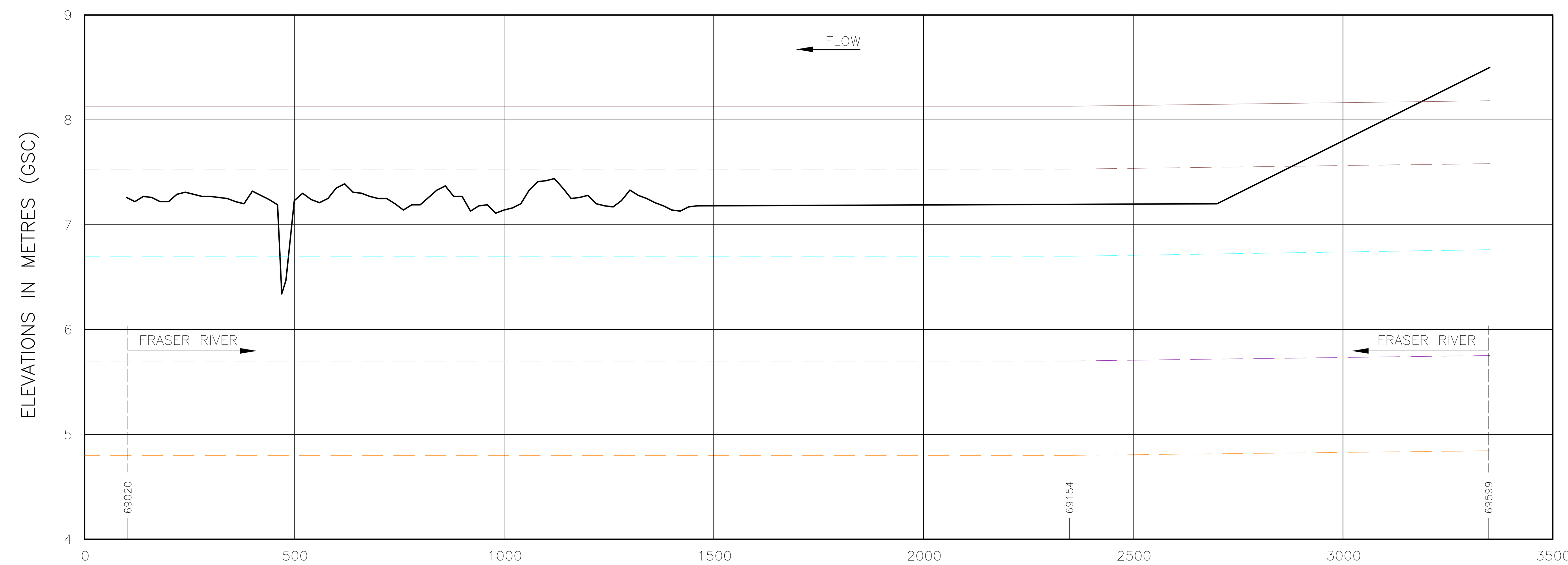
nhc northwest hydraulic consultants

BC Ministry of Environment Fraser River Hydraulic Model Update	SHEET SIZE D
Dike Crest and Flood Profile Comparison District of Mission Dewdney Area Improvement District	SCALE AS NOTED
	DATE 12 MAR 08
DRAWING NUMBER 34743-8	SHT.No. 1/1 — REV. 0

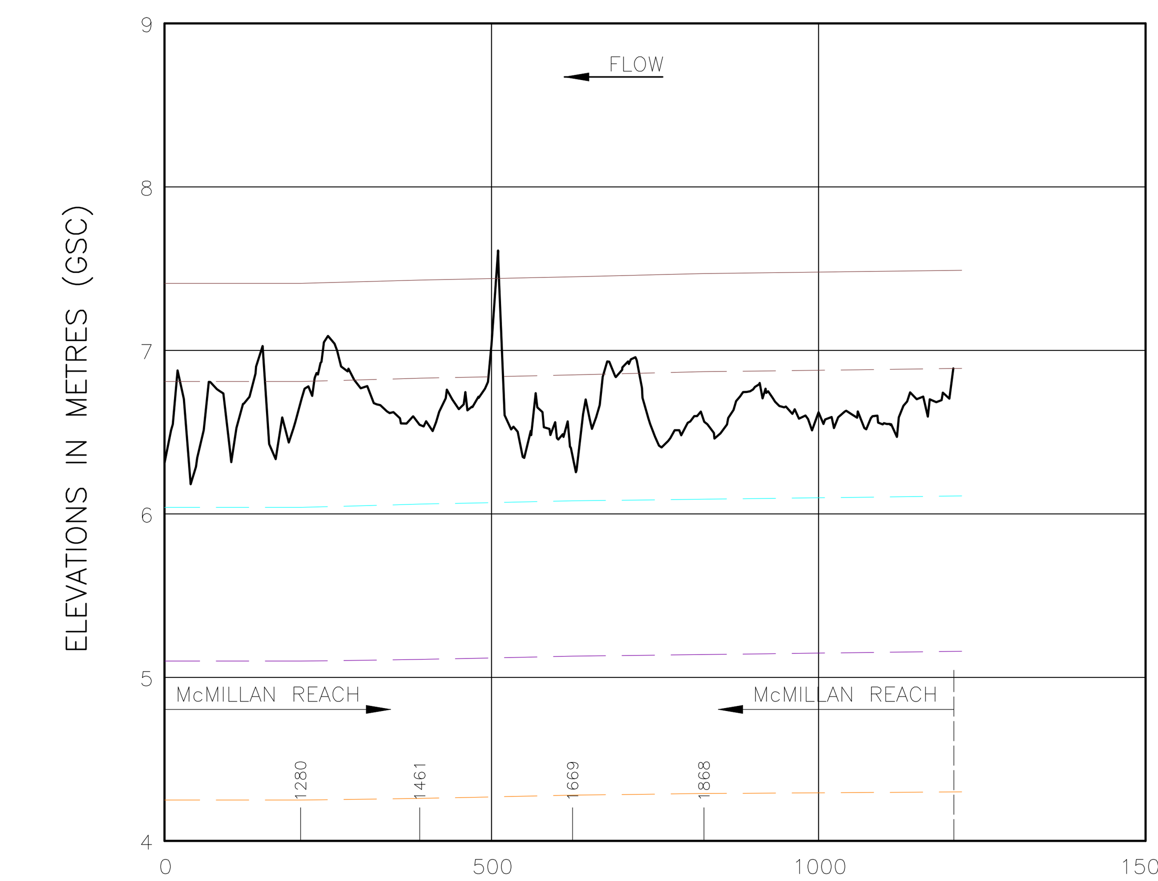
nhc-van: \ 4743-DIKES



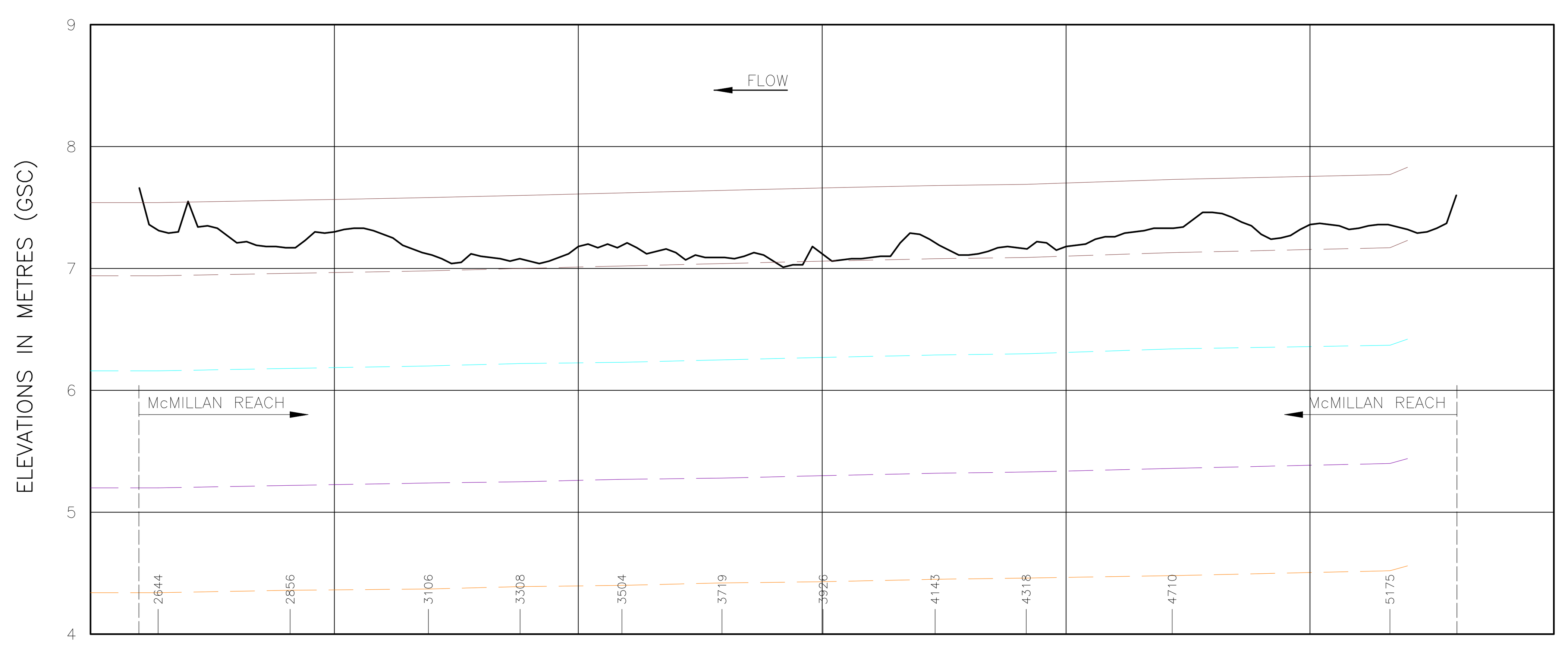
GLEN VALLEY EAST WING DIKE
(EXISTING DIKE TAKEN FROM FRFCP OPERATION & MAINTENANCE MANUAL, 1989)



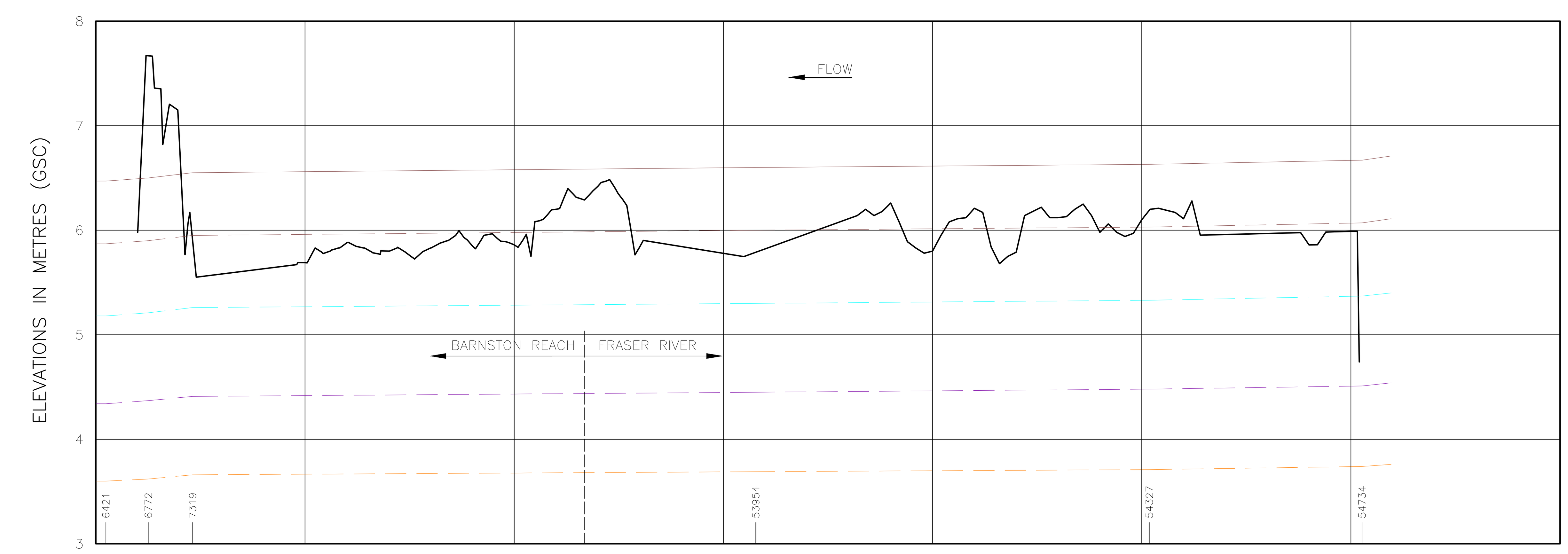
GLEN VALLEY WEST WING DIKE
(EXISTING DIKE TAKEN FROM TOWNSHIP OF LANGLEY, 2000 (STA 0-1460)
AND FRFCP OPERATION & MAINTENANCE MANUAL, 1988 (STA 2700-3350))



FORT LANGLEY DIKE
(EXISTING DIKE TAKEN FROM 2005 LIDAR)



CNR TRACK, GLOVER ROAD TO ARMSTRONG ROAD
(EXISTING DIKE TAKEN FROM TOWNSHIP OF LANGLEY, 2003)



WEST LANGLEY DIKE
(EXISTING DIKE TAKEN FROM TOWNSHIP OF LANGLEY, 2001)

SCALE:
HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:
1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
17,000 m^3/s AT HOPE
18,900 m^3/s AT MISSION
19,650 m^3/s AT NEW WESTMINSTER
(REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND
EXISTING DIKE CREST
UPDATED DESIGN FLOOD WATER SURFACE
UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

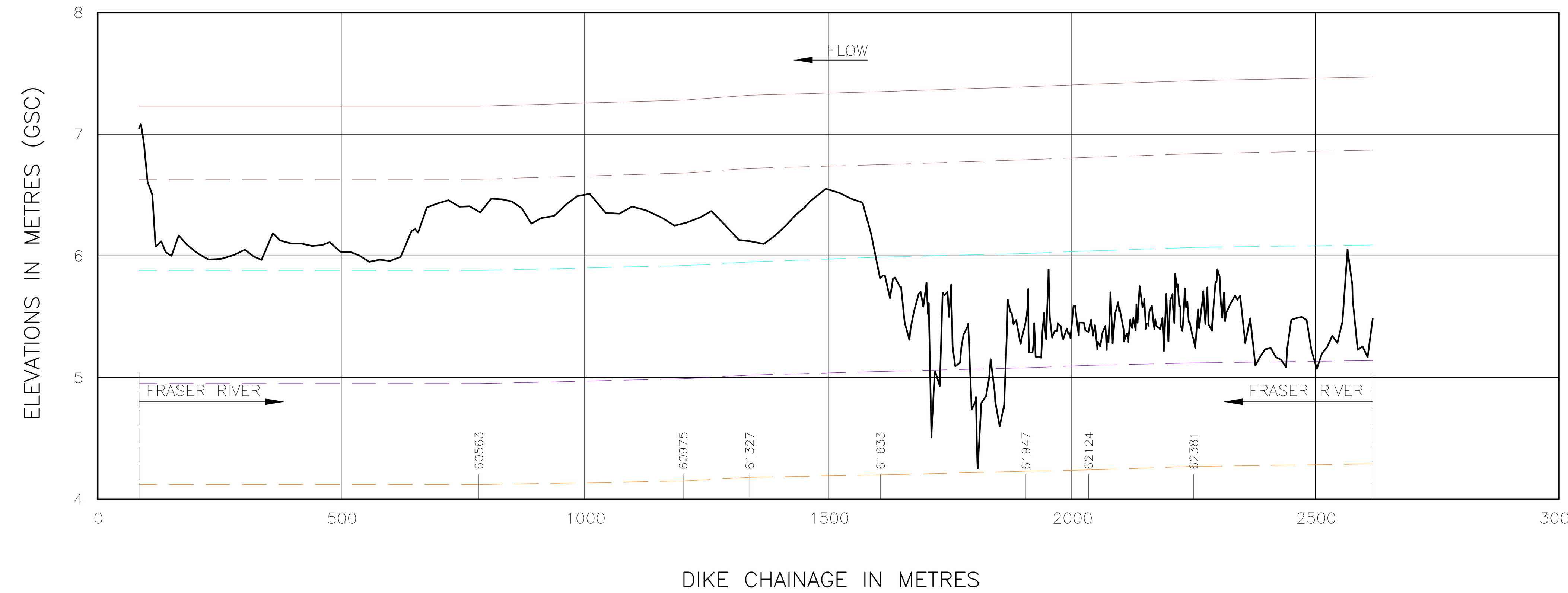
northwest hydraulic consultants

BC Ministry of Environment
Fraser River Hydraulic Model Update
Dike Crest and Flood Profile Comparison
Glen Valley Diking Authority
Township of Langley

SHEET SIZE D
SCALE AS NOTED
DATE 12 MAR 08

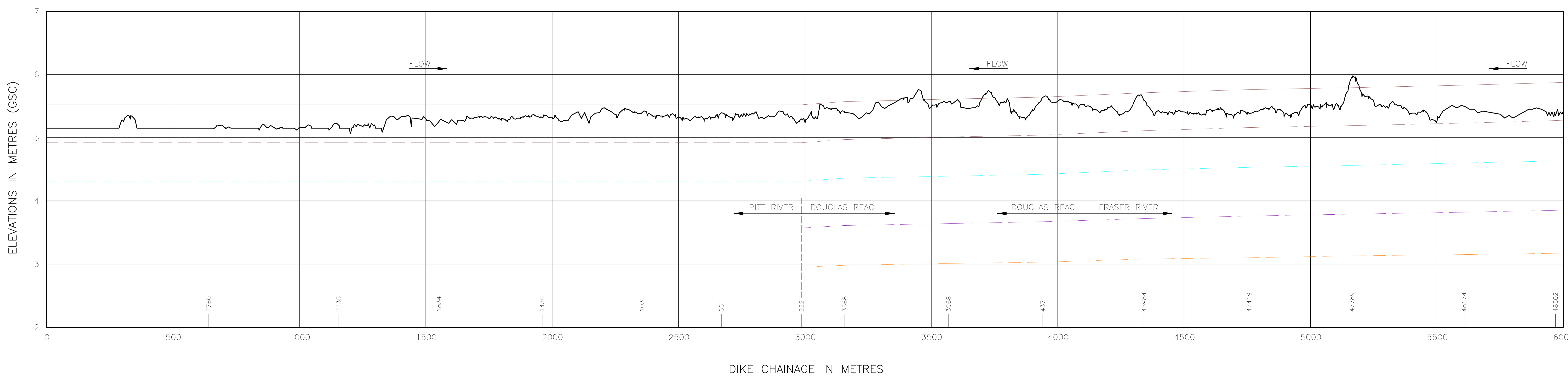
DRAWING NUMBER 34743-9
SHT.No. 1/1
REV. 0

nhc-van: \ 4743-DIKES



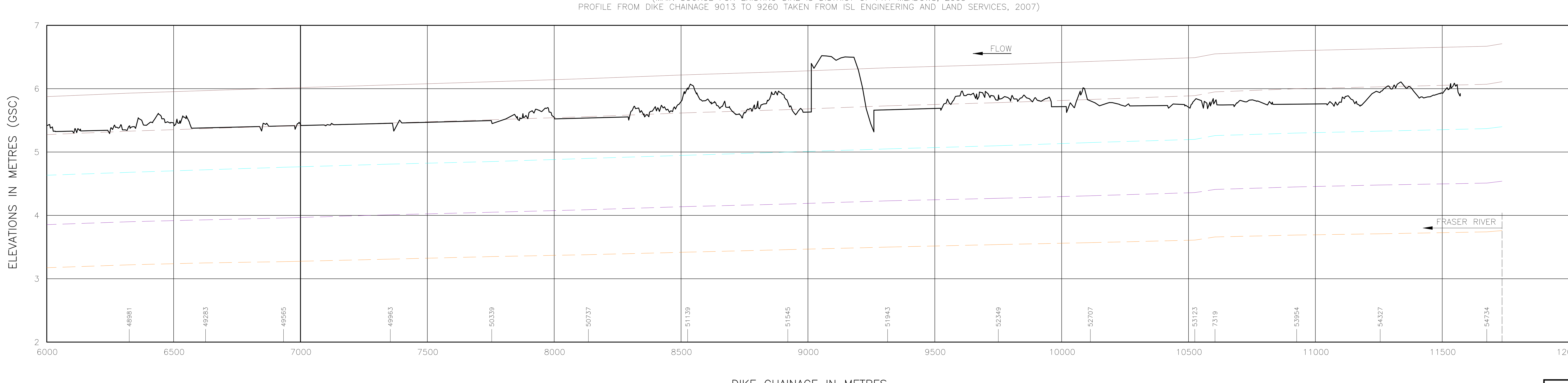
ALBION DIKE

(EXISTING DIKE TAKEN FROM DISTRICT OF MAPLE RIDGE, 2007 (STA 119-1588)
AND 2005 LiDAR (STA 85-118, 1589-2618)



PITT MEADOWS SOUTH DIKE

(MAIN SOURCE FOR EXISTING DIKE IS DISTRICT OF PITT MEADOWS, 2003
PROFILE FROM DIKE CHAINAGE 9013 TO 9260 TAKEN FROM ISL ENGINEERING AND LAND SERVICES, 2007)



PITT MEADOWS SOUTH DIKE (continued)

SCALE:
HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:
1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE: 17,000 m^3/s AT HOPE
18,900 m^3/s AT MISSION
19,650 m^3/s AT NEW WESTMINSTER
(REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND
- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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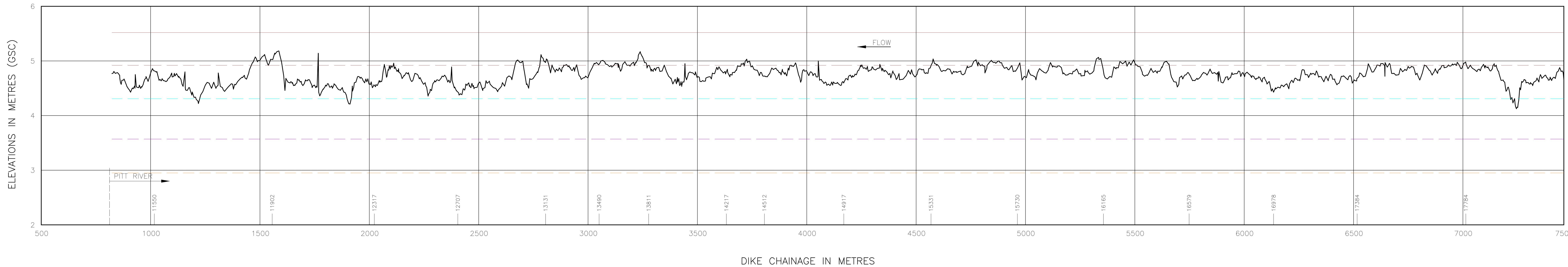
BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
District of Maple Ridge, District of Pitt Meadows

SHEET SIZE D
SCALE AS NOTED
DATE 12 MAR 08

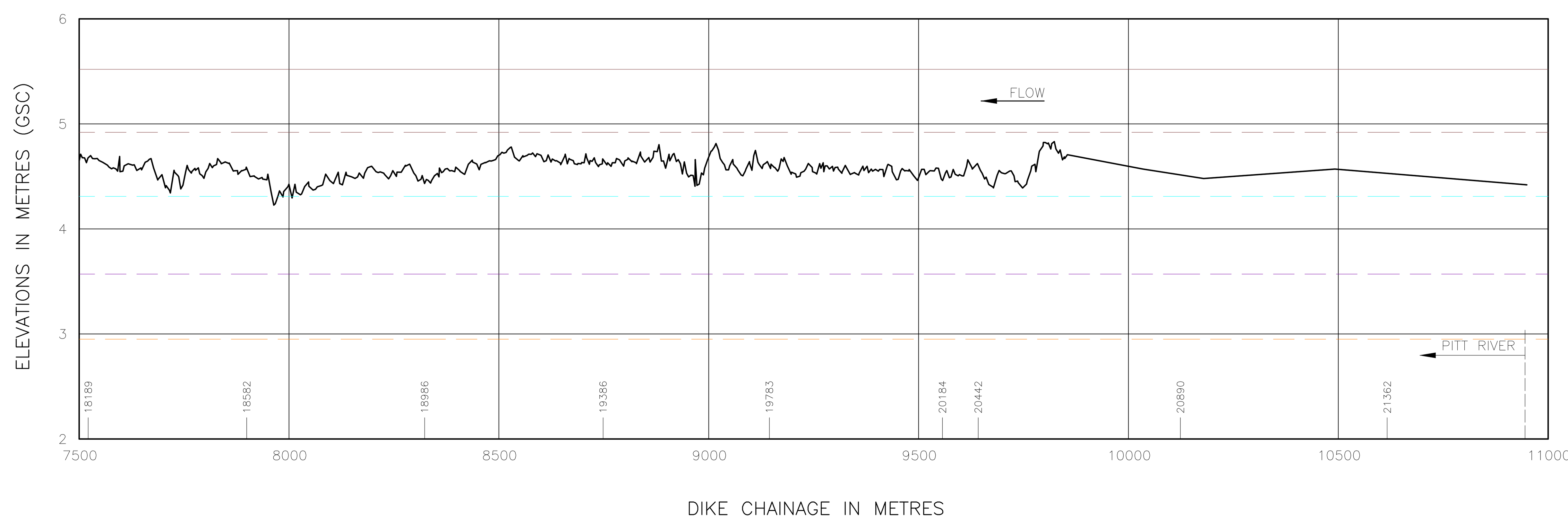
DRAWING NUMBER 34743-10
SHT.No. 1/1
REV. 0

nhc-van: \ 4743-DIKES

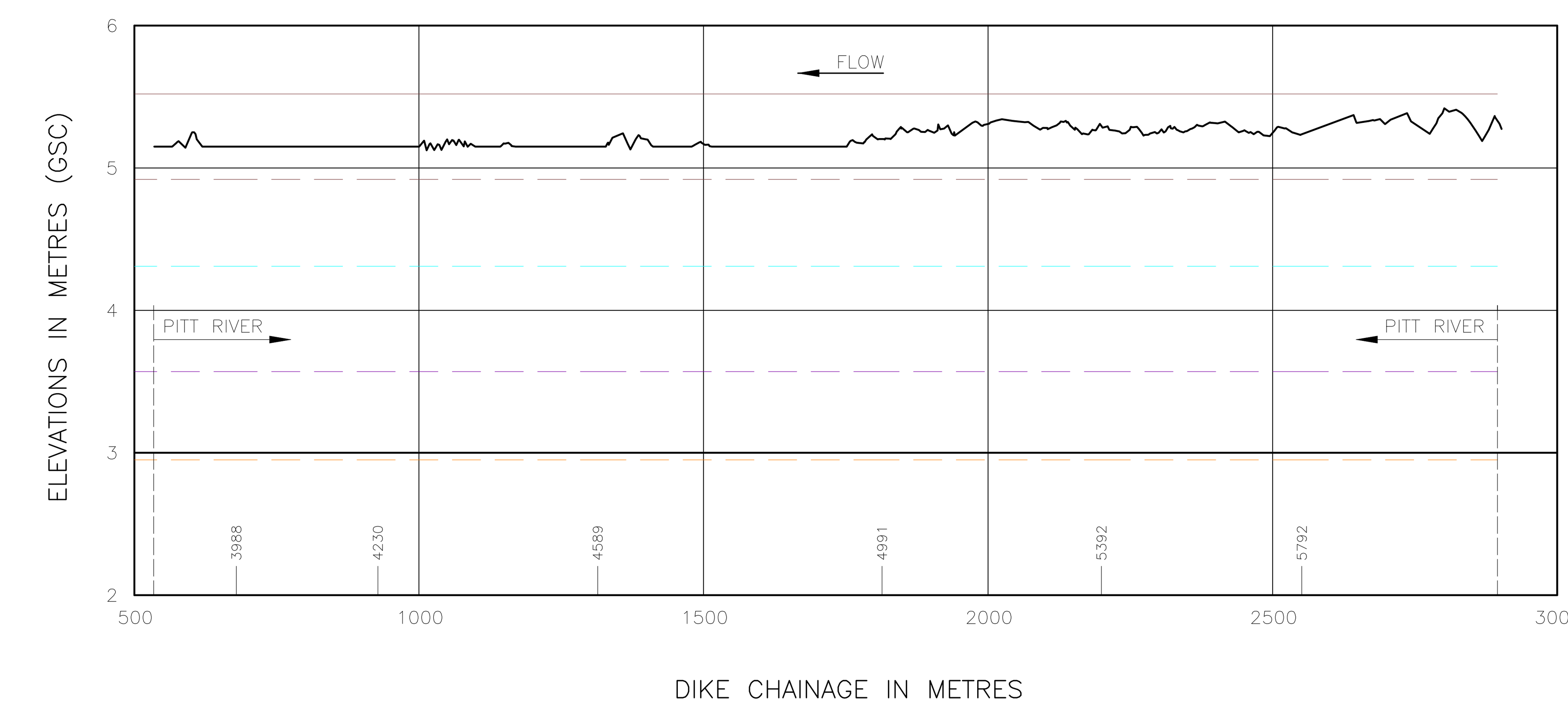


PITT POLDER DIKE

(MAIN SOURCE FOR EXISTING DIKE IS 2005 LiDAR.
PROFILE FROM DIKE CHAINAGE 9855 TO 10950 TAKEN FROM 1960'S DWG SUPPLIED BY PITT MEADOWS)

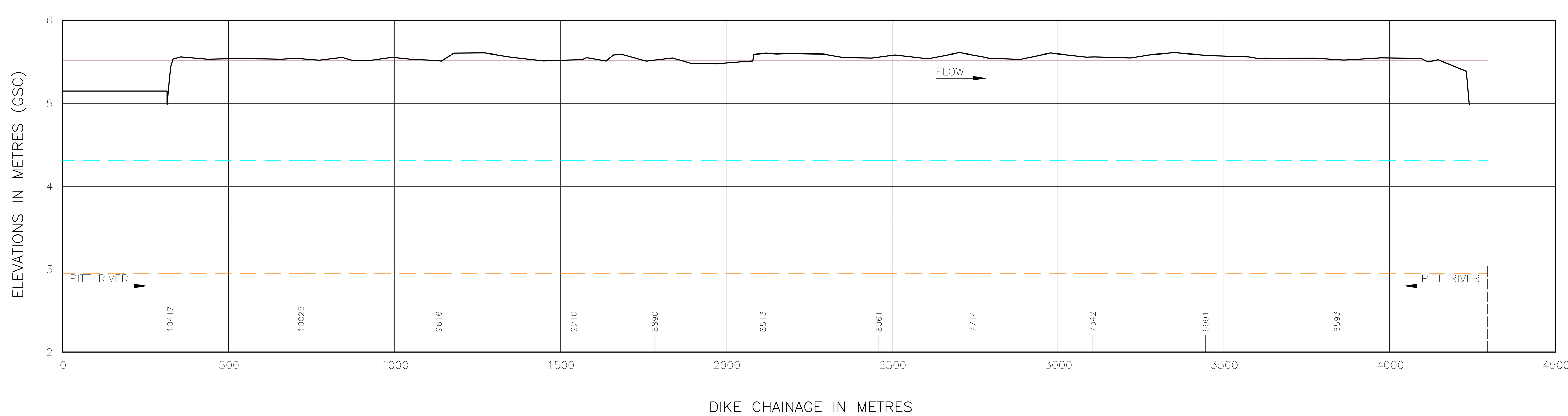


PITT POLDER DIKE (continued)



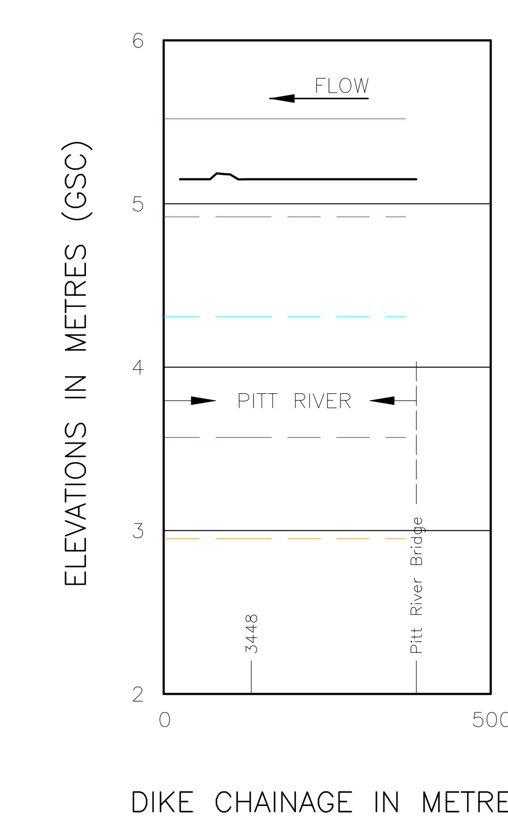
PITT MEADOWS NORTH DIKE

(EXISTING DIKE TAKEN FROM DISTRICT OF PITT MEADOWS, 2003)



PITT DIKE NORTH OF ALOUETTE RIVER

(MAIN SOURCE FOR EXISTING DIKE IS ISL ENGINEERING AND LAND SERVICES, 2007.
PROFILE FROM DIKE CHAINAGE 0 TO 314 TAKEN FROM FRFCP OPERATION & MAINTENANCE MANUAL, 1986)



PITT MEADOWS MIDDLE DIKE

(EXISTING DIKE TAKEN FROM DISTRICT OF PITT MEADOWS, 2003)

SCALE:

HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

northwest hydraulic consultants

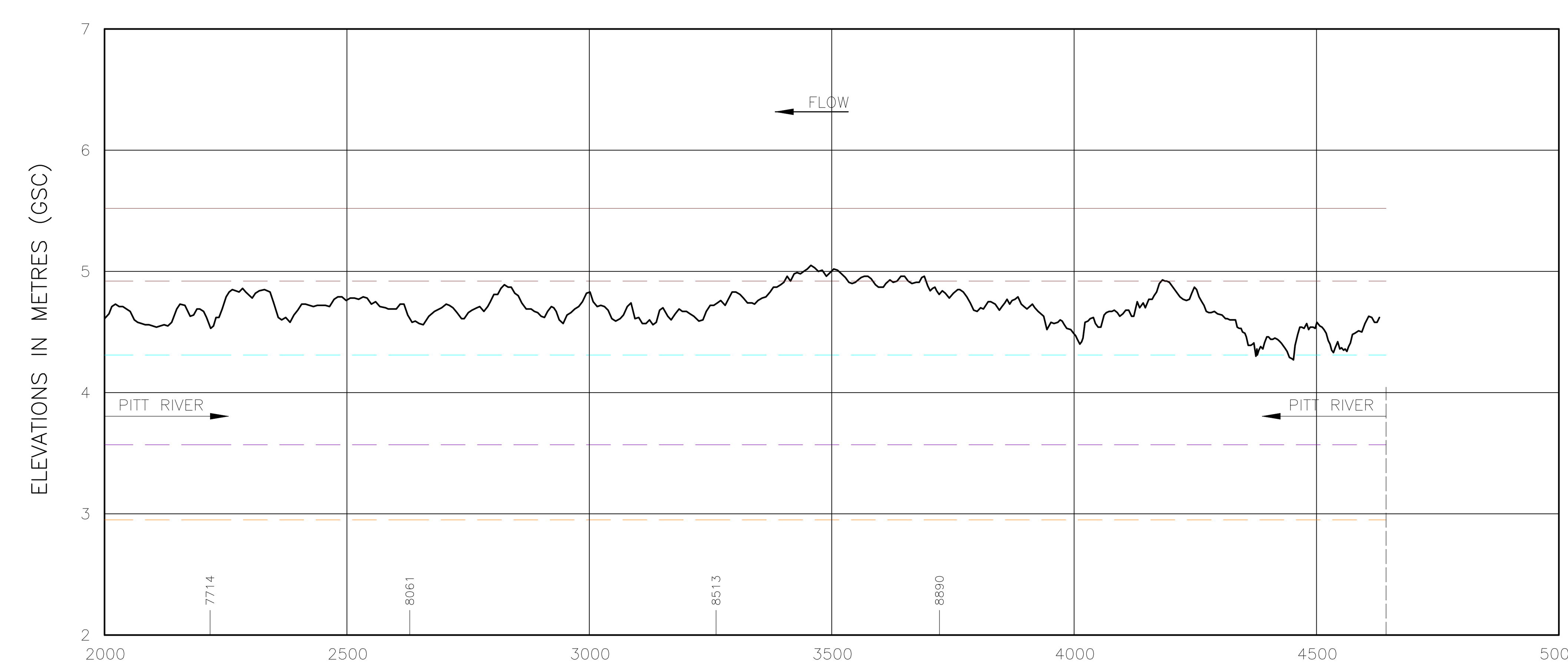
BC Ministry of Environment Fraser River Hydraulic Model Update	SHEET SIZE D
Dike Crest and Flood Profile Comparison District of Pitt Meadows	SCALE AS NOTED DATE 12 MAR 08
DRAWING NUMBER 34743–11	SHT.No. 1/1 REV. 0

nhc–van: \ 4743–DIKES

DIKE CHAINAGE IN METRES

PORT COQUITLAM DIKE

(EXISTING DIKE TAKEN FROM ASSOCIATED ENGINEERING, 2007)



DIKE CHAINAGE IN METRES

COQUITLAM DIKE

(EXISTING DIKE TAKEN FROM UNDERHILL & UNDERHILL/MINISTRY OF ENVIRONMENT, 2006)

SCALE:

HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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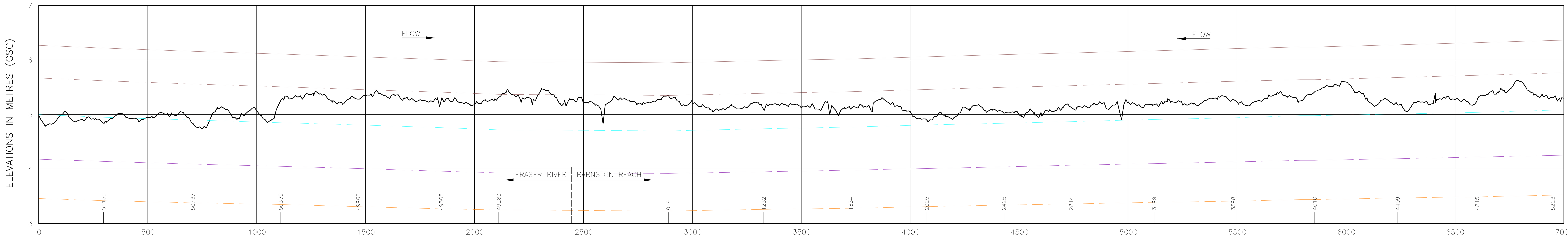
BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
City of Port Coquitlam
City of Coquitlam

SHEET SIZE	D
SCALE	AS NOTED
DATE	12 MAR 08

DRAWING NUMBER	SHT.No.	REV.
34743-12	1/1	0

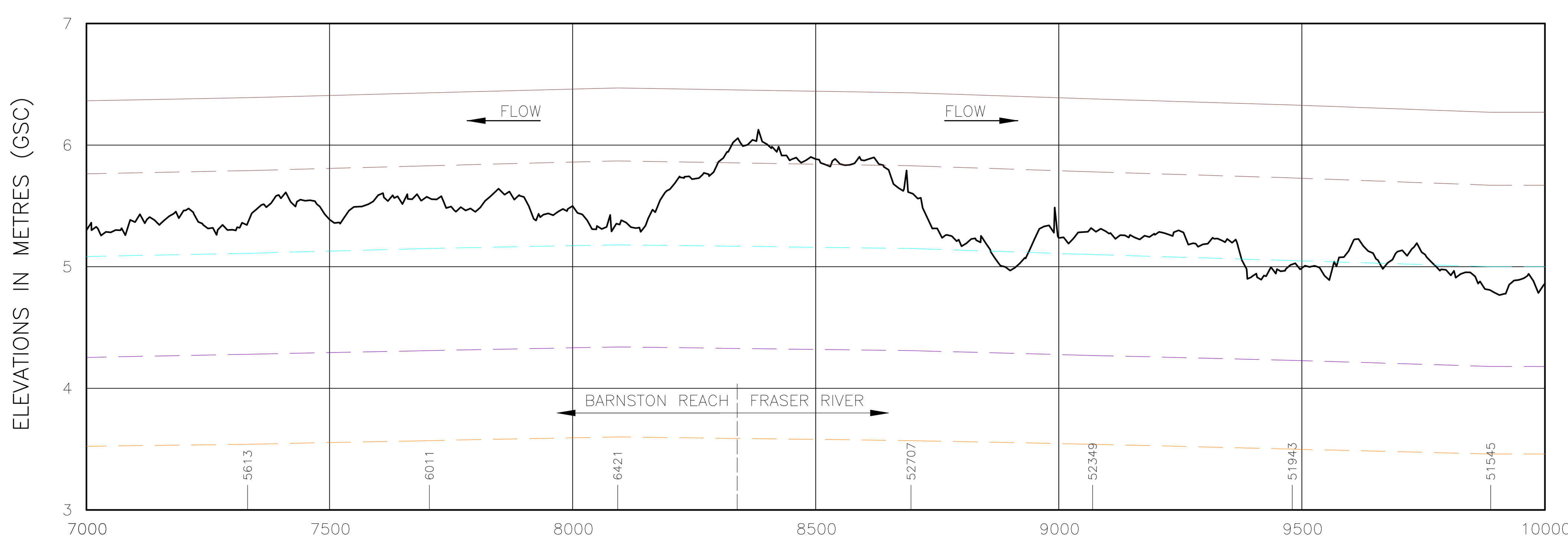
nhc-van: \ 4743-DIKES



DIKE CHAINAGE IN METRES

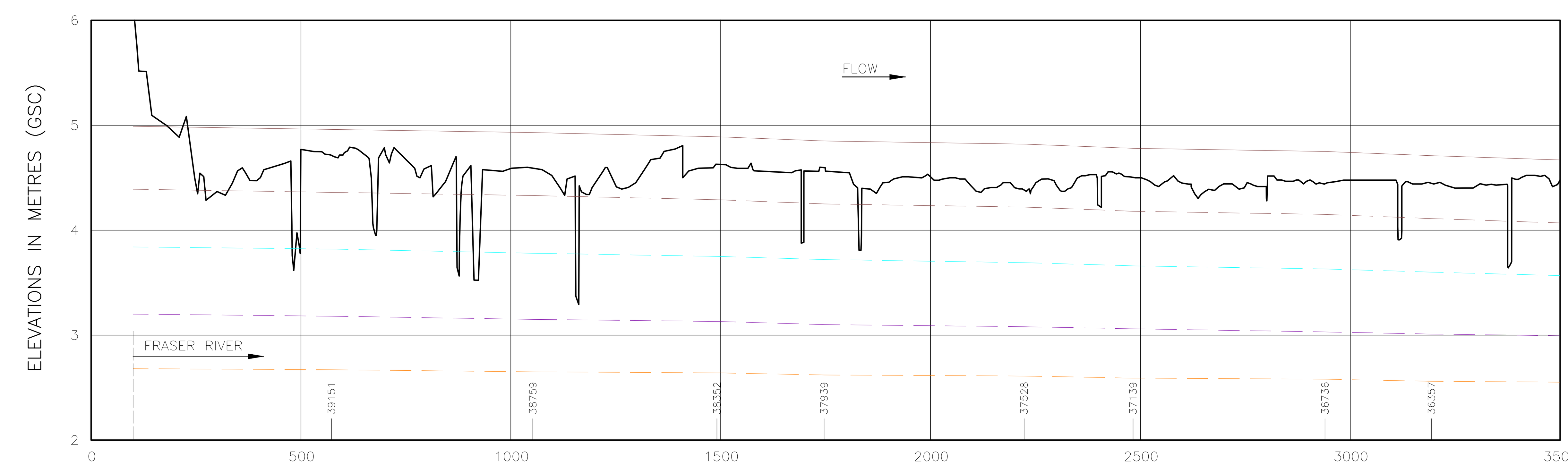
BARNSTON ISLAND DIKE

(EXISTING DIKE TAKEN FROM 2005 LIDAR, DIKE STATIONS APPROXIMATELY AS SHOWN ON DWG 4346-H, MARCH 1962, BC DEPT. OF LANDS AND FORESTS)



DIKE CHAINAGE IN METRES

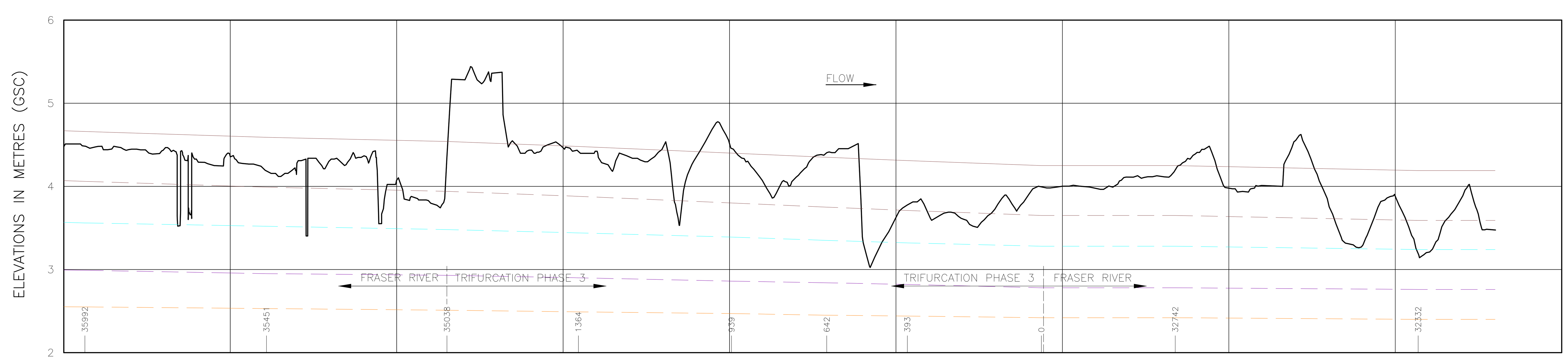
BARNSTON ISLAND DIKE (continued)



DIKE CHAINAGE IN METRES

SURREY DIKE

(EXISTING DIKE TAKEN FROM CITY OF SURREY, 2003)



DIKE CHAINAGE IN METRES

SURREY DIKE (continued)

SCALE:

HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
6. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
Electoral District A
City of Surrey

SHEET SIZE	SCALE	DATE
D	AS NOTED	12 MAR 08

DRAWING NUMBER	SHT.No.	REV.
34743-13	1/1	0

nhc-van: \ 4743-DIKES

DIKE CHAINAGE IN METRES

QUEENSBOROUGH DIKE

(EXISTING DIKE TAKEN FROM FRFCP OPERATION & MAINTENANCE MANUAL, 1976)

SCALE:

HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WINTER DESIGN PROFILE BASED ON 200–YEAR WINTER FLOWS AND THE FOLLOWING OCEAN LEVELS: POINT ATKINSON: 2.89m; NORTH ARM: 2.88m; MIDDLE ARM: 2.87m; MAIN ARM: 2.84m; CANOE PASS: 2.78m
5. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
6. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
7. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

EXISTING DIKE CREST
UPDATED DESIGN FLOOD WATER SURFACE
UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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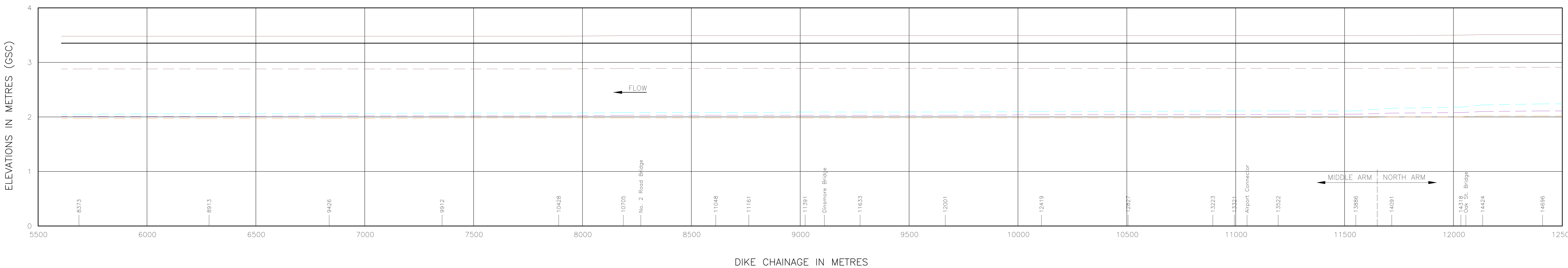
BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
City of New Westminster

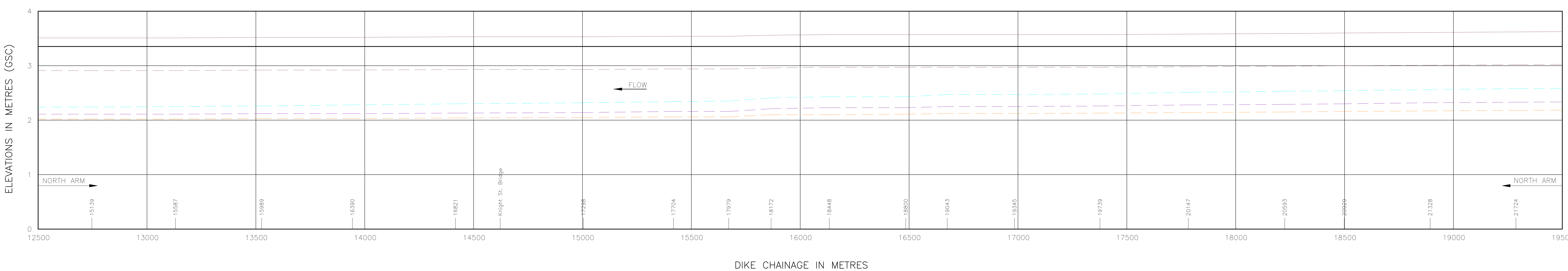
SHEET SIZE D
SCALE AS NOTED
DATE 12 MAR 08

DRAWING NUMBER	SHT.No.	REV.
34743–14	1/1	0

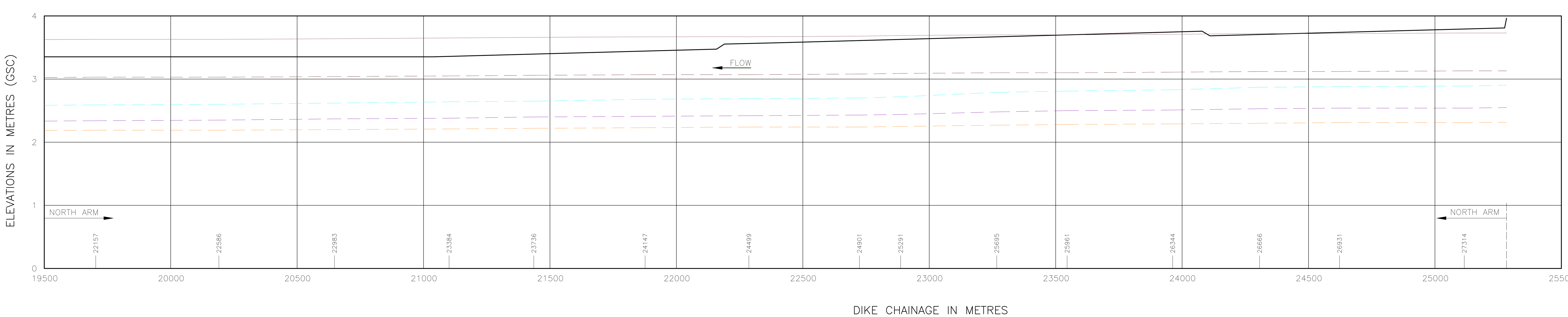
nhc–van: \ 4743–DIKES



RICHMOND NORTH DIKE
(EXISTING DIKE TAKEN FROM FRFCP CONTRACT, 1974)



RICHMOND NORTH DIKE (continued)



RICHMOND NORTH DIKE (continued)

SCALE:
HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:
1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE: 17,000 m^3/s AT HOPE; 18,900 m^3/s AT MISSION; 19,650 m^3/s AT NEW WESTMINSTER (REVIEW RECOMMENDED)
4. WINTER DESIGN PROFILE BASED ON 200–YEAR WINTER FLOWS AND THE FOLLOWING OCEAN LEVELS: POINT ATKINSON: 2.89m; NORTH ARM: 2.88m; MIDDLE ARM: 2.87m; MAIN ARM: 2.84m; CANOE PASS: 2.78m
5. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
6. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
7. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND
- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
City of Richmond

SHEET SIZE	D
SCALE	AS NOTED
DATE	12 MAR 08
DRAWING NUMBER	34743–15
SHT.No.	1/1
REV.	0

nhc–van: \ 4743–DIKES

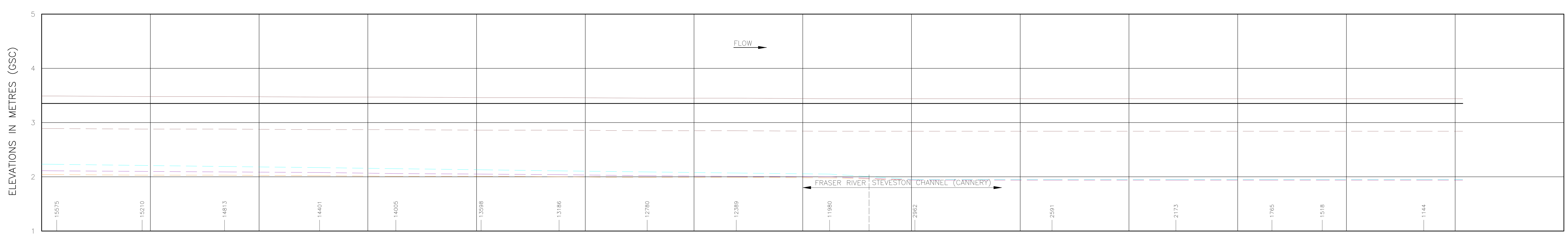
DIKE CHAINAGE IN METRES

RICHMOND SOUTH DIKE

(EXISTING DIKE TAKEN FROM FRFCP CONTRACT DRAWINGS, 1977)

DIKE CHAINAGE IN METRES

RICHMOND SOUTH DIKE (continued)



DIKE CHAINAGE IN METRES

RICHMOND SOUTH DIKE (continued)

SCALE:

HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WINTER DESIGN PROFILE BASED ON 200–YEAR WINTER FLOWS AND THE FOLLOWING OCEAN LEVELS: POINT ATKINSON: 2.89m; NORTH ARM: 2.88m; MIDDLE ARM: 2.87m; MAIN ARM: 2.84m; CANOE PASS: 2.78m
5. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
6. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
7. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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BC Ministry of Environment
Fraser River Hydraulic Model Update

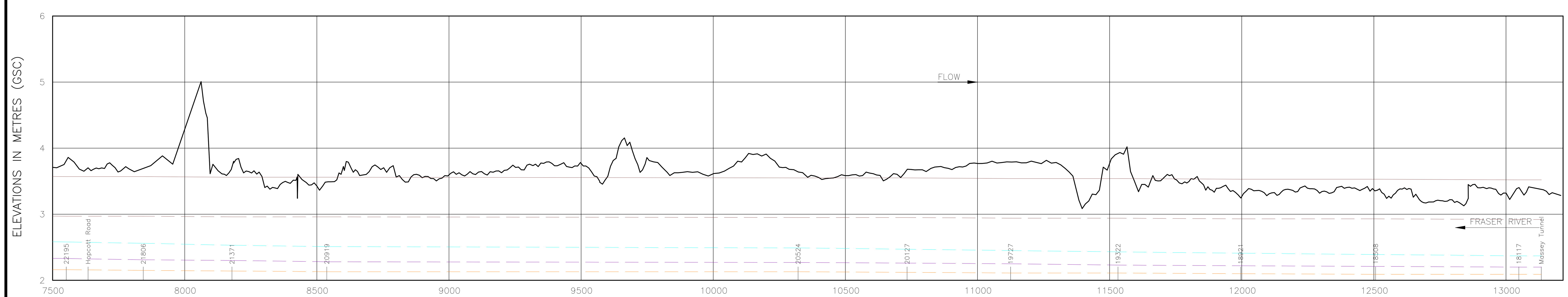
Dike Crest and Flood Profile Comparison
City of Richmond

SHEET SIZE D
SCALE AS NOTED
DATE 12 MAR 08

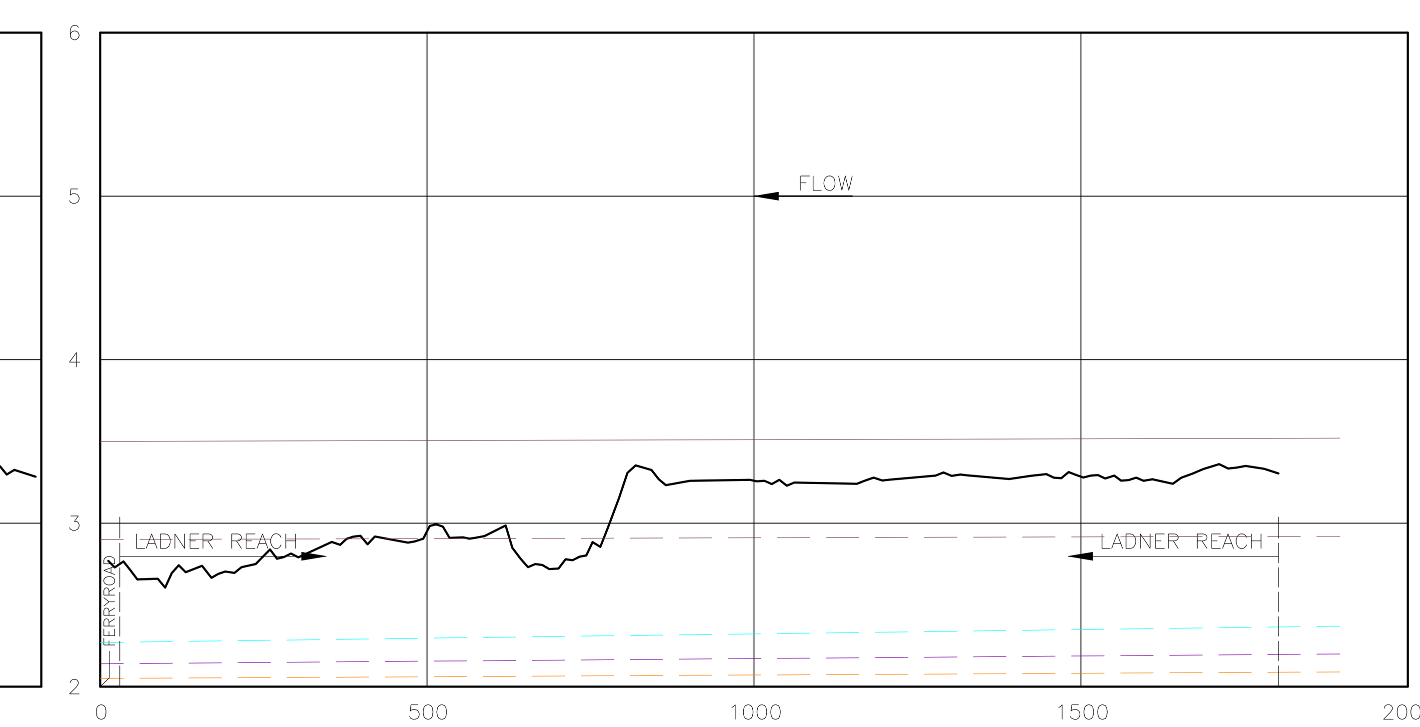
DRAWING NUMBER 34743–16
SHT.No. 1/1
REV. 0

nhc–van: \ 4743–DIKES

RIVER ROAD DIKE
(EXISTING DIKE TAKEN FROM CORPORATION OF DELTA, 1999 and 2000)



RIVER ROAD DIKE (continued)



RIVER ROAD DIKE (continued)

RIVER ROAD DIKE (continued)

SCALE:

HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:
1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WINTER DESIGN PROFILE BASED ON 200-YEAR WINTER FLOWS AND THE FOLLOWING OCEAN LEVELS: POINT ATKINSON: 2.89m; NORTH ARM: 2.88m; MIDDLE ARM: 2.87m; MAIN ARM: 2.84m; CANOE PASS: 2.78m
5. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
6. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
7. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

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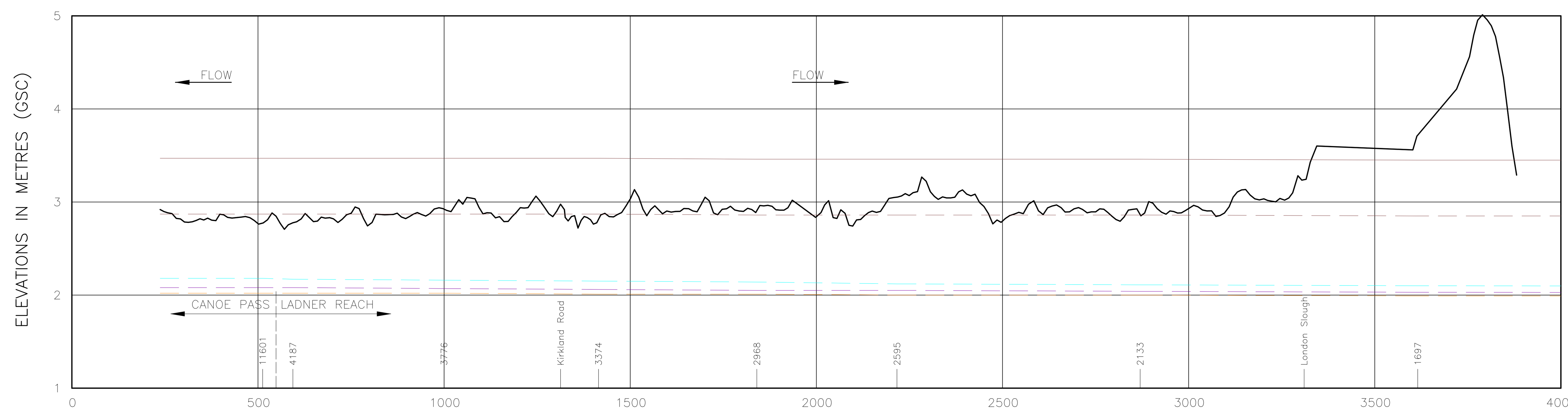
BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
Corporation of Delta

SHEET SIZE	D
SCALE	AS NOTED
DATE	12 MAR 08
DRAWING NUMBER	34743-17
SHT.No.	1/1
REV.	0

nhc-van: \ 4743-DIKES



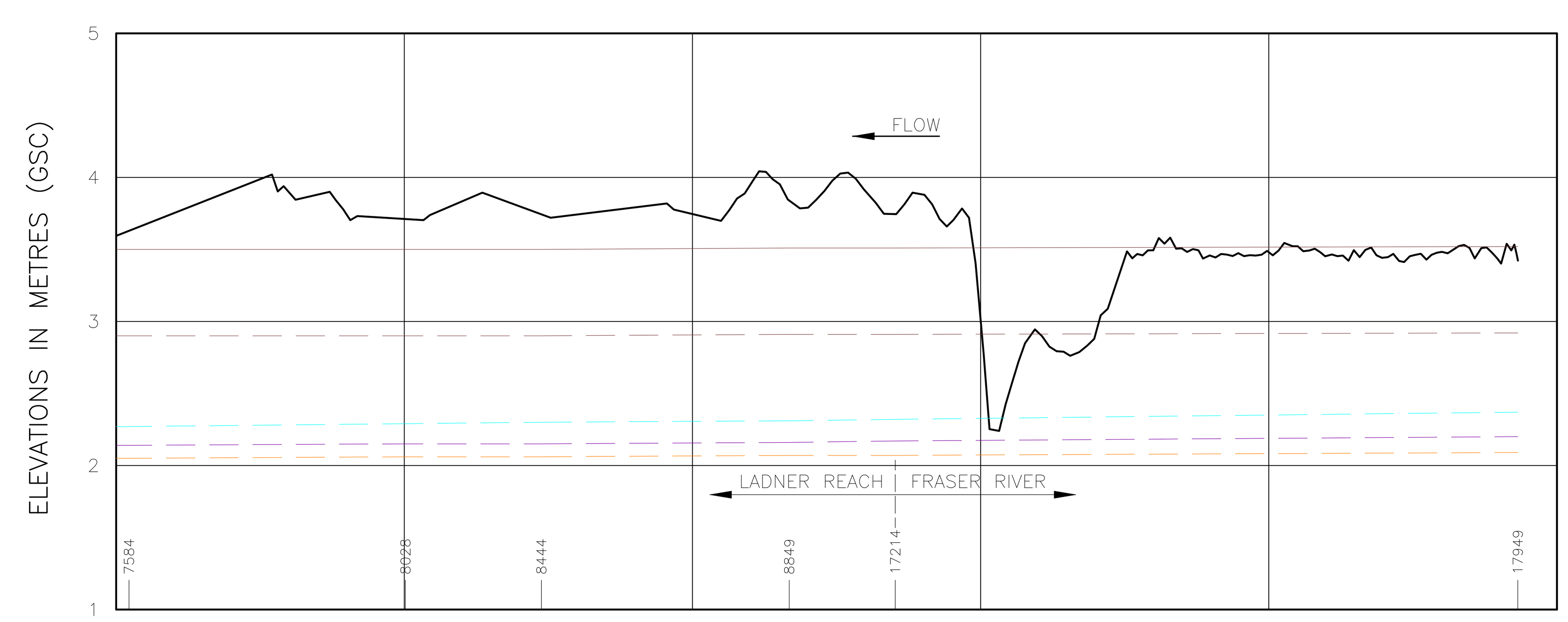
DIKE CHAINAGE IN METRES

WESTHAM DIKE

(EXISTING DIKE TAKEN FROM CORPORATION OF DELTA, 1999 and 2000)

DIKE CHAINAGE IN METRES

WESTHAM DIKE (continued)



DIKE CHAINAGE IN METRES

MARINA GARDENS DIKE

(EXISTING DIKE TAKEN FROM CORPORATION OF DELTA, 1999 and 2000)

SCALE:

HORIZONTAL 1 : 10,000
VERTICAL 1 : 40

NOTES:

1. DIKE CHAINAGES ARE AS SHOWN IN O&M MANUALS OR ON OTHER DRAWINGS
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. FLOWS USED FOR THE FRESHET DESIGN FLOOD ARE:
   17,000 m^3/s AT HOPE
   18,900 m^3/s AT MISSION
   19,650 m^3/s AT NEW WESTMINSTER
   (REVIEW RECOMMENDED)
4. WINTER DESIGN PROFILE BASED ON 200-YEAR WINTER FLOWS AND THE FOLLOWING OCEAN LEVELS: POINT ATKINSON: 2.89m; NORTH ARM: 2.88m; MIDDLE ARM: 2.87m; MAIN ARM: 2.84m; CANOE PASS: 2.78m
5. WATER LEVELS OF 6m, 7m AND 8m AT MISSION ASSUME FRESHET TIDE OF RECORD.
6. DIKE CREST ELEVATIONS WERE DERIVED FROM VARIOUS SOURCES AND REPRESENT THE BEST INFORMATION MADE AVAILABLE. ACTUAL ELEVATIONS MAY VARY AND SHOULD BE VERIFIED BY EACH DIKING AUTHORITY.
7. FOR DIKE LOCATION, LAYOUT AND CHAINAGE REFER TO MAP NO.4 AND 5.

LEGEND

- EXISTING DIKE CREST
- UPDATED DESIGN FLOOD WATER SURFACE
- UPDATED DESIGN FLOOD WATER SURFACE + 0.6m FREEBOARD
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 6m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 7m
- FLOOD WATER SURFACE FOR MISSION WATER LEVEL = 8m

NO.	DATE	REVISION	DR.	CHK.	APPR.

northwest hydraulic consultants

BC Ministry of Environment
Fraser River Hydraulic Model Update

Dike Crest and Flood Profile Comparison
Corporation of Delta

SHEET SIZE	SCALE	DATE	DRAWING NUMBER	SHT.No.	REV.
D	AS NOTED	12 MAR 08	34743-18	1/1	0

nhc-van: \ 4743-DIKES

APPENDIX A

WSC INFORMATION

R-4

REPORT FORM

Month Feb 19 1934

DEPARTMENT OF THE INTERIOR

WATER POWER BRANCH

OTTAWA

Report on Fraser river at Hope — 1894 high water marks

At point 1400 ft above bridge.

Mr. C. Lindstrom CPR Sec Foreman Hope (our observer) was 14 years old at time and lived at Haig Station on CPR. He states canoes with mail had to go over flat at landing (Yale road). He estimates flat was covered 2 feet deep.

The elev of flat is ~~[illegible]~~ 23.57 or 1894 hw would be ~~[illegible]~~ 25.57 ft above gh this date (13.2 ft) or gh 38.77 feet.

Flat is about 200 ft downstream from section bunk house at Haig Station and 1400 ft more or less above bridge. Slope from bridge to this point is very small at stage 13.2 ft.

At point 2600 ft about 1/2 mile below bridge.

Mr. Cottrell showed me where step of old store house was in front of Post office & his store. 1894 hw came to door knob of the warehouse according to several old timers. The estimated position of door knob was shown by Mr Cottrell and found to be 24.94 ft above present W.L. of 13.2 ft. which would make gh 38.14 ft for 1894 flood. Slope from bridge to this point is more than ~~from~~ above bridge.

Data by Mr. Beard was not found to check and as he was only 7 at time and the roads have no doubt been filled in are not considered reliable.

[illegible]

COPY

Feb. 19, 1934

Report on	Fraser river at Hope	1894 high water marks

At point 1400 ft. above bridge.

Mr. C. Landstrum, C.P.R. Sec. Foreman, Hope (our observer) was 14 years old at time and lived at Haig Station on C.P.R. He states canoes with mail had to go over flat at landing (Yale road). He estimates flat was covered 2 feet deep.

The elev. of flat is 23.57 or 1894 hw would be 25.57 ft. above gh this date (13.2 ft.) or gh 38.77 feet.

Flat is about 200 ft. downstream from section bunk house at Haig Station and 1400 ft. more or less above bridge. Slope from bridge to this point is very small at stage 13.2 ft.

At point 2600 ft. about ½ mile below bridge.

Mr. Cottrell showed me where step of old store house was in front of Post Office and his store. 1894 hw came to door knob of this warehouse according to several old timers. The estimated position of door knob was shown by Mr. Cottrell and found to be 24.94 ft. above present W.L. of 13.2 ft. which would make gh 38.14 ft. for 1894 flood. Slope from bridge to this point is more than above bridge.

Data by Mr. Beard was not found to check and as he was only 7 at time and the roads have no doubt been filled in are not considered reliable.

"G.H. Whyte"

Original filed with bench station descriptions in hydro office
[illegible]

NOT FOR DISTRIBUTION

Environment Canada Environnement Canada
Meteorological Service of Canada
201 - 401 Burrard St.
Vancouver, BC V6C 3S5

Your file Votre référence

November 16, 2007

Our file Notre reference

Bruce Letvak, Head, Hydrology Programs & Standards
Science and Information Branch
BC Ministry of Environment
PO Box 9358
Station Provincial Government
Victoria V8W 9M2

Dear Mr. Letvak:

Re: Fraser Flows at Hope and Mission gauges and Harrison River at Lake outlet

Water Survey of Canada (WSC) wishes to reply to some of the statements made by Northwest Hydraulic Consultants (NHC) in their Memorandum of September 20th, 2007 to Ron Henry of MOE Surrey. Our purpose is three-fold; to correct some inaccuracies, to place the historical record in context and finally to try to define the questions that must be addressed if monitoring on the Fraser River is to provide information that can support modeling activities. Please see the following attachment.

We look forward to working with you to improve our delivery of information and services to stakeholders based on the priorities you identify.

Sincerely Yours

Bruno Tassone, P. Eng.
Manager, Water Survey Division
Meteorological Service of Canada
201 - 401 Burrard St.
Vancouver, BC V6C 3S5
Tel (604) 664-4003
Fax (604) 664-9004

Fraser Flows at Hope and Mission gauges and Harrison River at Lake outlet

Measurement History

The description of the history of measurements collected at Hope and Mission since 1989 was not fully accurate. For example, the memorandum states that no measurements were collected at Mission between 1989 and 1998 where as 17 measurements were collected during this period. Table 1 lists the measurements conducted at Hope and Mission from 1989 to the present day.

While the picture presented by NHC may not have been fully accurate, it is clear that the number of measurements collected is not sufficient to clearly resolve the morphological dynamics of the river. There are two main reasons for this deficiency; firstly a reduction in funding to the program resulted in the loss of the infrastructure, in the form of boats and staff, required to deliver a monitoring program by conventional means. Secondly, in the absence of the ability to conduct conventional current meter measurements alternative technologies were being developed and employed. These new technologies, Moving Boat and ADCP, were in their infancy; hence protocols were evolving as were the experience and knowledge of our staff. We make these points not to justify our shortcomings but to emphasize our position that the delivery of high quality data for the Fraser River requires adequate dedicated resources in terms of trained staff, appropriate technology and equipment infrastructure.

Fraser River at Hope Rating Curve

The NHC Memorandum states that the 2007 measurements collected at Fraser River at Hope conform more closely to the 1964 curve than the current curve from 1987. While in a strictly numerical sense this is true it is worth considering the confidence bounds of WSC data and how they should be interpreted.

WSC publishes data to a precision of ± 5%. This is not a computed confidence interval but a blanket estimate of uncertainty applied to all data which includes measurement error as well variability in the rating relation. While this estimate rests on sound knowledge and experimentation the actual precision of WSC data is dependent on site specific factors as well the efficacy of our methodology.

The conditions at Fraser River at Hope can be considered extreme. At high flow the river is deep and fast; all measurements, be they conventional with a 300lb weight or ADCP measurements from a jet boat, are challenging to conduct. As NHC demonstrate in their memorandum, within-event hysterisis effects alone can introduce uncertainty on the order of ±5%.

When evaluating whether a new rating curve should be applied at a particular station WSC considers whether a pervasive morphological change has occurred which will be detected by subsequent measurements. Given the characteristics of the Hope measurement site a suite of measurements is required to identify such a change.

The history of measurements collected at Hope since 2001 indicates a shift in the curve due to aggradation that has occurred in the channel. Consequently a new curve, Curve #9, was drawn. This curve is based on the trend of the 17 measurements collected during this period, not on two measurements collected during 2007 which minimally exceed the ±5% criteria.

Future considerations

Precision of WSC Data

The Fraser River Hydraulic Model is an important addition to the body of knowledge regarding the Fraser River and will become a valuable management tool. WSC fully supports this effort and wishes to provide the highest quality data possible.

It would be useful to determine the confidence level of discharge measurements, as well as discharges predicted by rating curves, which is required by NHC to support the water level predictions. This would allow WSC to assess the feasibility and cost of providing data to this level of precision.

WSC publishes computed discharges to a precision of ±5%. The Fraser River Hydraulic model uses WSC discharge data as its primary input for calibration as well as the upstream boundary condition. The precision of water levels predicted by the model are dependent to some extent on the precision of the WSC discharge data. If the rating curve at Mission were used in reverse, to predict a water level, the uncertainty in the discharge would translate to an uncertainty band around the water level prediction. A discharge of 10 000 m^3/s ±5% would translate to an uncertainty band of 0.5m around the water level prediction. While this may not be a fully valid analogy it would be prudent to ensure that the precision of the water level prediction made by the model is not assumed to be better than the precision of the calibration data.

Real-time data considerations

When the model is used in forecast mode care should be taken when comparing modeled water levels to observed water levels obtained via WSC's real time web site. Water levels can drift from the reference datum for several reasons, such as orifice movements or sedimentation restricting intakes to wells. The real time data is uncorrected and subject to revision if station visits reveal a discrepancy between the water level at the reference gauge and the recorder. For example, in figure 3 of the NHC memorandum the water level observation collected on June 11 at15:50 in conjunction with the measurement plots 0.031m lower than the real-time water level. Once a correction has been applied to account for sensor drift, however, these two water levels are coincident.

If the Fraser River Hydraulic Model is dependent on real time WSC data and if the validity of the model predictions is dependent on the quality of WSC real time data it may be necessary to perform quality assurance more frequently than normal WSC operations prescribe. Naturally, increased resources would be required to deliver an enhanced level of service.

As mentioned by NHC, the discharge data for Harrison River requires correction for backwater effects from the Fraser during the freshet. WSC intends to develop a facility to enable this correction to be performed in near real time such that corrected discharge for Harrison River will be available on the real time site with a six or twelve hour delay.

Alternate hydrometric methods for estimating discharge

WSC generally estimates discharge using the stage-discharge method. Here a rating relation is derived between the river stage and the measured discharge. Stage, the depth of the river above a datum, is monitored continuously and the rating relation is used to estimate discharge. While this method is well established and widely used it is not the only method available.

At Mission the tidal influence introduces variability into the rating relation. NHC modeled fluctuations in discharge caused by tidal fluctuations which the stage-discharge method could not replicate as it assumes a single possible discharge for each water level. It may be prudent to test the use of an index velocity model for computing discharge at this station. This method involves using an acoustic velocity meter to continuously monitor velocity, relating the velocity in an index volume to mean channel velocity and then calculating discharge based on the velocity and channel area. Channel area is computed from the measured stage. This method still requires calibration by numerous discharge measurements over the range of expected flows and the model precision of the discharge prediction remains at ± 5%. As the velocity is monitored quasi-continuously the temporal resolution of the discharge data is improved and the influence of tidal backwater is removed as water level is not used to calculate discharge. It will likely take at least two field seasons to fully test and compare these methods.

Acoustic velocity meters and the index velocity model have been used with success in numerous locations in Canada and the US. The conditions at Fraser River at Mission are suitable for the deployment of the equipment and execution of the technique.

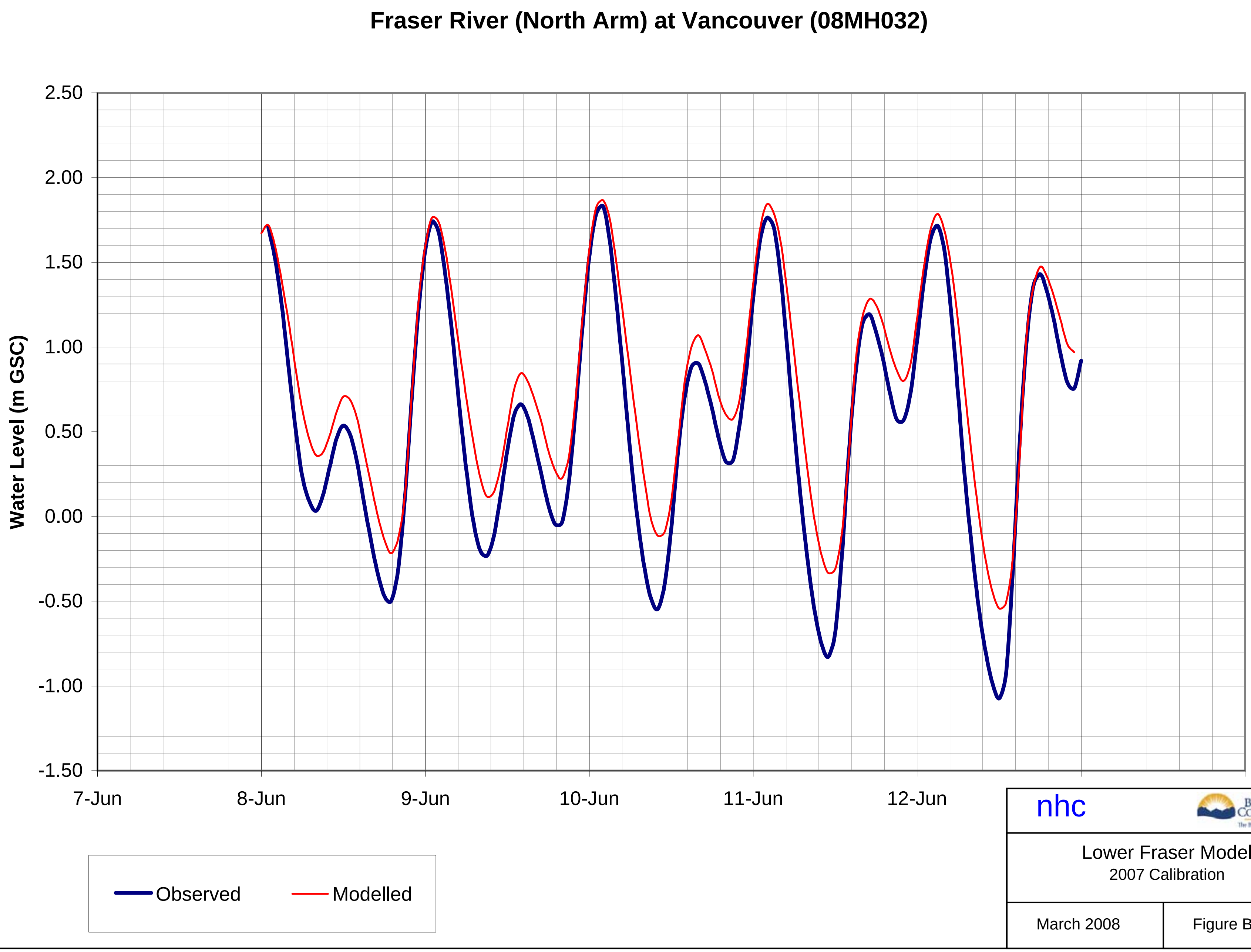
Table 1. History of measurements at Fraser River at Hope and Fraser River at Mission

Year	Fraser River at Mission Discharge (m^3/s)	*n*
1989	5170, 6400, 7930, 4590, 4740	*5*
1990	7540, 10200, 7980,	3
1991	6980, 5860	2
1992	3140	*1*
1993	9425, 7530, 5026	*3*
1997	9852	*1*
1998	4902, 4003	*2*
1999	4774, 11045, 7887, 7068	4
2000	4287, 8203, 3920	3
2001	5916	1
2002	9469, 11183, 3053,	3
2003	2358, 5599,	2
2004	2370,	1
2005	5248	1
2006	4422, 2366, 2680,	3
2007	7450, 10500, 10548, 10600, 11200, 12100, 11500, 8760, 8751, 8755,	10
Year	**Fraser River at Hope Discharge (m^3/s)**	***n***
1990	889, 5490, 8050, 6720	4
1991	971, 5030, 5100	3
1992	2140, 2150, 5620, 858	4
1993	1580	1
1994	753	1
1997	9728, 8324, 1848	3
1998	3314, 4038	2
1999	4587, 10626, 5388, 1543	4
2000	7631, 3339, 748	3
2001	4957, 1233	2
2002	3044, 7783, 8961	3
2003	882, 3320, 2440	3
2004	2680	1
2005	4760	1
2006	6150, 1750	2
2007	6240, 9830, 10300, 7400, 7123	5

APPENDIX B

CALIBRATION/VALIDATION PLOTS FOR LOWER MODEL

2007 Calibration			2002 Validation	
Plot Number	Gauge Name		Plot Number	Gauge Name
B-1	Fraser River (North Arm) at Vancouver		B-29	Fraser River (North Arm) at Vancouver
B-2	Bathslough		B-30	Bathslough
B-3	Fraser River at Byrne Creek		B-31	Fraser River at Steveston (08MH028)
B-4	Queensborough		B-32	No. 6 Road
B-5	Fraser River at Steveston (08MH028)		B-33	Nelson Road
B-6	3395 River Road		B-34	New Westminster
B-7	Elliott and River Road		B-35	Manson
B-8	62B and River Road		B-36	Fraser River at Port Mann (08MH126)
B-9	No. 6 Road		B-37	Pitt River near Port Coquitlam (08MH035)
B-10	Nelson Road		B-38	192nd Street
B-11	9600 River Road		B-39	Salmon River Confluence
B-12	New Westminster		B-40	Fraser River at Whonnock (08MH044)
B-13	Manson		B-41	Fraser River at Mission (08MH024)
B-14	Fraser River at Port Mann (08MH126)			
B-15	Pitt River at Argue Street			
B-16	Pitt River near Port Coquitlam (08MH035)			
B-17	Baynes Road			
B-18	192nd Street			
B-19	Yorkson PS			
B-20	GEB Burnco			
B-21	Salmon River Confluence			
B-22	Salmon River PS			
B-23	Albion Ferry Dock			
B-24	Fraser River at Whonnock (08MH044)			
B-25	Silverdale PS			
B-26	McLennan Creek PS			
B-27	Matsqui Slough			
B-28	Fraser River at Mission (08MH024)			

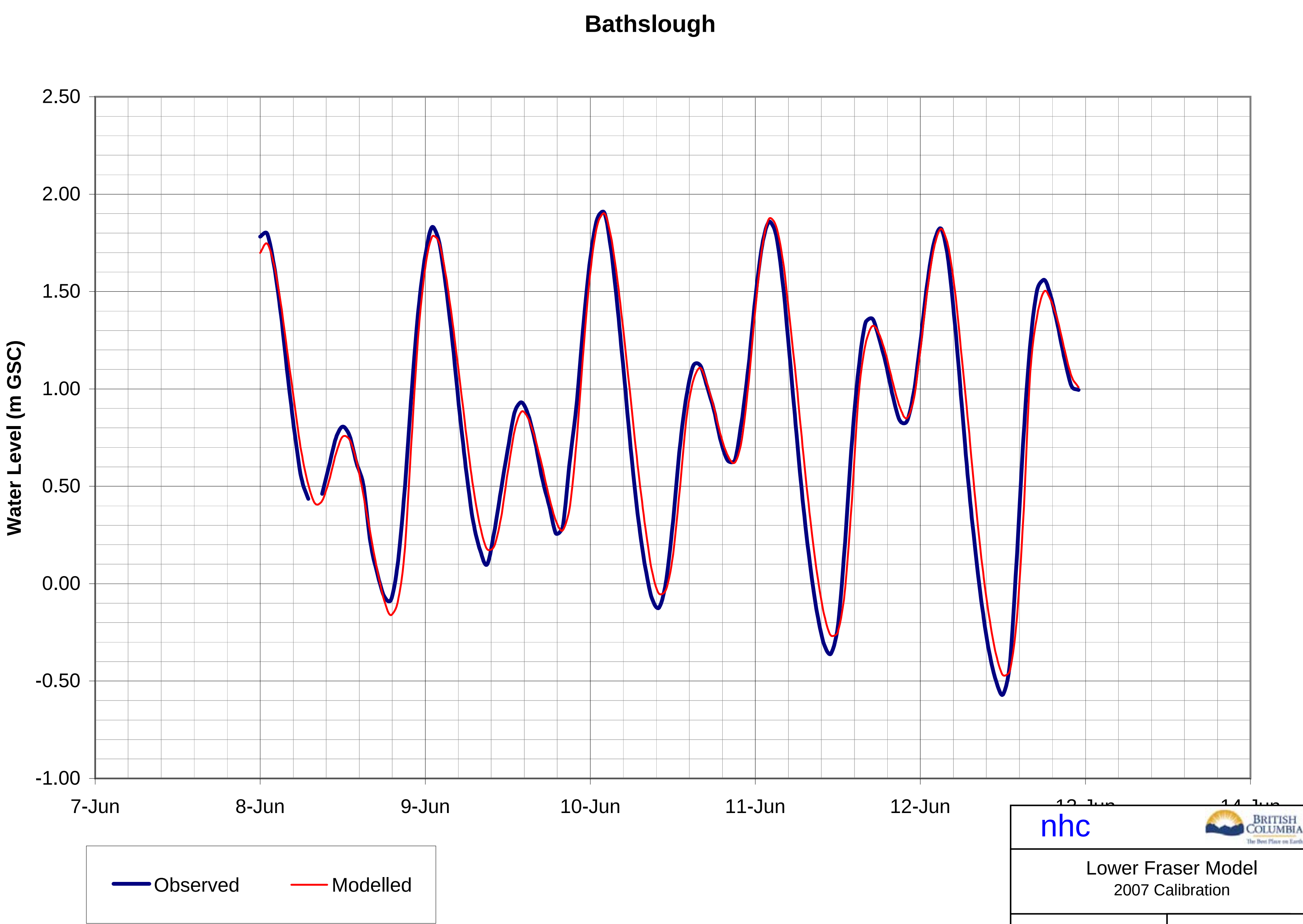


nhc

Lower Fraser Model
2007 Calibration

March 2008

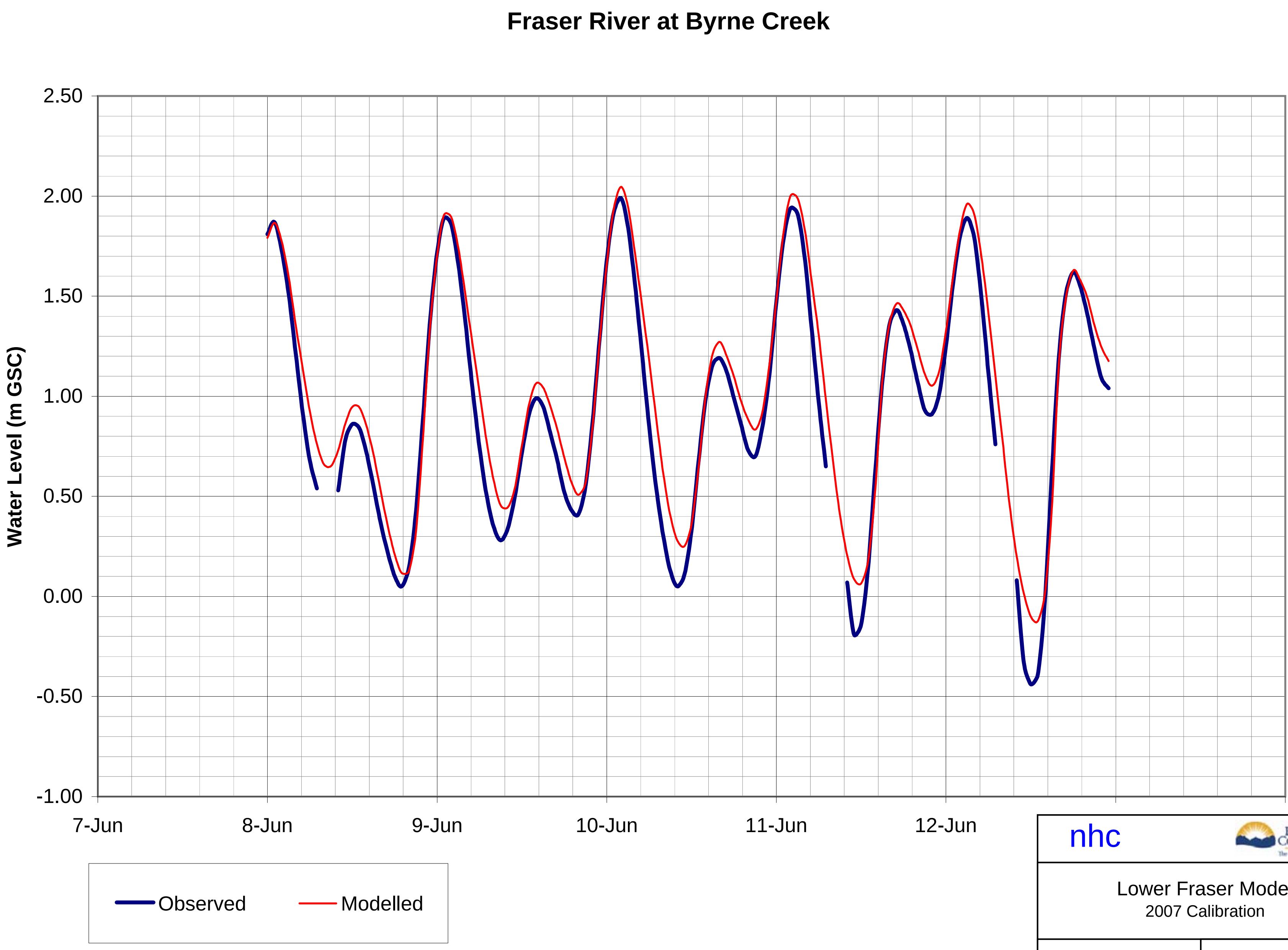
Figure B.1



nhc

Lower Fraser Model
2007 Calibration

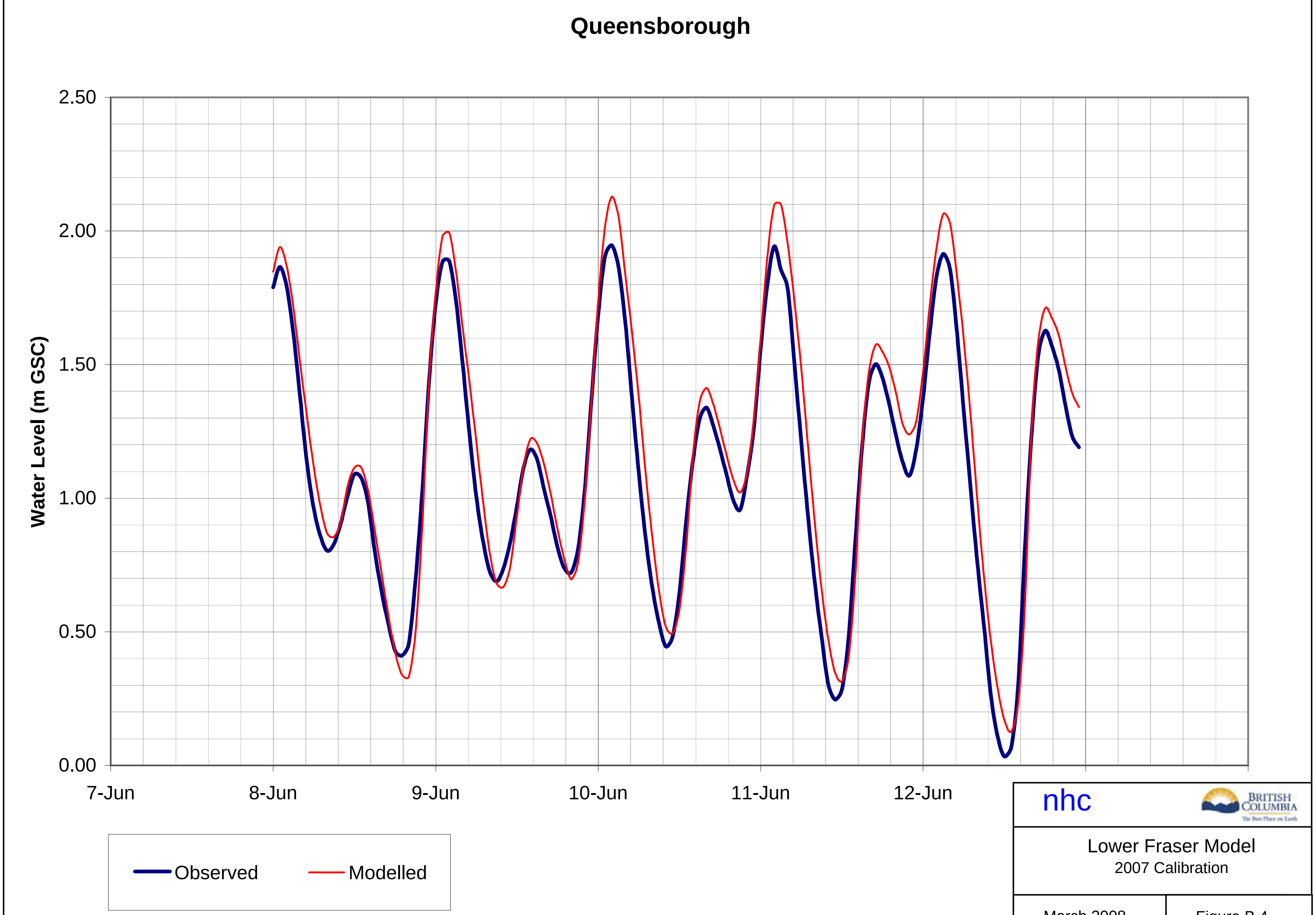
March 2008	Figure B.2



nhc

Lower Fraser Model
2007 Calibration

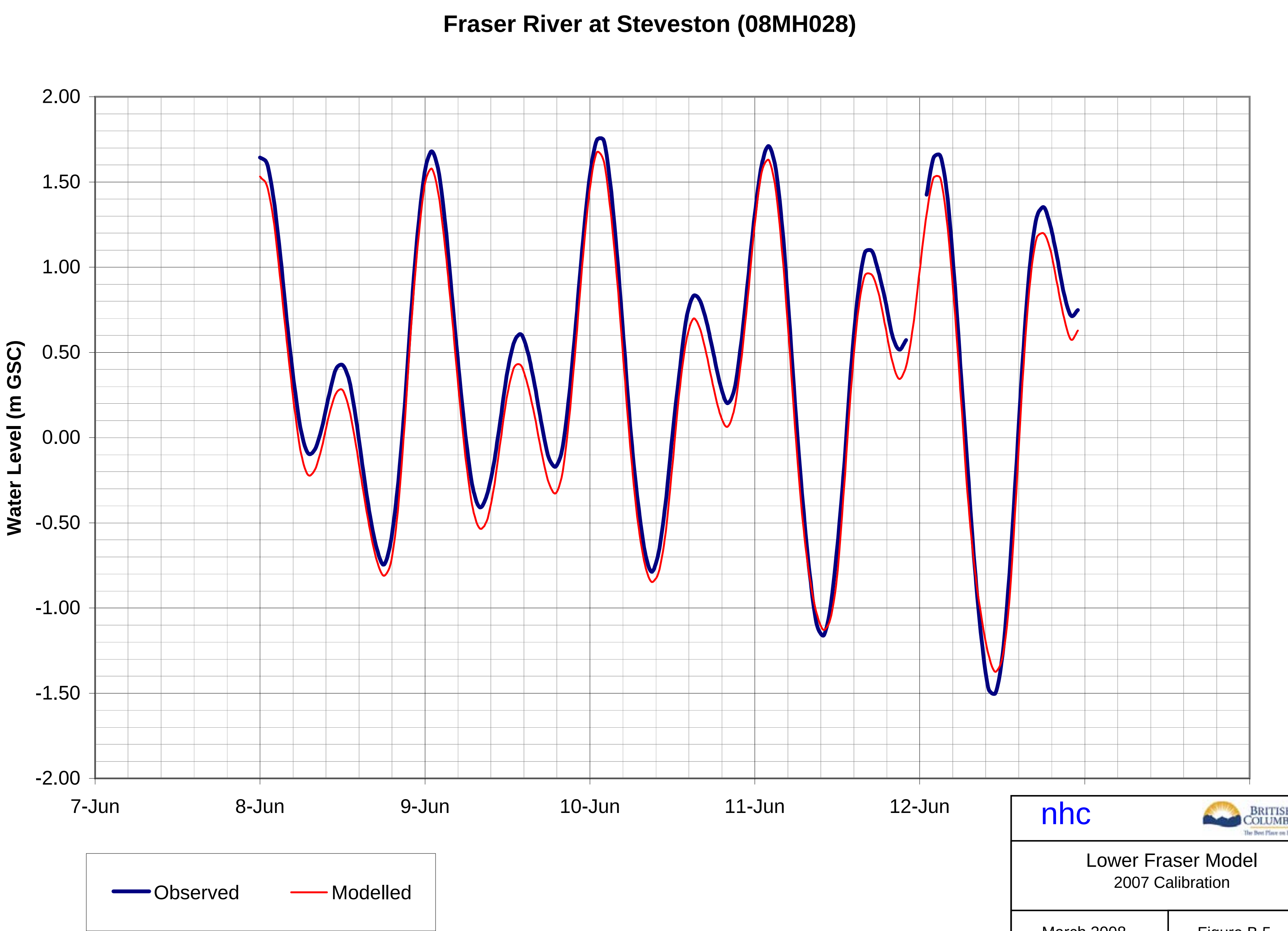
March 2008	Figure B.3



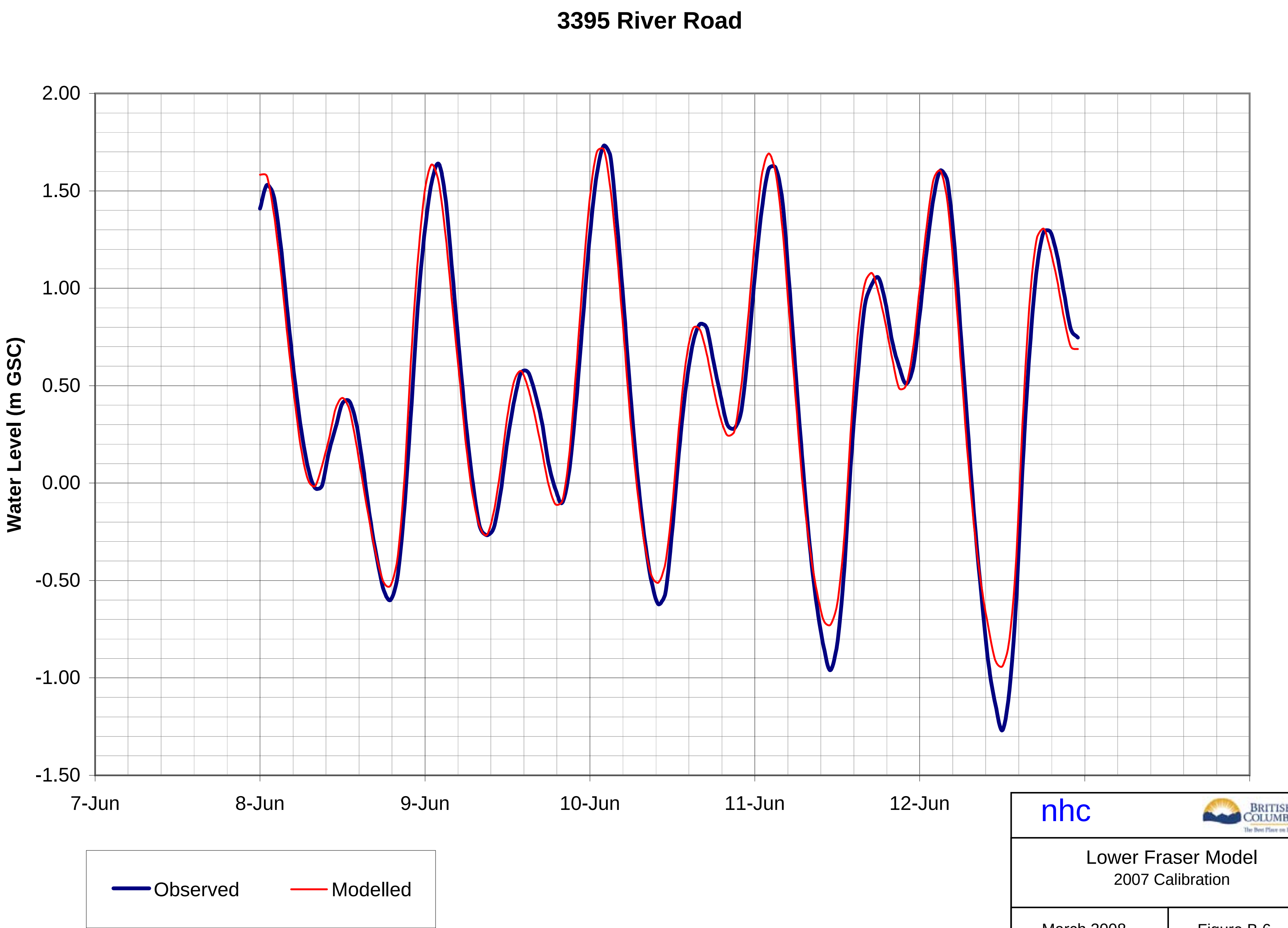
nhc

Lower Fraser Model
2007 Calibration

March 2008	Figure B.4



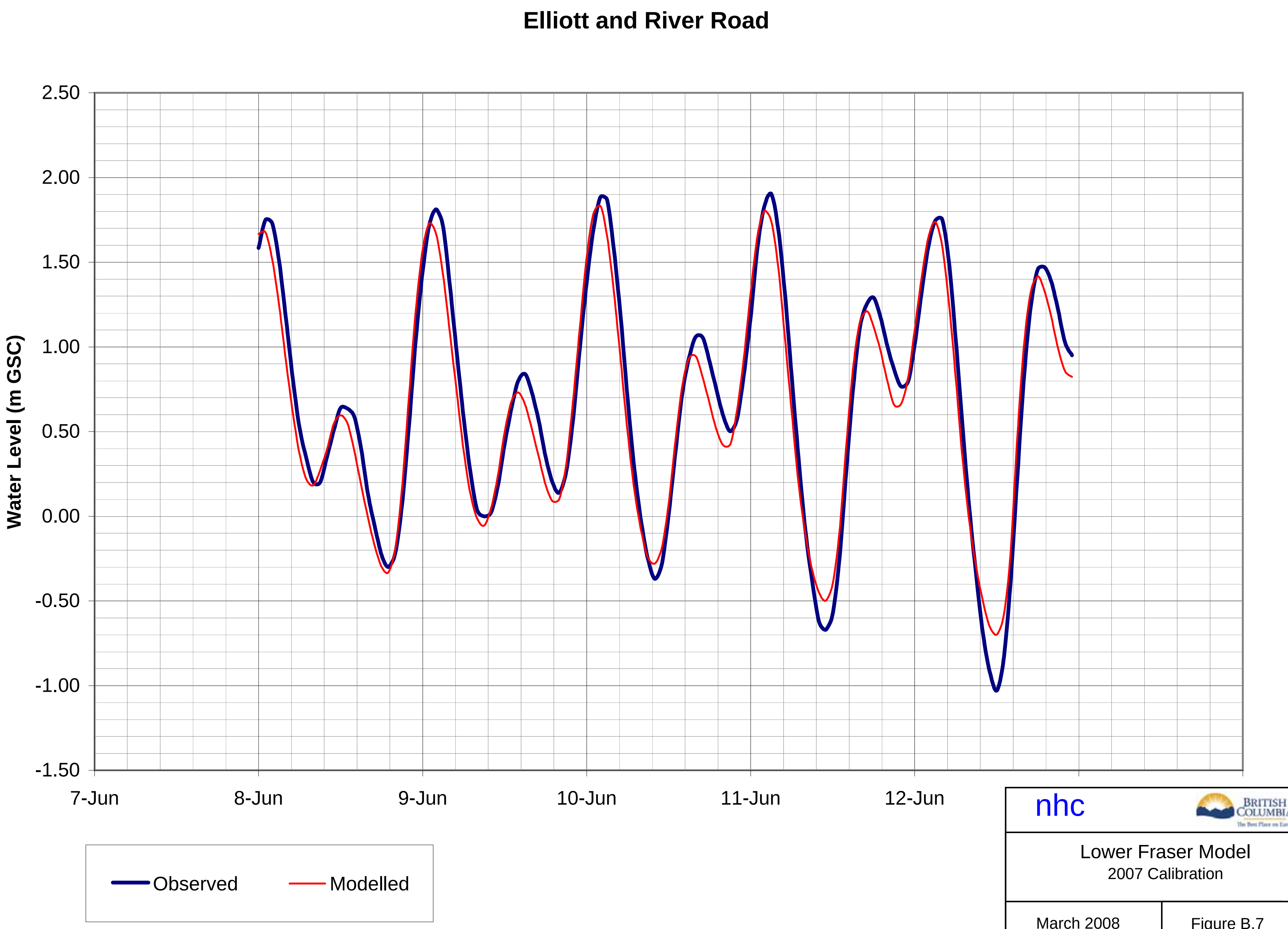
nhc	BRITISH COLUMBIA
Lower Fraser Model 2007 Calibration	
March 2008	Figure B.5



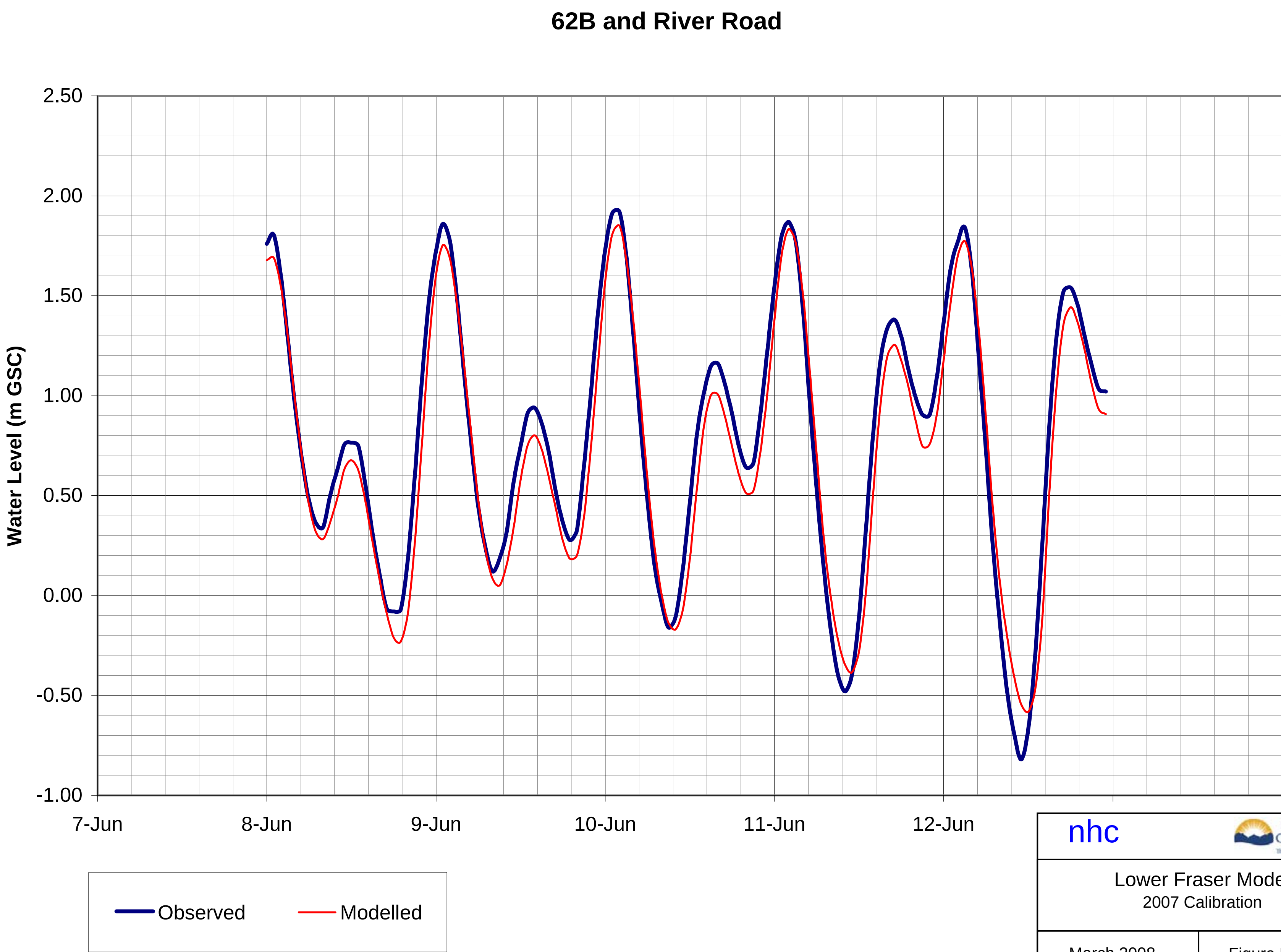
nhc

Lower Fraser Model
2007 Calibration

March 2008	Figure B.6



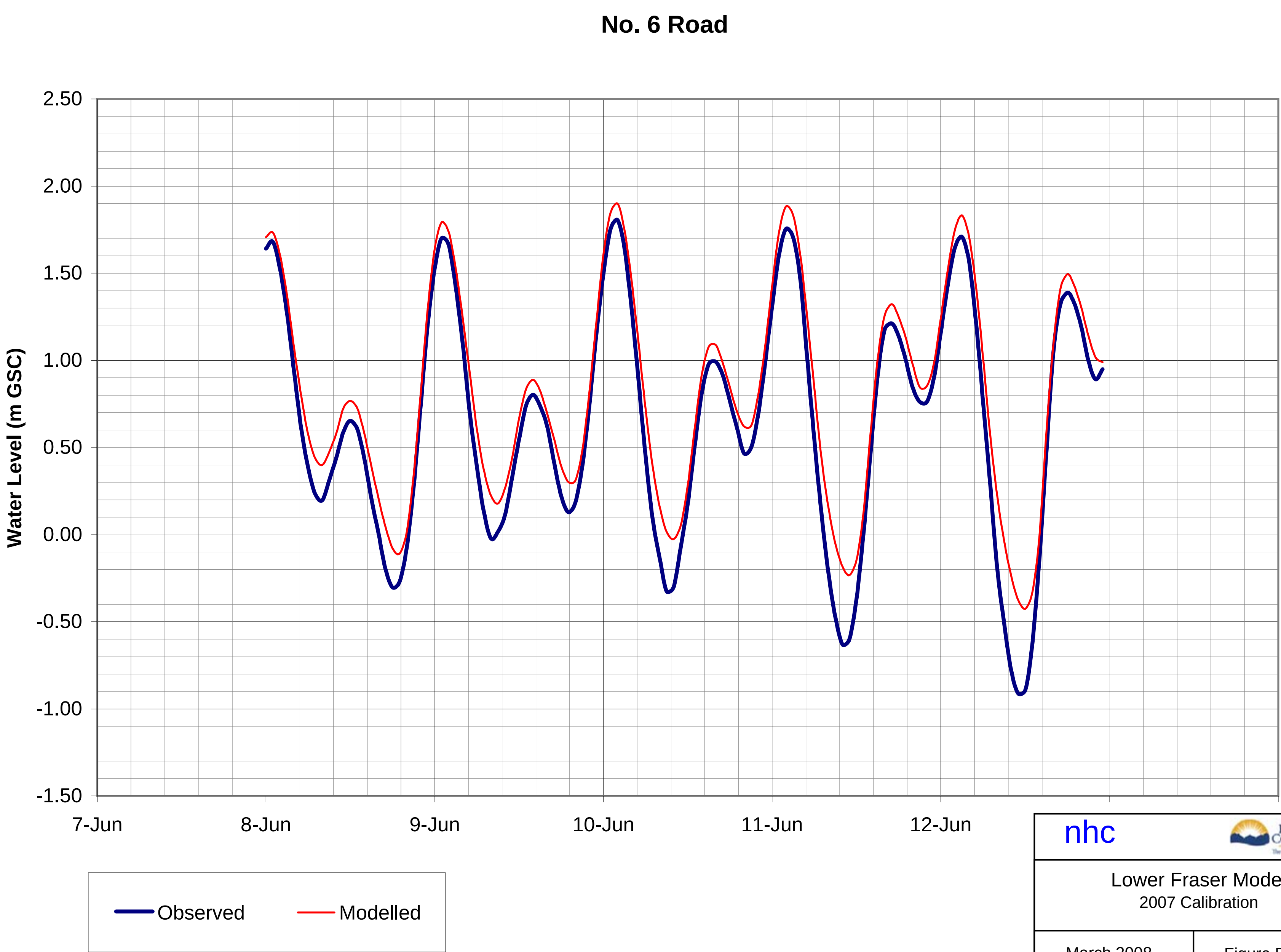
nhc	British Columbia
Lower Fraser Model 2007 Calibration	
March 2008	Figure B.7



nhc

Lower Fraser Model
2007 Calibration

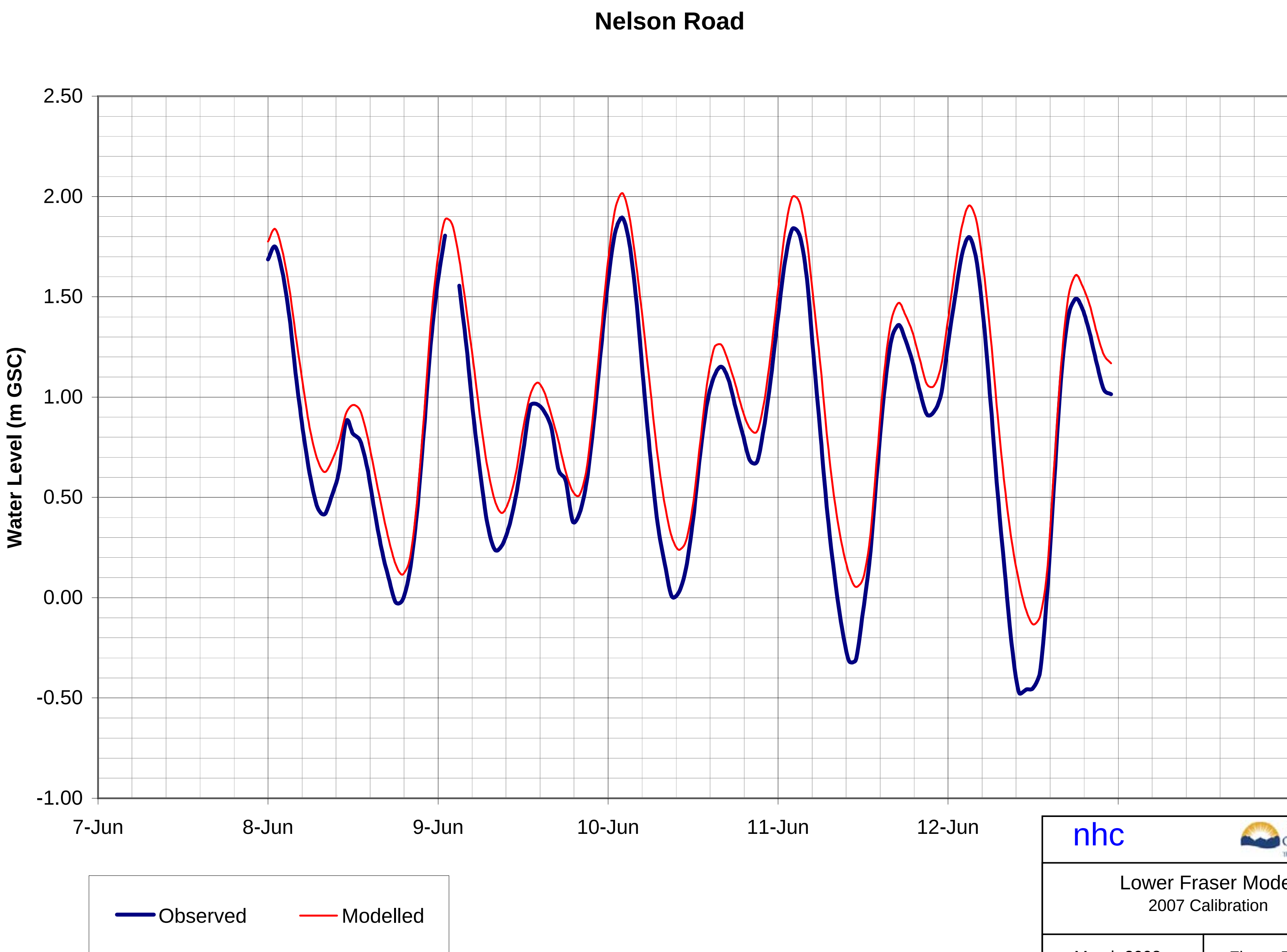
March 2008	Figure B.8



nhc

Lower Fraser Model
2007 Calibration

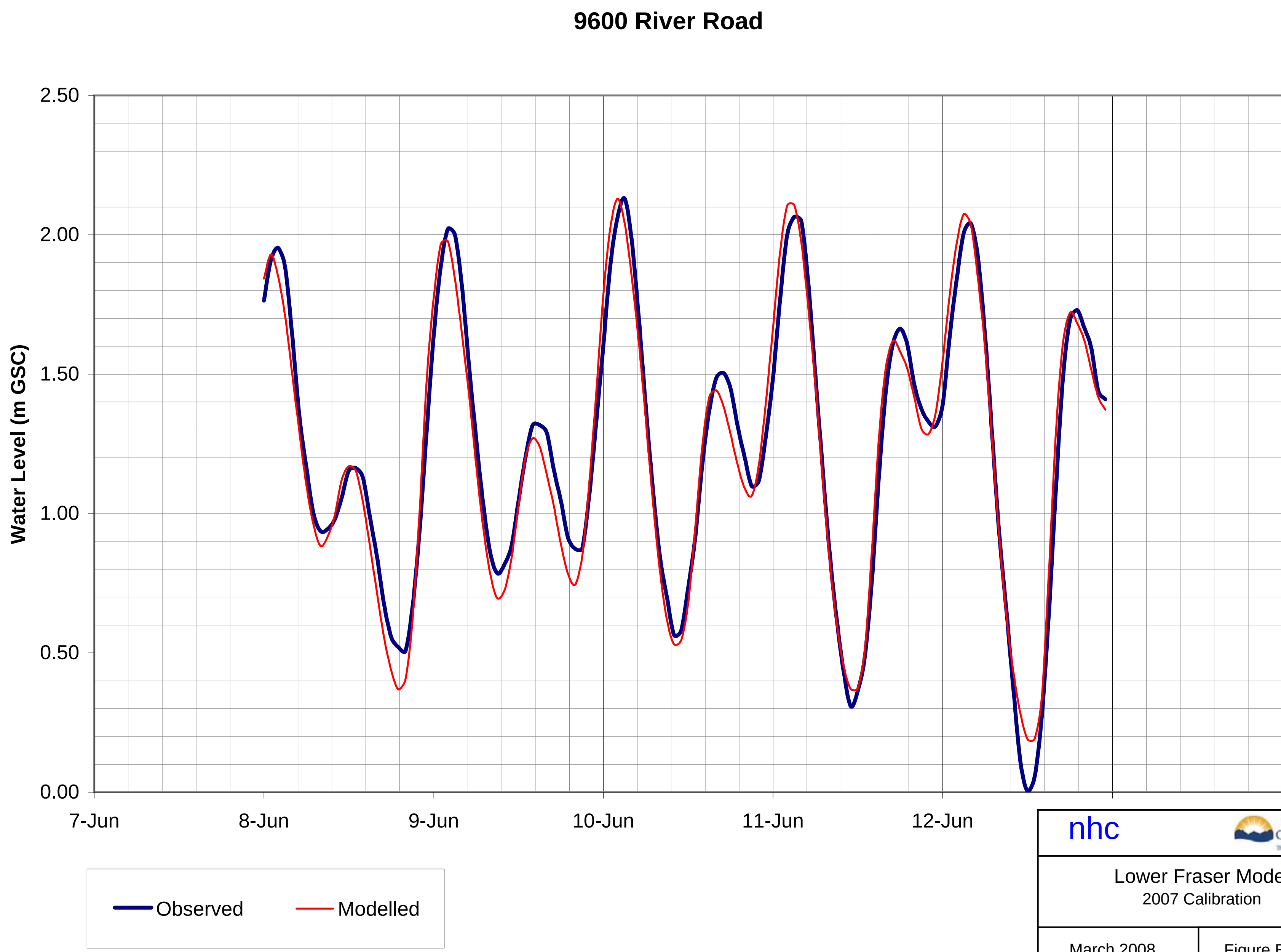
March 2008	Figure B.9



nhc

Lower Fraser Model
2007 Calibration

March 2008	Figure B.10



nhc

Lower Fraser Model
2007 Calibration

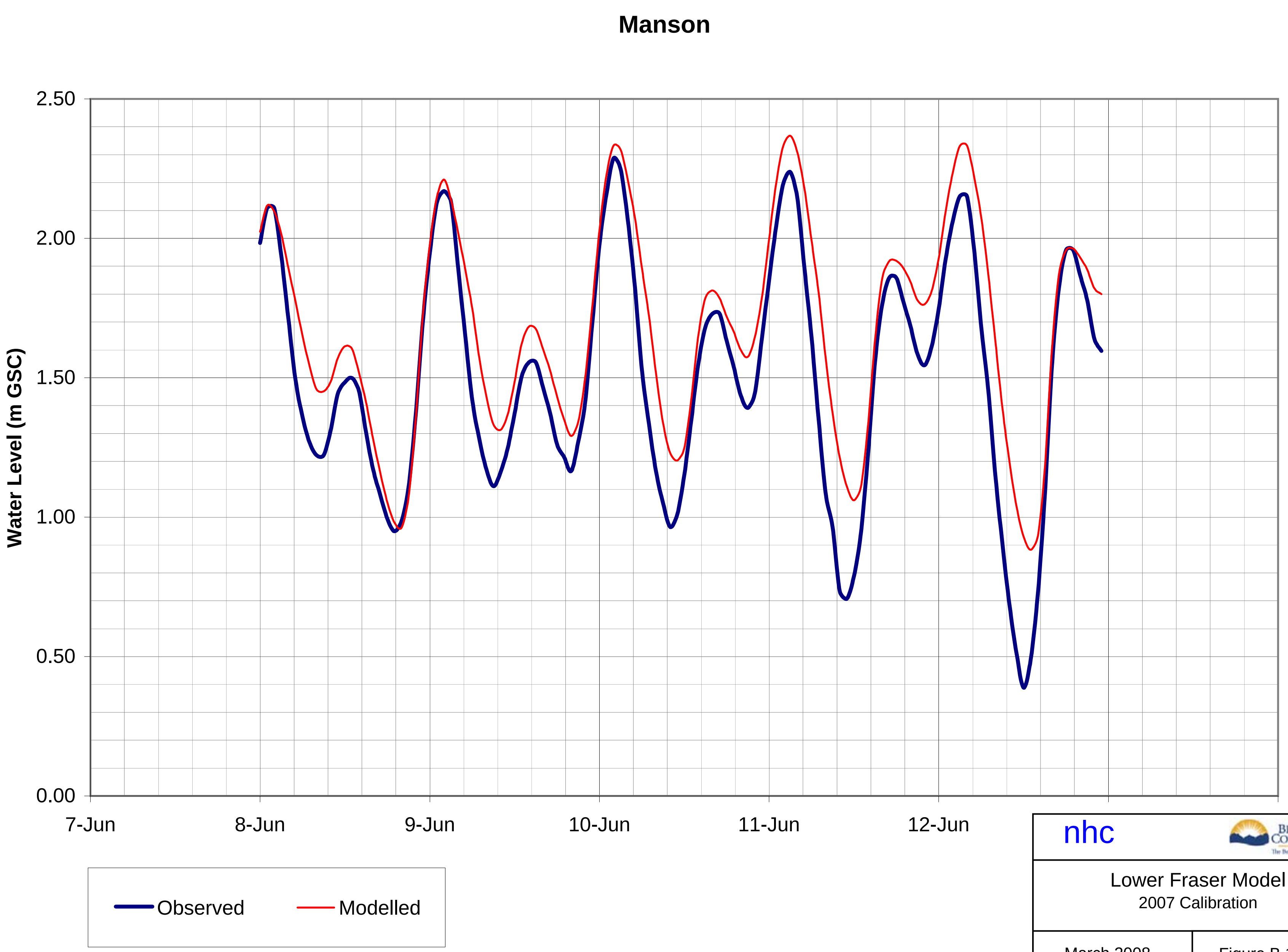
March 2008	Figure B.11

nhc

Lower Fraser Model
2007 Calibration

March 2008

Figure B.12

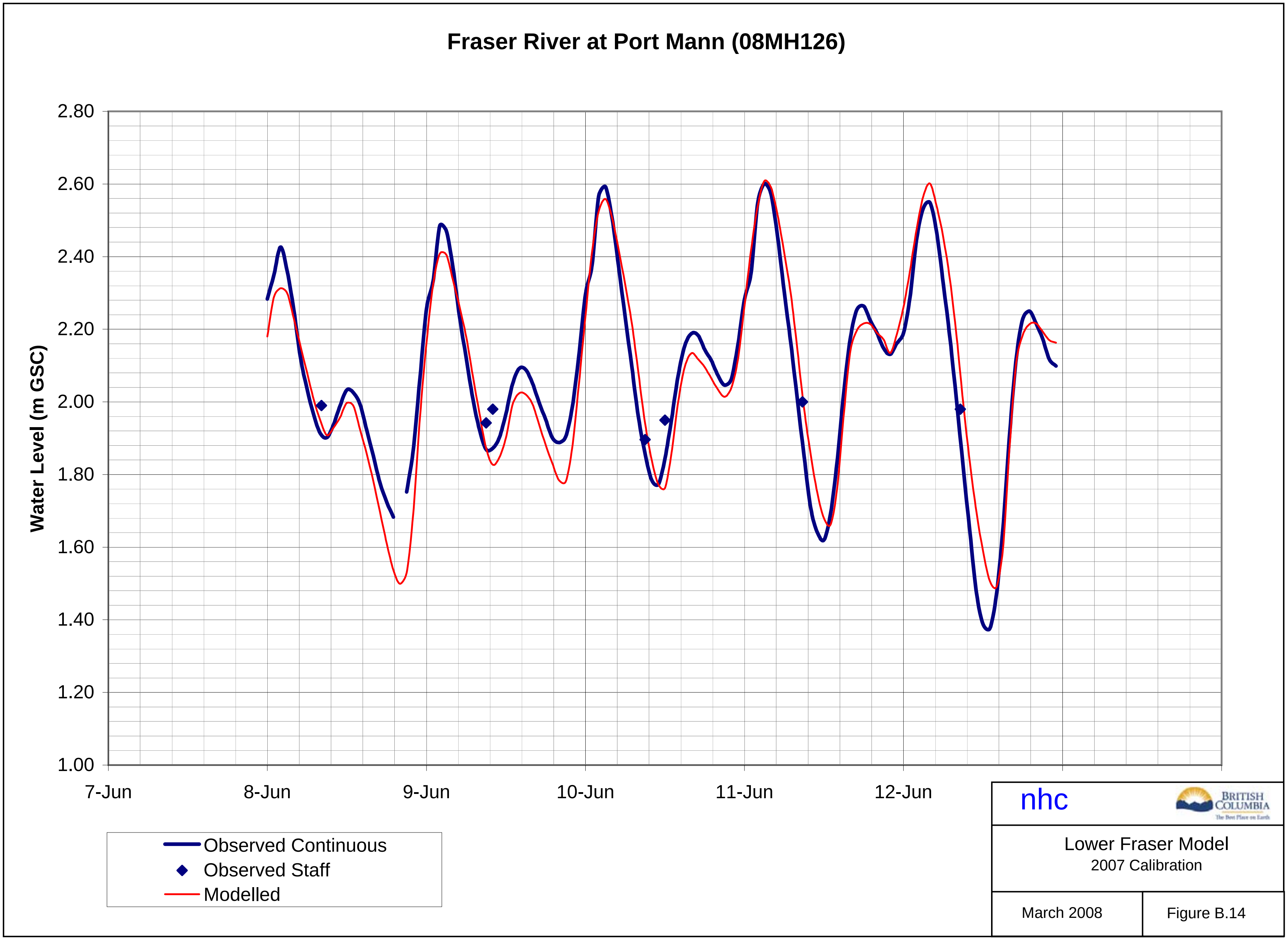


nhc

Lower Fraser Model
2007 Calibration

March 2008

Figure B.13



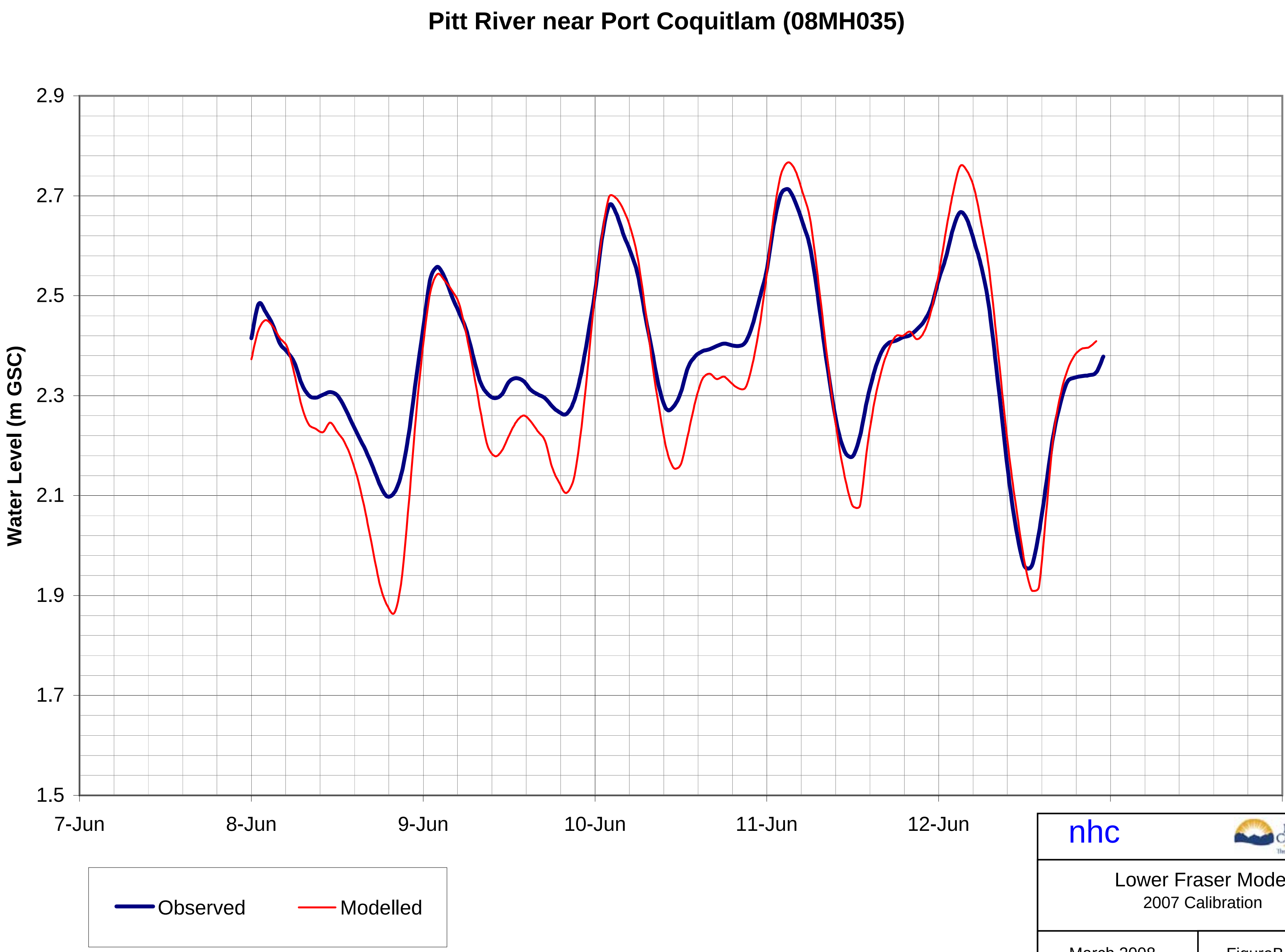
Fraser River at Port Mann (08MH126)
Water Level (m GSC)
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
7-Jun
8-Jun
9-Jun
10-Jun
11-Jun
12-Jun
Observed Continuous
Observed Staff
Modelled
nhc
British Columbia
Lower Fraser Model
2007 Calibration
March 2008
Figure B.14

nhc

Lower Fraser Model
2007 Calibration

March 2008

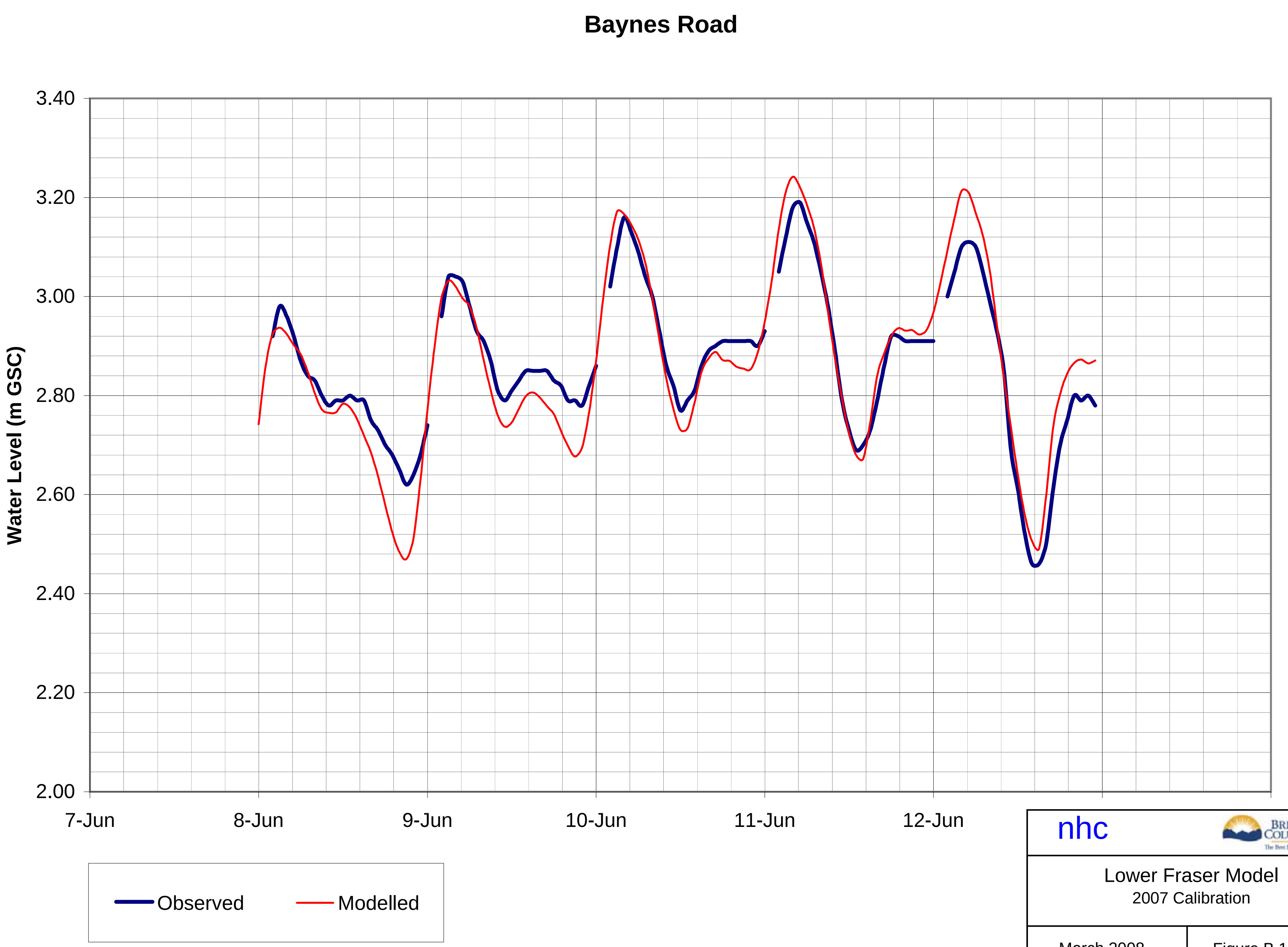
Figure B.15



nhc

Lower Fraser Model
2007 Calibration

March 2008	FigureB.16



nhc

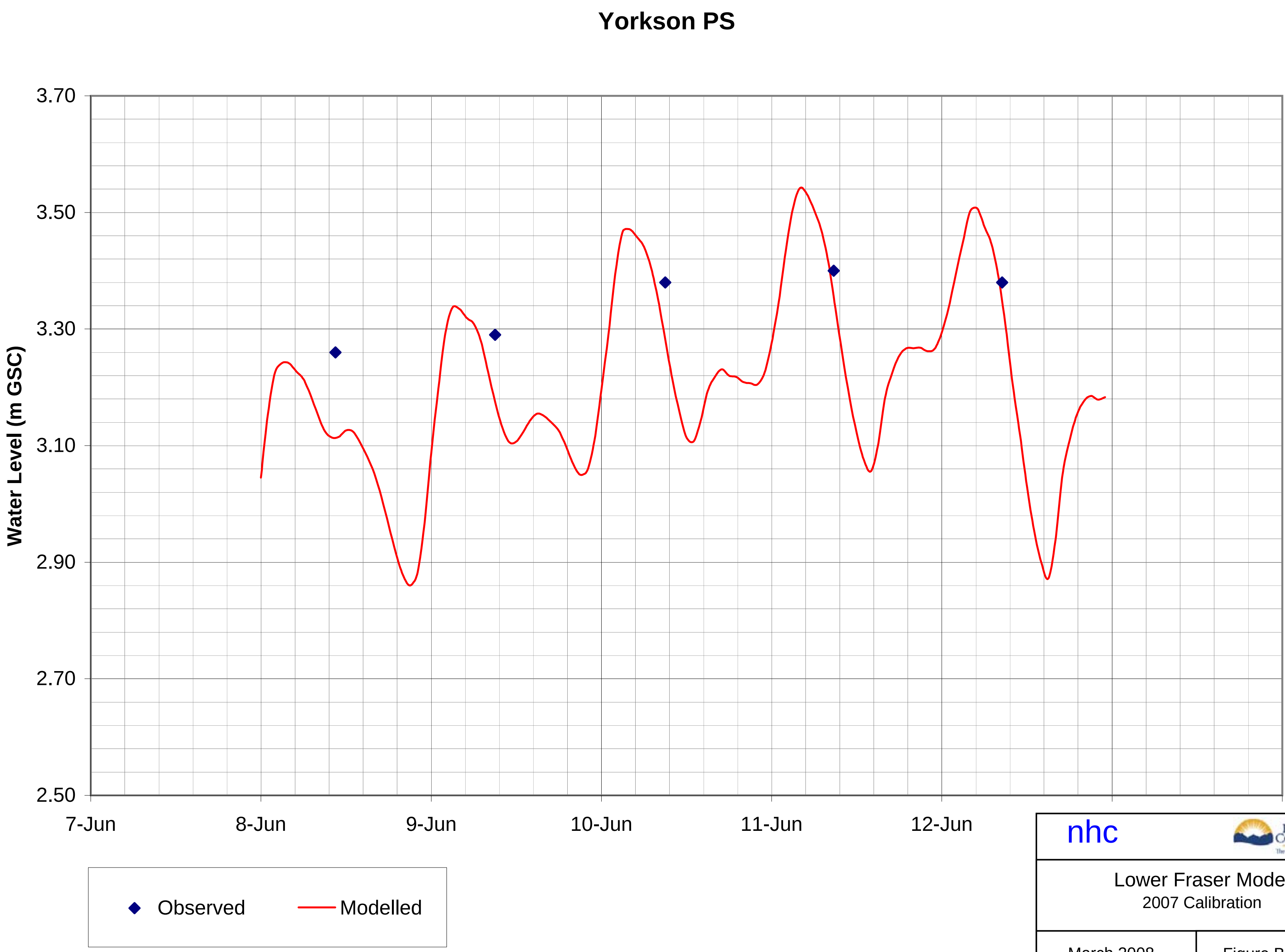
Lower Fraser Model
2007 Calibration

March 2008	Figure B.17

nhc

Lower Fraser Model
2007 Calibration

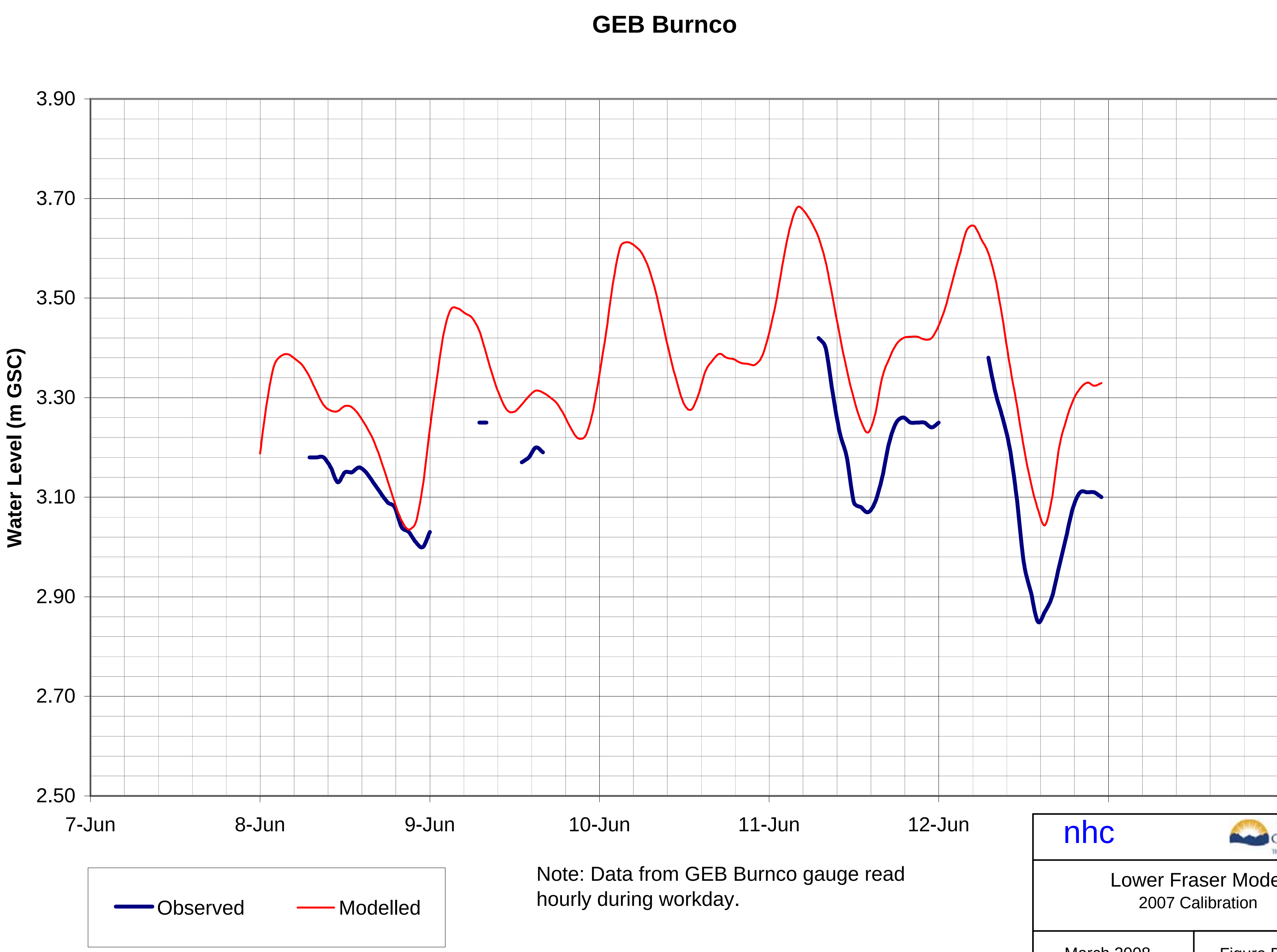
March 2008	Figure B.18



nhc

Lower Fraser Model
2007 Calibration

March 2008	Figure B.19



Note: Data from GEB Burnco gauge read hourly during workday.

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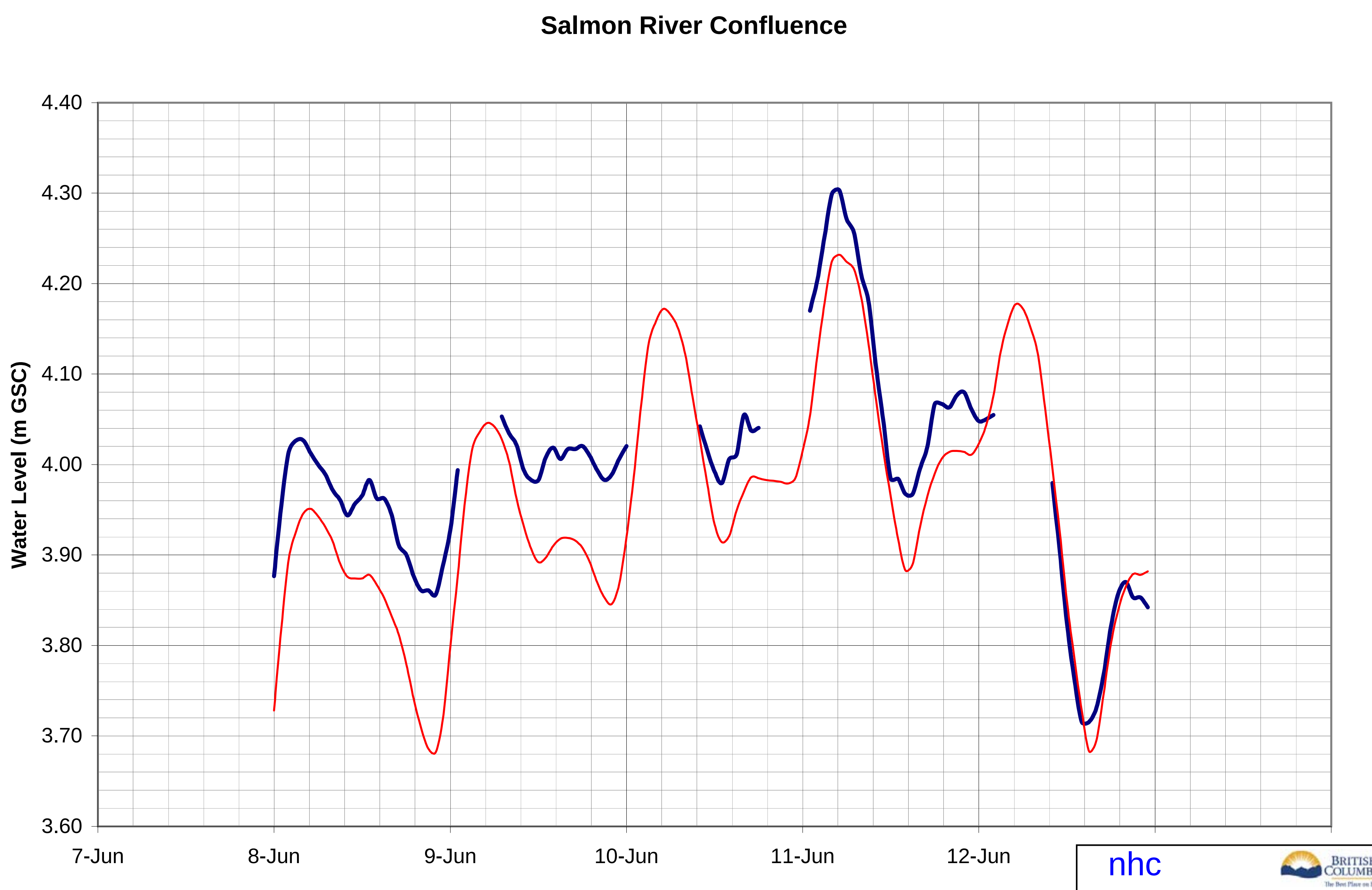
BRITISH COLUMBIA

Lower Fraser Model
2007 Calibration

March 2008

Figure B.20



Note: Significant data removed from data set.

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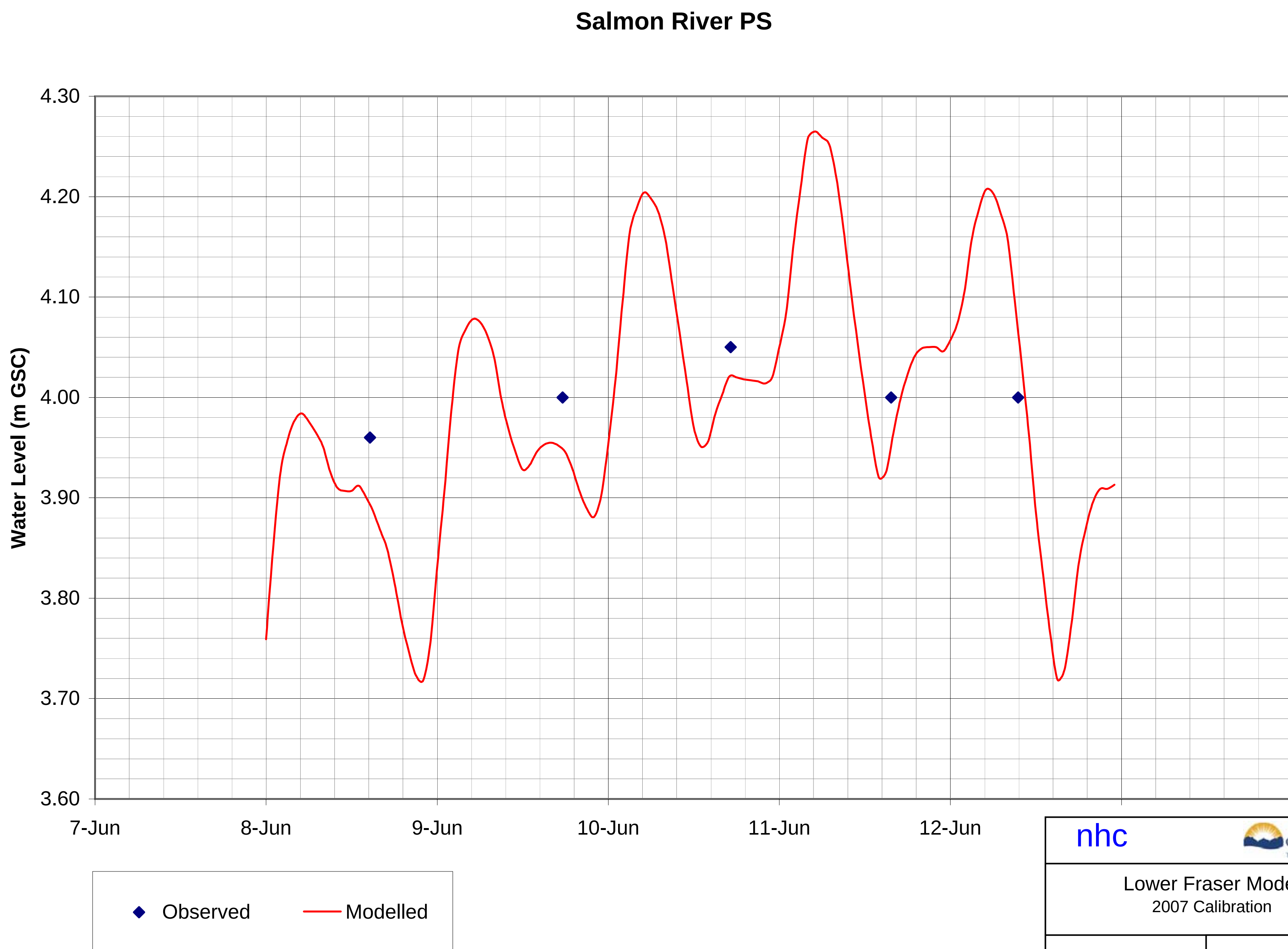
BRITISH COLUMBIA

Lower Fraser Model
2007 Calibration

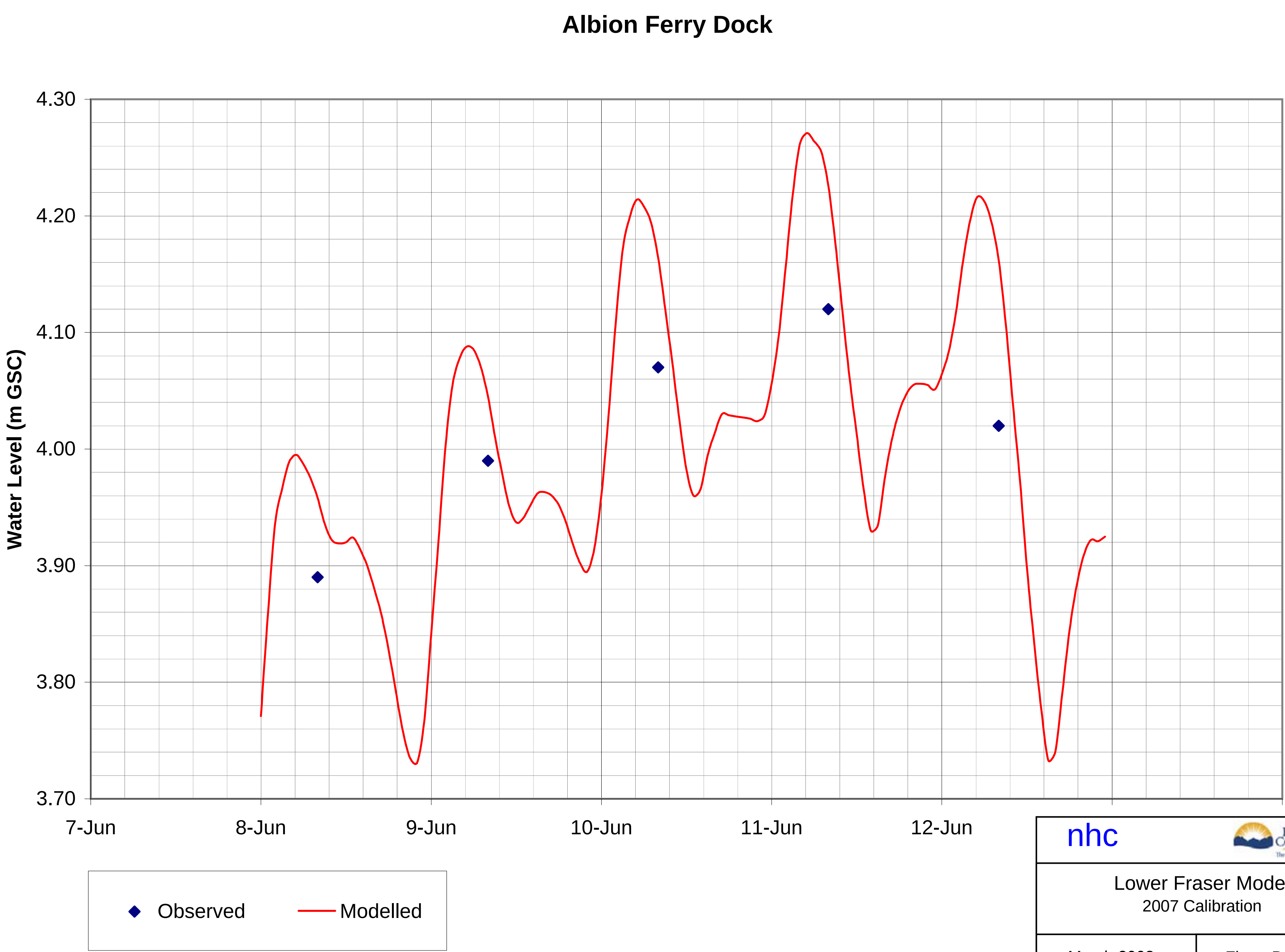
March 2008 | Figure B.21



nhc

Lower Fraser Model
2007 Calibration

March 2008	Figure B.22



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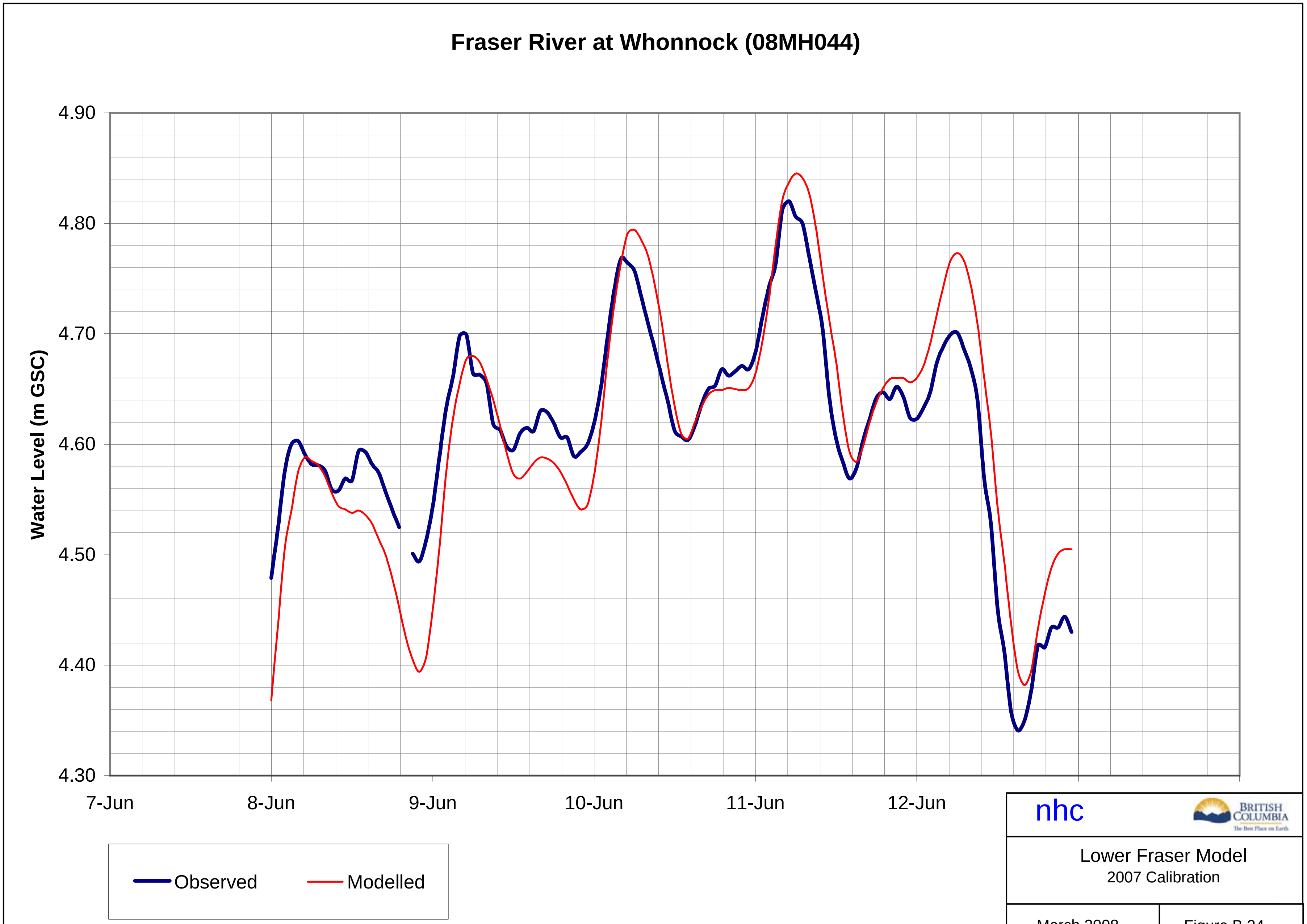
Lower Fraser Model
2007 Calibration

March 2008	FigureB.23



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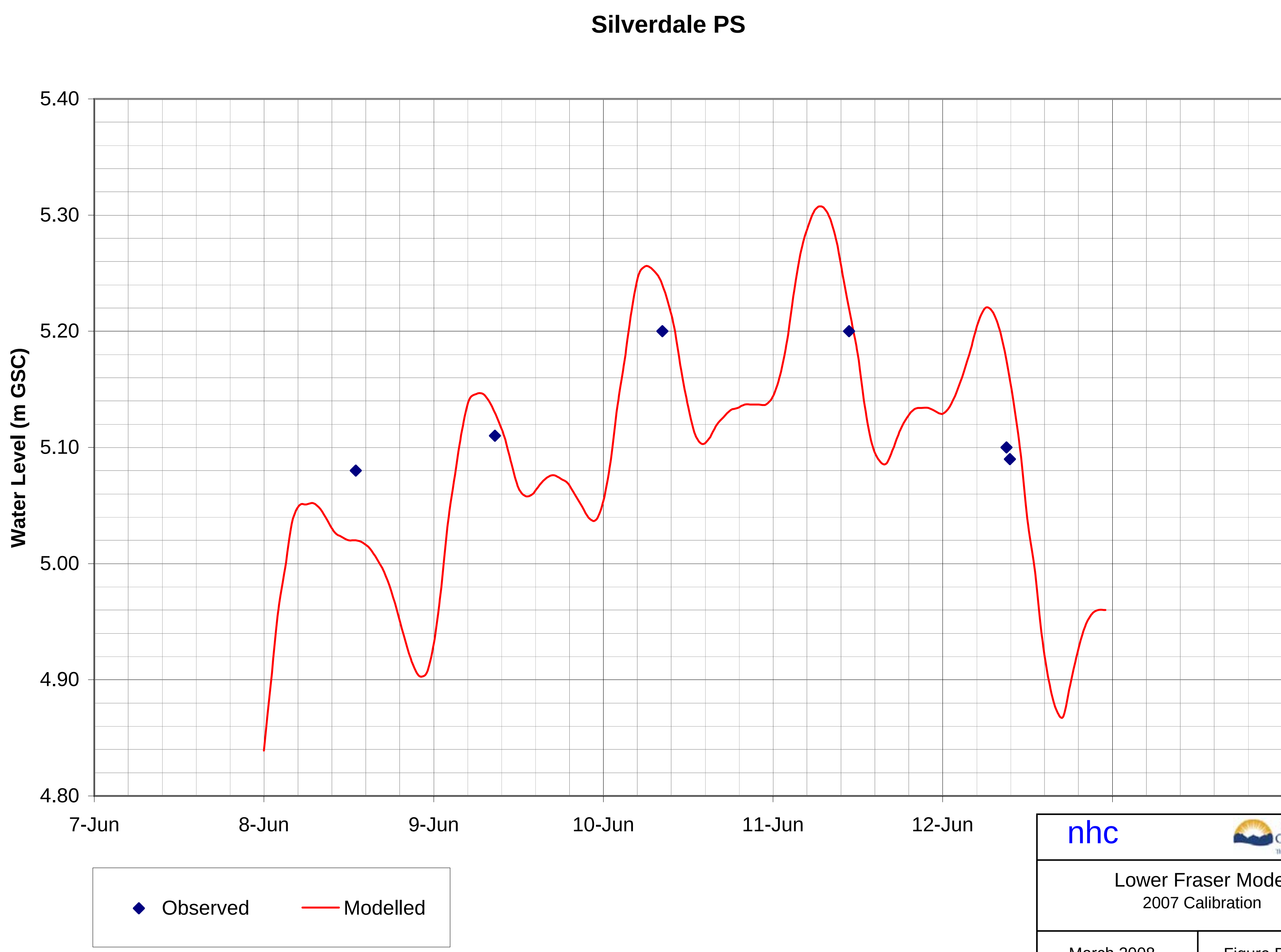
Lower Fraser Model
2007 Calibration

March 2008

Figure B.24



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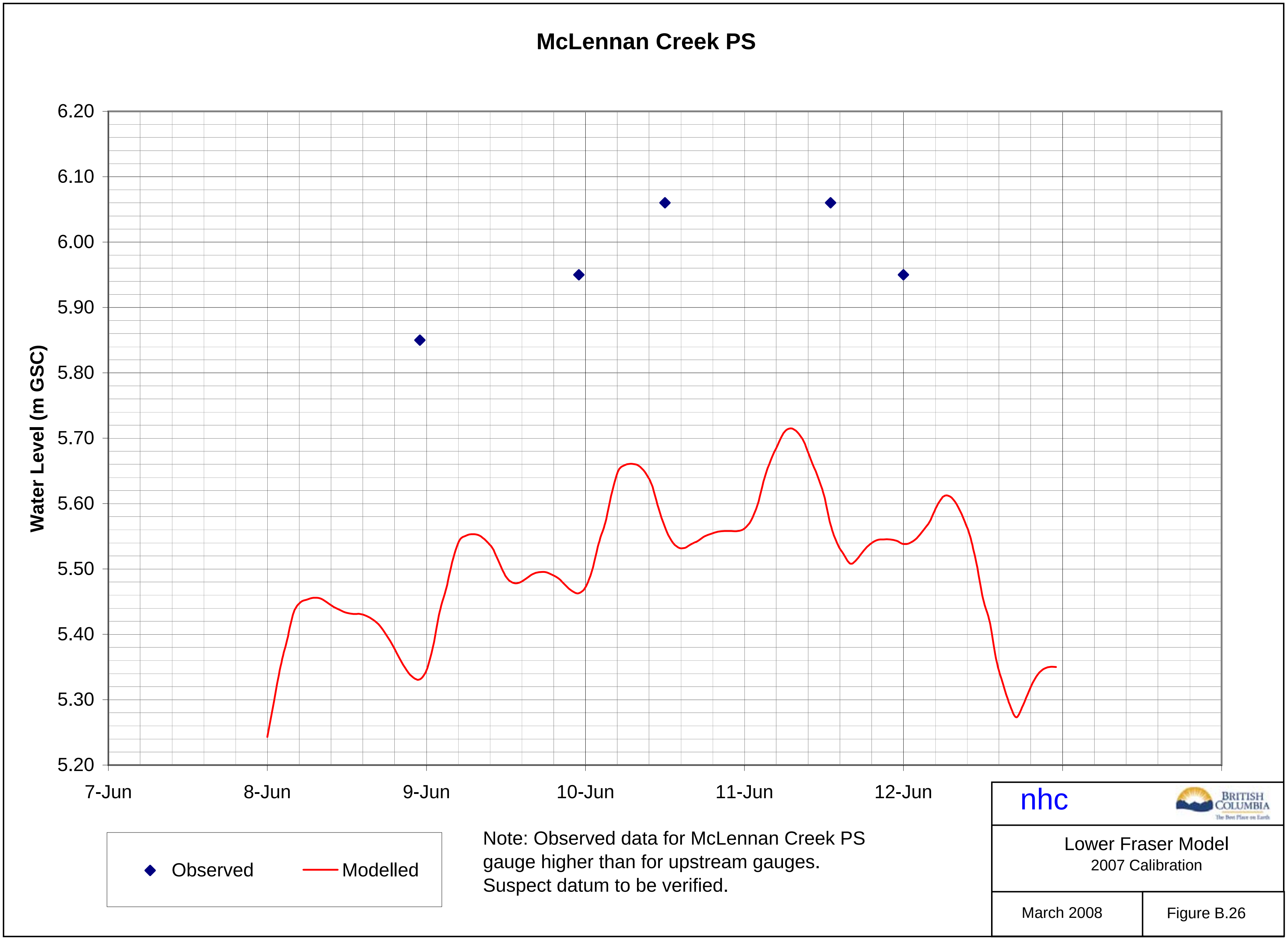
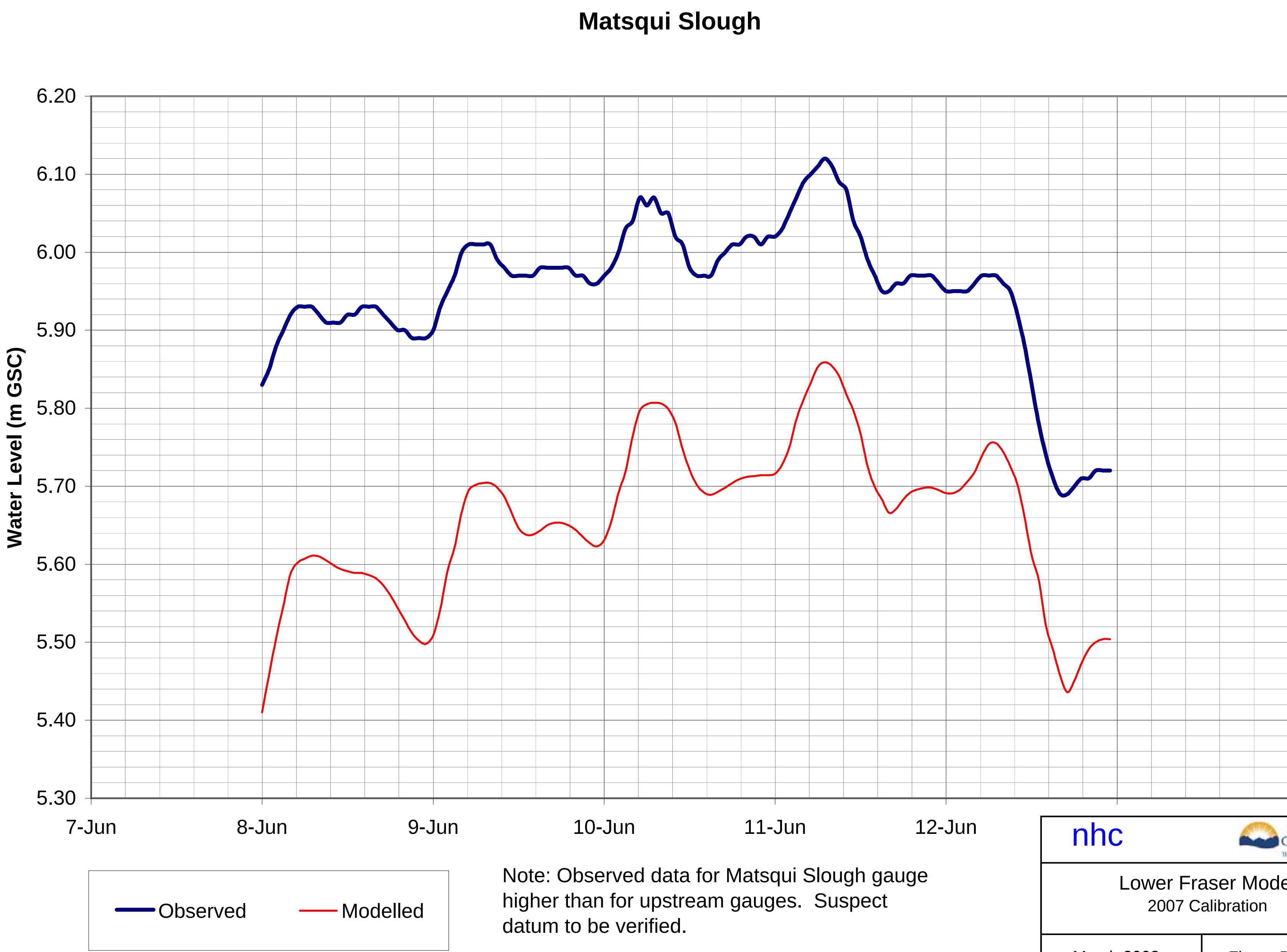
Lower Fraser Model
2007 Calibration

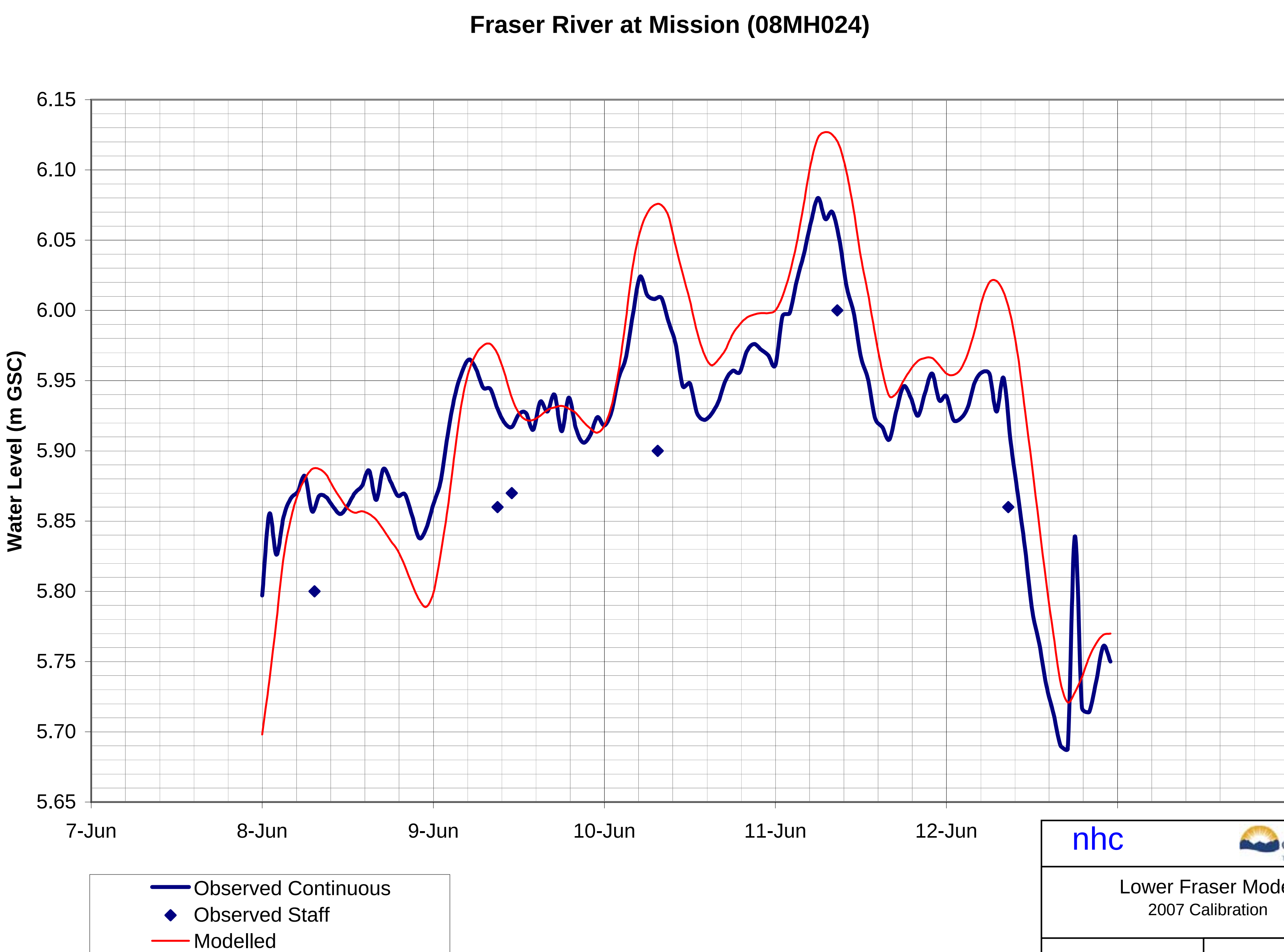
March 2008	Figure B.25


McLennan Creek PS
Water Level (m GSC)
6.20
6.10
6.00
5.90
5.80
5.70
5.60
5.50
5.40
5.30
5.20
7-Jun
8-Jun
9-Jun
10-Jun
11-Jun
12-Jun
Observed
Modelled
Note: Observed data for McLennan Creek PS gauge higher than for upstream gauges. Suspect datum to be verified.
nhc
British Columbia
Lower Fraser Model
2007 Calibration
March 2008
Figure B.26



Note: Observed data for Matsqui Slough gauge higher than for upstream gauges. Suspect datum to be verified.

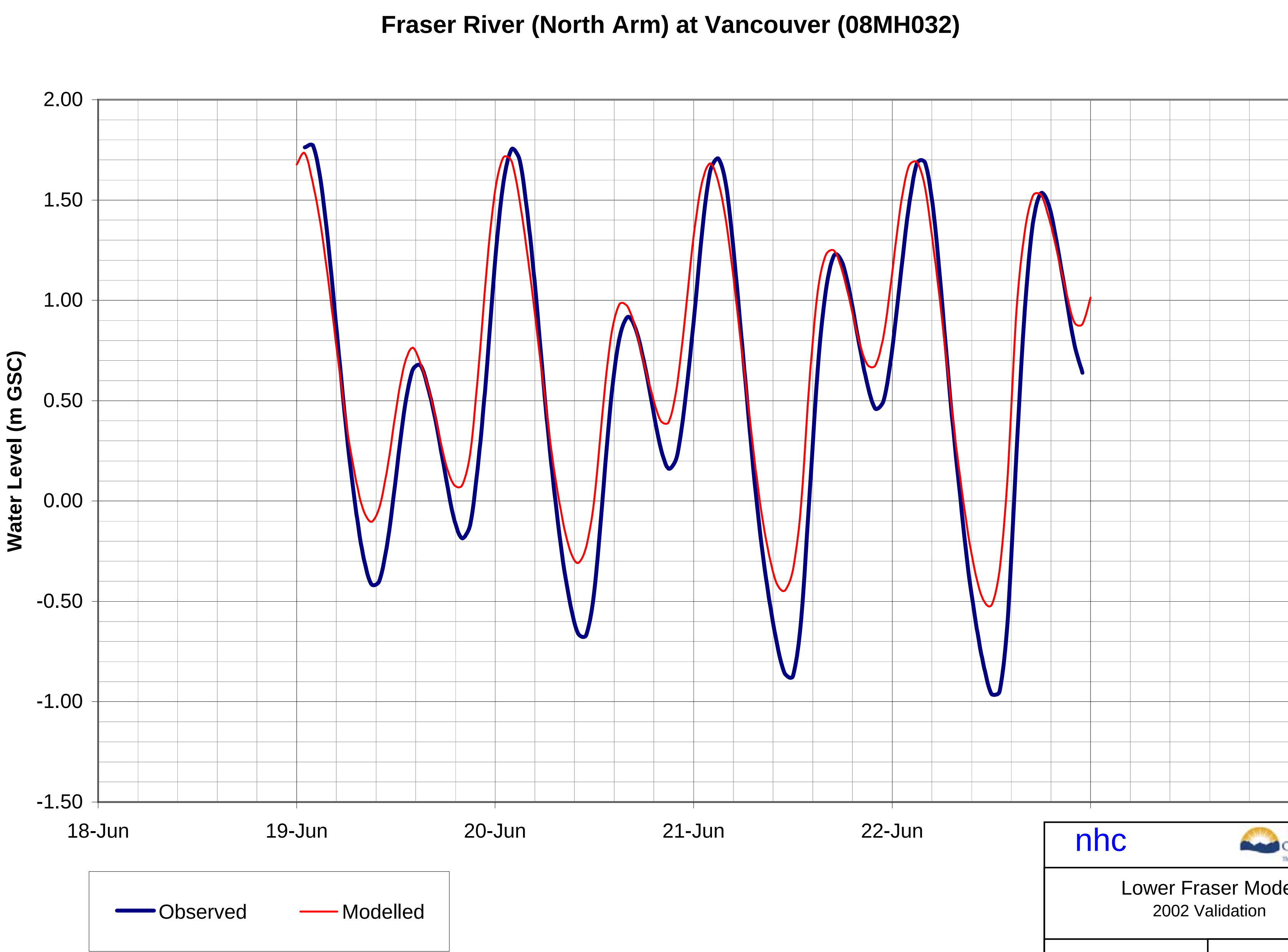
nhc	BRITISH COLUMBIA
Lower Fraser Model 2007 Calibration	
March 2008	Figure B.27



nhc

Lower Fraser Model
2007 Calibration

March 2008 | Figure B.28



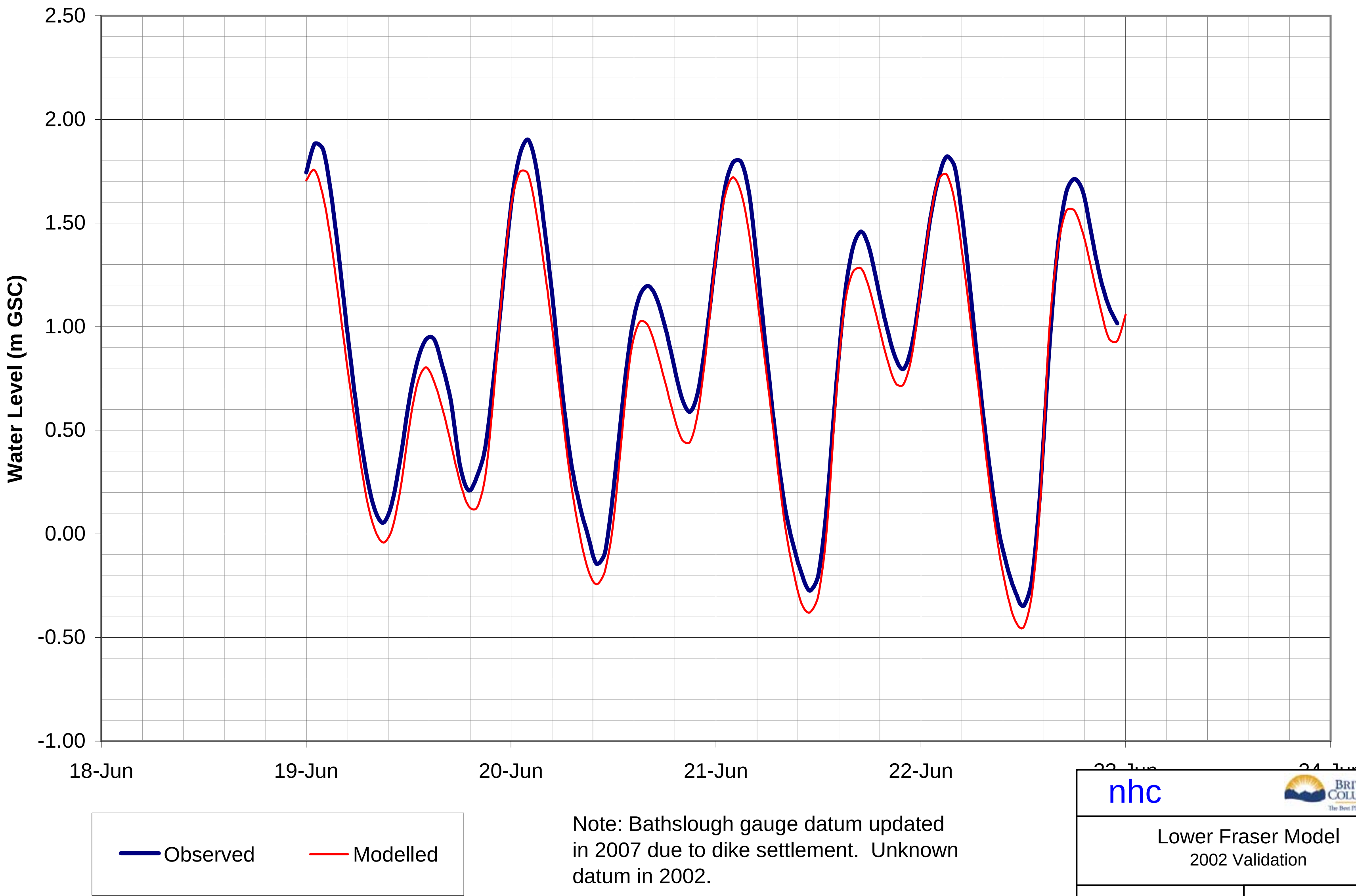
nhc

BRITISH COLUMBIA

Lower Fraser Model
2002 Validation

March 2008	Figure B.29

Bathslough



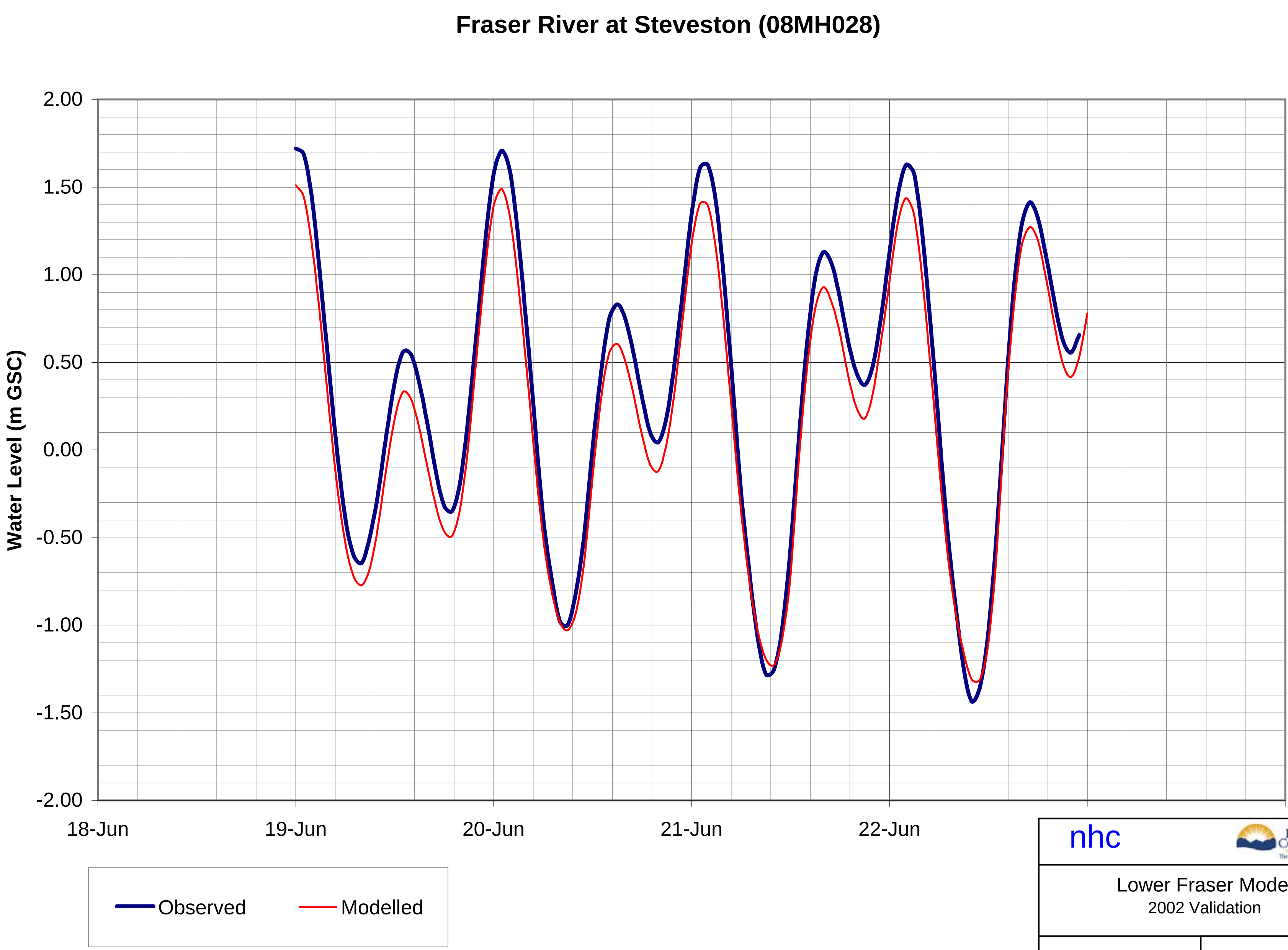
Note: Bathslough gauge datum updated in 2007 due to dike settlement. Unknown datum in 2002.

nhc

BRITISH COLUMBIA

Lower Fraser Model
2002 Validation

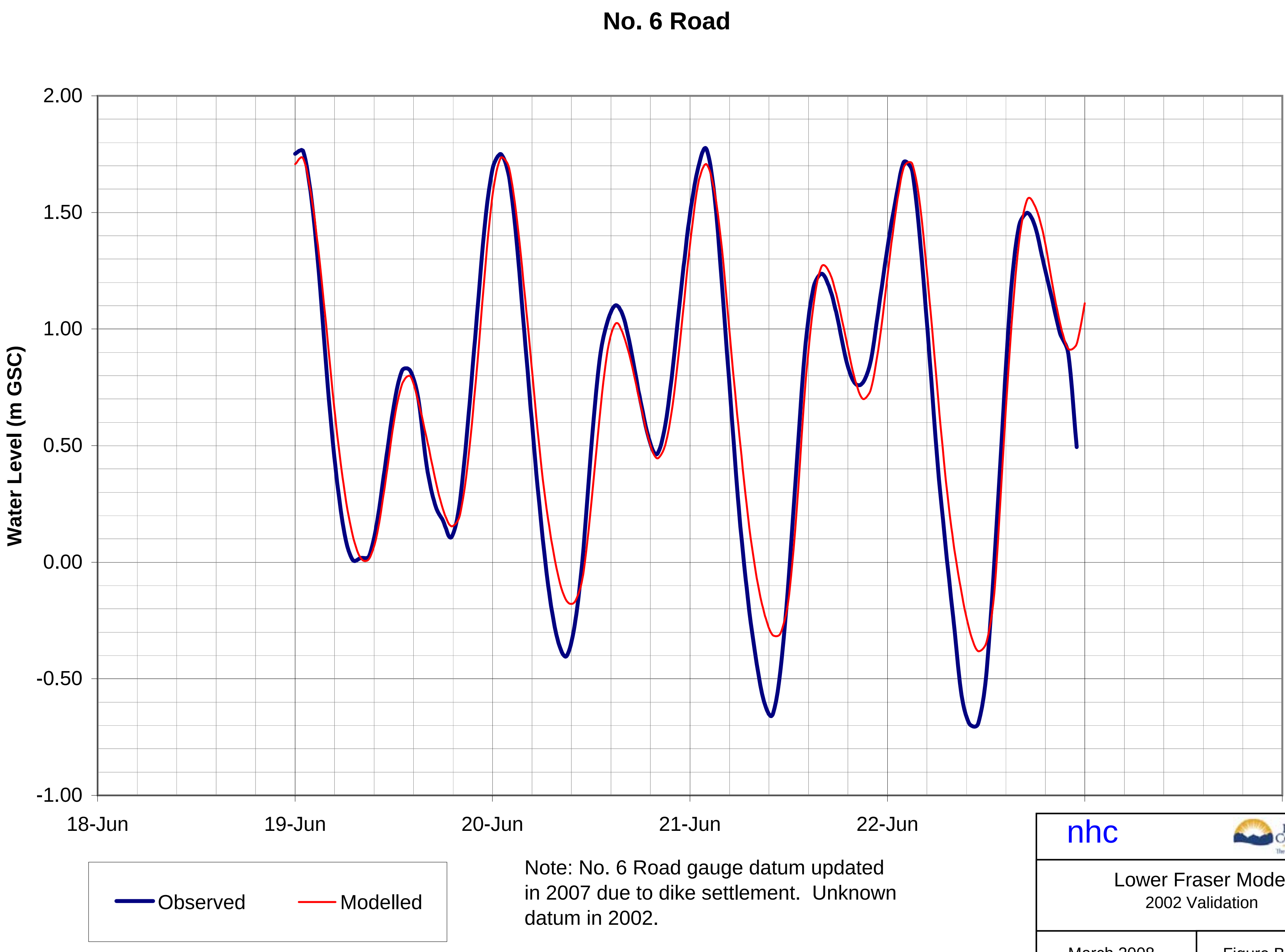
March 2008 | Figure B.30



nhc

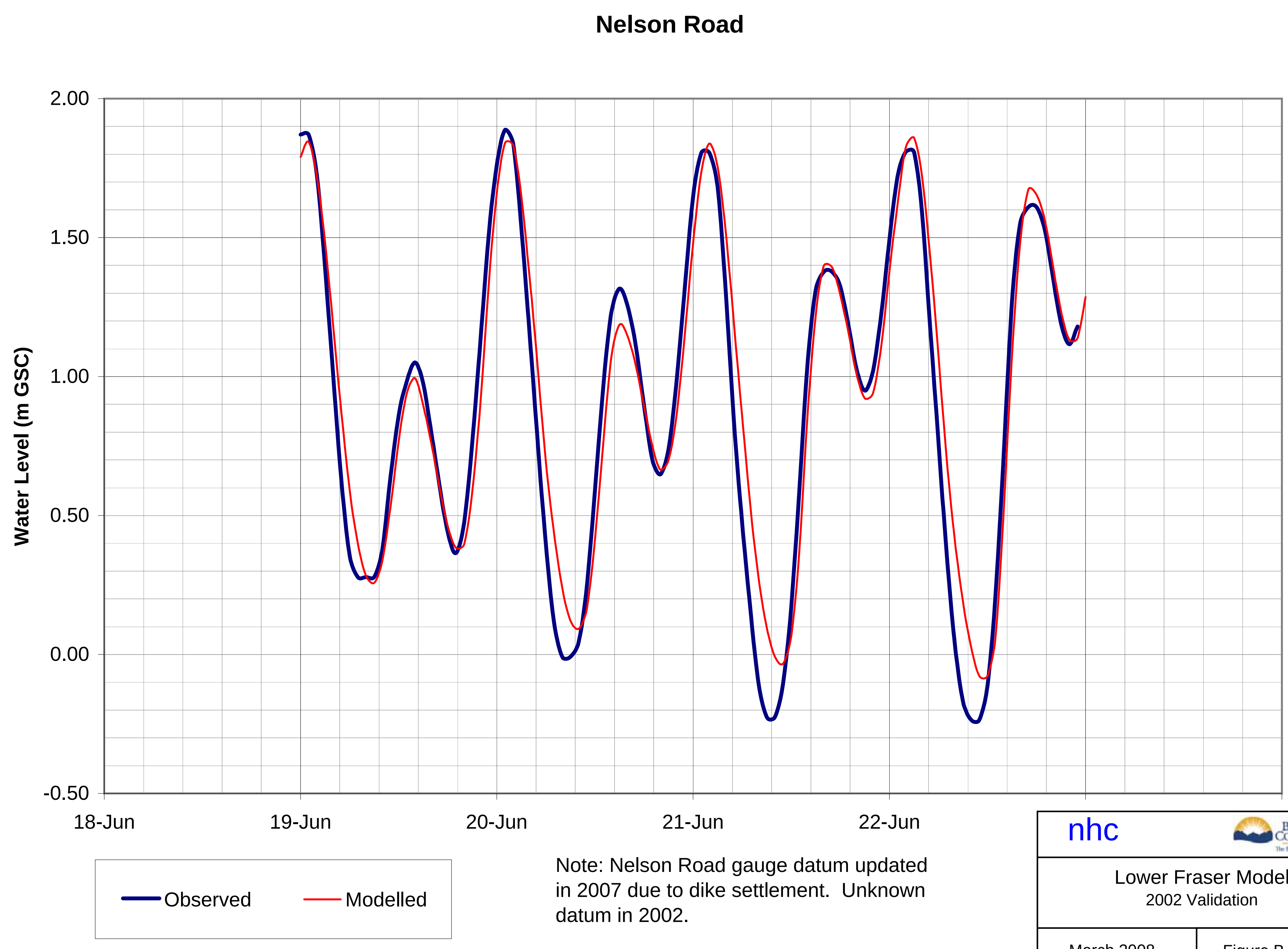
Lower Fraser Model
2002 Validation

March 2008	Figure B.31



Note: No. 6 Road gauge datum updated in 2007 due to dike settlement. Unknown datum in 2002.

nhc	BRITISH COLUMBIA
Lower Fraser Model 2002 Validation	
March 2008	Figure B.32

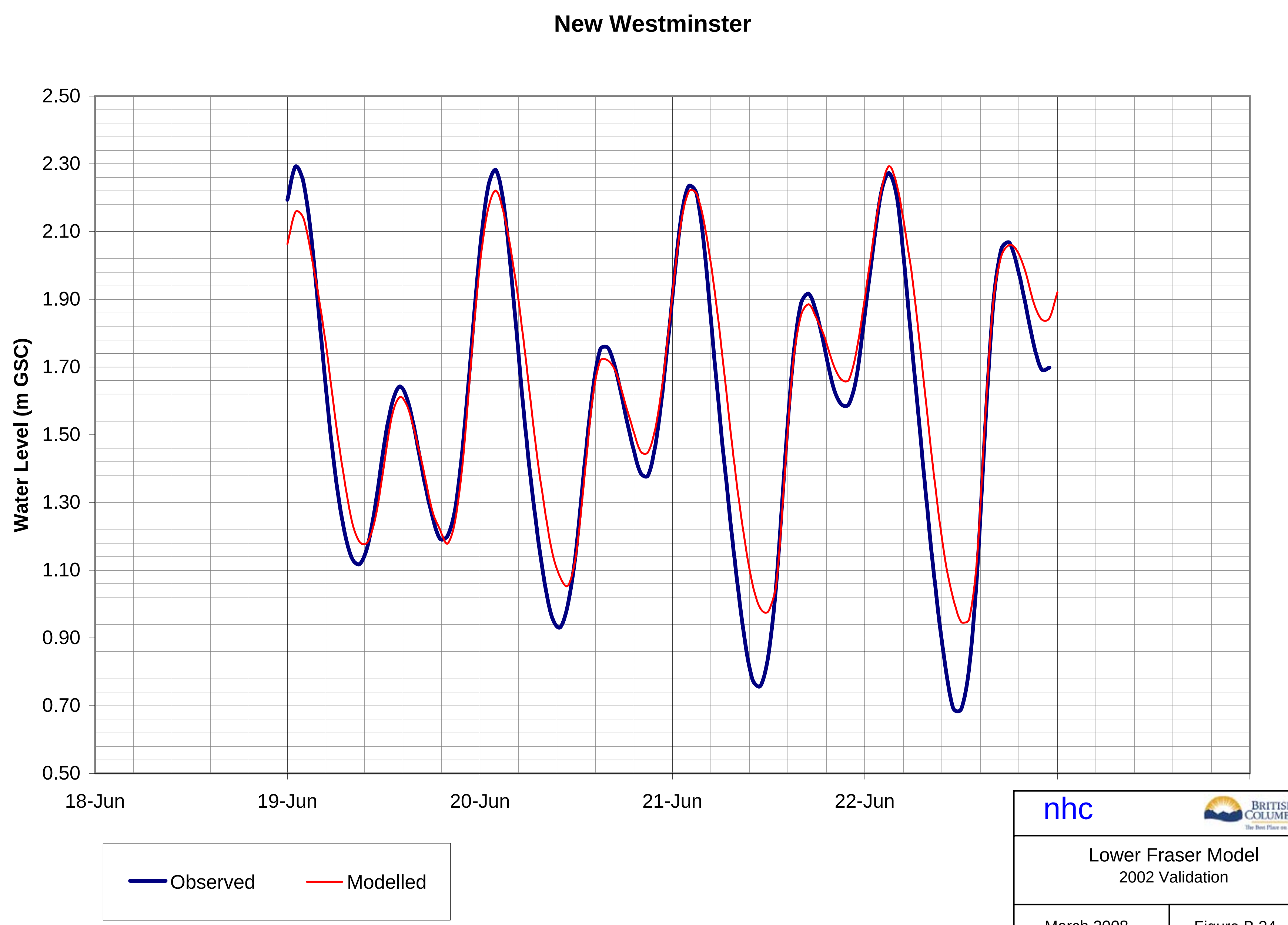


Note: Nelson Road gauge datum updated in 2007 due to dike settlement. Unknown datum in 2002.

nhc

Lower Fraser Model
2002 Validation

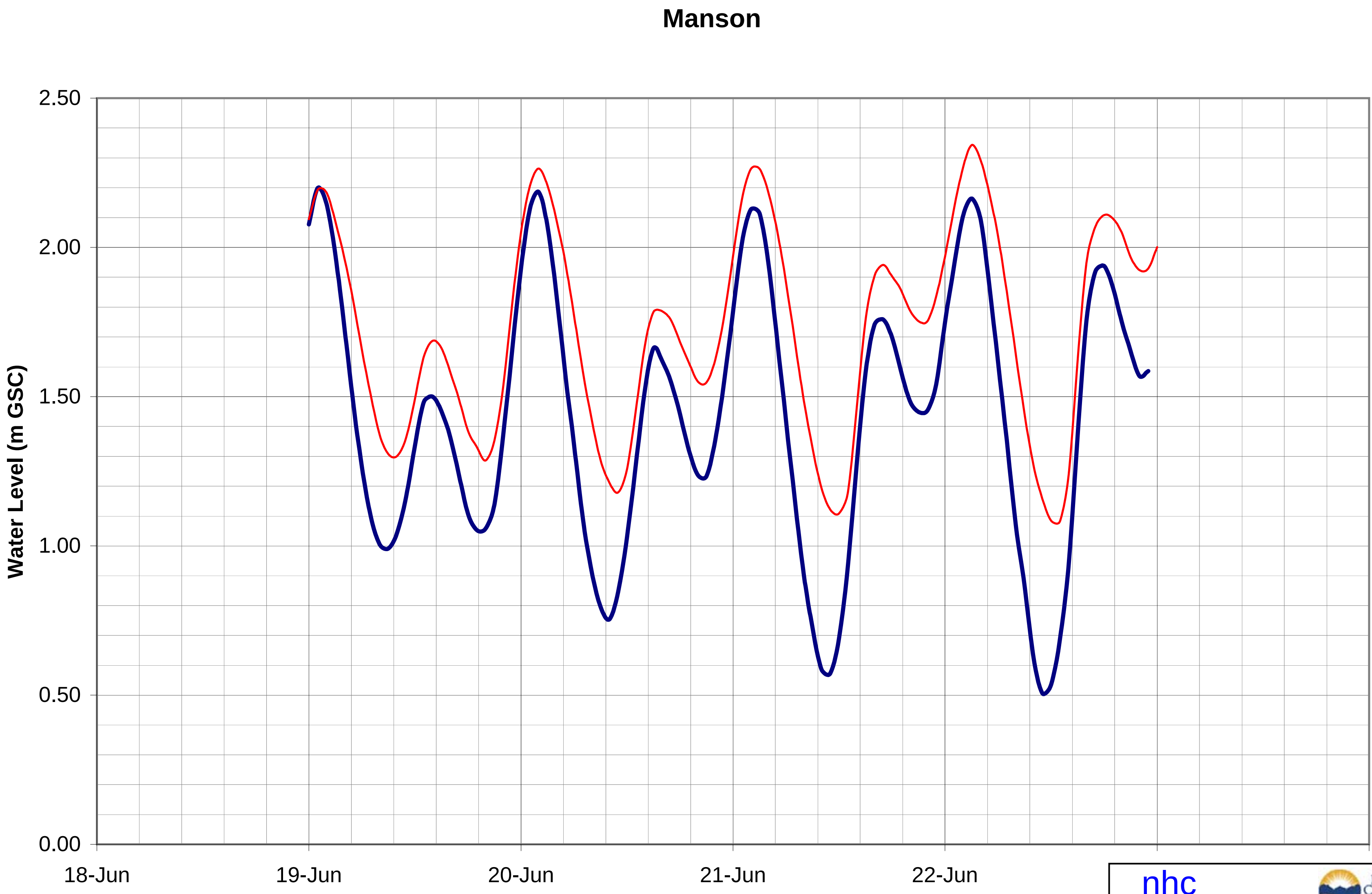
March 2008 | Figure B.33



nhc

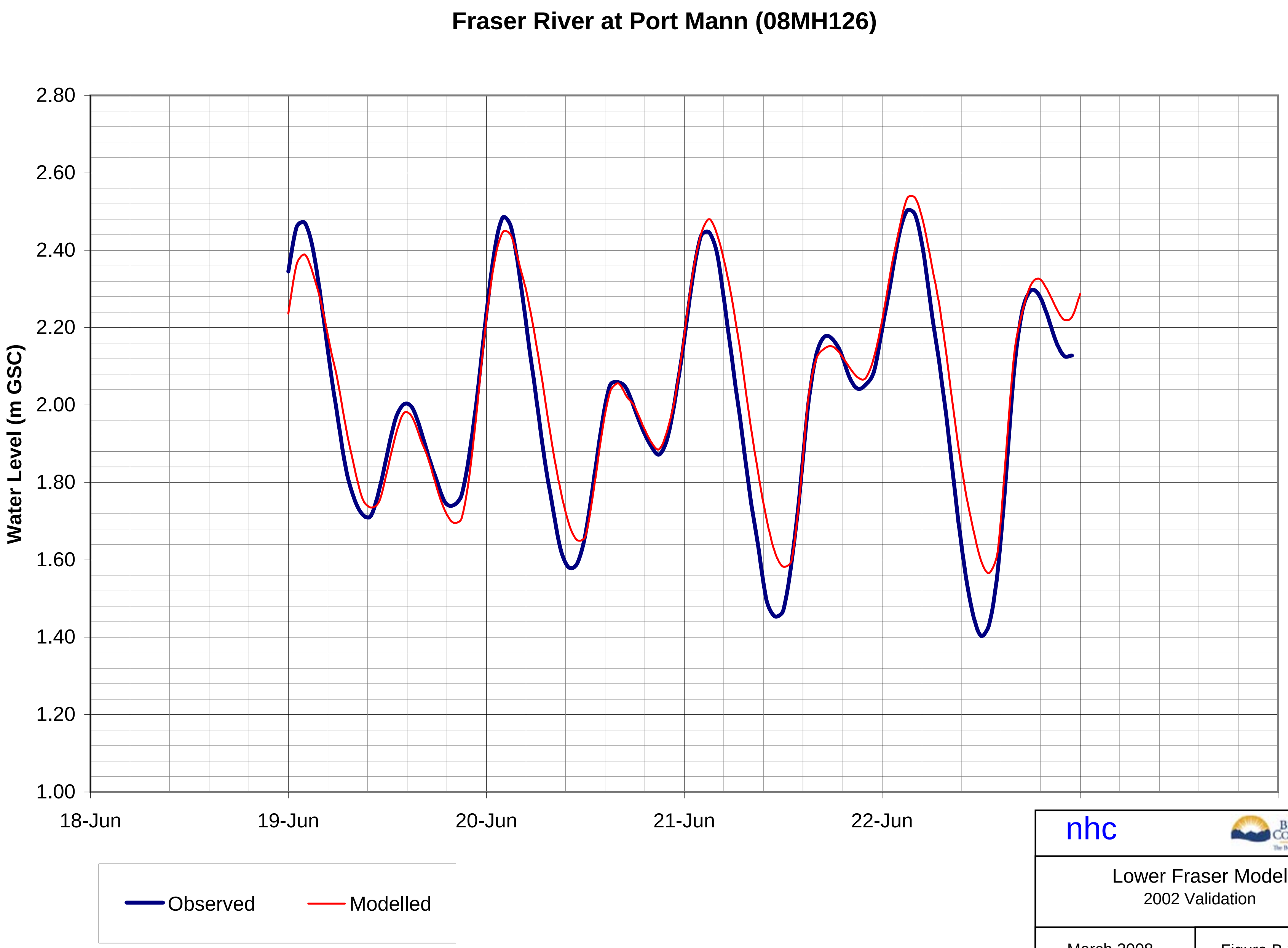
Lower Fraser Model
2002 Validation

March 2008	Figure B.34



Note: Manson gauge is near same location as New Westminster gauge but shows different recorded levels.

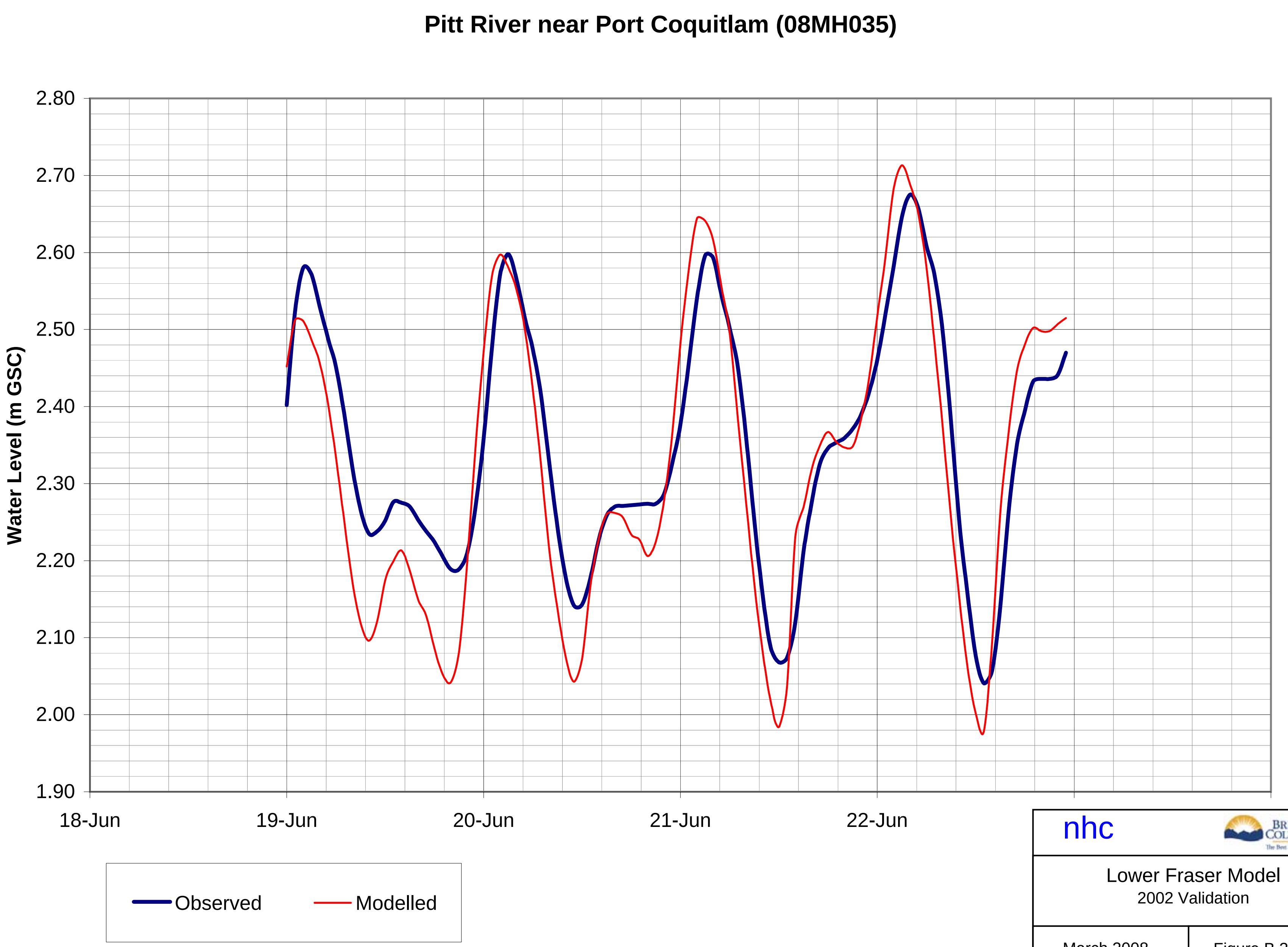
nhc	
Lower Fraser Model 2002 Validation	
March 2008	Figure B.35



nhc

Lower Fraser Model
2002 Validation

March 2008	Figure B.36

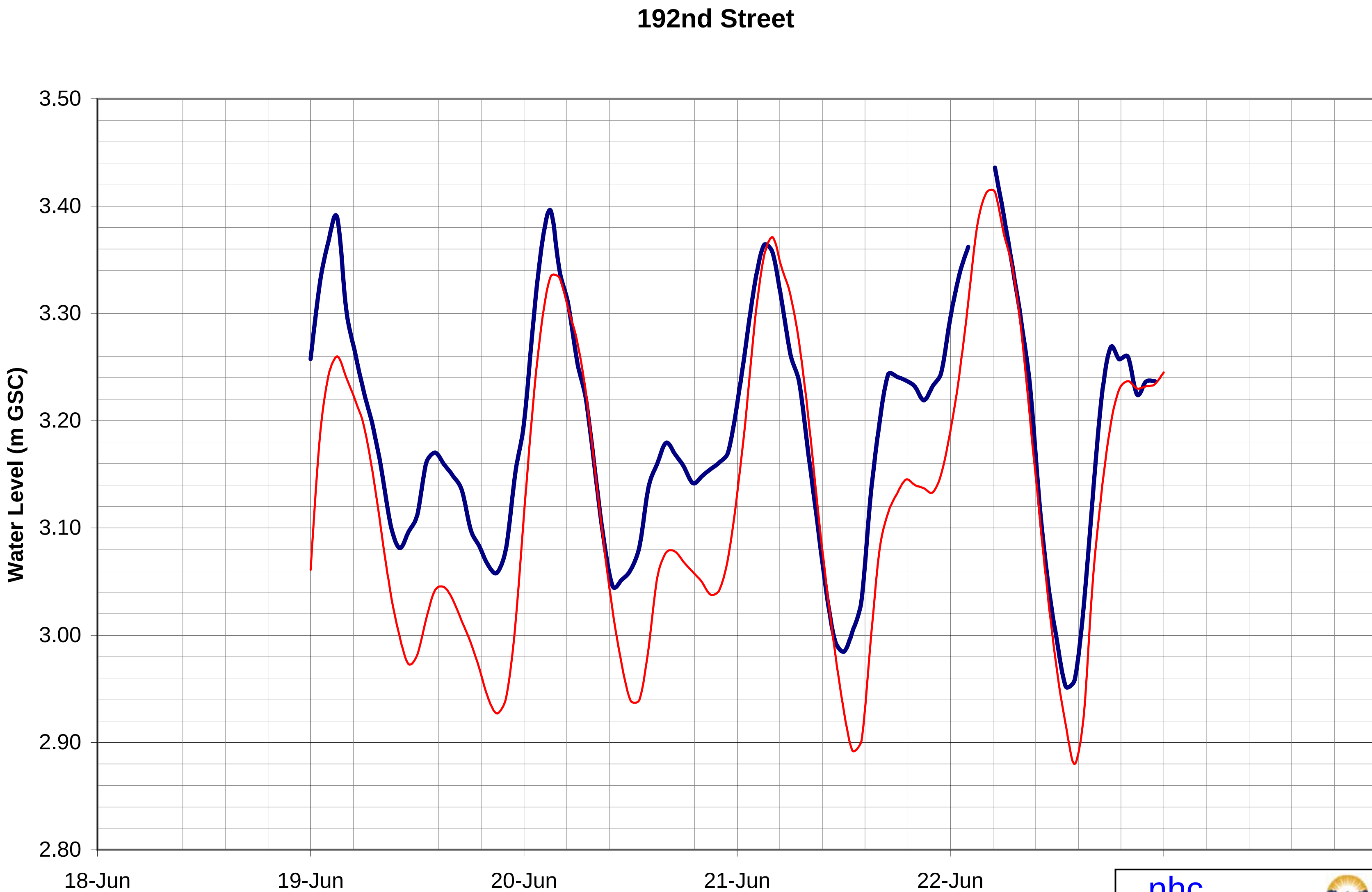


nhc

Lower Fraser Model
2002 Validation

March 2008

Figure B.37

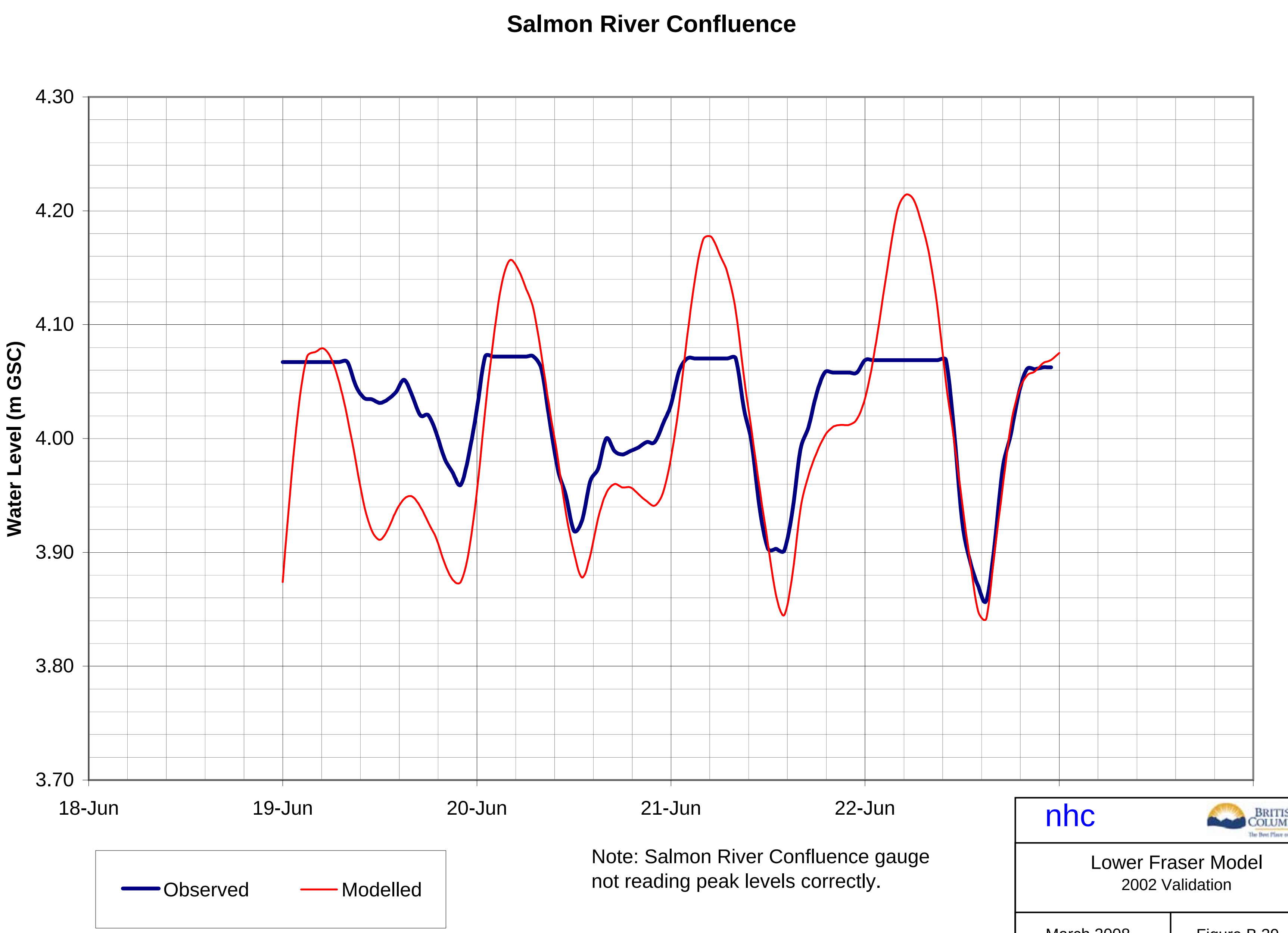


Note: Suspect data for peak tide on 22nd of June removed from data set.

nhc

Lower Fraser Model
2002 Validation

March 2008	Figure B.38



Note: Salmon River Confluence gauge not reading peak levels correctly.

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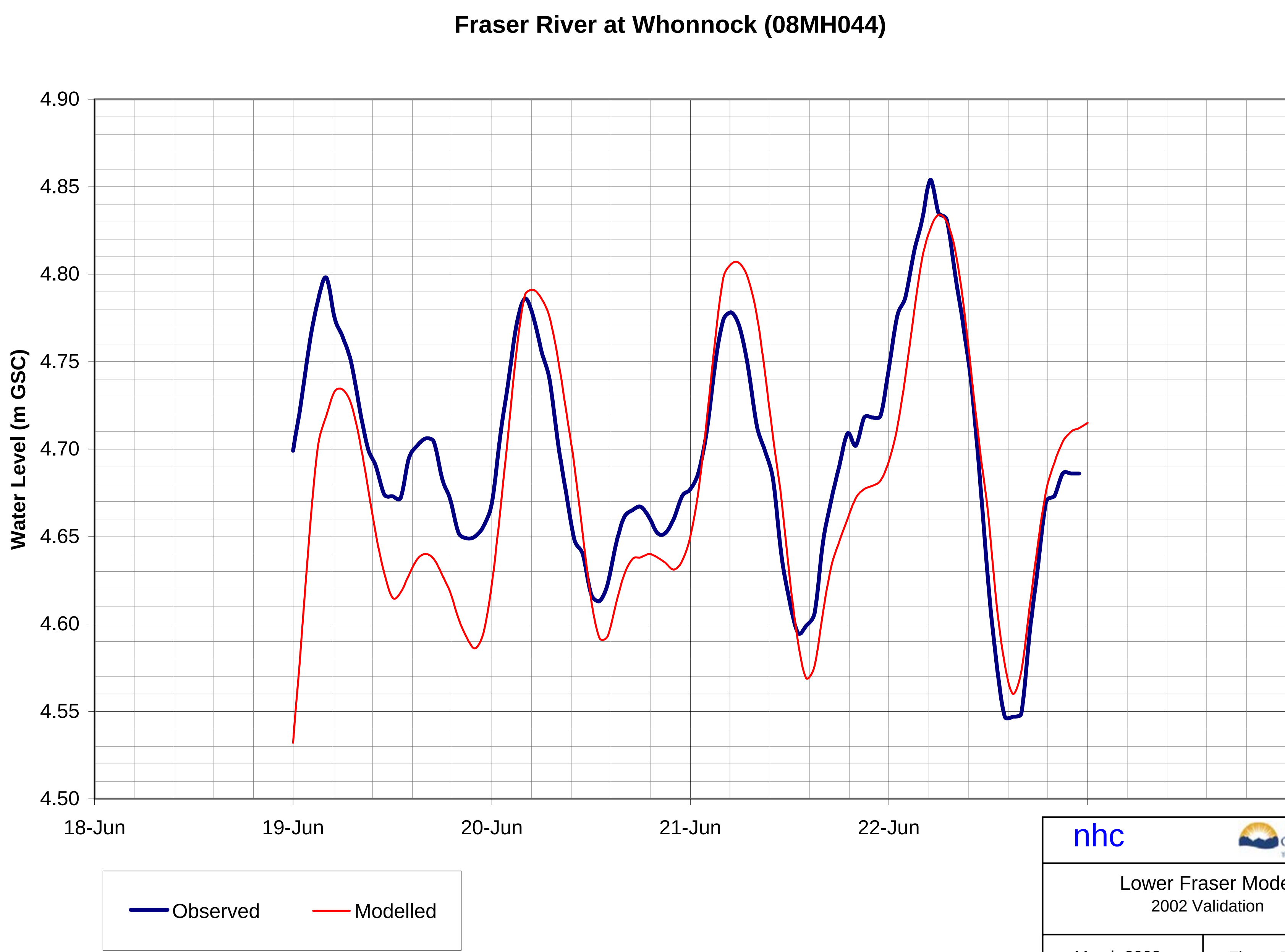
Lower Fraser Model
2002 Validation

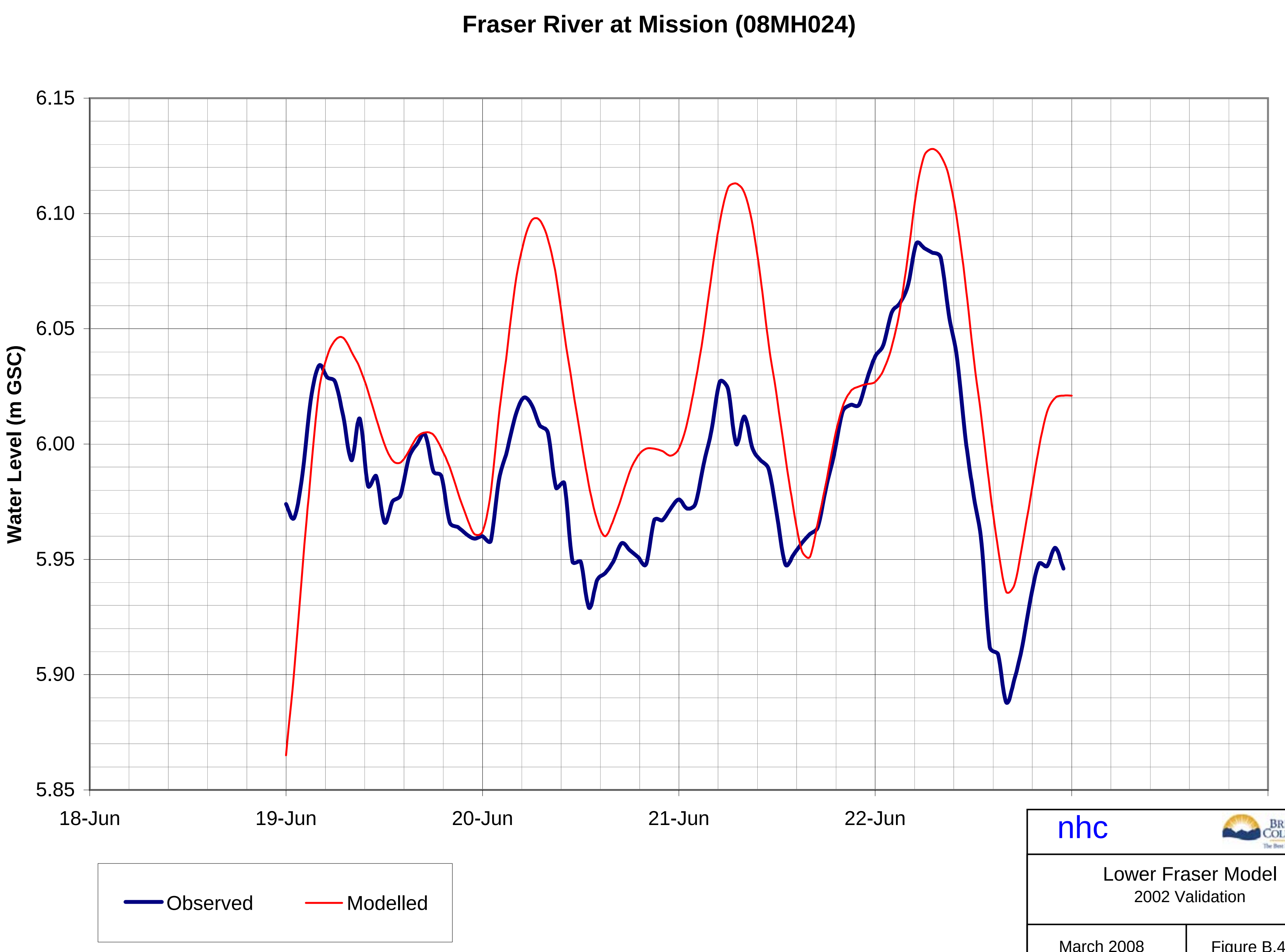
March 2008 | Figure B.39



nhc

Lower Fraser Model
2002 Validation

March 2008	Figure B.40



nhc

Lower Fraser Model
2002 Validation

March 2008

Figure B.41

APPENDIX C

ROUGHNESS FROM ADCP DATA

nhc
memorandum

northwest hydraulic consultants

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To:	FILE	**Date:**	5-Feb-2008
From:	**Jose (Pepe) Vasquez (nhc)**	**No. Pages:**	7
CC:		**Project No.:**	3-4743
		Ref. No.:	

Re: **Roughness from ADCP Data**
Fraser River Hydraulic Model Update

SCOPE AND APPROACH

This memo summarizes the results of a novel approach to estimate riverbed roughness from velocity data collected in the Fraser River at Mission using Acoustic Doppler Current Profilers (ADCP) mounted on moving boats. Roughness height (k_s) and shear velocity (u*) are computed by log-fitting measured vertical velocity profiles $u(z)$ as shown in Figure 1, using the equation:

$$\frac{u(z)}{u*} = \frac{1}{0.4}\log\left(\frac{30z}{k_s}\right)$$

Where z is the vertical coordinate measured from the bed upwards. The main challenge of this approach is the high level of noise in the data (Figure 1) caused by turbulent fluctuations. Using ADCP data requires the application of an averaging strategy in order to filter-out the noise. At some verticals, unphysical values of negative shear velocity ($u* < 0$) can occur. Sime *et al.* (2006) discarded those negative values and found the resulting shear stress (and shear velocity) to be overestimated, concluding that it was not advisable to log-fit shear velocity for estimating bed roughness or bed shear stress.

In the new approach introduced here, first a number of vertical ADCP measurements (ensembles) are averaged laterally using a span-wise averaging step (Δs); then these averaged vertically are used to compute $u*$. Finally, the transect-averaged shear velocity $U*$ is found simply by arithmetically averaging all the computed $u*$ values, including the negative ones. Manning's roughness n is computed as:

$$n = \left(\frac{U*}{U}\right)\frac{H^{1/6}}{\sqrt{g}}$$

where, U and H are the ADCP transect-averaged values of flow velocity and water depth respectively.

DATA AND RESULTS

Figure 2 shows the Manning's roughness values computed from ADCP data collected in the Fraser River at Mission by Water Survey of Canada (WSC) on June 5, 6, 11, 12 and 18, 2007 (circles); and by nhc on June 7, 2007 (diamonds).

A total of 35 flow measurements collected by WSC were used to compute roughness, the average discharge and roughness values for each day are shown in Table 1. Five measurements collected by nhc were also used for the same purpose, the results for each discharge are shown in Table 2. The results from nhc ADCP data are consistently lower than those computed from WSC data (Figure 1). The average Manning's roughness for WSC data is n = 0.038 ± 0.003 (Table 1); while for nhc data it is n = 0.031 ± 0.002 (Table 2). The reason for this discrepancy is unclear, but it is probably a consequence of the different ADCP instrument settings used during the field surveys (Figure 3) and missing ensembles in nhc data (Figure 4). Notably, the bin size used by WSC's ADCP was 50 cm; while nhc's ADCP used half that value.

Values in Tables 1 and 2 were computed from data post-processed by the program ADCP XP (Kim *et al*. 2007). This program can use different lateral span-wise averaging steps (Δs) to compute both shear velocities u^* and depth-averaged flow velocities u. The computed Manning's roughness is quite sensitive to Δs. For the WSC data, $\Delta s = 2.0$ m was adopted for both u and u^*. For nhc's data, because of several missing pings (Figure 4), ADCP XP crashed if $\Delta s < 6.0$ m, therefore $\Delta s = 6.0$ m was adopted for u^*. u was computed without lateral averaging; which led to a lower (negatively biased) transect-averaged velocity U for nch results; which may be another source for discrepancy between the results derived from the two data sets.

The roughness values from the WSC –although positively biased- show a weak decrease with discharge (Figure 2, Table 2). The minimum roughness is achieved during the peak flow. Post-peak roughness appears to remain lower than pre-peak values; as if the peak flow had smoothed bedforms. However, these subtle changes in roughness are in the range of the computed scatter and hence are too small to be conclusive.

The new approach introduced here for estimating roughness appears promising, as no other quick approach for measuring roughness in the field presently exists. Since this method uses ADCP data collected from routine flow measurements, no additional field effort is required. Considering the high level of noise in the data, the resulting coefficient of variation (CoV) shown in Tables 1 and 2 is not excessively high, proving the results are consistent, although biased.

This attempt to calculate roughness identified limitations with the available data. It is recommended that additional ADCP measurements be performed to investigate the effects of instrument settings on the results, especially the bin size. Measurements using fixed ADCPs (e.g. boat anchored or tethered to the bridge) are also recommended to eliminate turbulent noise by long time-averaging.

REFERENCES

Kim, D., Muste, M., Weber, L. and Asman, R. (2007). “Getting to know AdcpXP: ADCP eXtended Processing”. IIHR- Hydroscience & Engineering, University of Iowa.

Sime, L.C., Ferguson, R.I. and Church, M. (2007). “Estimating shear stress from moving boat acoustic Doppler velocity measurements in a large gravel bed river”. Water Resources Research, Vol. 43, W03418, doi:10.1029/2006WR005069.

Table 1. Daily averaged results for WSC data (2007).

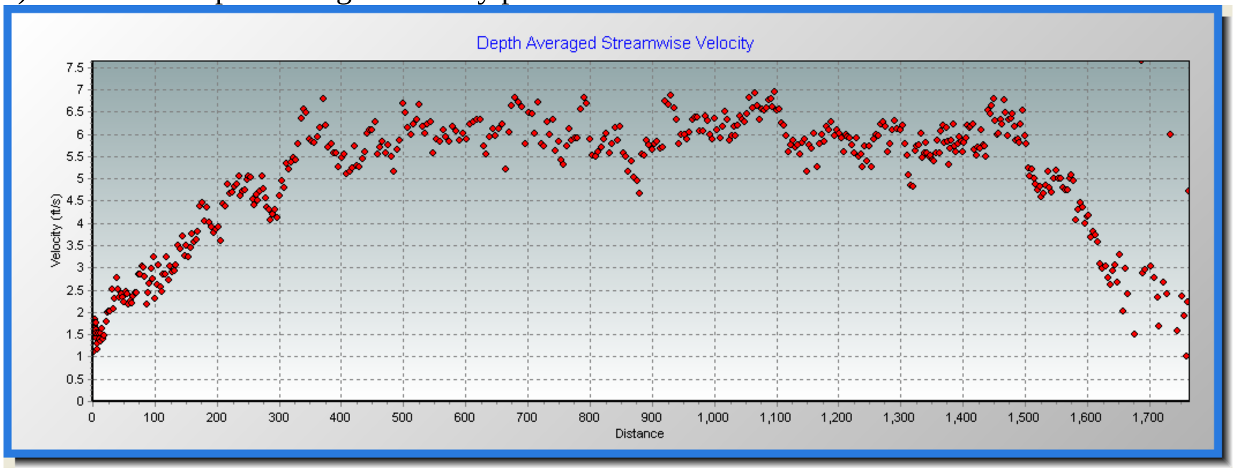
Survey Date	Spanwise step (m)	Discharge (m^3/s)	Manning's Roughness
May 24	2	7445	0.039
June 5	2	10526	0.038
June 6	2	11303	0.039
June 11	2	12147	0.035
June 12	2	11463	0.037
June 18	2	8760	0.037
		mean	**0.038**
		st. dev	**0.003**
		CoV	**7%**

Table 2. Summary of results for nhc data (June 7, 2007).

Transect Number	Spanwise step (m)	Discharge (m^3/s)	Manning's Roughness
140906	6	10983	0.030
142004	6	11276	0.035
143938	6	11347	0.031
145422	6	11009	0.028
150026	6	11362	0.030
		mean	**0.031**
		st. dev	**0.002**
		CoV	**8%**

st. dev. = standard deviation
CoV = coefficient of variation = (st. dev.) / (mean)

a) Transverse depth-averaged velocity profile



b) Vertical velocity profiles *u*(*z*)

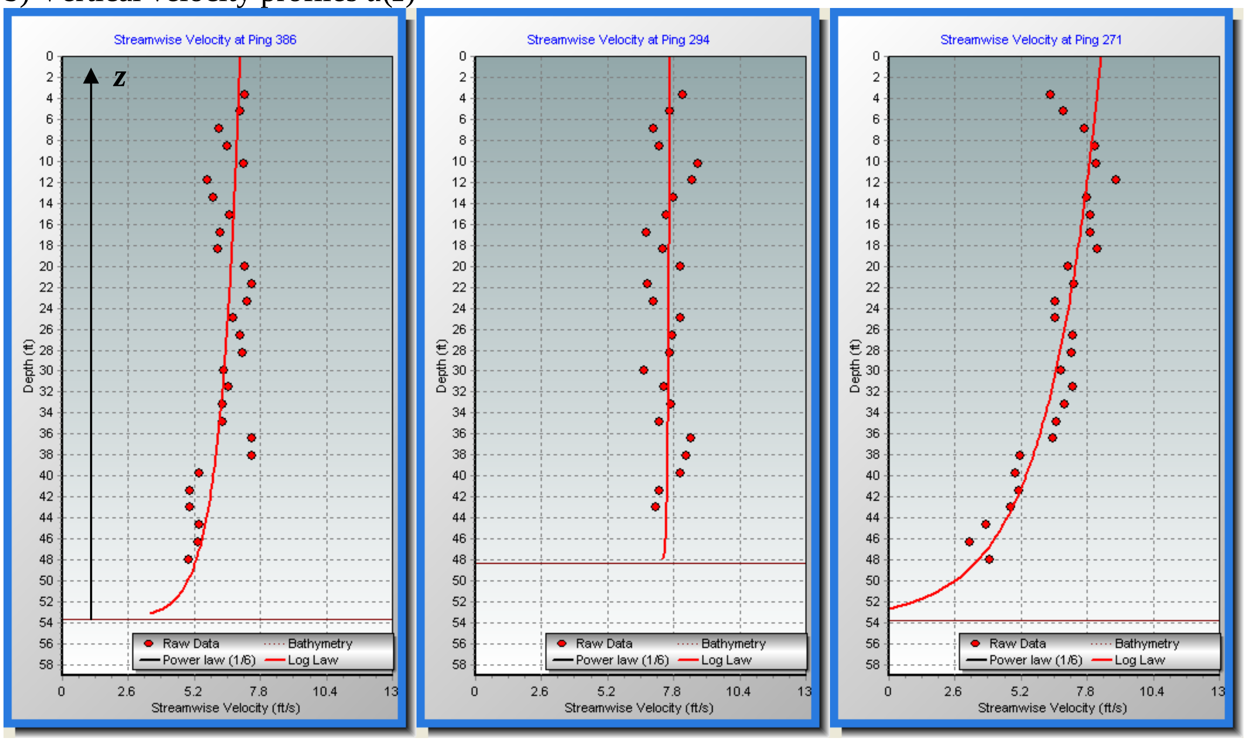


Figure 1 Examples of (a) depth-averaged transverse velocity profiles and (b) vertical velocity profiles measured by ADCP in the Fraser River at Mission (WSC Transect 08mh024_20070611002).

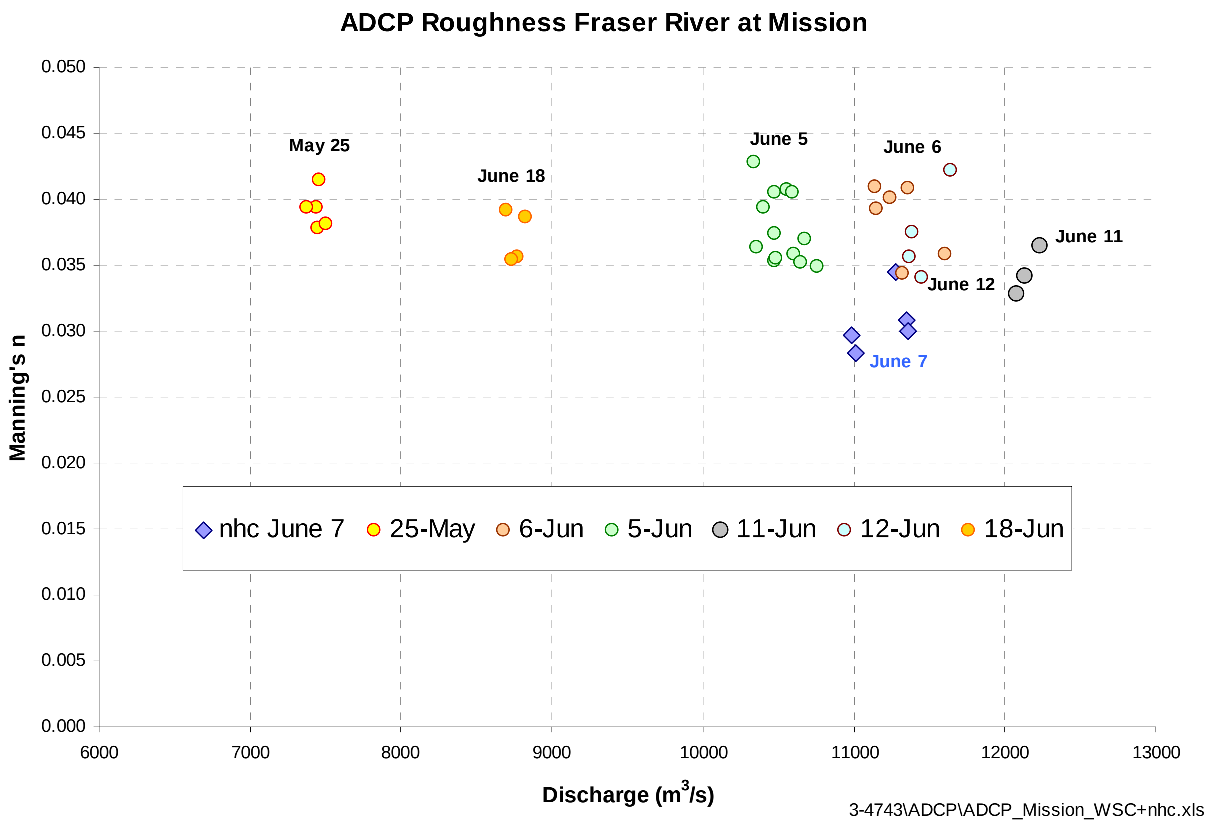
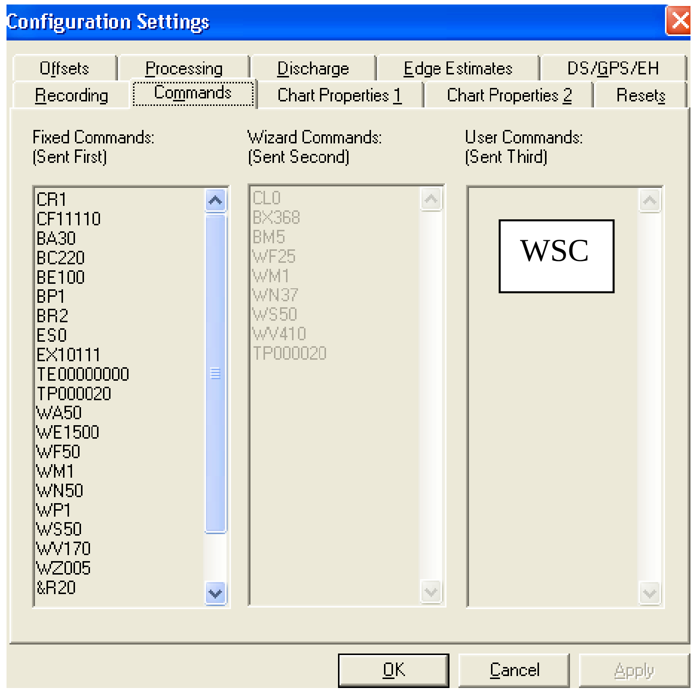


Figure 2 Manning's roughness, Fraser River at Mission, computed from 2007 ADCP data (diamonds are nhc data and circles WSC data).



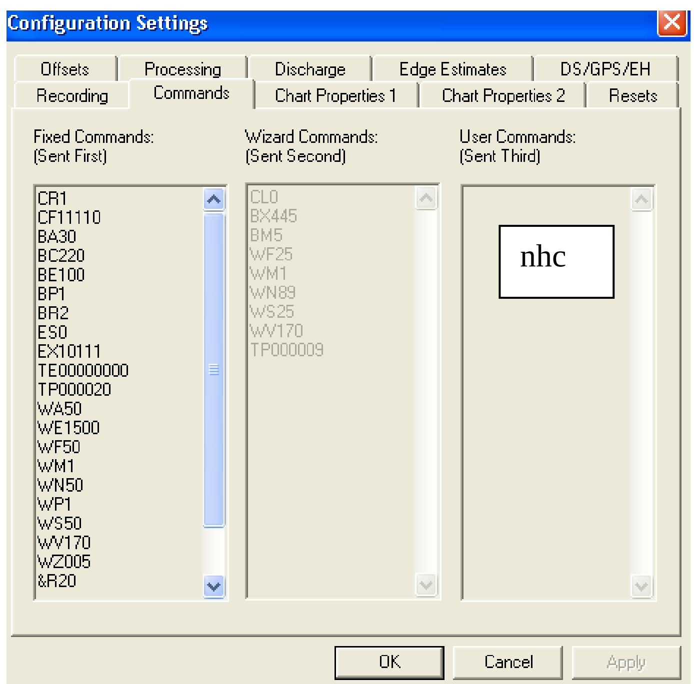
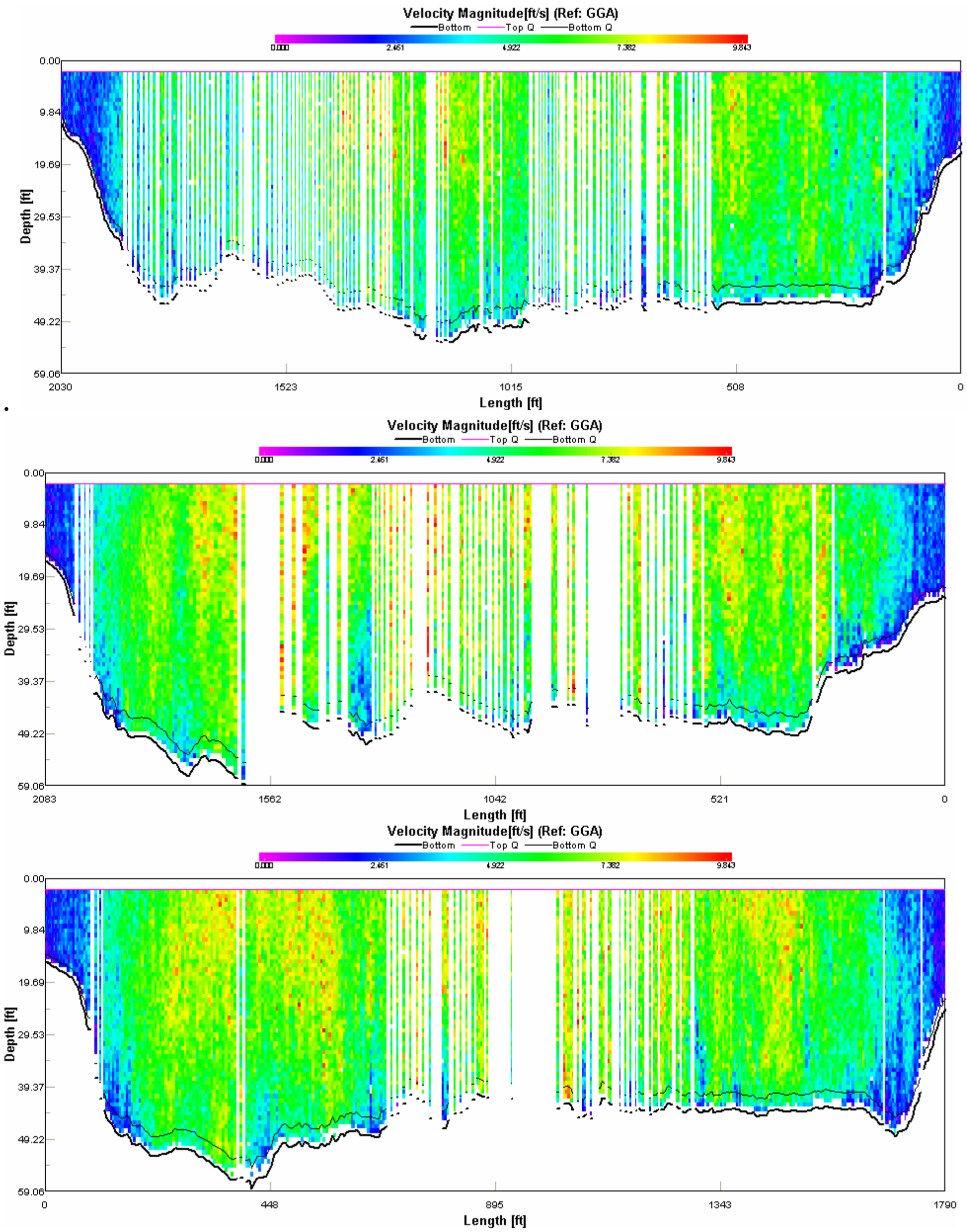


Figure 3 ADCP configuration settings for both WSC and nhc instruments. BX = maximum tracking depth [1/10 m]; WN = number of depth cells; WS = bin size [cm]; TP = time between pings [1/100 s]; WV = maximum relative velocity between boat and water [cm/s].



140906

145422

150026

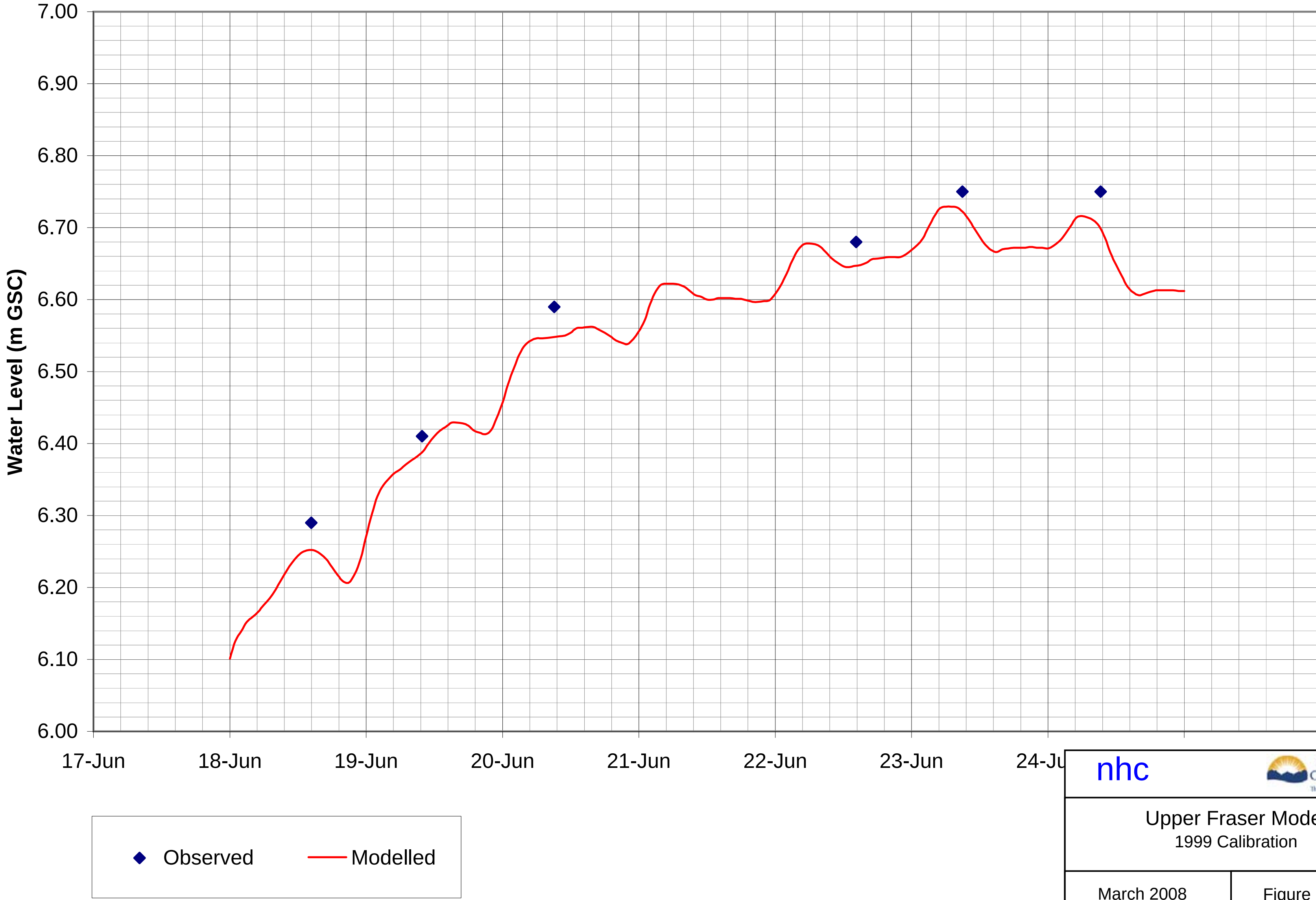
Figure 4 Example of ADCP transects surveyed by nhc.

APPENDIX D

CALIBRATION/VALIDATION PLOTS FOR UPPER MODEL

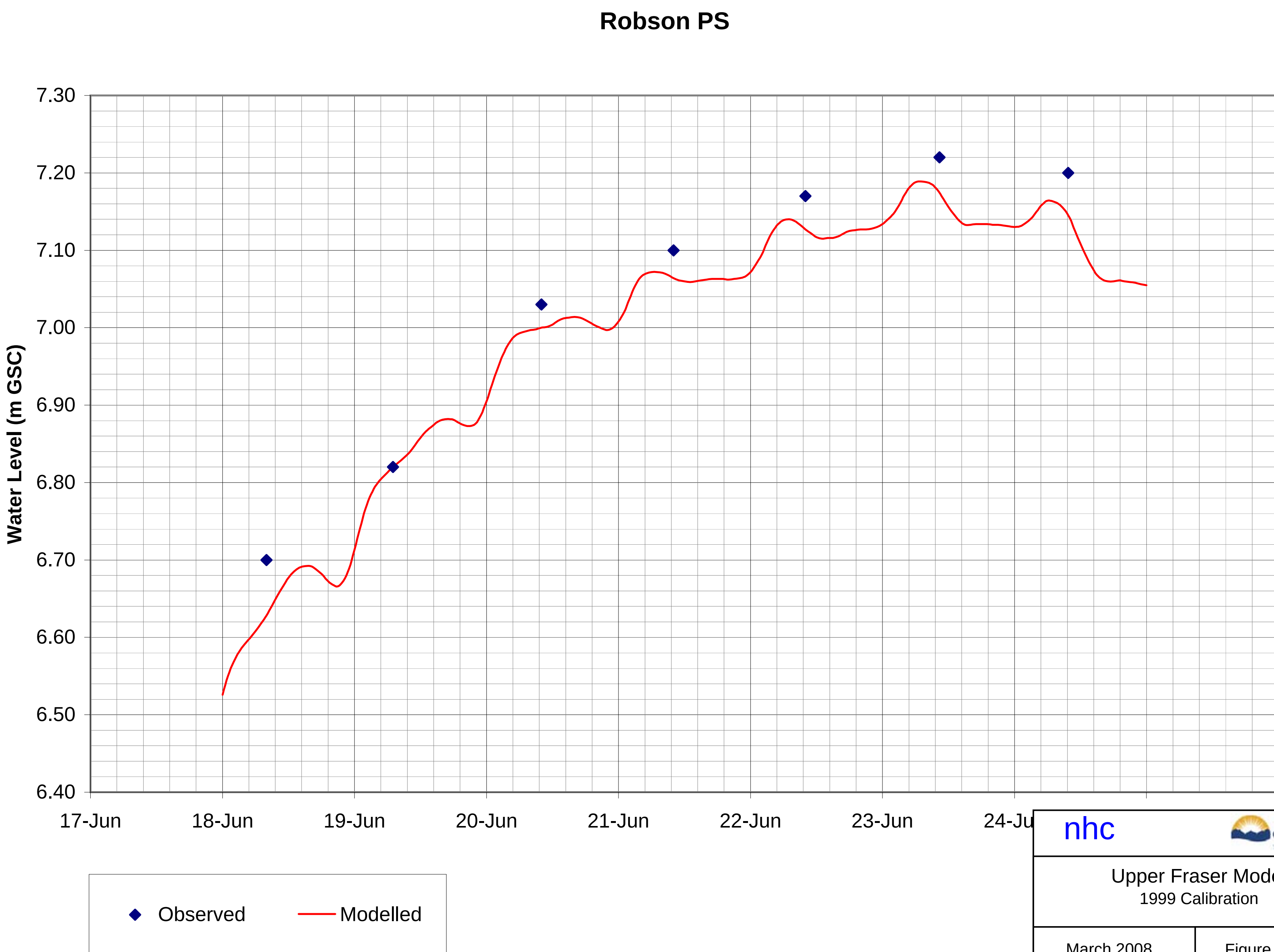
1999 Calibration			2007 Validation	
Plot Number	Gauge Name		Plot Number	Gauge Name
D-1	Dewdney PS		D-22	Fraser River at Mission (08MH024)
D-2	Robson PS		D-23	Dewdney PS
D-3	McGillivray Slough PS		D-24	Robson PS
D-4	Collinson PS		D-25	McGillivray Slough PS
D-5	Quaamitch Slough		D-26	Collinson PS
D-6	Chilliwack Creek PS (Wolfe Road)		D-27	Quaamitch Slough
D-7	Hope Slough at Young Street		D-28	Chilliwack Creek PS (Wolfe Road)
D-8	Bell Dam		D-29	Hope Slough at Young Street
D-9	Minto Landing Area (Bell Slough)		D-30	Bell Dam
D-10	Harrison Mills (Kilby)		D-31	Minto Landing Area (Bell Slough)
D-11	Scowlitz (Harrison Bay)		D-32	Harrison Mills (Kilby)
D-12	Duncan Bateson PS		D-33	Duncan Bateson PS
D-13	Carey Point		D-34	Harrison River below Morris Creek
D-14	Hammersley PS		D-35	Carey Point
D-15	Chip (Camp-Hope) Intake		D-36	Hammersley PS
D-16	Agassiz-Rosedale Bridge		D-37	Chip (Camp-Hope) Intake
D-17	Maria Slough		D-38	Agassiz-Rosedale Bridge
D-18	Herrling Island		D-39	Cuthbert Road
D-19	Seabird Island		D-40	Maria Slough
D-20	Johnson Slough		D-41	Herrling Island
D-21	Wahleach (Jones Creek)		D-42	Johnson Slough
			D-43	Wahleach Powerhouse
			D-44	Wahleach (Jones Creek)

Dewdney PS



nhc

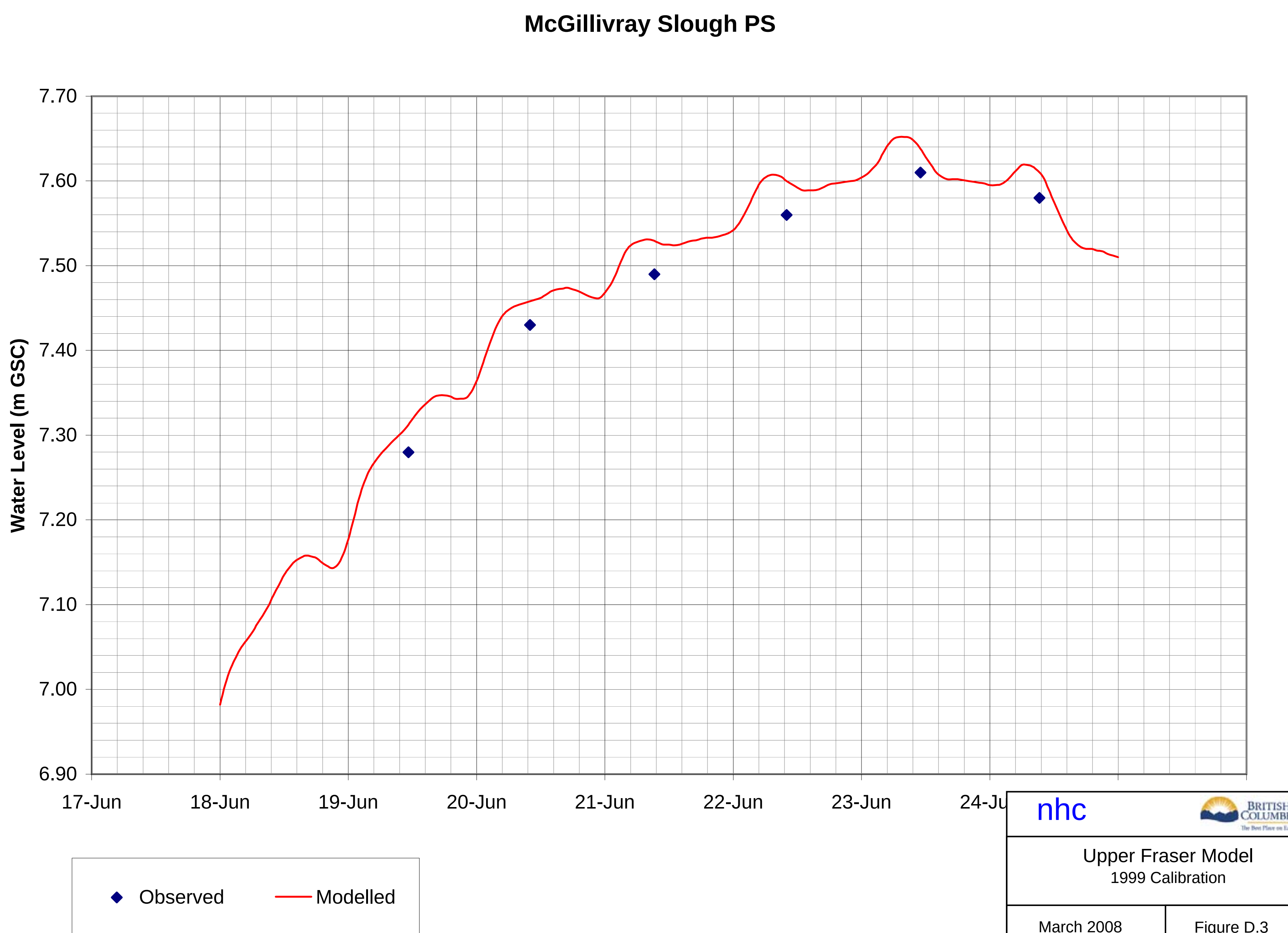
Upper Fraser Model 1999 Calibration	
March 2008	Figure D.1



nhc

Upper Fraser Model
1999 Calibration

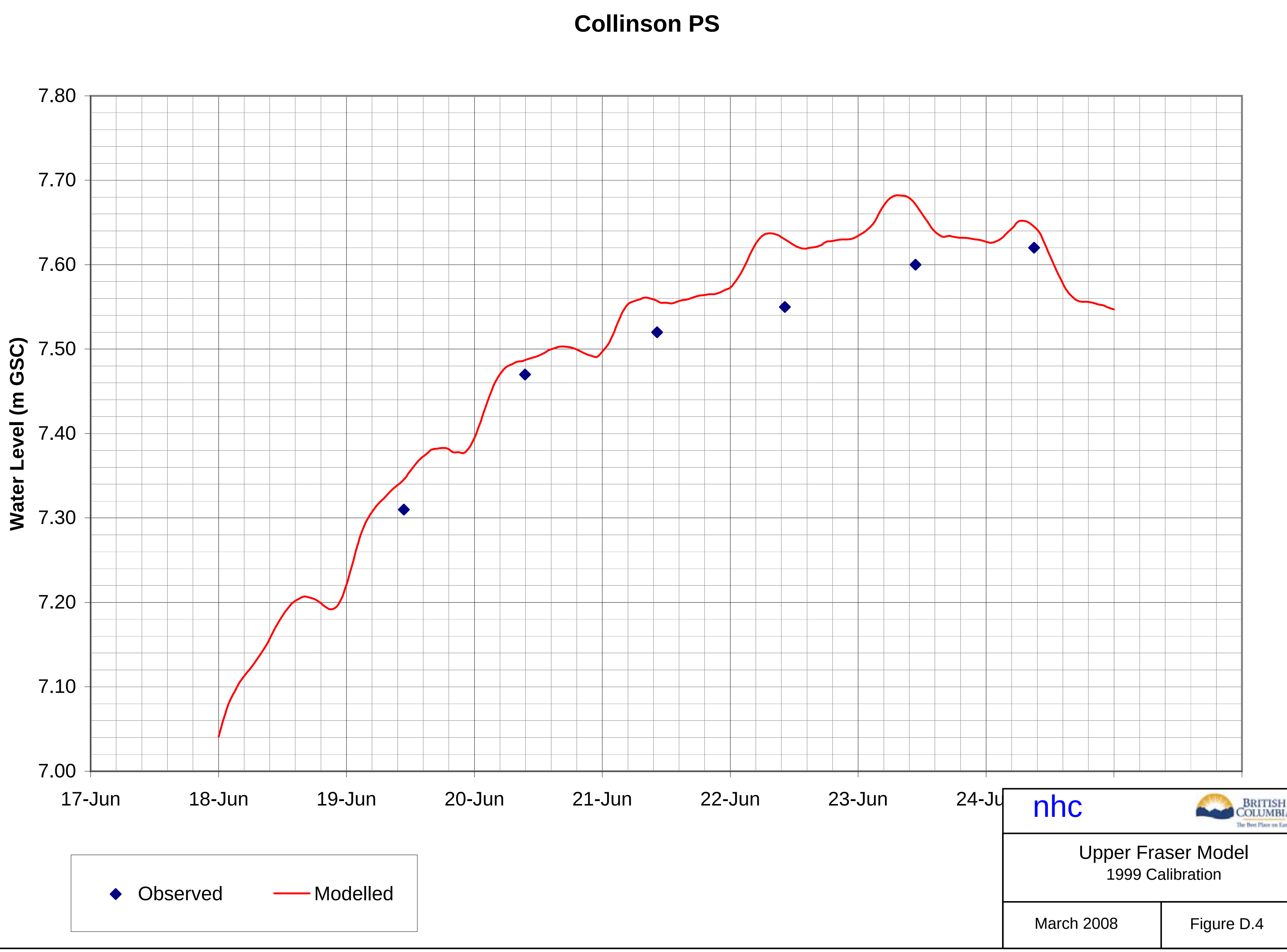
March 2008	Figure D.2



nhc

Upper Fraser Model
1999 Calibration

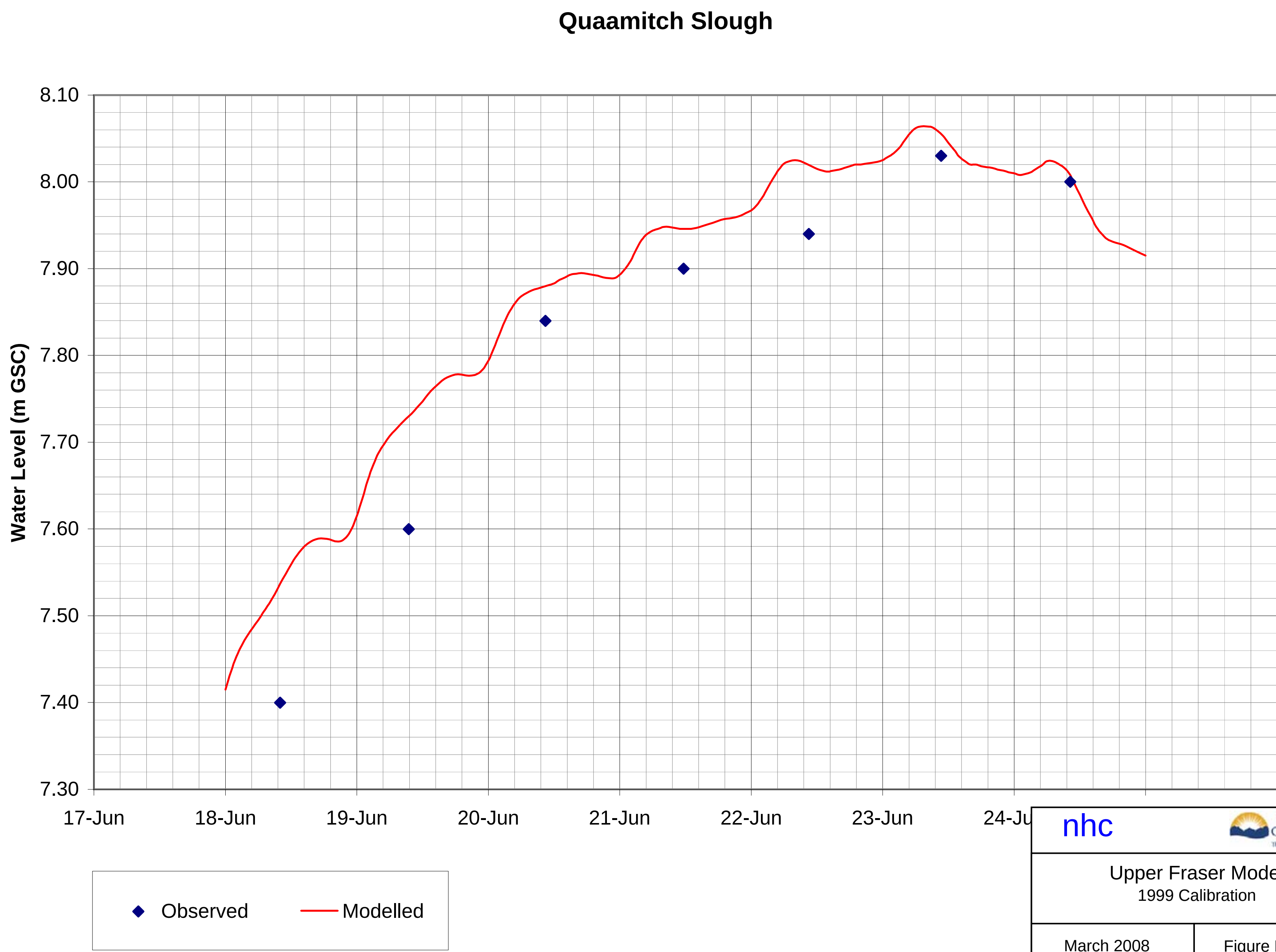
March 2008	Figure D.3



nhc

Upper Fraser Model
1999 Calibration

March 2008	Figure D.4

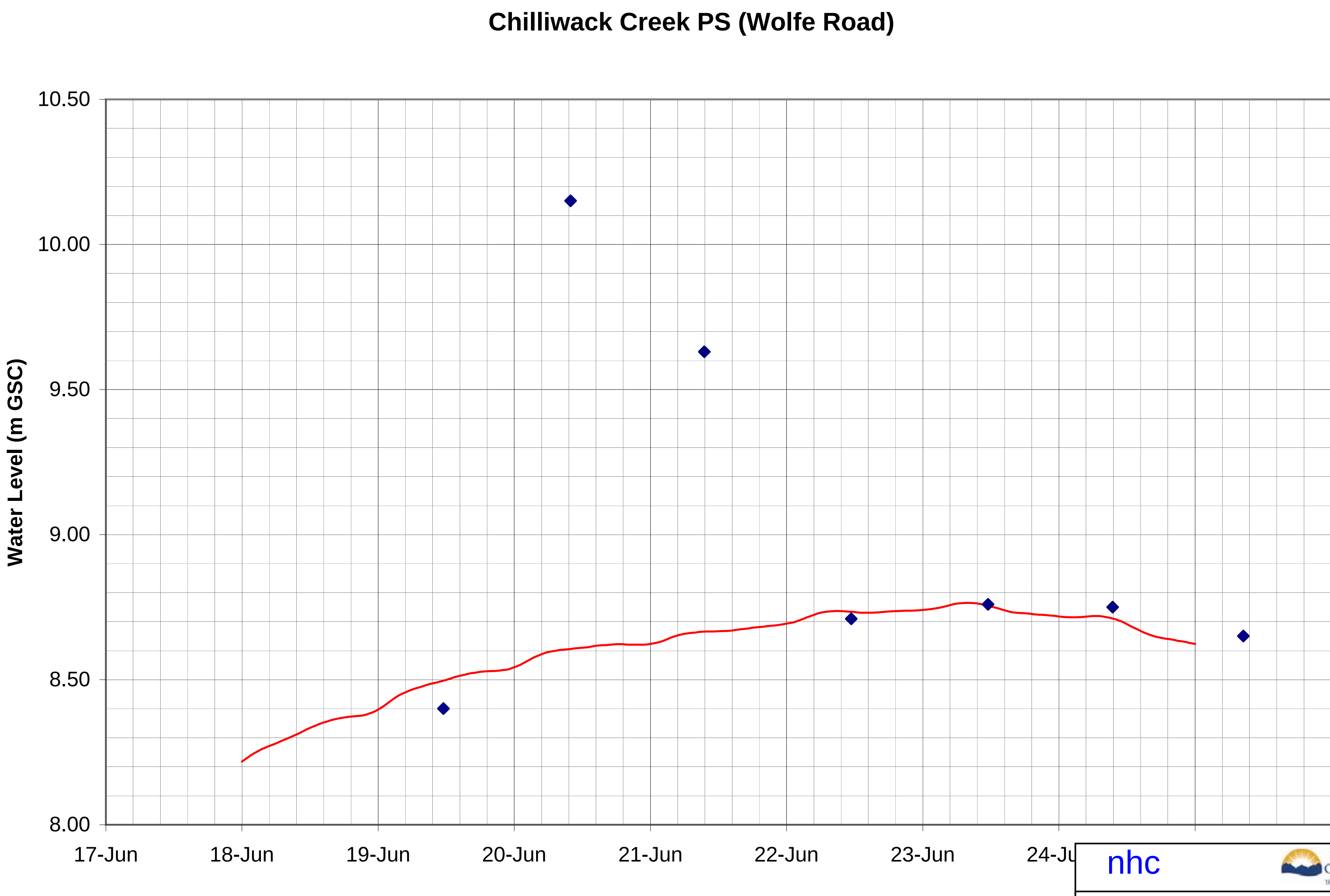


nhc

BRITISH COLUMBIA

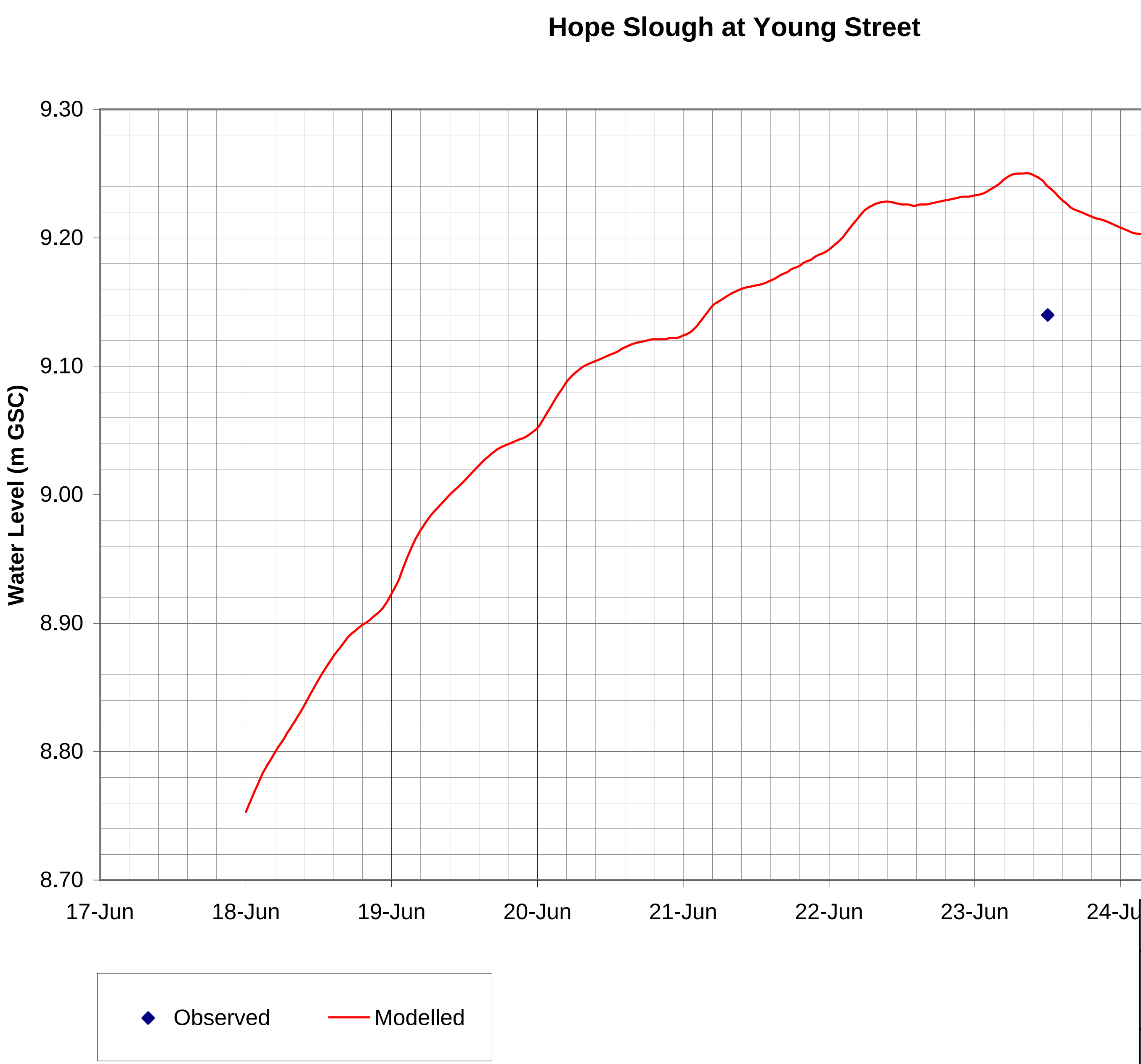
Upper Fraser Model
1999 Calibration

March 2008	Figure D.5



Note: Suspect data recorded on 20th and 21st.
Pump station may have been operating.

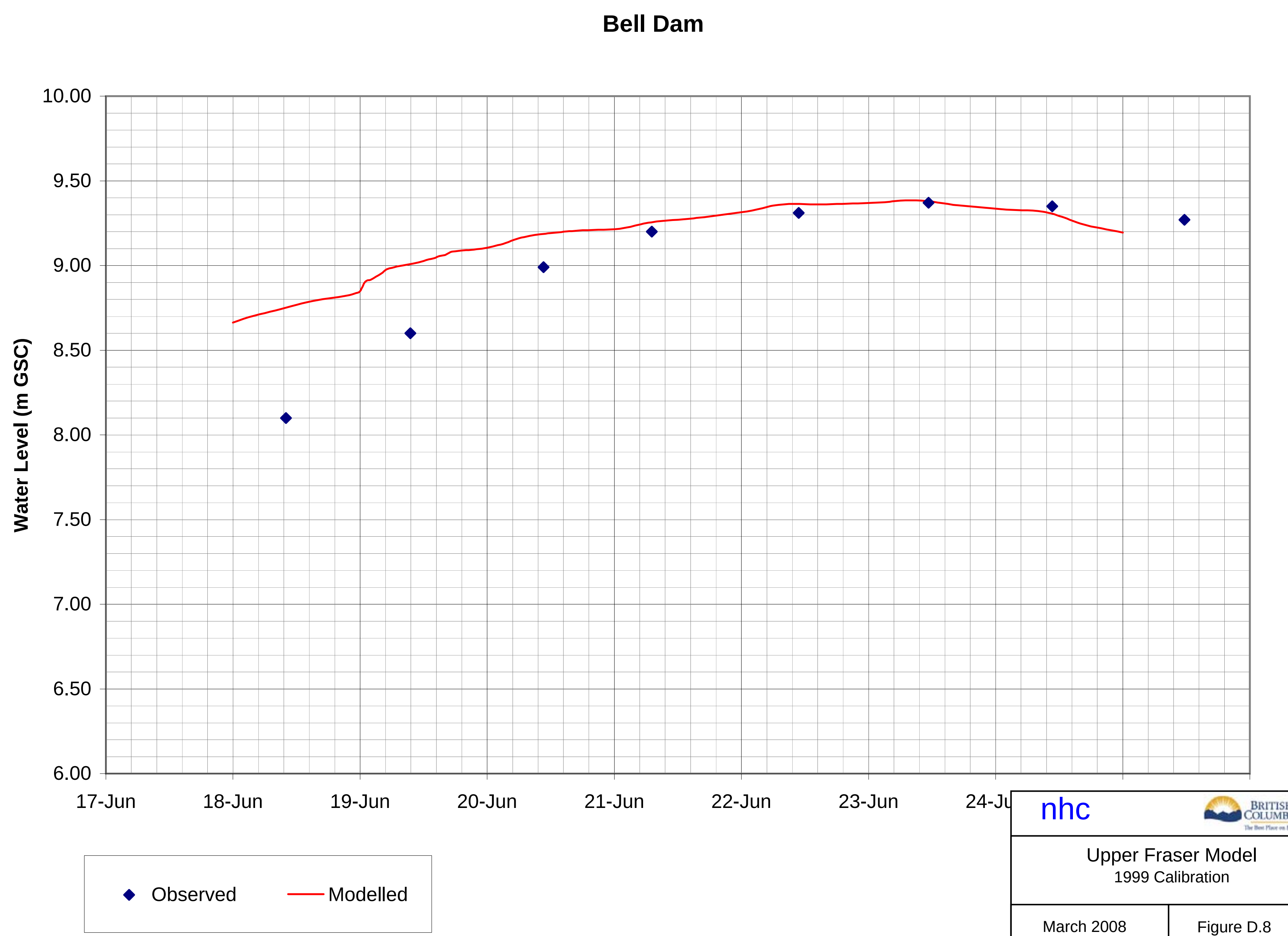
nhc	British Columbia
Upper Fraser Model 1999 Calibration	
March 2008	Figure D.6



nhc

Upper Fraser Model
1999 Calibration

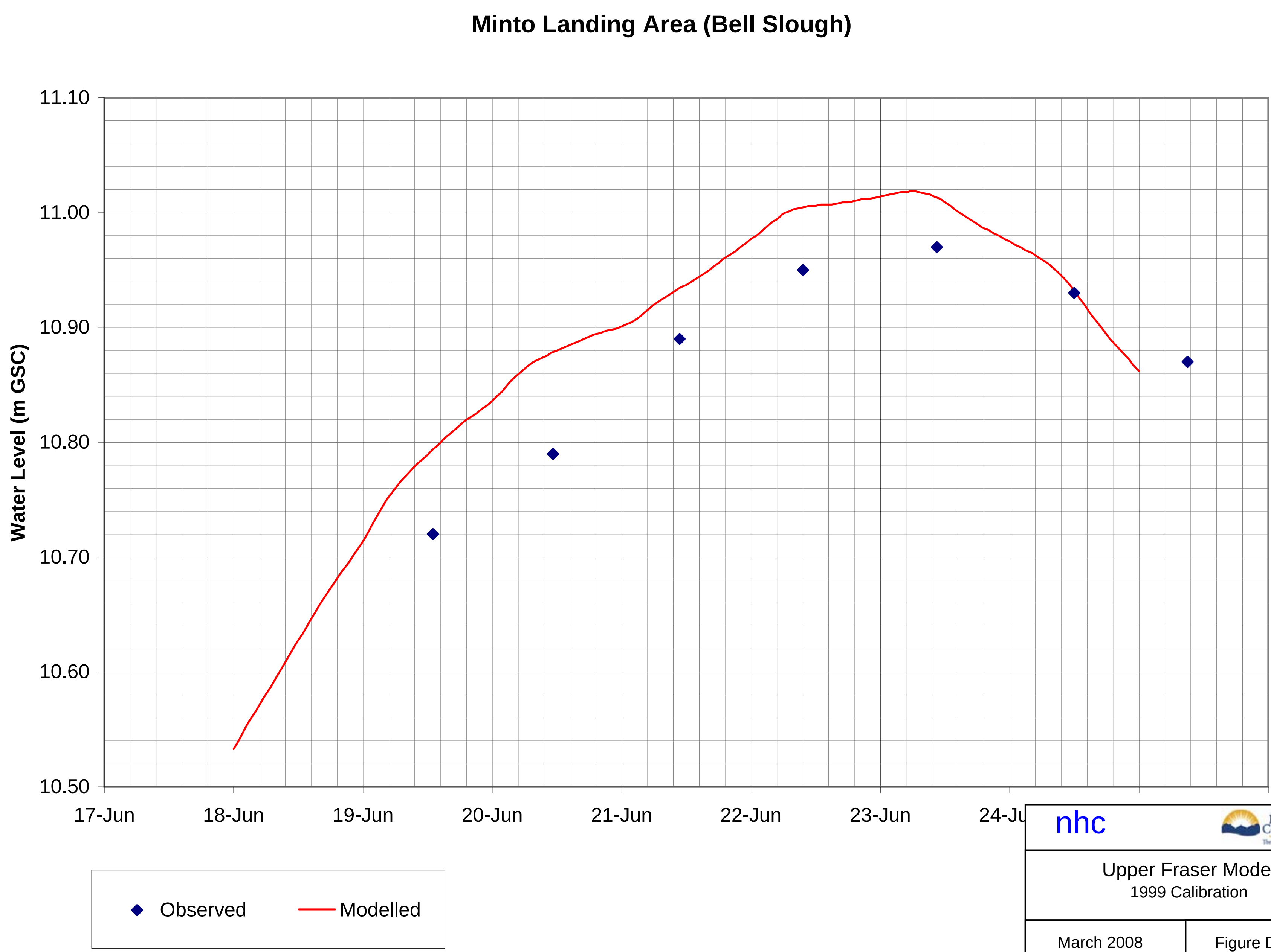
March 2008	Figure D.7



nhc

Upper Fraser Model
1999 Calibration

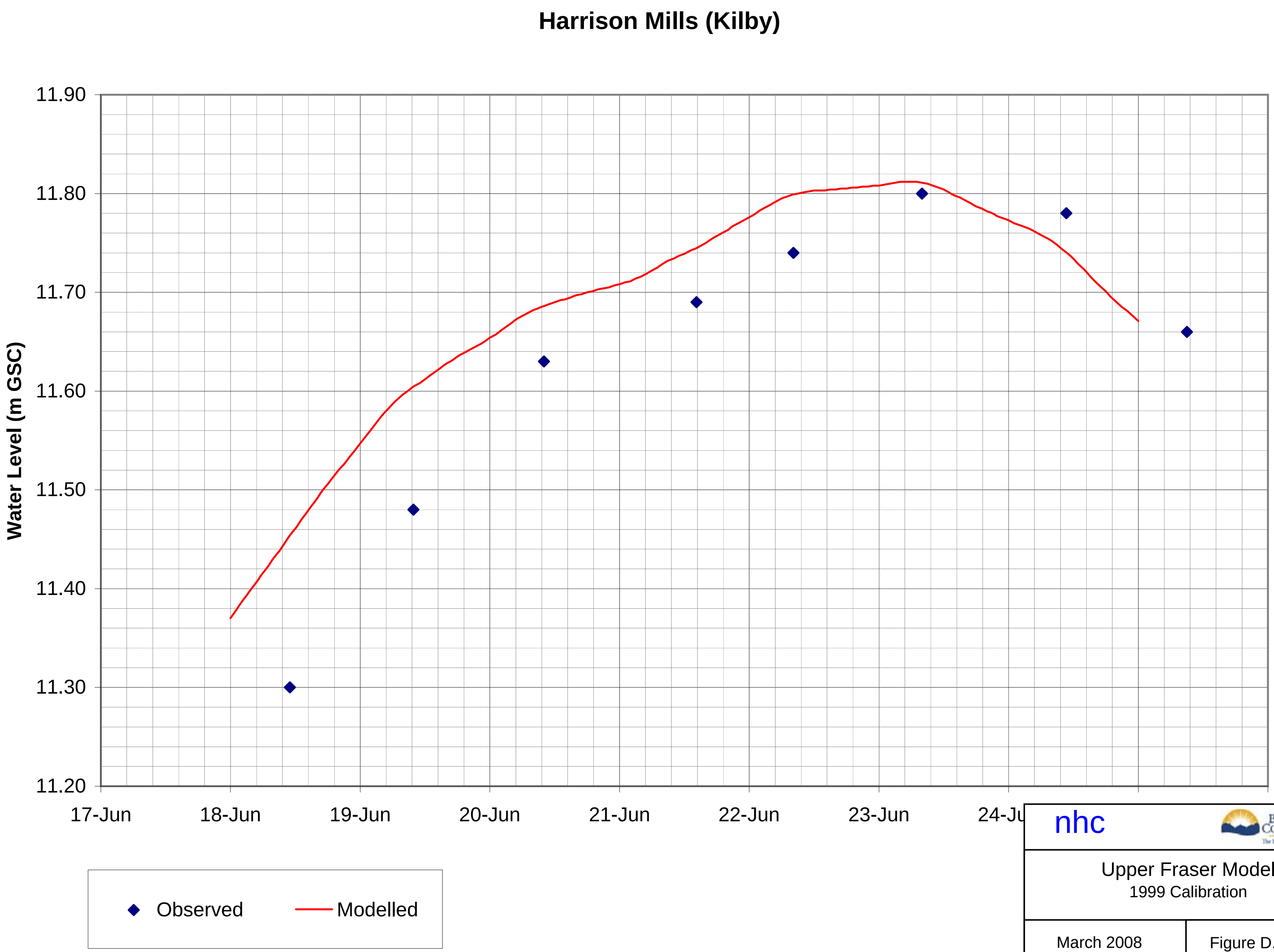
March 2008	Figure D.8



nhc

Upper Fraser Model
1999 Calibration

March 2008	Figure D.9

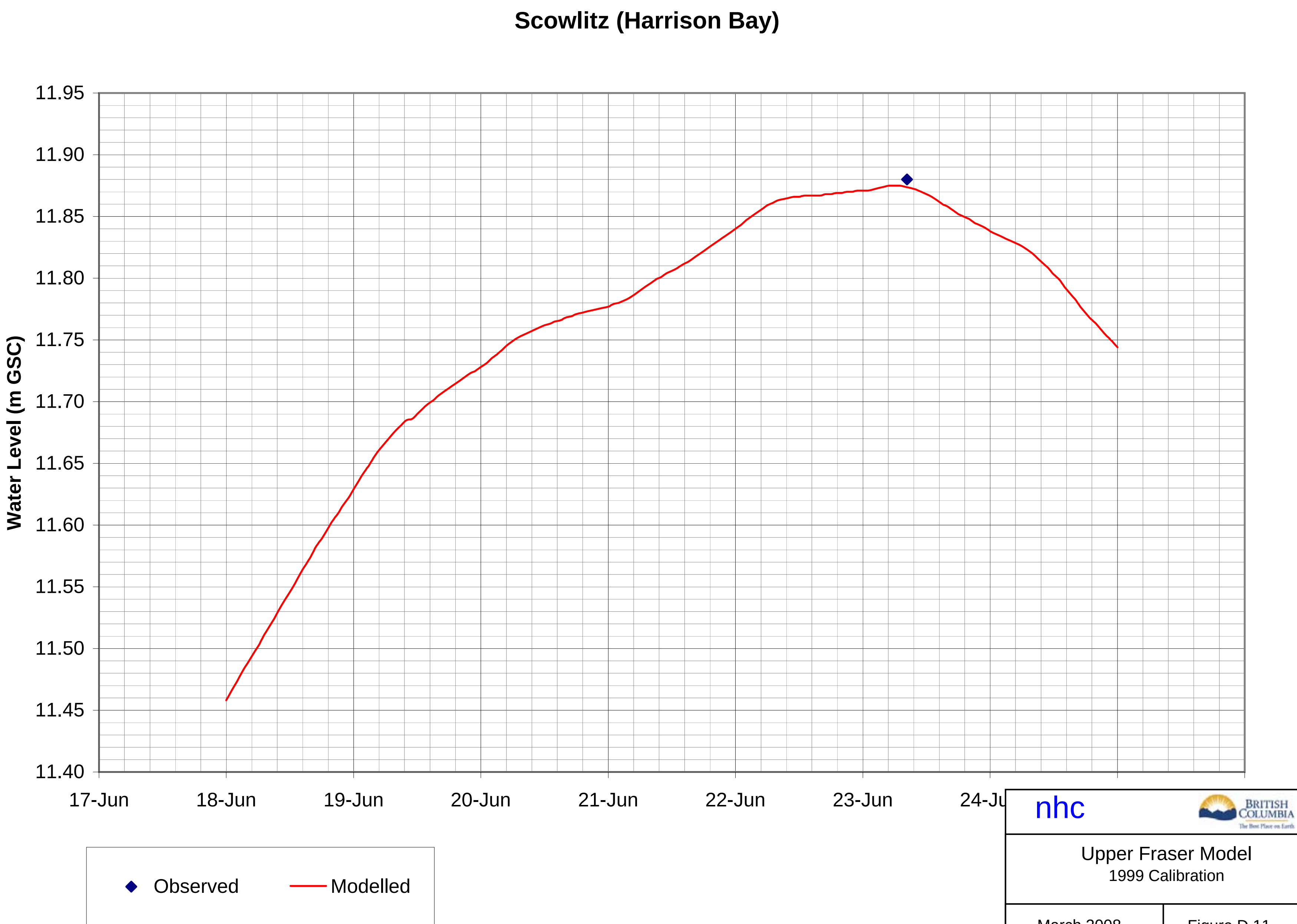


nhc

BRITISH COLUMBIA

Upper Fraser Model
1999 Calibration

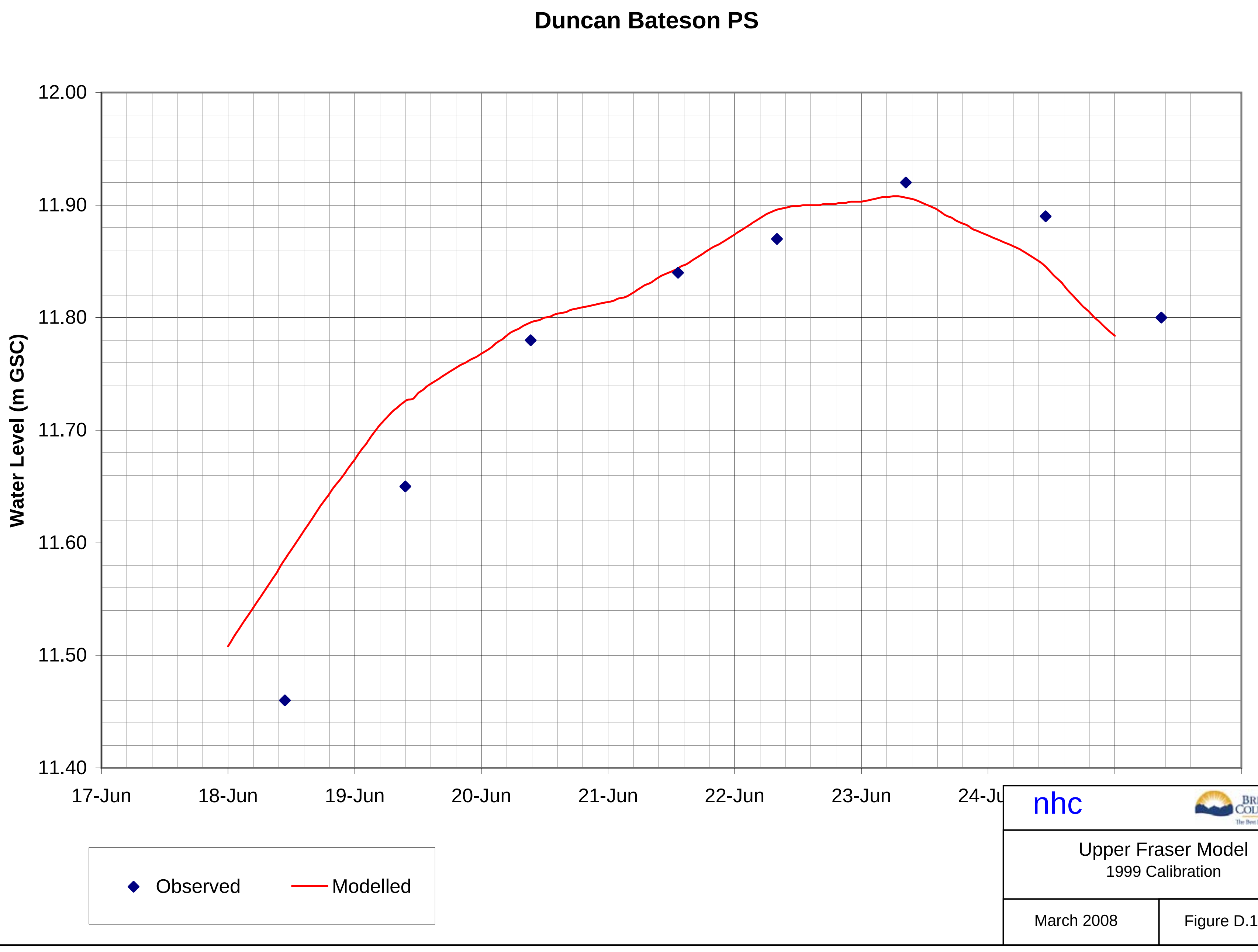
March 2008	Figure D.10



nhc

Upper Fraser Model
1999 Calibration

March 2008	Figure D.11

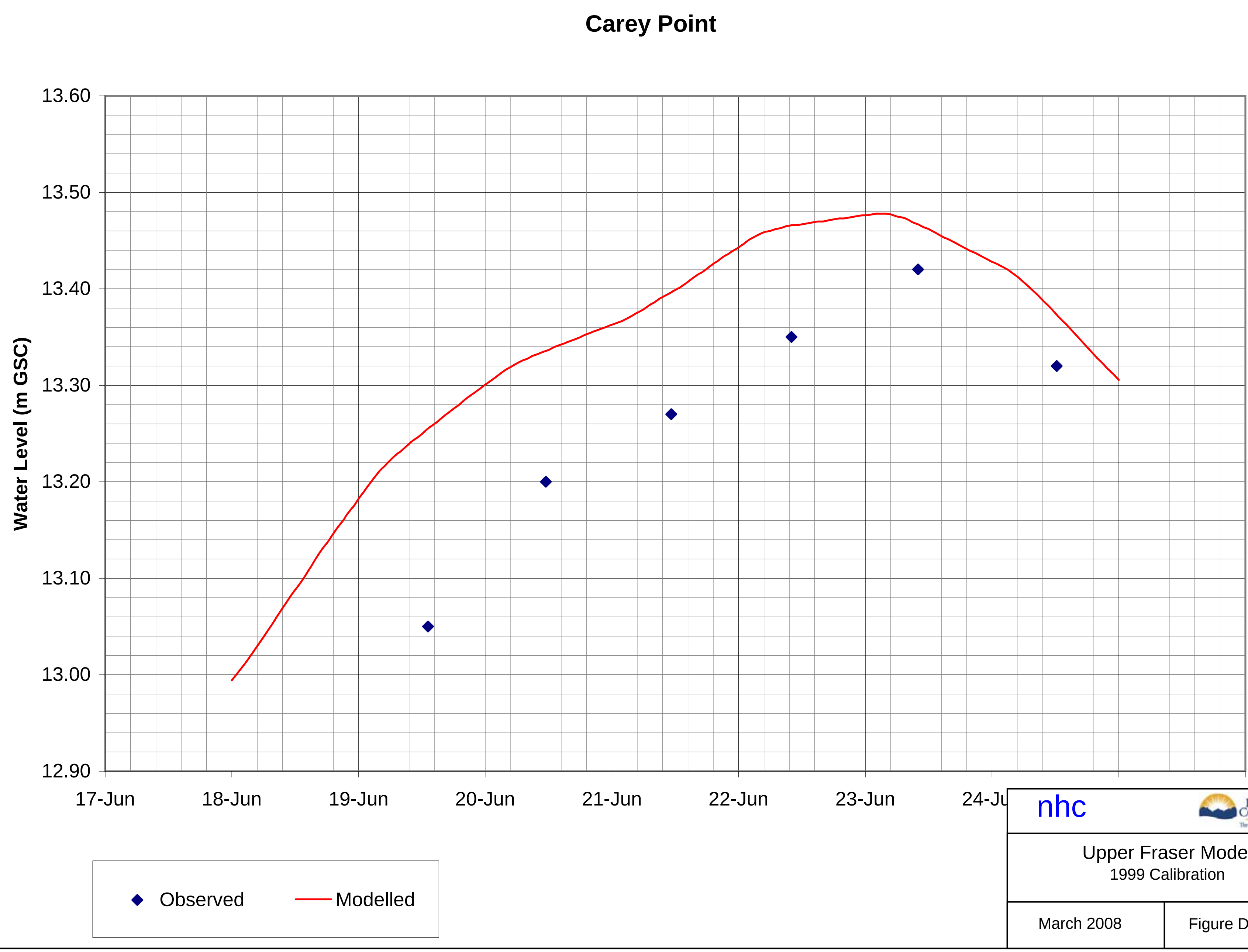


nhc

Upper Fraser Model
1999 Calibration

March 2008

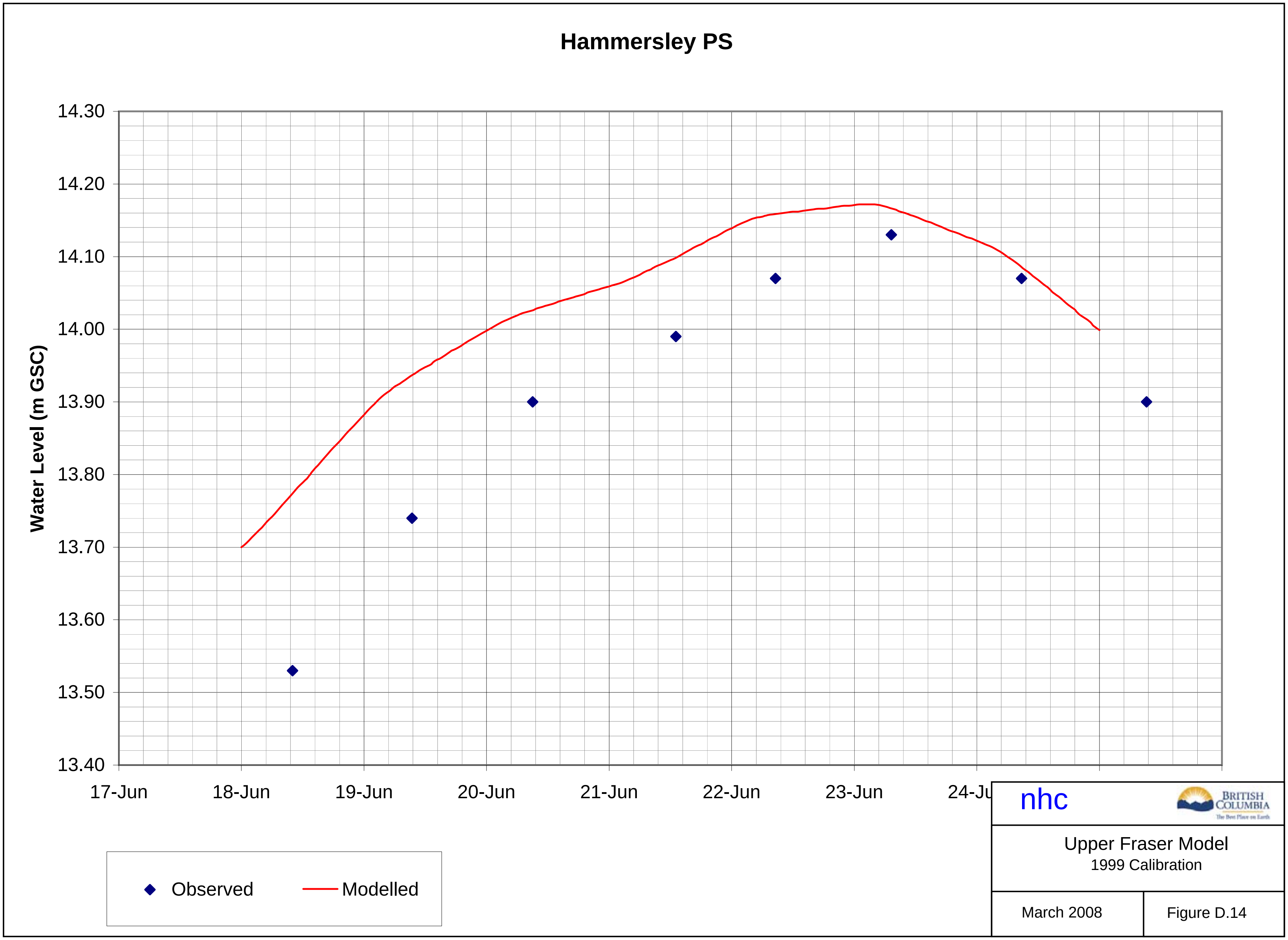
Figure D.12



nhc

Upper Fraser Model
1999 Calibration

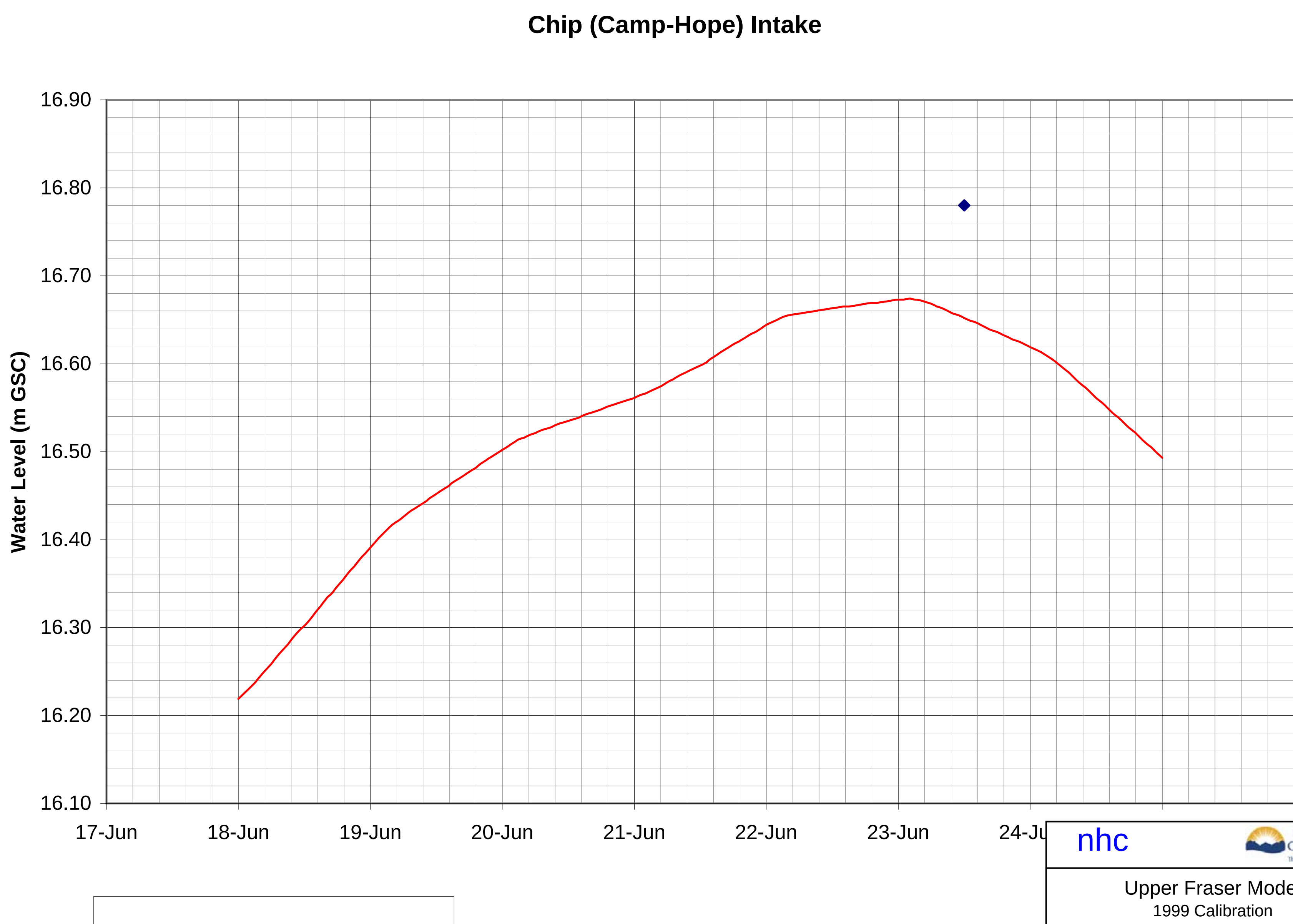
March 2008	Figure D.13



nhc

Upper Fraser Model
1999 Calibration

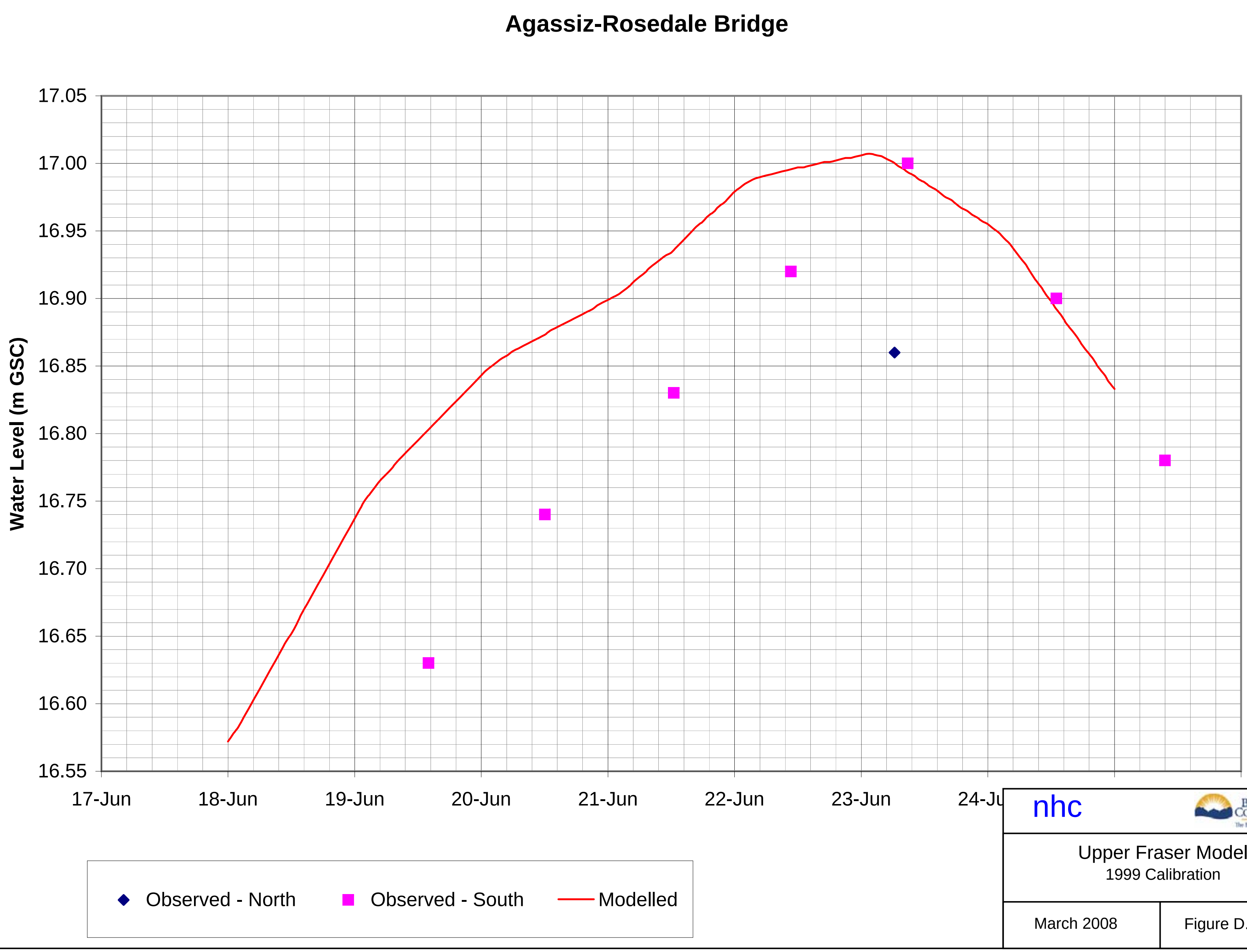
March 2008	Figure D.14



nhc

Upper Fraser Model
1999 Calibration

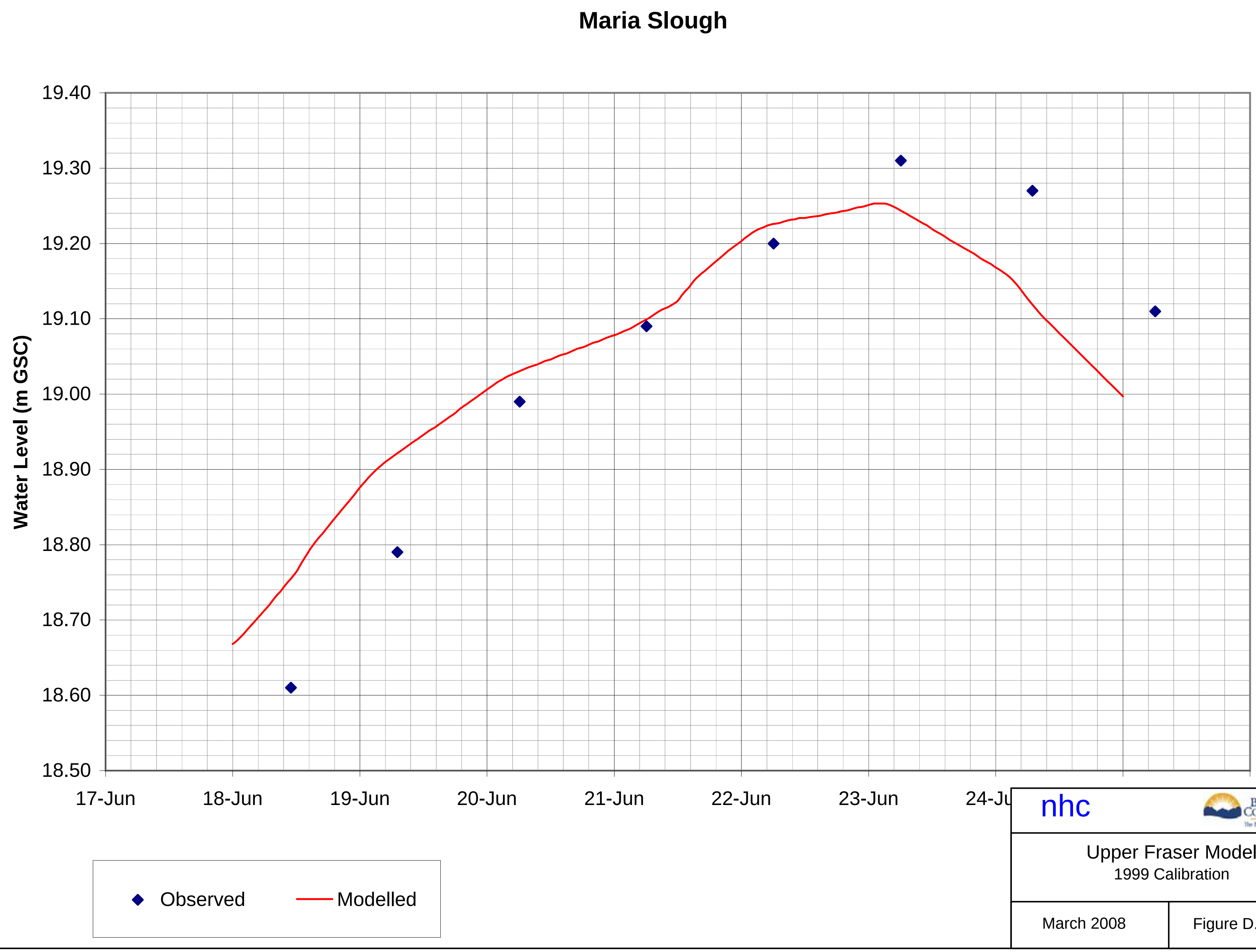
March 2008	Figure D.15



nhc

Upper Fraser Model
1999 Calibration

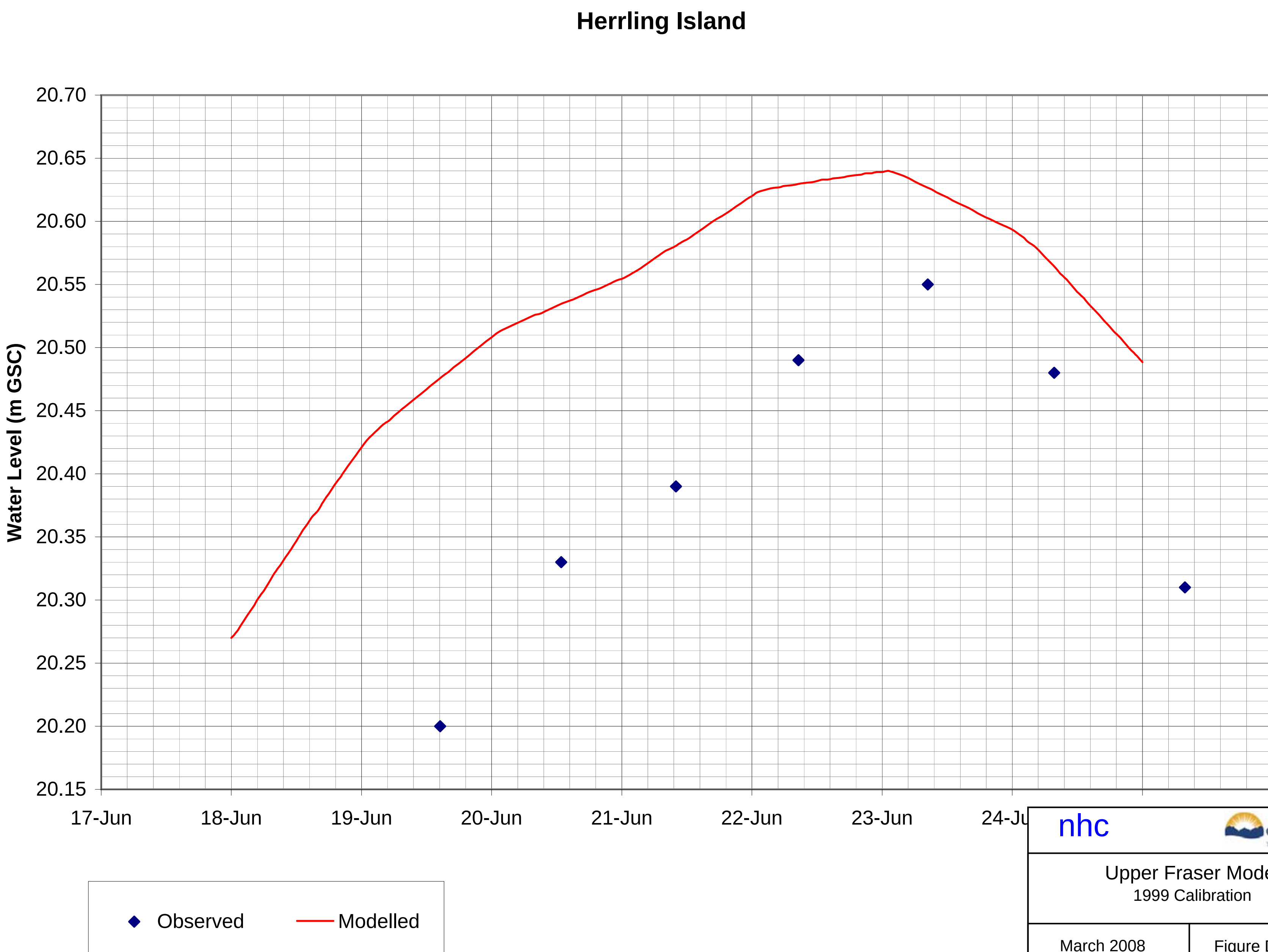
March 2008 | Figure D.16



nhc

Upper Fraser Model
1999 Calibration

March 2008	Figure D.17

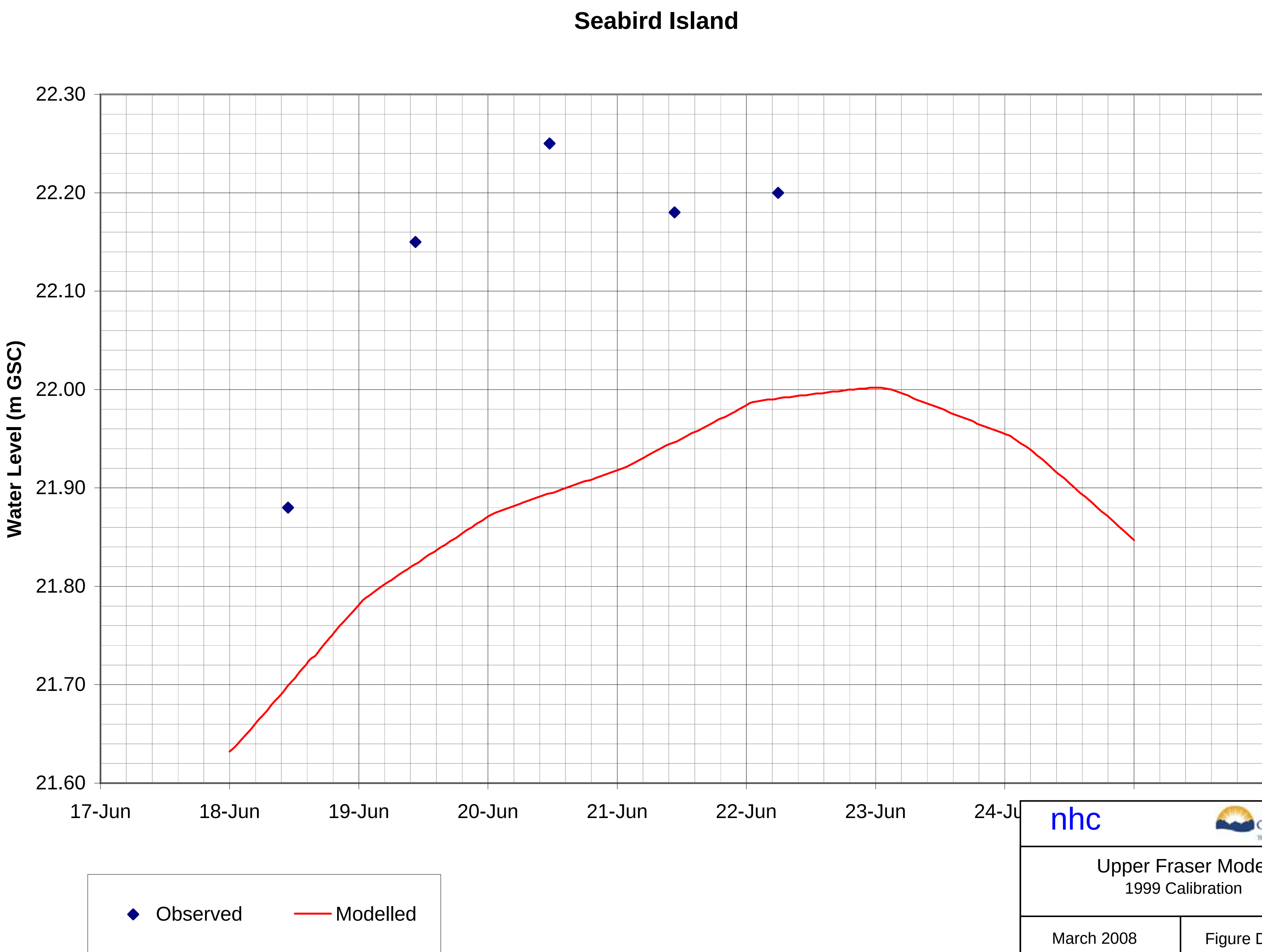


nhc

Upper Fraser Model
1999 Calibration

March 2008

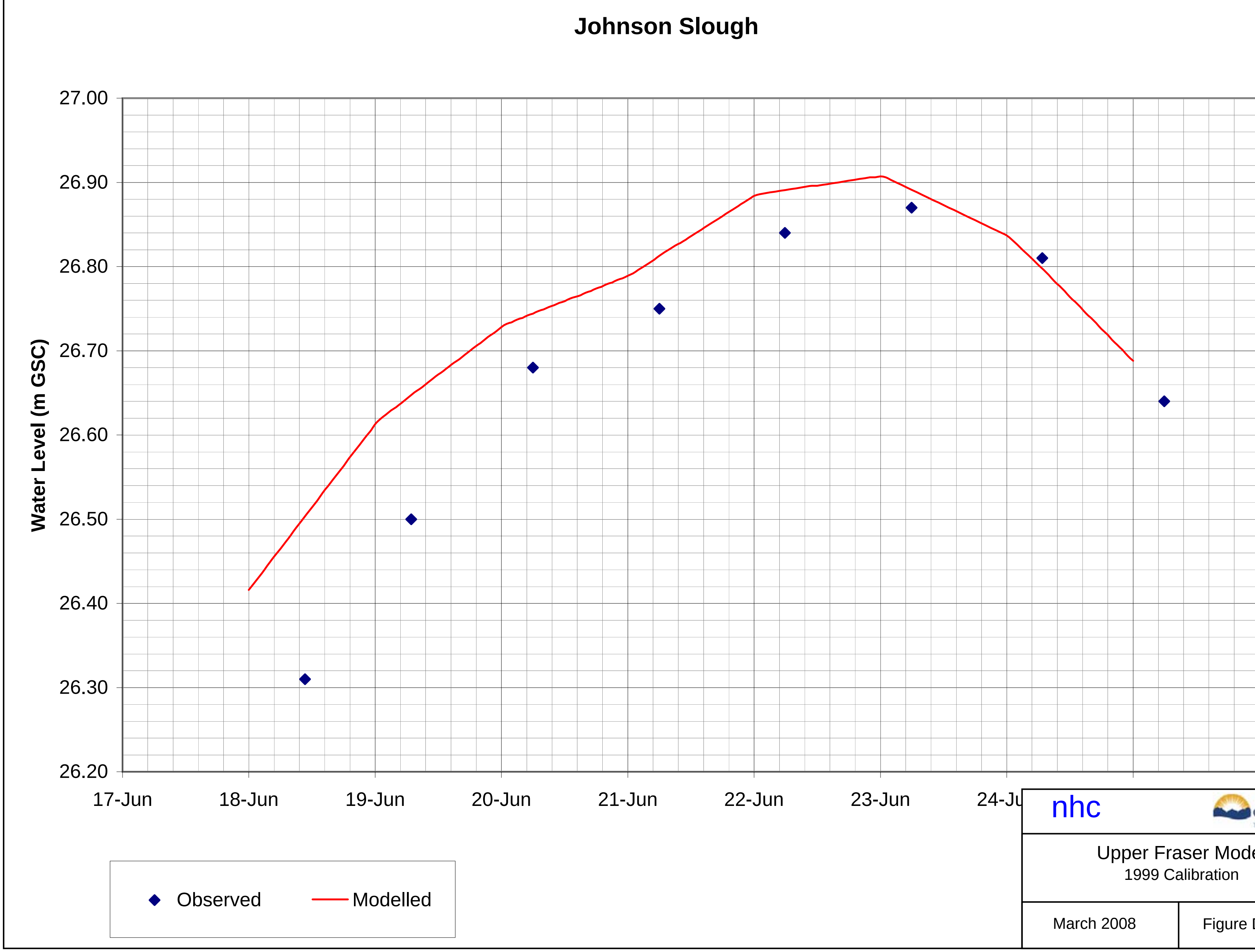
Figure D.18



nhc

Upper Fraser Model
1999 Calibration

March 2008	Figure D.19

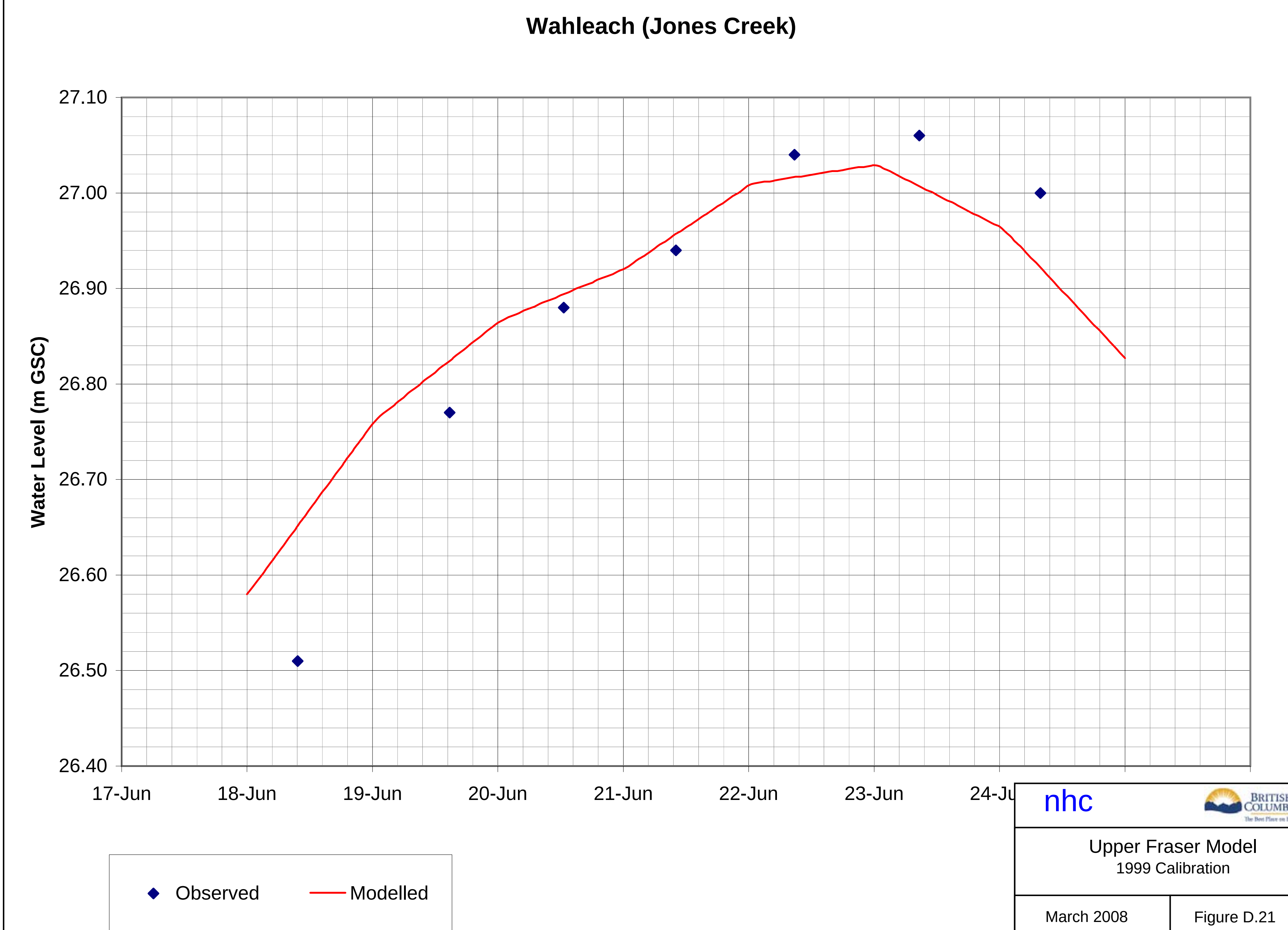


nhc

Upper Fraser Model
1999 Calibration

March 2008

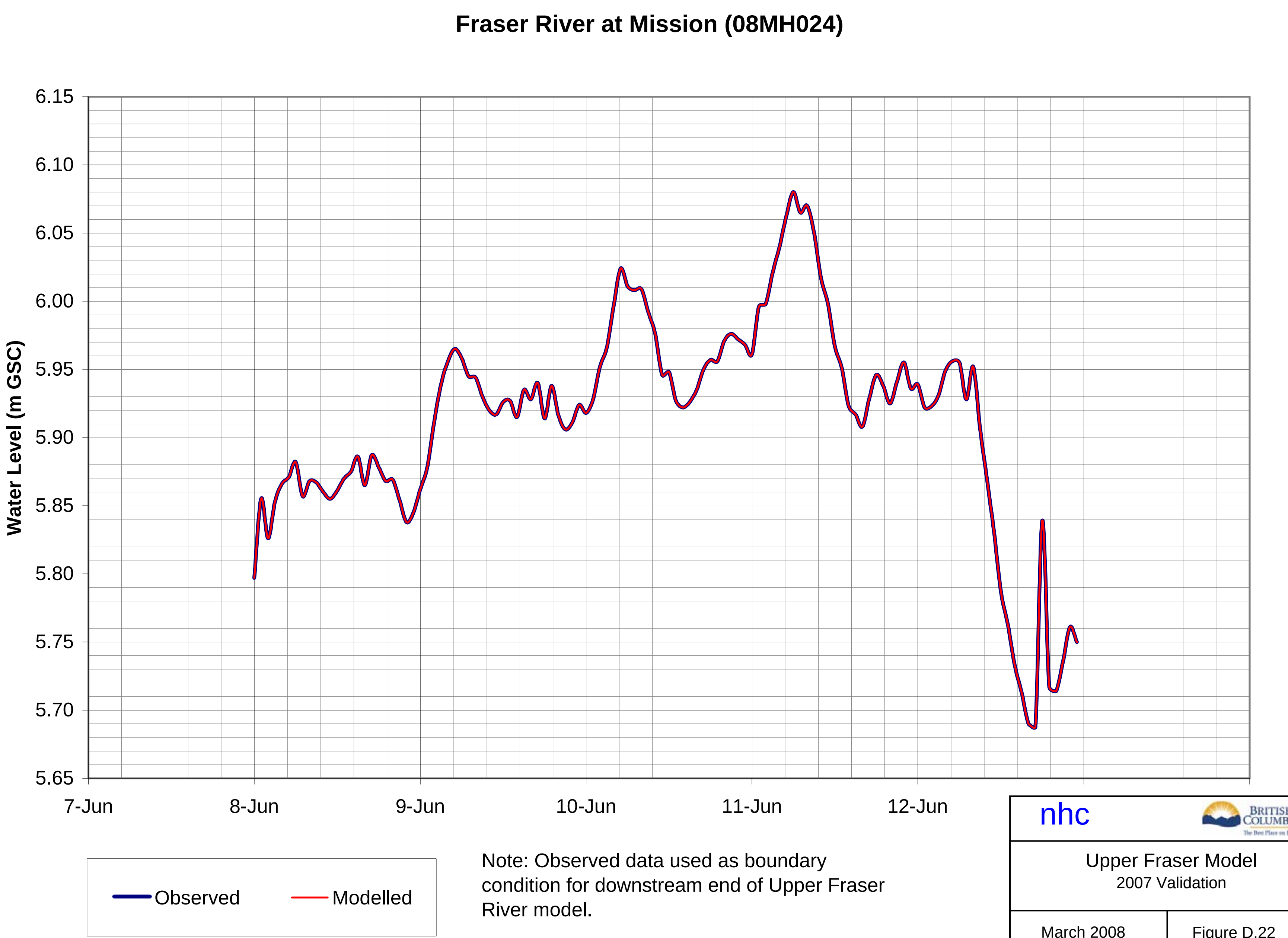
Figure D.20



nhc

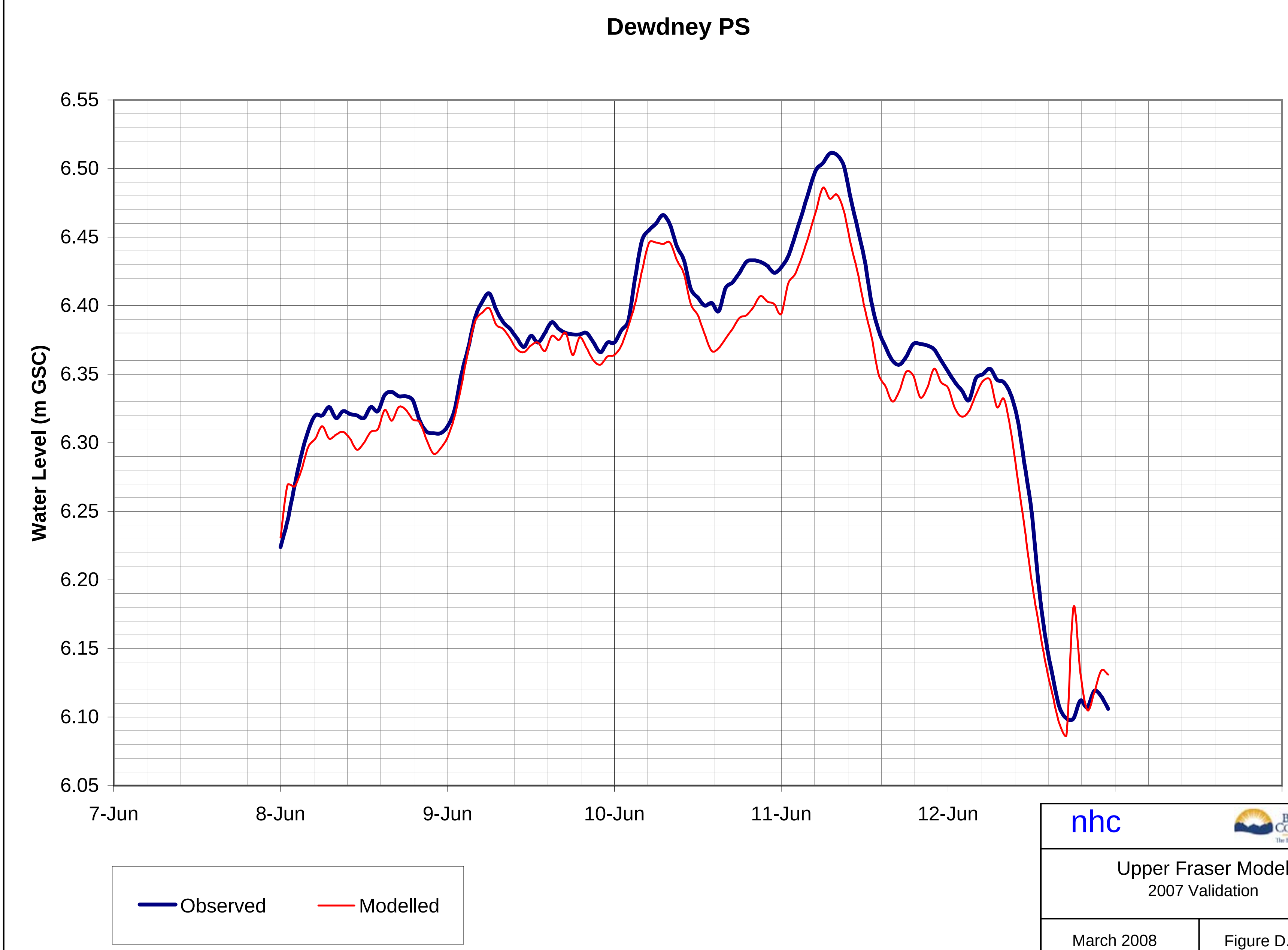
Upper Fraser Model
1999 Calibration

March 2008	Figure D.21



Note: Observed data used as boundary condition for downstream end of Upper Fraser River model.

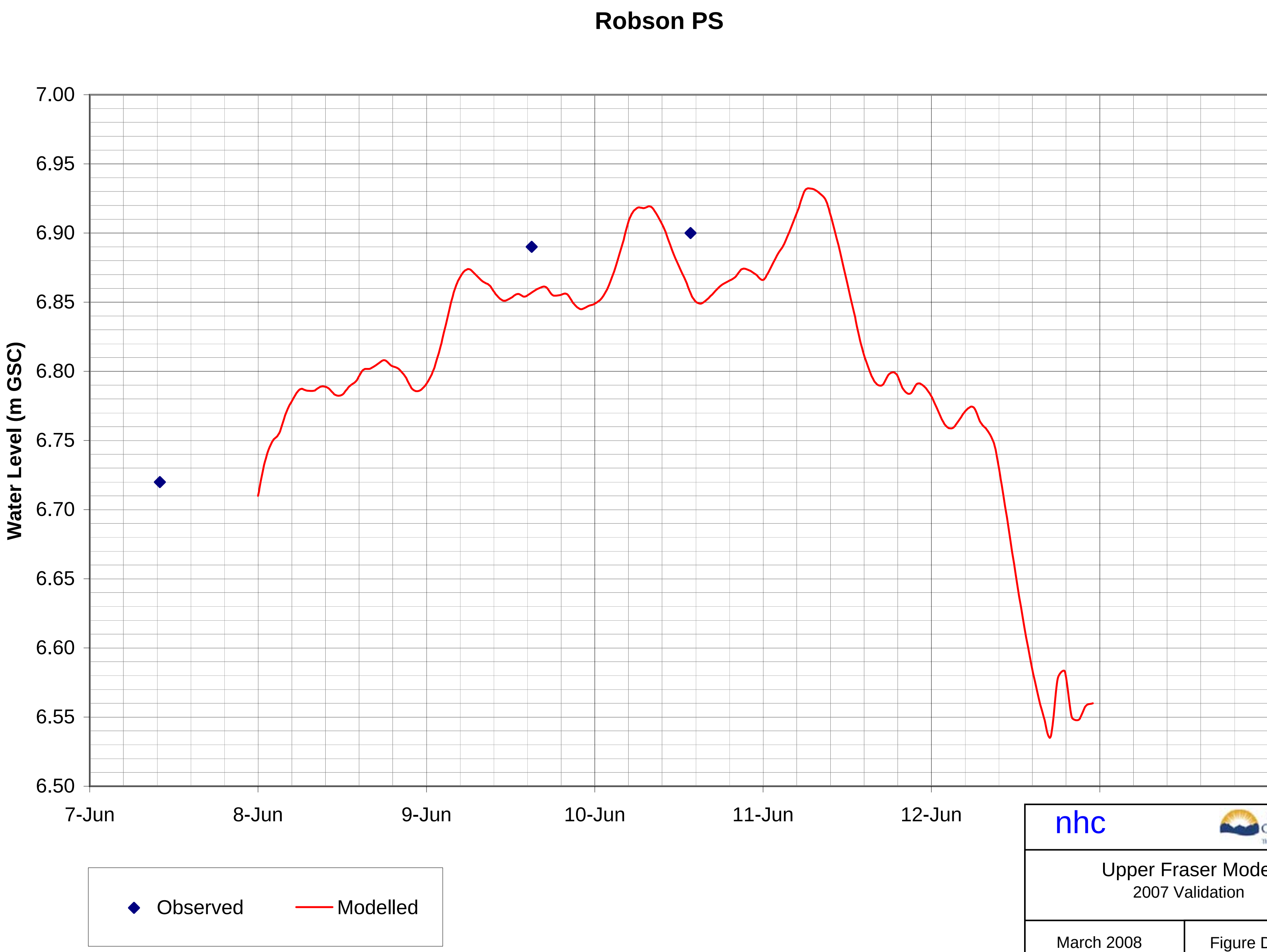
nhc	BRITISH COLUMBIA
Upper Fraser Model 2007 Validation	
March 2008	Figure D.22



nhc

Upper Fraser Model
2007 Validation

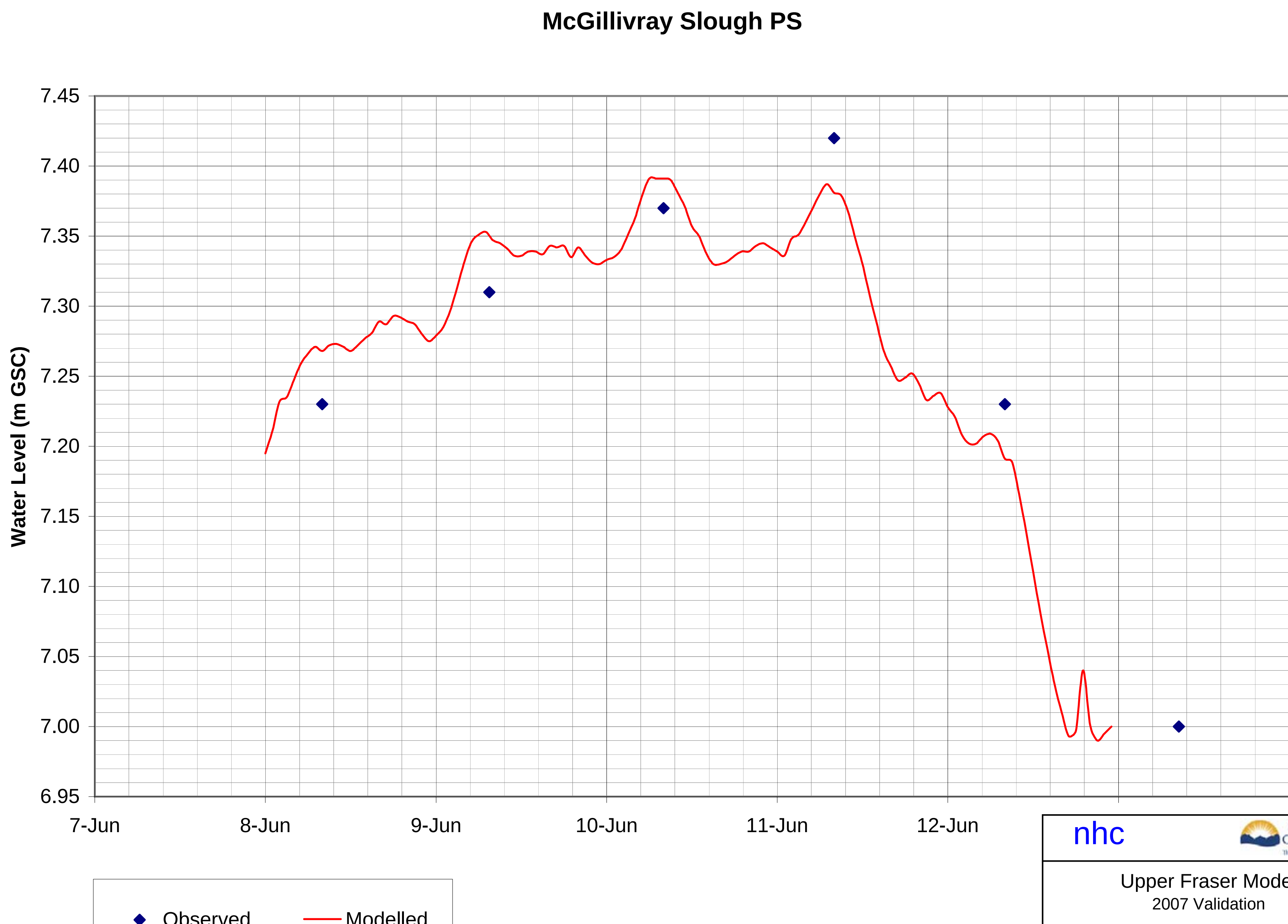
March 2008	Figure D.23



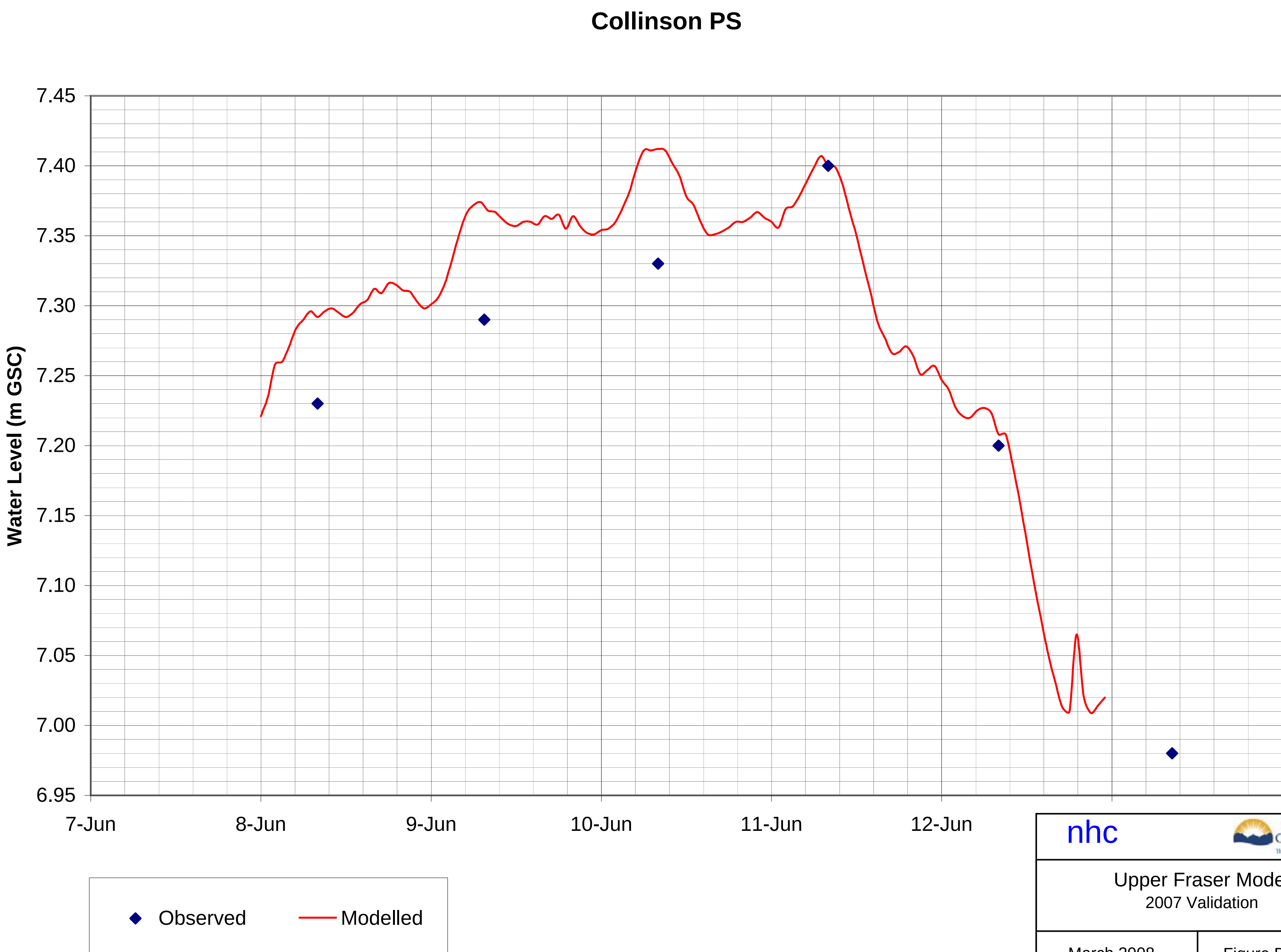
nhc

Upper Fraser Model
2007 Validation

March 2008 | Figure D.24



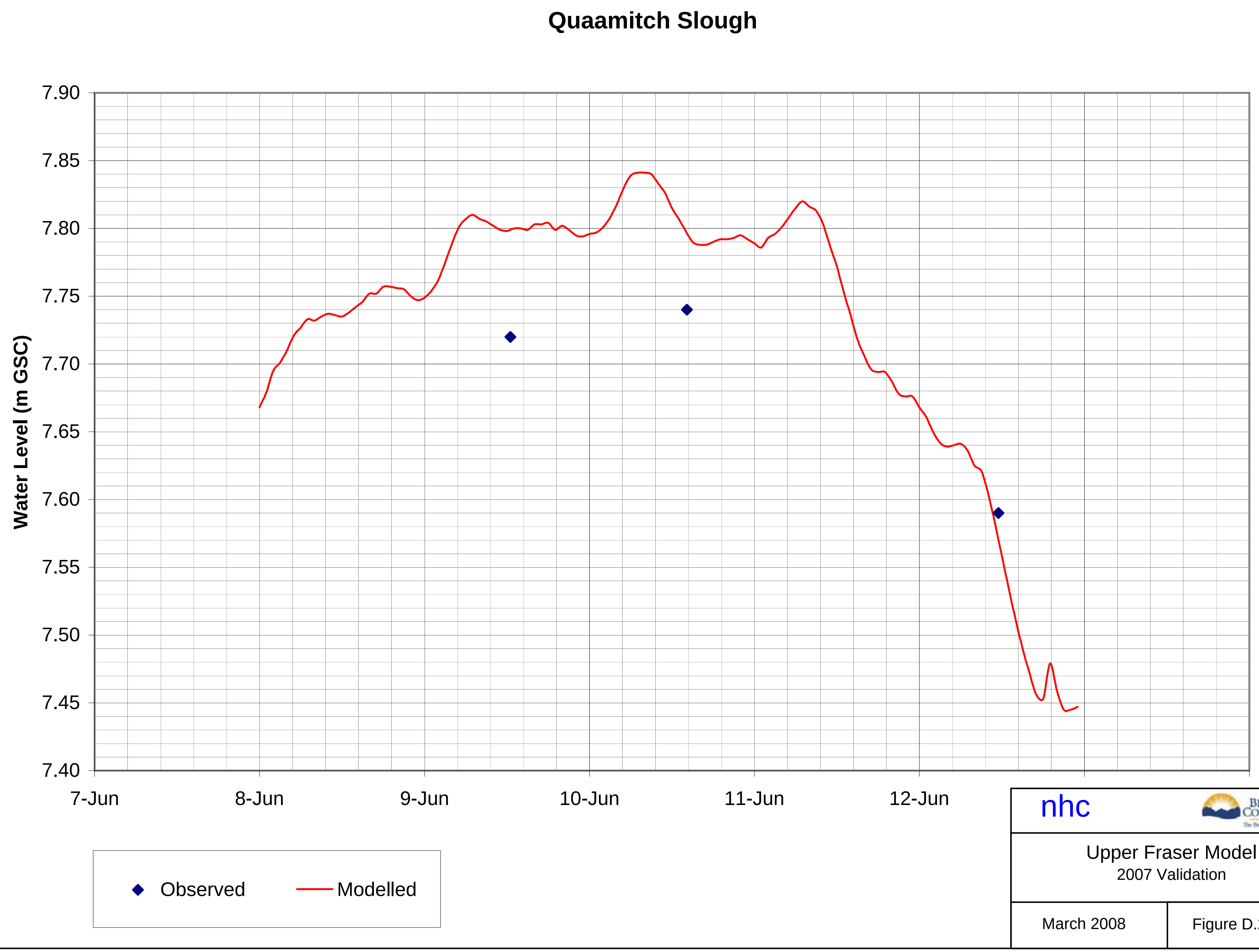
nhc	
Upper Fraser Model 2007 Validation	
February 2008	Figure D.25



nhc

Upper Fraser Model
2007 Validation

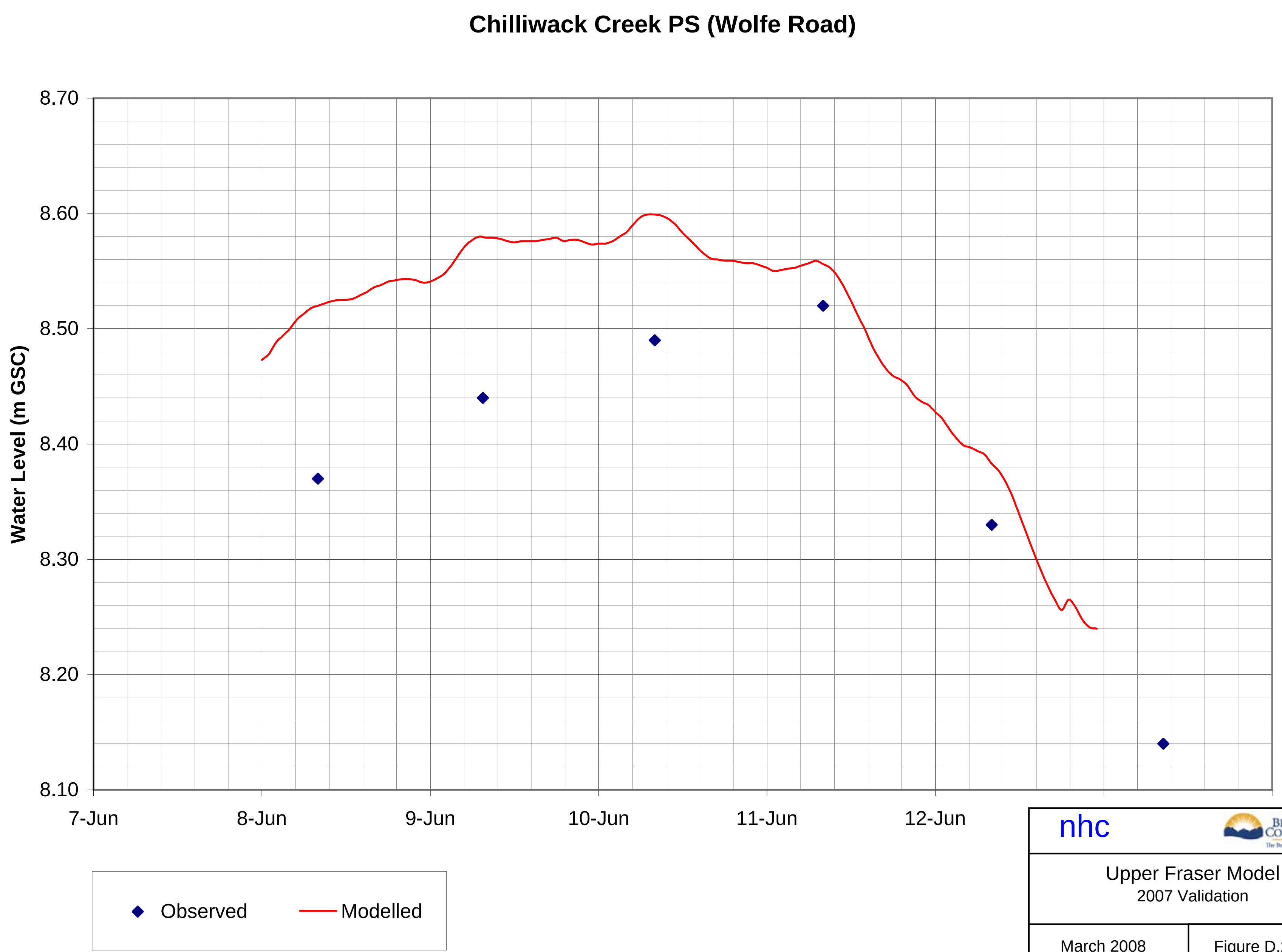
March 2008 | Figure D.26



nhc

Upper Fraser Model
2007 Validation

March 2008	Figure D.27



nhc

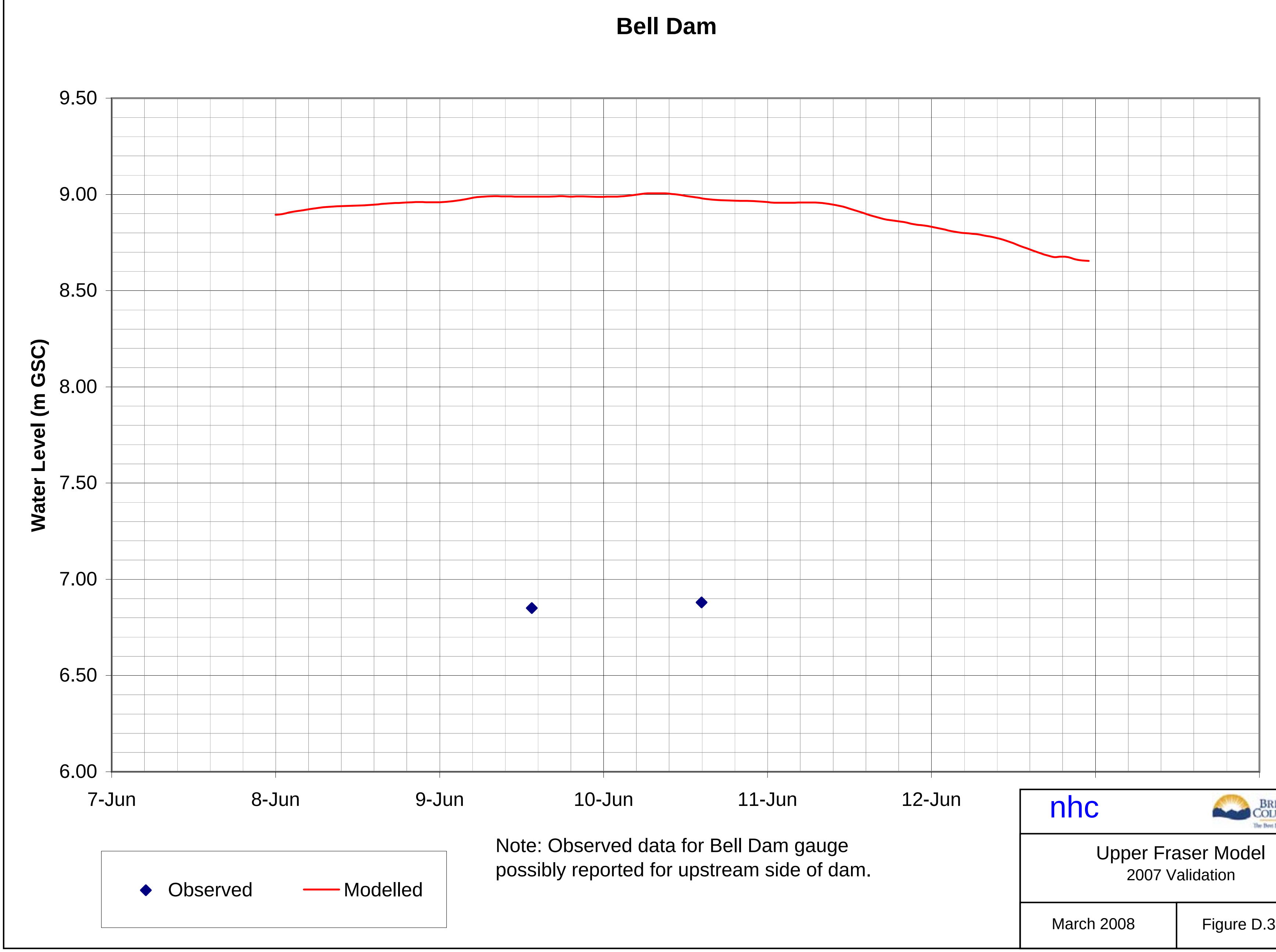
Upper Fraser Model
2007 Validation

March 2008	Figure D.28

nhc

Upper Fraser Model
2007 Validation

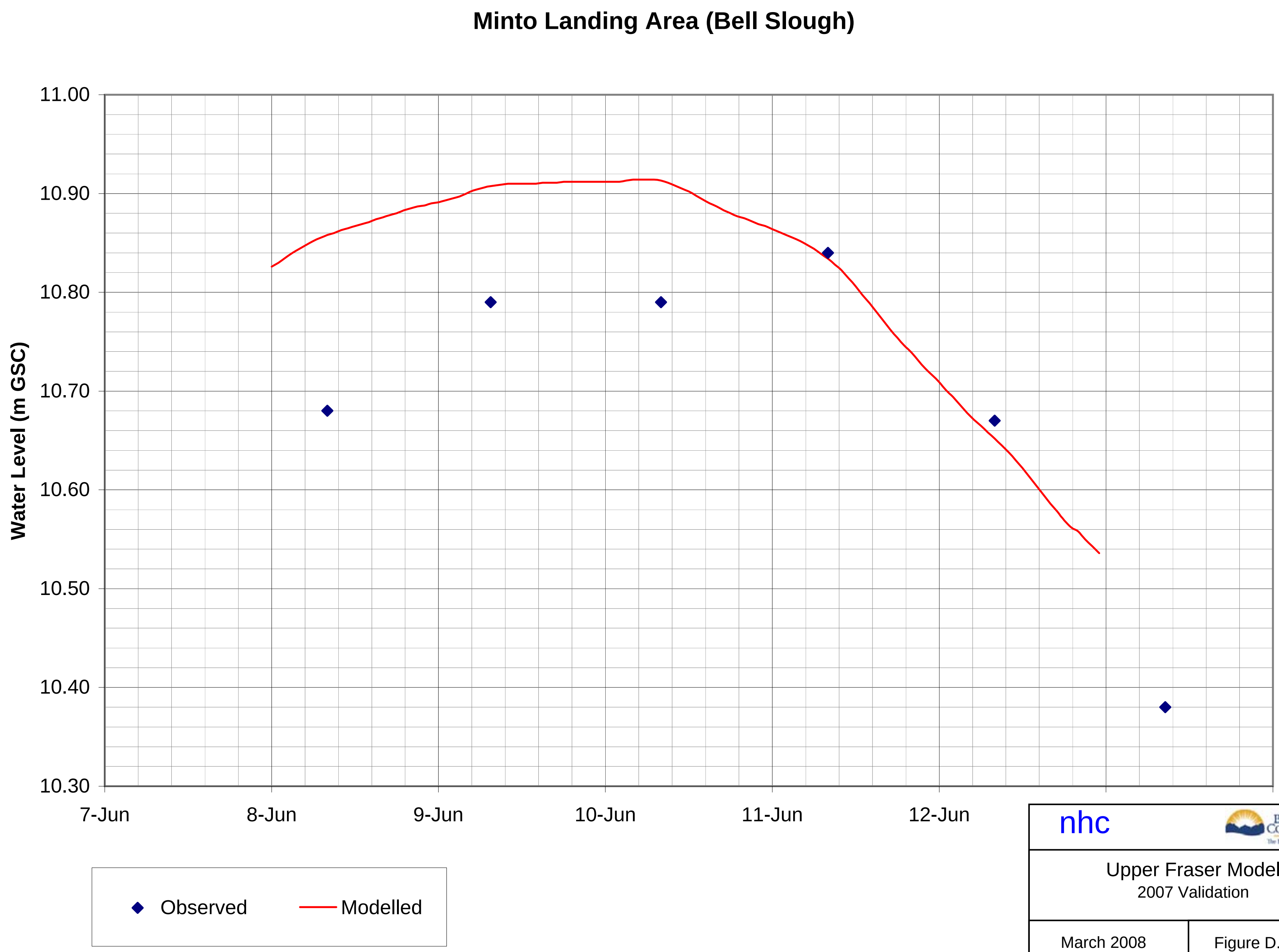
March 2008	Figure D.29



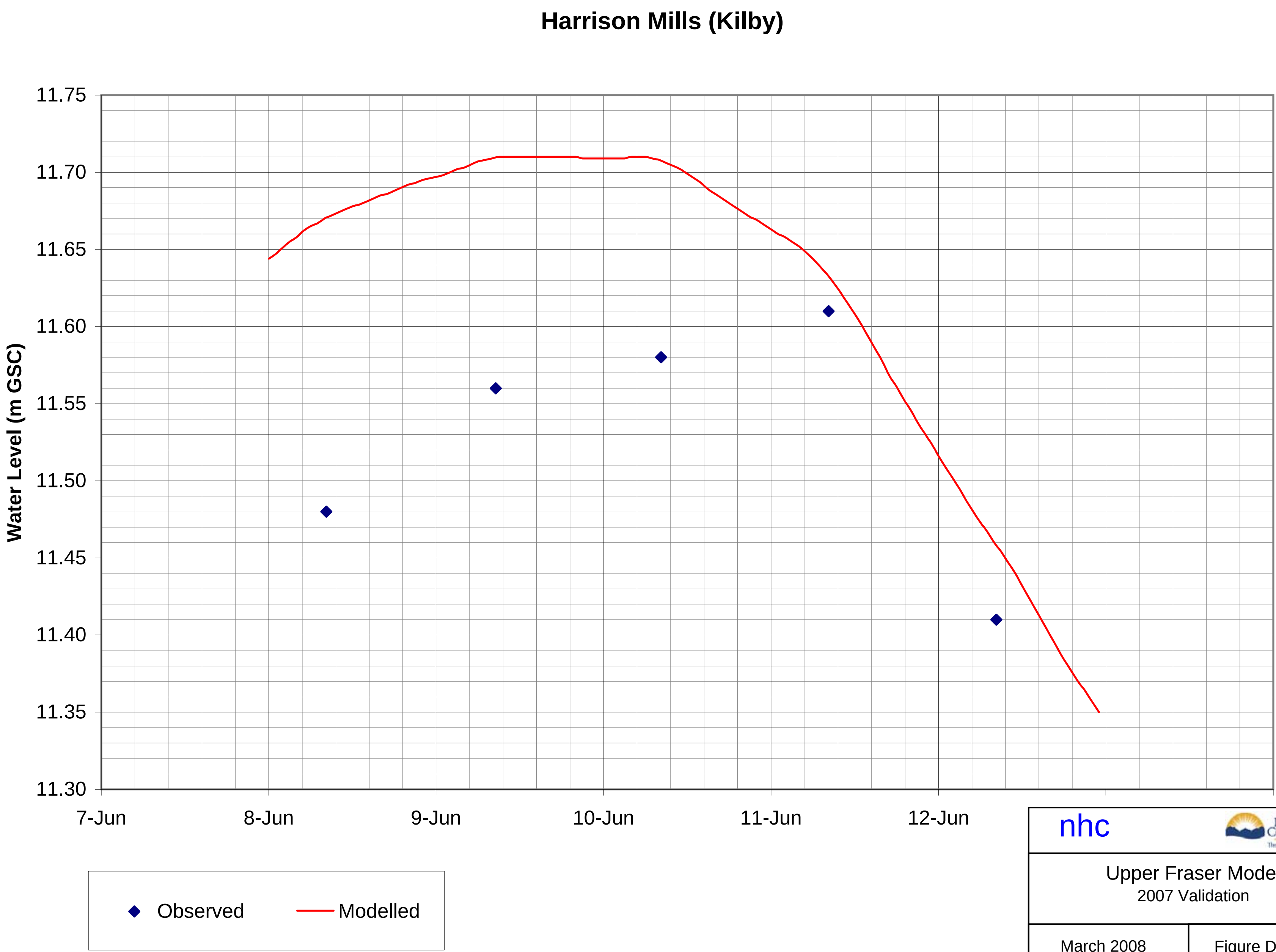
nhc

Upper Fraser Model
2007 Validation

March 2008	Figure D.30



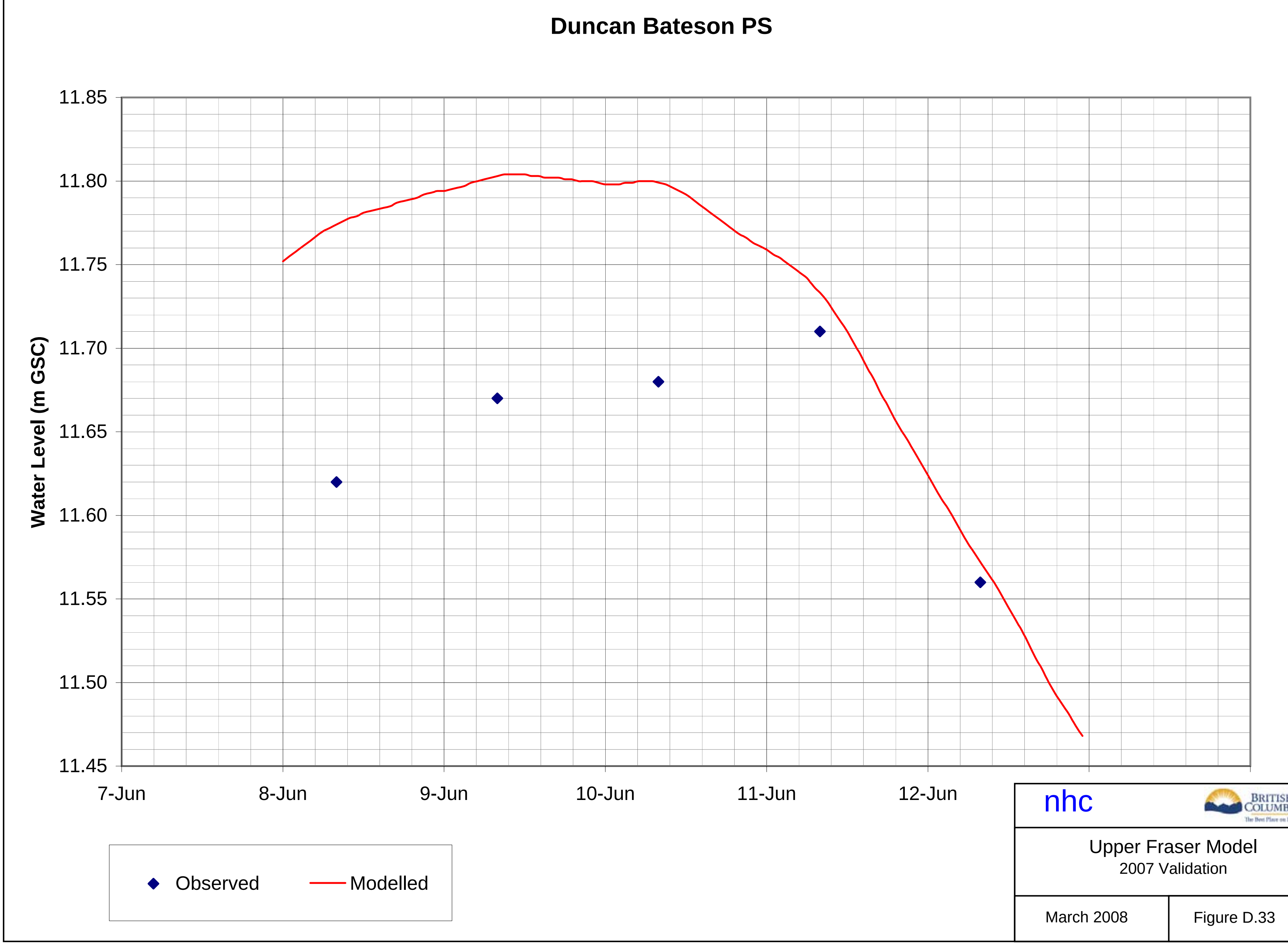
nhc	BRITISH COLUMBIA
Upper Fraser Model 2007 Validation	
March 2008	Figure D.31



nhc

Upper Fraser Model
2007 Validation

March 2008	Figure D.32

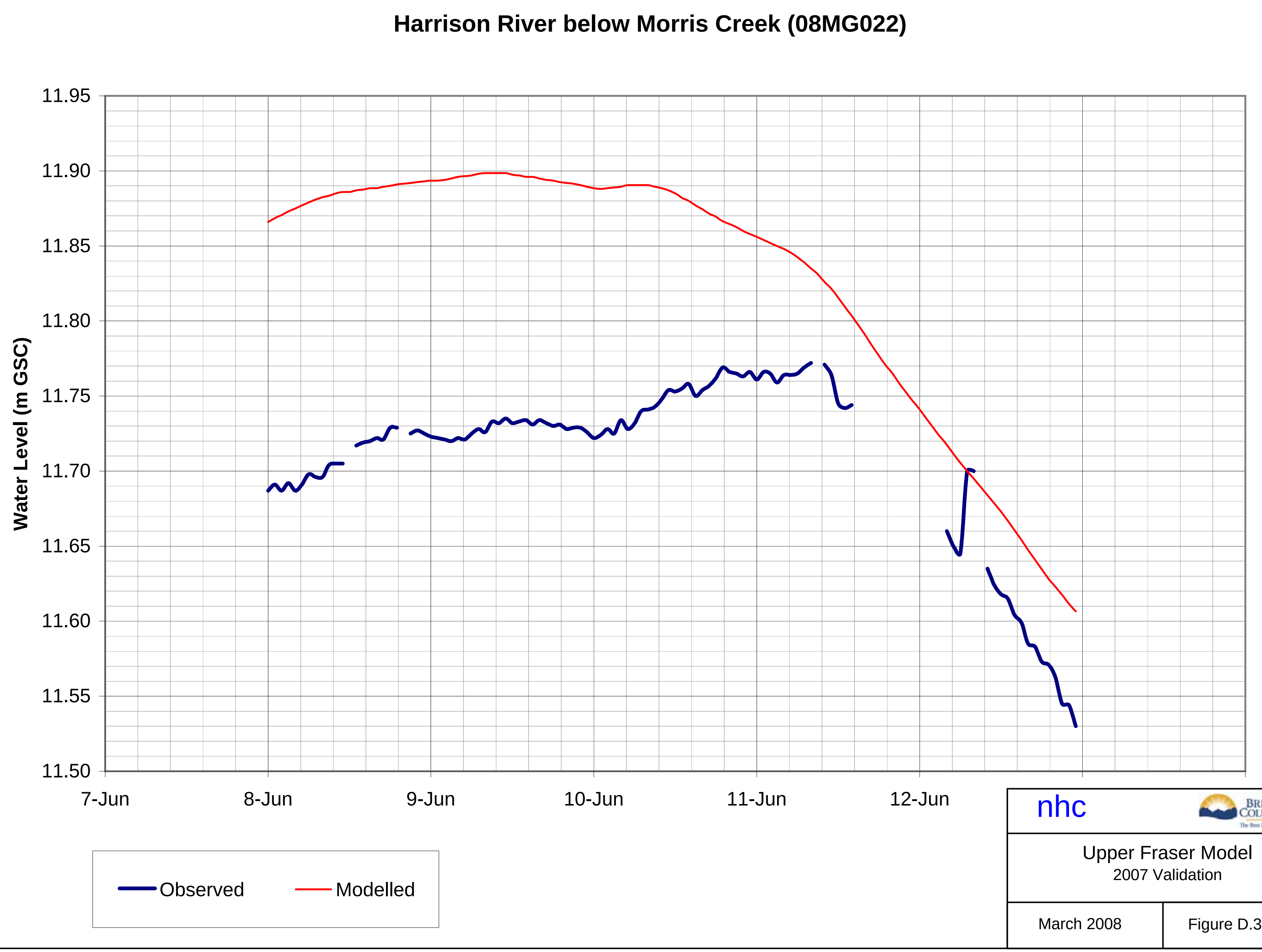


nhc

Upper Fraser Model
2007 Validation

March 2008

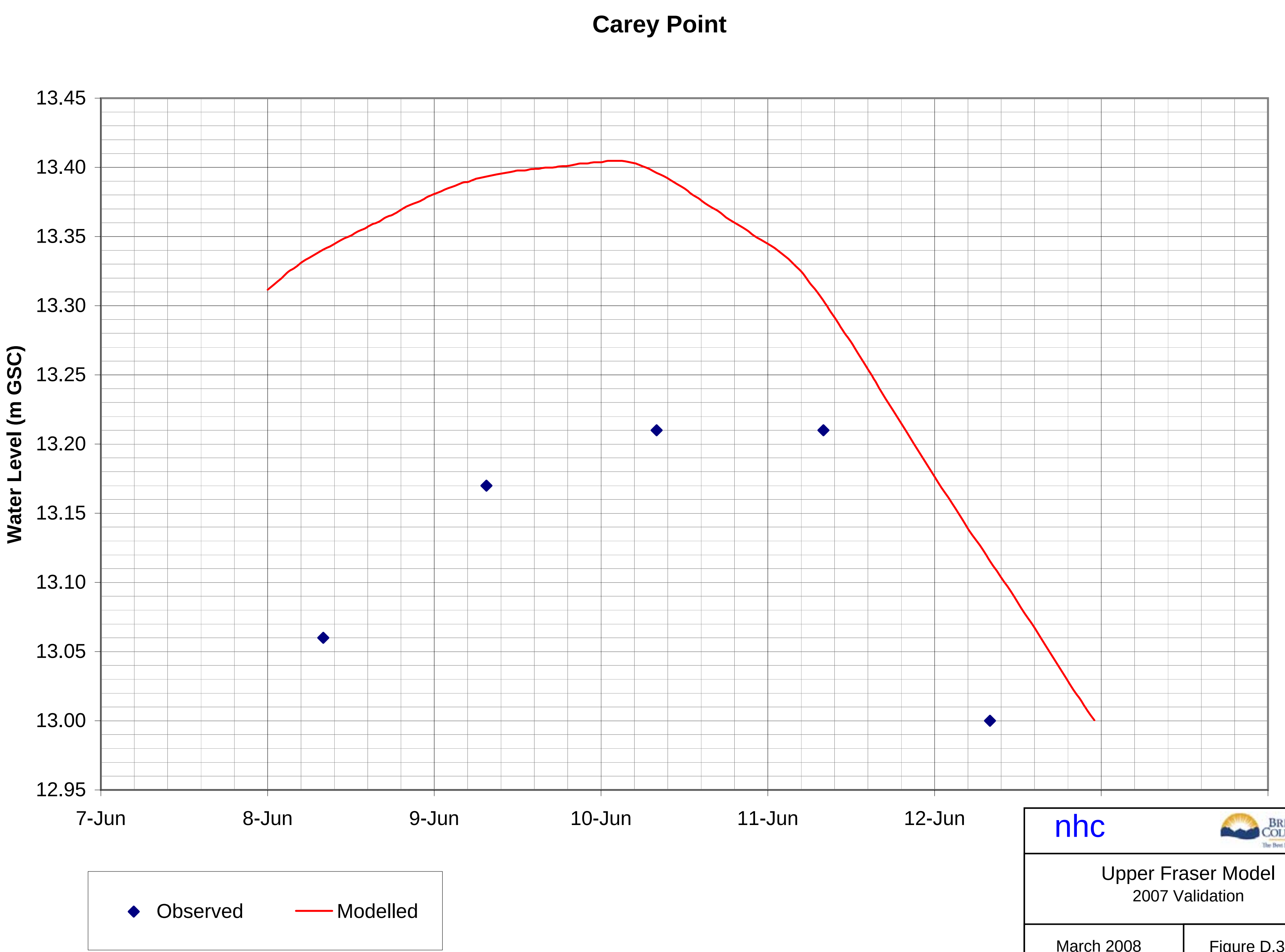
Figure D.33



nhc

Upper Fraser Model
2007 Validation

March 2008	Figure D.34



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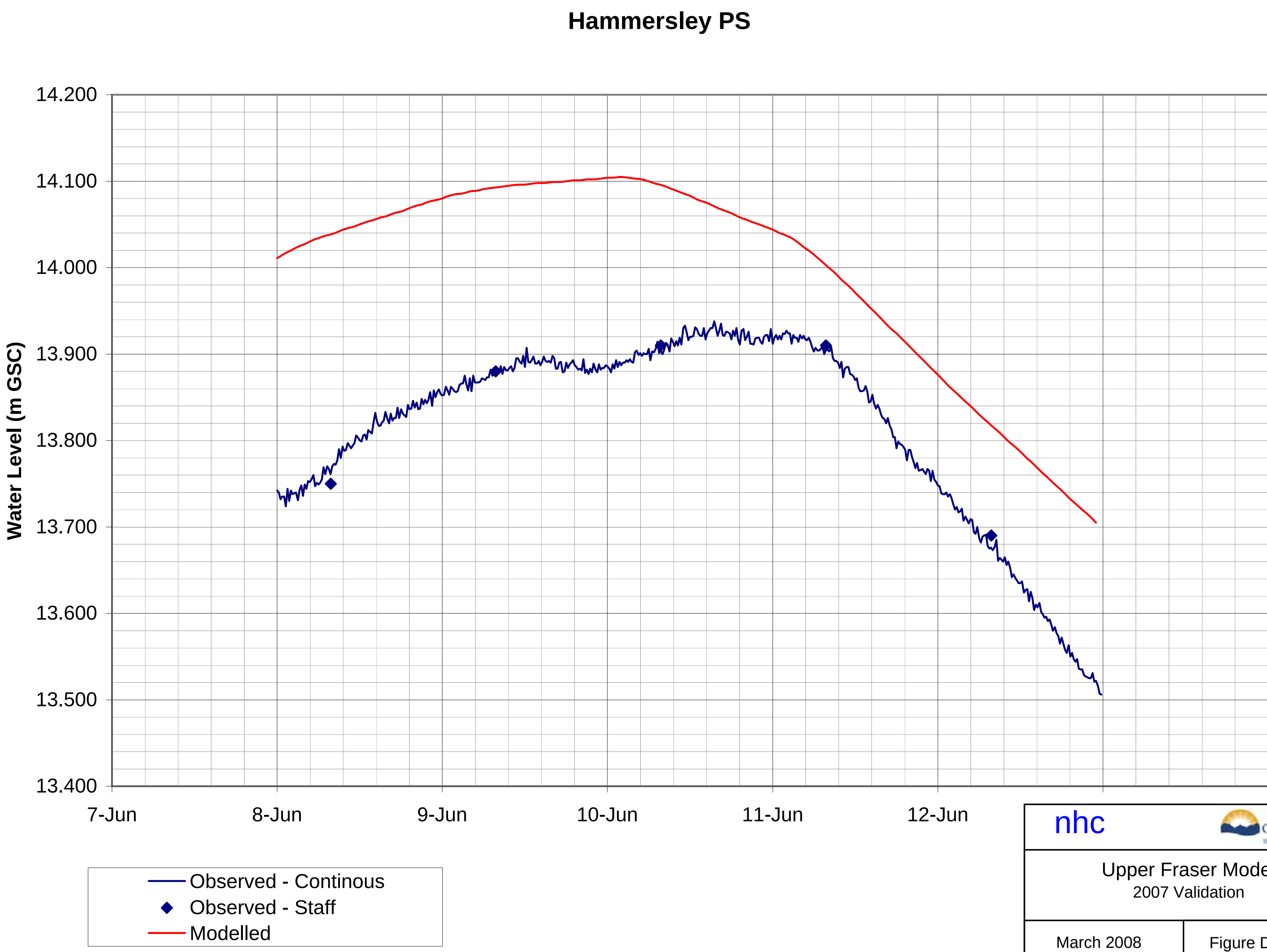
Upper Fraser Model
2007 Validation

March 2008

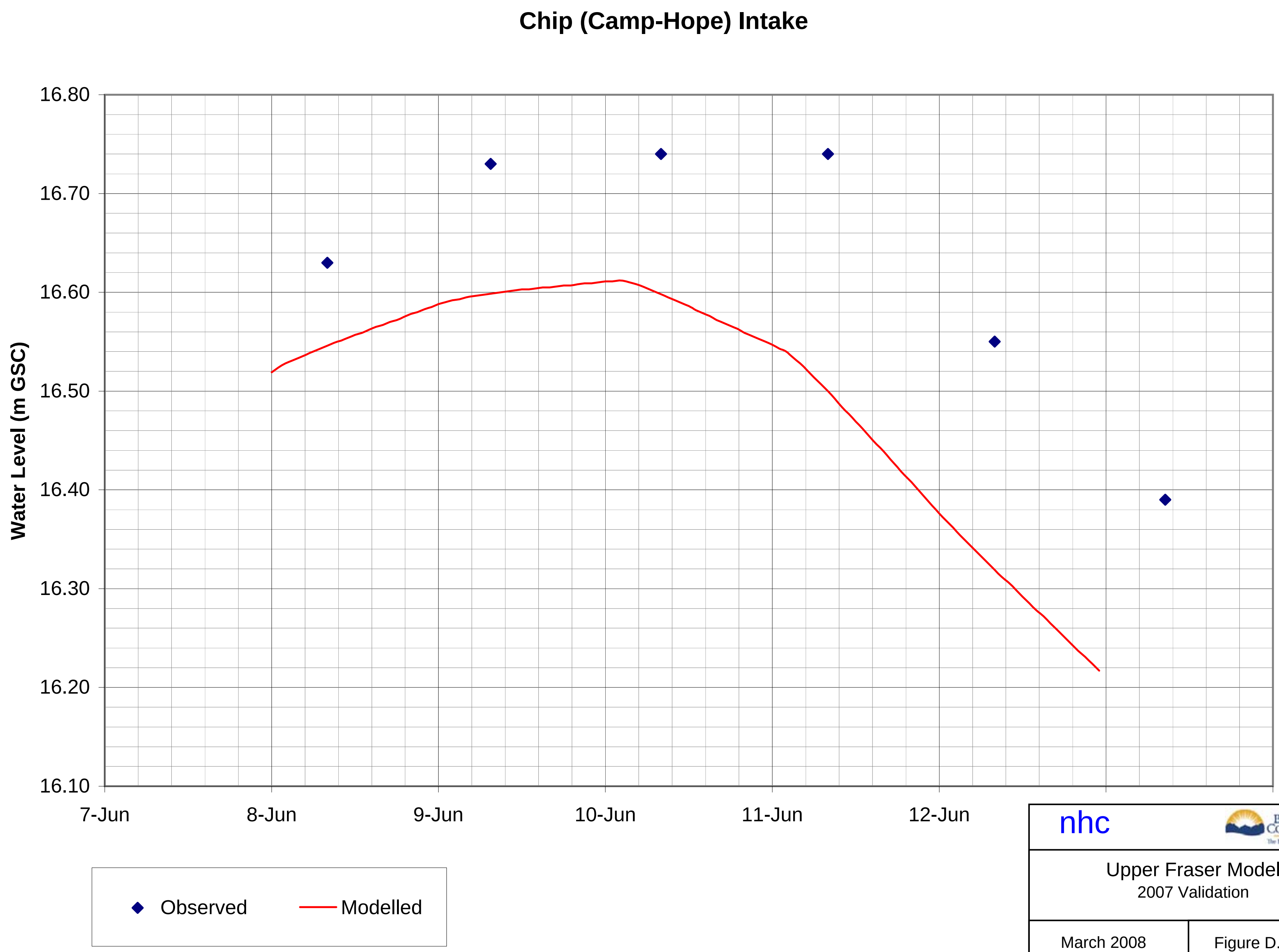
Figure D.35



nhc

Upper Fraser Model
2007 Validation

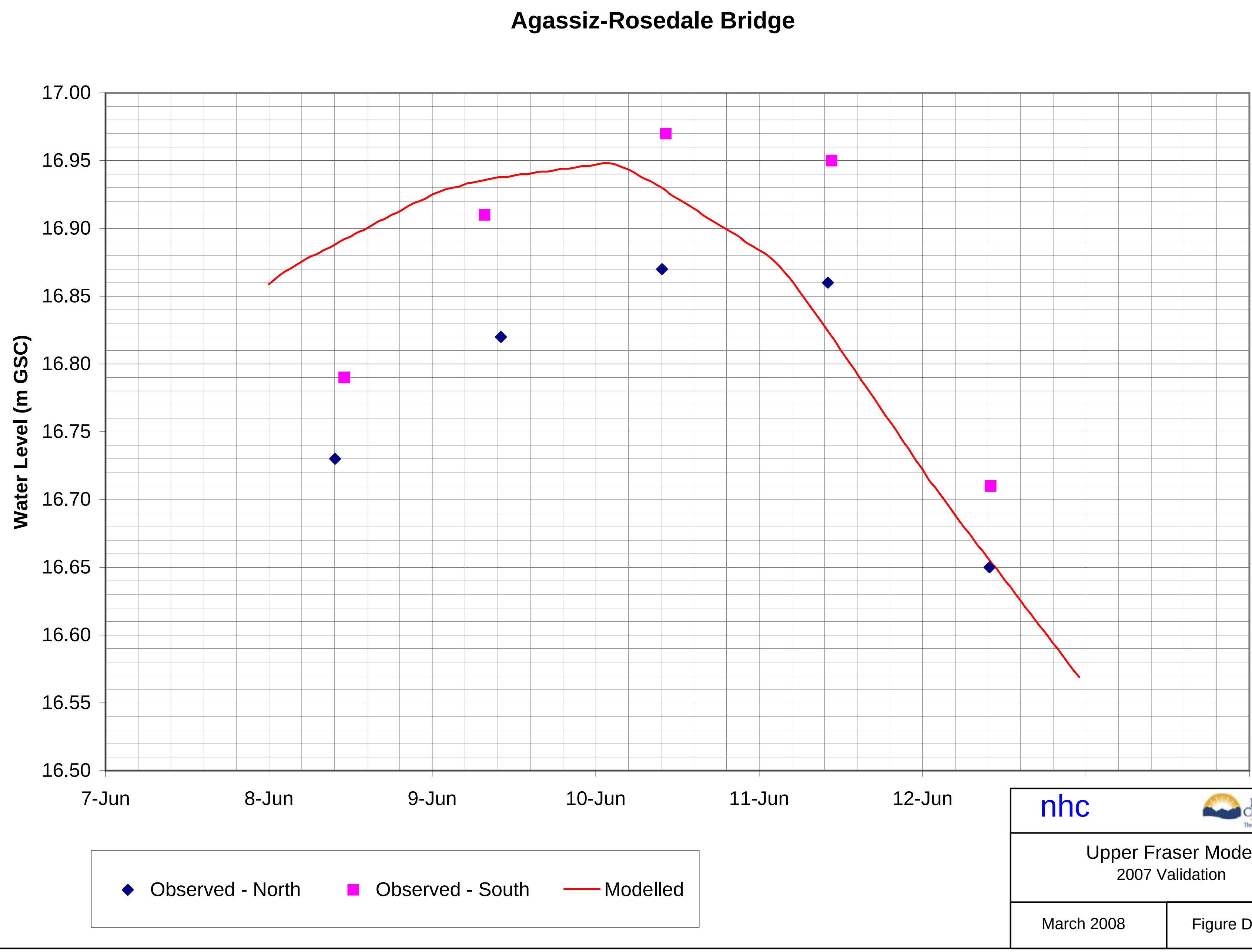
March 2008 | Figure D.36



nhc

Upper Fraser Model
2007 Validation

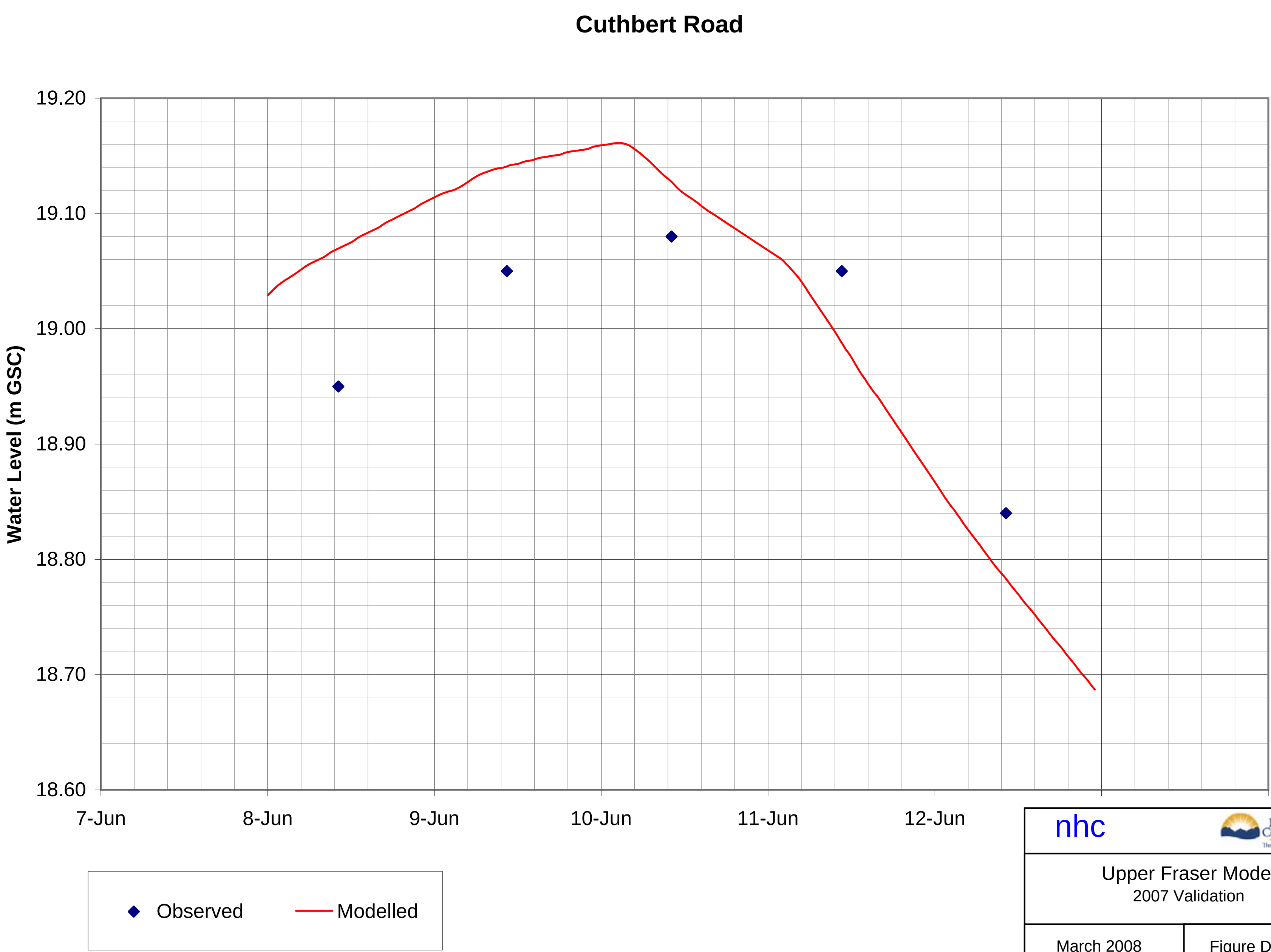
March 2008 | Figure D.37



nhc

Upper Fraser Model
2007 Validation

March 2008	Figure D.38

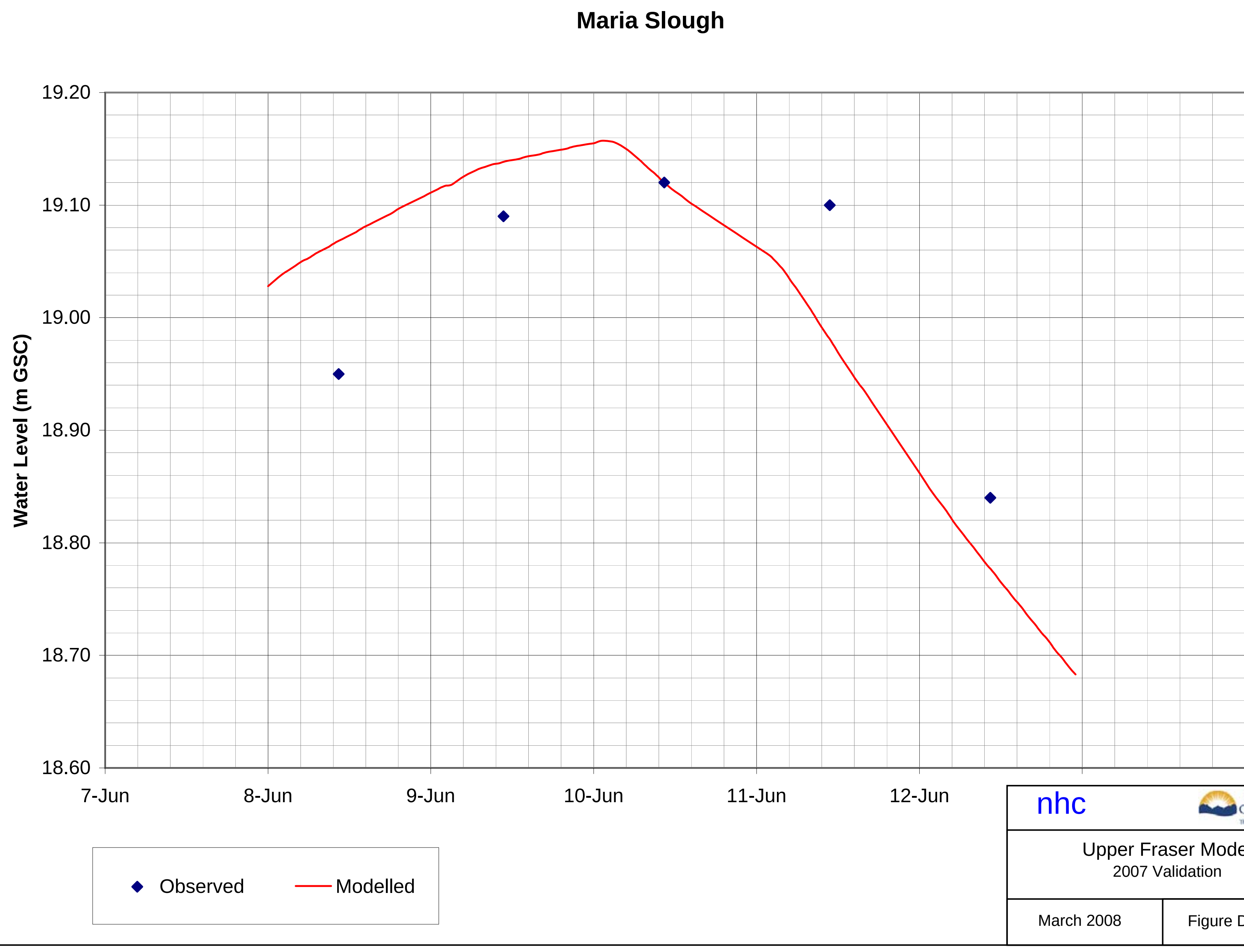


nhc

Upper Fraser Model
2007 Validation

March 2008

Figure D.39



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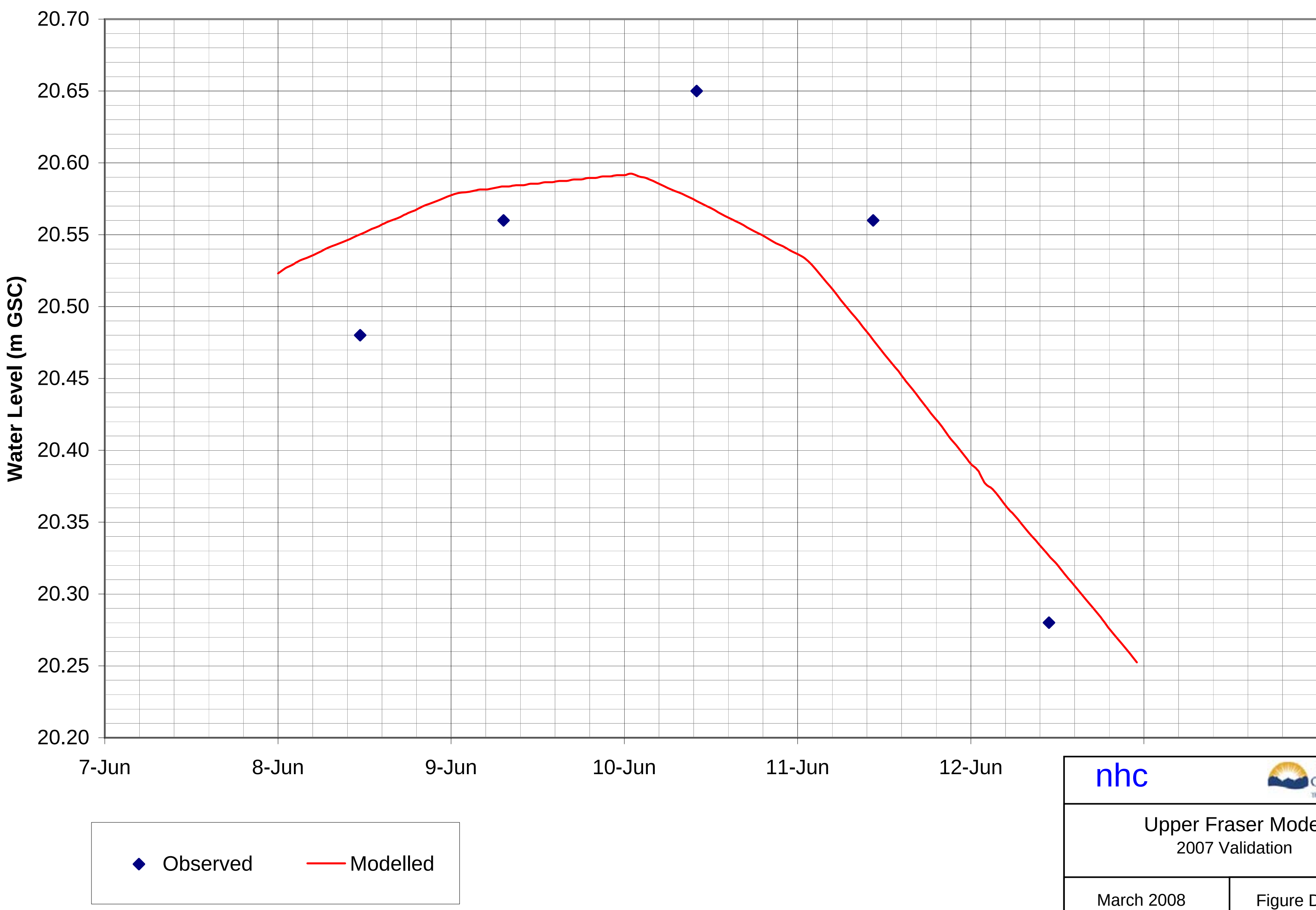
Upper Fraser Model
2007 Validation

March 2008	Figure D.40

Herrling Island



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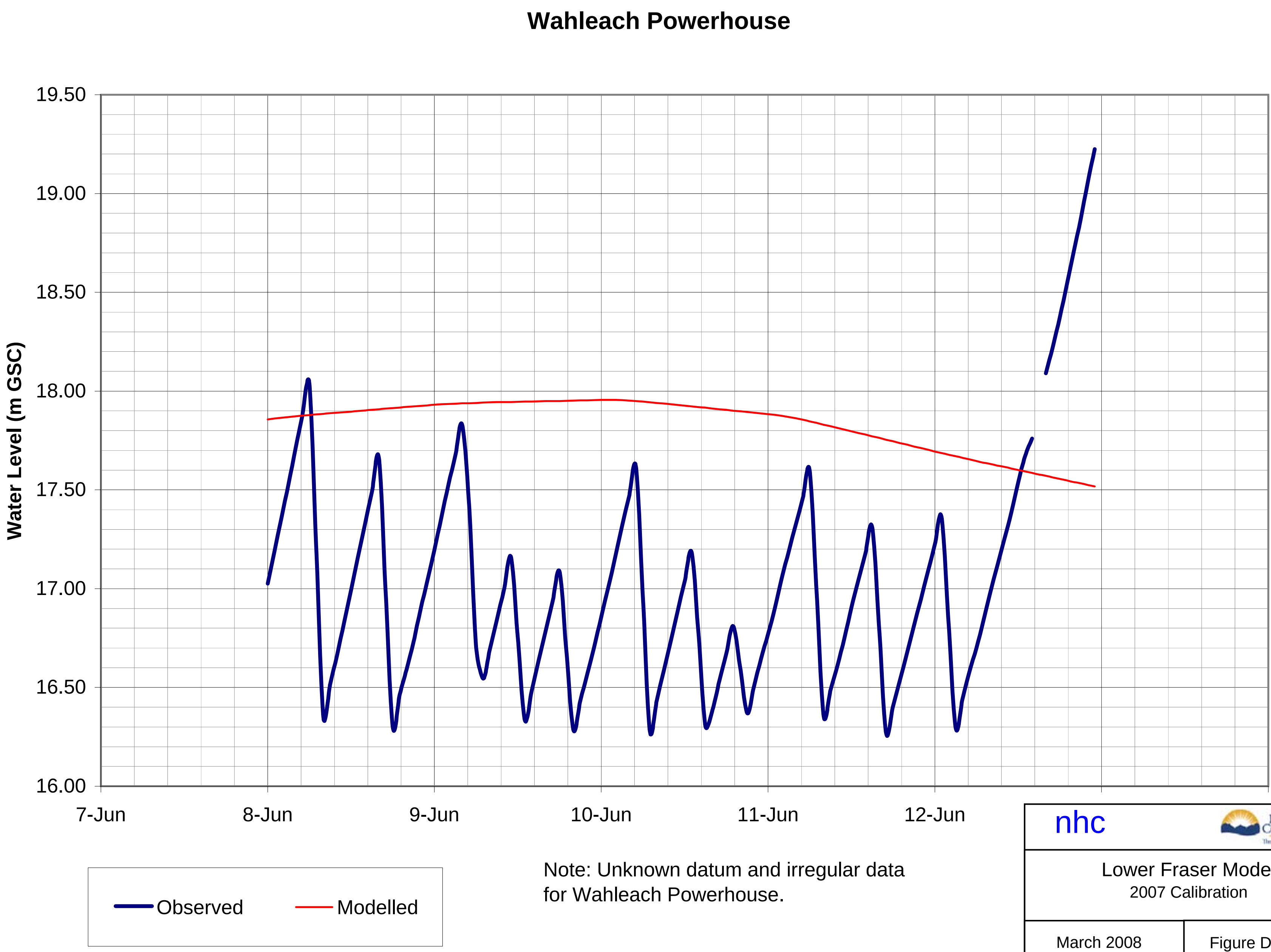
Upper Fraser Model
2007 Validation

March 2008	Figure D.41

nhc

Upper Fraser Model
2007 Validation

March 2008 | Figure D.42



Note: Unknown datum and irregular data
for Wahleach Powerhouse.

nhc

BRITISH COLUMBIA
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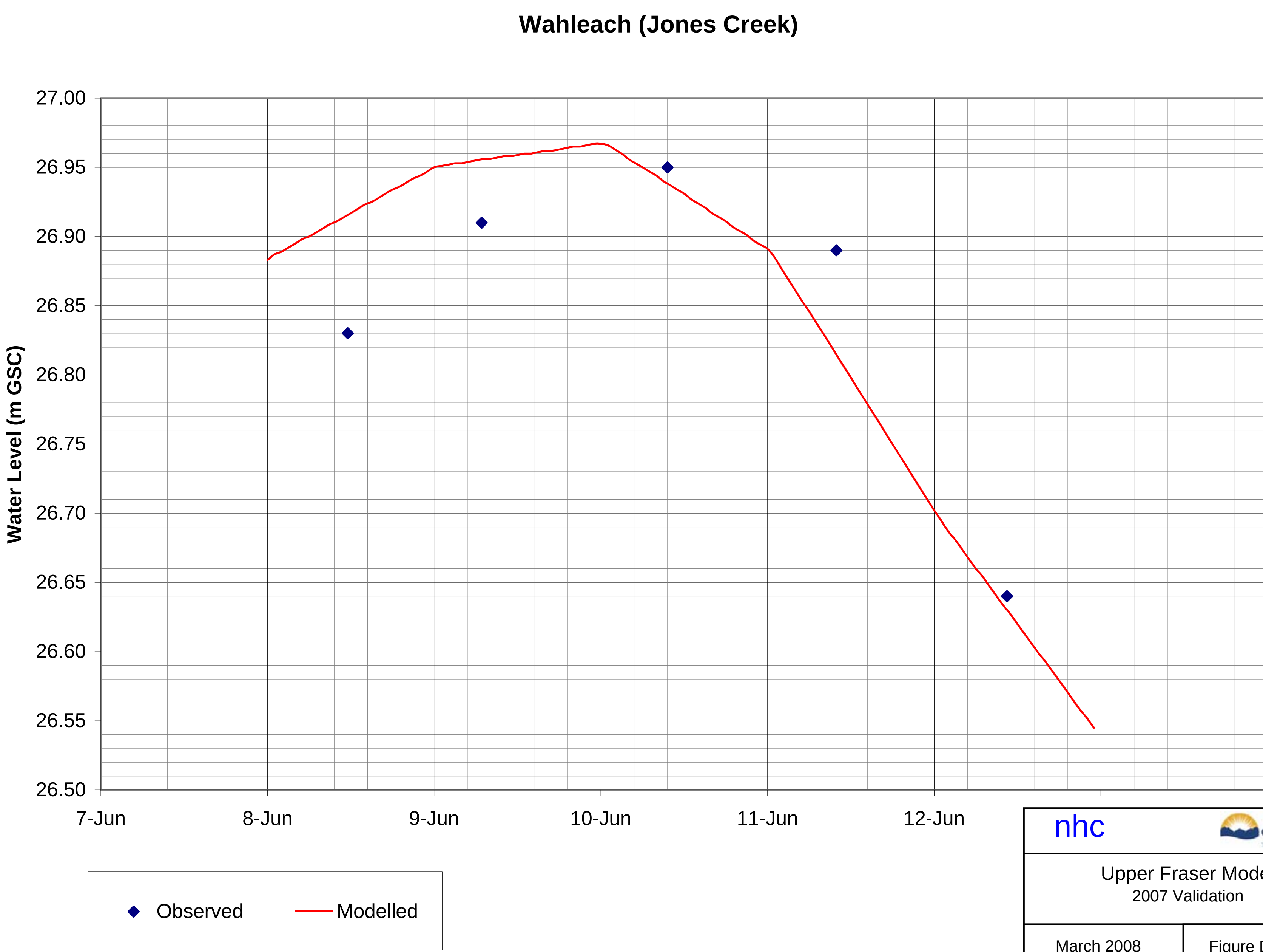
Lower Fraser Model
2007 Calibration

March 2008	Figure D.43



nhc

Upper Fraser Model
2007 Validation

March 2008	Figure D.44

APPENDIX E

SENSITIVITY ANALYSES FOR LOWER MODEL

(TABLES AND CHARTS)

Tables			Charts	
Number	Name		Number	Name
E-1	Roughness Sensitivity		E-1	Roughness Sensitivity
E-2	Inflow Sensitivity		E-2	Inflow Sensitivity
E-3	Ocean Level Sensitivity		E-3	Ocean Level Sensitivity

Table E.1: Roughness Sensitivity for Lower Model (Freshet Design Condition)
By Muncipality

Municipality/Diking District	Location	MIKE 11 Chainage		Base Model (m GSC)	+10% n Diff. (m)	+20% n Diff. (m)	-10% n Diff. (m)
North Fraser							
City of Vancouver	West end UBC	'NORTH ARM'	1238	1.56	0.00	0.00	0.00
	Burnaby border	'NORTH ARM'	22157	2.57	0.22	0.45	-0.20
City of Richmond	Sea Island: McDonald Slough	'NORTH ARM'	9913	1.68	0.04	0.10	-0.05
	Sea Island: West end at Middle Arm	'MIDDLE ARM'	6788	1.51	0.00	0.00	0.00
	Middle and North Arm Confluence	'MIDDLE ARM'	14066	1.90	0.11	0.23	-0.10
	Terra Nova Park at Middle Arm	'MIDDLE ARM'	7834	1.51	0.00	0.00	-0.01
	New Westminster border	'NORTH ARM'	28105	3.12	0.33	0.65	-0.30
City of Burnaby	Vancouver border	'NORTH ARM'	22157	2.57	0.22	0.45	-0.20
	New Westminster border	'NORTH ARM'	28761	3.14	0.33	0.67	-0.31
City of New Westminster	Burnaby border	'NORTH ARM'	28761	3.14	0.33	0.67	-0.31
	Coquitlam border	'FRASER'	37528	4.09	0.40	0.78	-0.41
City of Coquitlam	Burnaby border	'FRASER'	37528	4.09	0.40	0.78	-0.41
	Port Coquitlam border	'FRASER'	42617	4.65	0.44	0.85	-0.45
City of Port Coquitlam	Coquitlam border	'FRASER'	42617	4.65	0.44	0.85	-0.45
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.74	0.47	0.89	-0.48
	Pitt River at De Bouville Slough	'PITT'	7342	4.71	0.44	0.82	-0.48
District of Pitt Meadows	Pitt River at Sheridan Hill	'PITT'	10817	4.71	0.43	0.82	-0.47
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.74	0.47	0.89	-0.48
	Maple Ridge border	'FRASER'	53954	6.00	0.49	0.92	-0.52
District of Maple Ridge	Pitt Meadows border	'FRASER'	53954	6.00	0.49	0.92	-0.52
	Whonnock Creek	'FRASER'	71256	7.46	0.58	1.11	-0.66
	Mission border	'FRASER'	73842	7.90	0.57	1.10	-0.65
District of Mission	Maple Ridge border	'FRASER'	73842	7.90	0.57	1.10	-0.65
	Silverdale Creek	'FRASER'	80578	8.40	0.60	1.16	-0.68
	Mission bridge	'FRASER'	85182	8.87	0.58	1.13	-0.65
South Fraser							
Corporation of Delta	Roberts Bank at Canoe Pass	'CANOE'	8065	1.42	0.00	0.01	0.00
	Massey Tunnel	'FRASER'	18117	2.16	0.17	0.35	-0.15
	Surrey border	'FRASER'	31926	3.52	0.36	0.70	-0.33
	Westham Island: Roberts Bank at Canoe Pass	'CANOE'	8065	1.42	0.00	0.01	0.00
	Westham Island: Reifel Island at Ladner Reach	'FRASER'	9650	1.55	0.02	0.04	-0.02
	Westham Island: Upstream end	'LADNER'	4506	1.81	0.07	0.17	-0.06
City of Richmond	Steveston, Garry Point Park	'FRASER'	7589	1.50	0.01	0.02	-0.01
	Massey Tunnel	'FRASER'	18117	2.16	0.17	0.35	-0.15
	New Westminster Border	'ANNACIS'	3136	3.11	0.33	0.64	-0.29
City of New Westminster	City of Richmond Border	'ANNACIS'	3136	3.11	0.33	0.64	-0.29
	Trifurcation	'FRASER'	34089	3.57	0.39	0.75	-0.35
City of Surrey	Delta border	'FRASER'	31926	3.52	0.36	0.70	-0.33
	Township of Langley border	'BARNSTON'	6011	5.72	0.50	0.94	-0.53
Barnston Diking District	Barnston Island: downstream end	'BARNSTON'	0	5.27	0.47	0.89	-0.49
	Barnston Island: upstream end	'BARNSTON'	7446	5.87	0.50	0.94	-0.53
Township of Langley	Surrey border	'BARNSTON'	6011	5.72	0.50	0.94	-0.53
	Jacob-Haldi Bridge	'MCMILLAN'	2644	7.11	0.50	0.98	-0.68
	Abbotsford border	'FRASER'	70804	7.58	0.56	1.09	-0.64
City of Abbotsford	Langley border	'FRASER'	70804	7.58	0.56	1.09	-0.64
	Mission Bridge	'FRASER'	85182	8.87	0.58	1.13	-0.65

Notes:
1. Difference is calculated as scenario model less base model water level.
2. All levels are based on freshet design condition.
3. Values show un-smoothed results direct from model and may differ from design profile.
4. Percentage increases in roughness refer to a global increase to Manning's n.
5. All boundary conditions the same as for base design profile.

Table E.2: Inflow Sensitivity for Lower Model (Freshet Design Condition)
By Muncipality

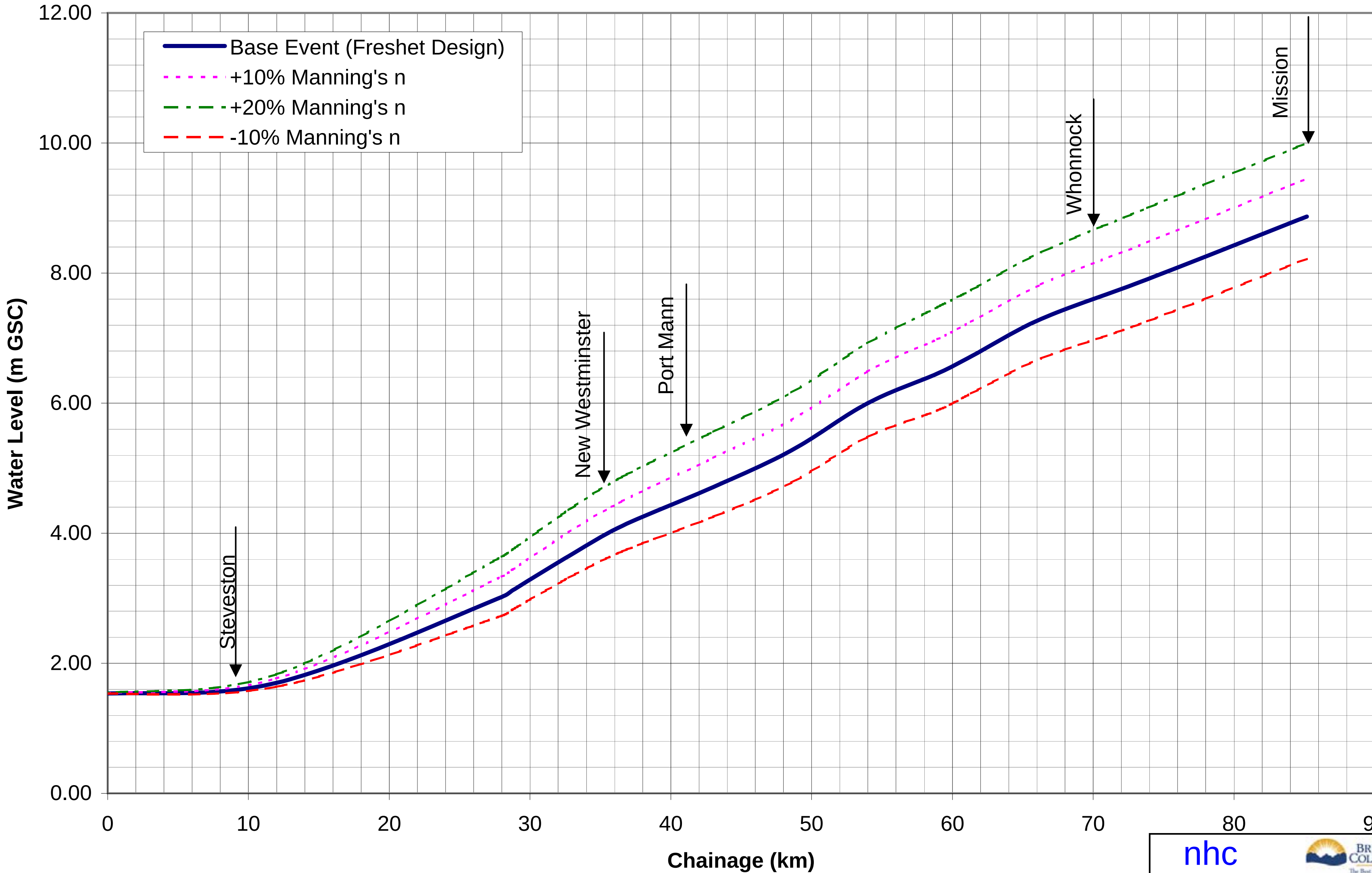
Municipality/Diking District	Location	MIKE 11 Chainage		Base Model (m GSC)	+10% Inflow Diff. (m)	-10% Inflow Diff. (m)
North Fraser						
City of Vancouver	West end UBC	'NORTH ARM'	1238	1.56	0.00	0.00
	Burnaby border	'NORTH ARM'	22157	2.57	0.23	-0.22
City of Richmond	Sea Island: McDonald Slough	'NORTH ARM'	9913	1.68	0.04	-0.05
	Sea Island: West end at Middle Arm	'MIDDLE ARM'	6788	1.51	0.00	0.00
	Middle and North Arm Confluence	'MIDDLE ARM'	14066	1.90	0.10	-0.10
	Terra Nova Park at Middle Arm	'MIDDLE ARM'	7834	1.51	0.00	0.00
	New Westminster border	'NORTH ARM'	28105	3.12	0.32	-0.32
City of Burnaby	Vancouver border	'NORTH ARM'	22157	2.57	0.23	-0.22
	New Westminster border	'NORTH ARM'	28761	3.14	0.32	-0.32
City of New Westminster	Burnaby border	'NORTH ARM'	28761	3.14	0.32	-0.32
	Coquitlam border	'FRASER'	37528	4.09	0.45	-0.46
City of Coquitlam	Burnaby border	'FRASER'	37528	4.09	0.45	-0.46
	Port Coquitlam border	'FRASER'	42617	4.65	0.50	-0.53
City of Port Coquitlam	Coquitlam border	'FRASER'	42617	4.65	0.50	-0.53
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.74	0.50	-0.54
	Pitt River at De Bouville Slough	'PITT'	7342	4.71	0.48	-0.50
District of Pitt Meadows	Pitt River at Sheridan Hill	'PITT'	10817	4.71	0.48	-0.50
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.74	0.50	-0.54
	Maple Ridge border	'FRASER'	53954	6.00	0.54	-0.60
District of Maple Ridge	Pitt Meadows border	'FRASER'	53954	6.00	0.54	-0.60
	Whonnock Creek	'FRASER'	71256	7.46	0.58	-0.68
	Mission border	'FRASER'	73842	7.90	0.61	-0.70
District of Mission	Maple Ridge border	'FRASER'	73842	7.90	0.61	-0.70
	Silverdale Creek	'FRASER'	80578	8.40	0.63	-0.72
	Mission bridge	'FRASER'	85182	8.87	0.63	-0.71
South Fraser						
Corporation of Delta	Roberts Bank at Canoe Pass	'CANOE'	8065	1.42	0.00	0.00
	Massey Tunnel	'FRASER'	18117	2.16	0.17	-0.14
	Surrey border	'FRASER'	31926	3.52	0.39	-0.38
	Westham Island: Roberts Bank at Canoe Pass	'CANOE'	8065	1.42	0.00	0.00
	Westham Island: Reifel Island at Ladner Reach	'FRASER'	9650	1.55	0.01	-0.01
	Westham Island: Upstream end	'LADNER'	4506	1.81	0.08	-0.07
City of Richmond	Steveston, Garry Point Park	'FRASER'	7589	1.50	0.00	0.00
	Massey Tunnel	'FRASER'	18117	2.16	0.17	-0.14
	New Westminster Border	'ANNACIS'	3136	3.11	0.35	-0.31
City of New Westminster	City of Richmond Border	'ANNACIS'	3136	3.11	0.35	-0.31
	Trifurcation	'FRASER'	34089	3.57	0.40	-0.39
City of Surrey	Delta border	'FRASER'	31926	3.52	0.39	-0.38
	Township of Langley border	'BARNSTON'	6011	5.72	0.53	-0.58
Barnston Diking District	Barnston Island: downstream end	'BARNSTON'	0	5.27	0.52	-0.57
	Barnston Island: upstream end	'BARNSTON'	7446	5.87	0.54	-0.59
Township of Langley	Surrey border	'BARNSTON'	6011	5.72	0.53	-0.58
	Jacob-Haldi Bridge	'MCMILLAN'	2644	7.11	0.54	-0.73
	Abbotsford border	'FRASER'	70804	7.58	0.60	-0.69
City of Abbotsford	Langley border	'FRASER'	70804	7.58	0.60	-0.69
	Mission Bridge	'FRASER'	85182	8.87	0.63	-0.71

Notes:
1. Difference is calculated as scenario model less base model water level.
2. All levels are based on freshet design condition.
3. Values show un-smoothed results direct from Model and may differ from design profile.
4. Percentage increases in flow refer to global increases to all five inflow boundaries.
5. Downstream boundary condition and roughness values the same as for base design profile.

Table E.3: Downstream Boundary Condition Sensitivity for Lower Model (Freshet Design Condition) By Muncipality

Municipality/Diking District	Location	MIKE 11 Chainage		Base Model (m GSC)	+0.6 m at Ocean Diff. (m)
North Fraser					
City of Vancouver	West end UBC	'NORTH ARM'	1238	1.56	0.60
	Burnaby border	'NORTH ARM'	22157	2.57	0.40
City of Richmond	Sea Island: McDonald Slough	'NORTH ARM'	9913	1.68	0.54
	Sea Island: West end at Middle Arm	'MIDDLE ARM'	6788	1.51	0.62
	Middle and North Arm Confluence	'MIDDLE ARM'	14066	1.90	0.49
	Terra Nova Park at Middle Arm	'MIDDLE ARM'	7834	1.51	0.62
	New Westminster border	'NORTH ARM'	28105	3.12	0.34
City of Burnaby	Vancouver border	'NORTH ARM'	22157	2.57	0.40
	New Westminster border	'NORTH ARM'	28761	3.14	0.33
City of New Westminster	Burnaby border	'NORTH ARM'	28761	3.14	0.33
	Coquitlam border	'FRASER'	37528	4.09	0.28
City of Coquitlam	Burnaby border	'FRASER'	37528	4.09	0.28
	Port Coquitlam border	'FRASER'	42617	4.65	0.22
City of Port Coquitlam	Coquitlam border	'FRASER'	42617	4.65	0.22
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.74	0.21
	Pitt River at De Bouville Slough	'PITT'	7342	4.71	0.22
District of Pitt Meadows	Pitt River at Sheridan Hill	'PITT'	10817	4.71	0.22
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	4.74	0.21
	Maple Ridge border	'FRASER'	53954	6.00	0.14
District of Maple Ridge	Pitt Meadows border	'FRASER'	53954	6.00	0.14
	Whonnock Creek	'FRASER'	71256	7.46	0.09
	Mission border	'FRASER'	73842	7.90	0.09
District of Mission	Maple Ridge border	'FRASER'	73842	7.90	0.09
	Silverdale Creek	'FRASER'	80578	8.40	0.08
	Mission bridge	'FRASER'	85182	8.87	0.07
South Fraser					
Corporation of Delta	Roberts Bank at Canoe Pass	'CANOE'	8065	1.42	0.62
	Massey Tunnel	'FRASER'	18117	2.16	0.47
	Surrey border	'FRASER'	31926	3.52	0.30
	Westham Island: Roberts Bank at Canoe Pass	'CANOE'	8065	1.42	0.62
	Westham Island: Reifel Island at Ladner Reach	'FRASER'	9650	1.55	0.59
	Westham Island: Upstream end	'LADNER'	4506	1.81	0.53
City of Richmond	Steveston, Garry Point Park	'FRASER'	7589	1.50	0.60
	Massey Tunnel	'FRASER'	18117	2.16	0.47
	New Westminster Border	'ANNACIS'	3136	3.11	0.34
City of New Westminster	City of Richmond Border	'ANNACIS'	3136	3.11	0.34
	Trifurcation	'FRASER'	34089	3.57	0.29
City of Surrey	Delta border	'FRASER'	31926	3.52	0.30
	Township of Langley border	'BARNSTON'	6011	5.72	0.15
Barnston Diking District	Barnston Island: downstream end	'BARNSTON'	0	5.27	0.18
	Barnston Island: upstream end	'BARNSTON'	7446	5.87	0.15
Township of Langley	Surrey border	'BARNSTON'	6011	5.72	0.15
	Jacob-Haldi Bridge	'MCMILLAN'	2644	7.11	0.11
	Abbotsford border	'FRASER'	70804	7.58	0.09
City of Abbotsford	Langley border	'FRASER'	70804	7.58	0.09
	Mission Bridge	'FRASER'	85182	8.87	0.07

Notes:
1. Difference is calculated as scenario model less base model water level.
2. All levels are based on freshet design condition.
3. Values show un-smoothed results direct from Model and may differ from design profile.
4. Downstream boundary condition increased by 0.6 m to represent possible sea level rise and delta settlement condition.
5. Upstream boundary conditions and roughness values the same as for base design profile.

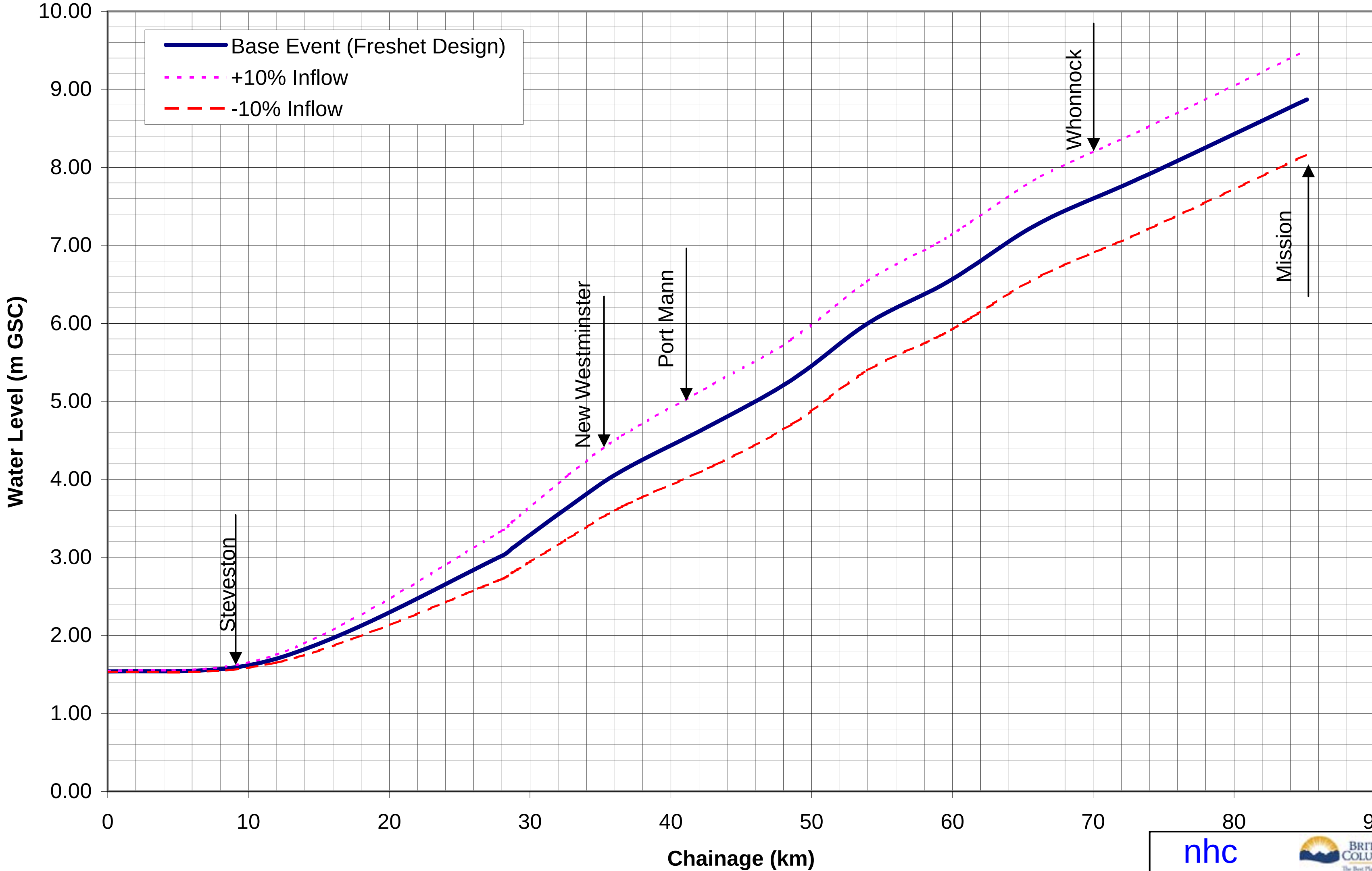


nhc

Roughness Sensitivity
Lower Model

March 2008

Figure E.1



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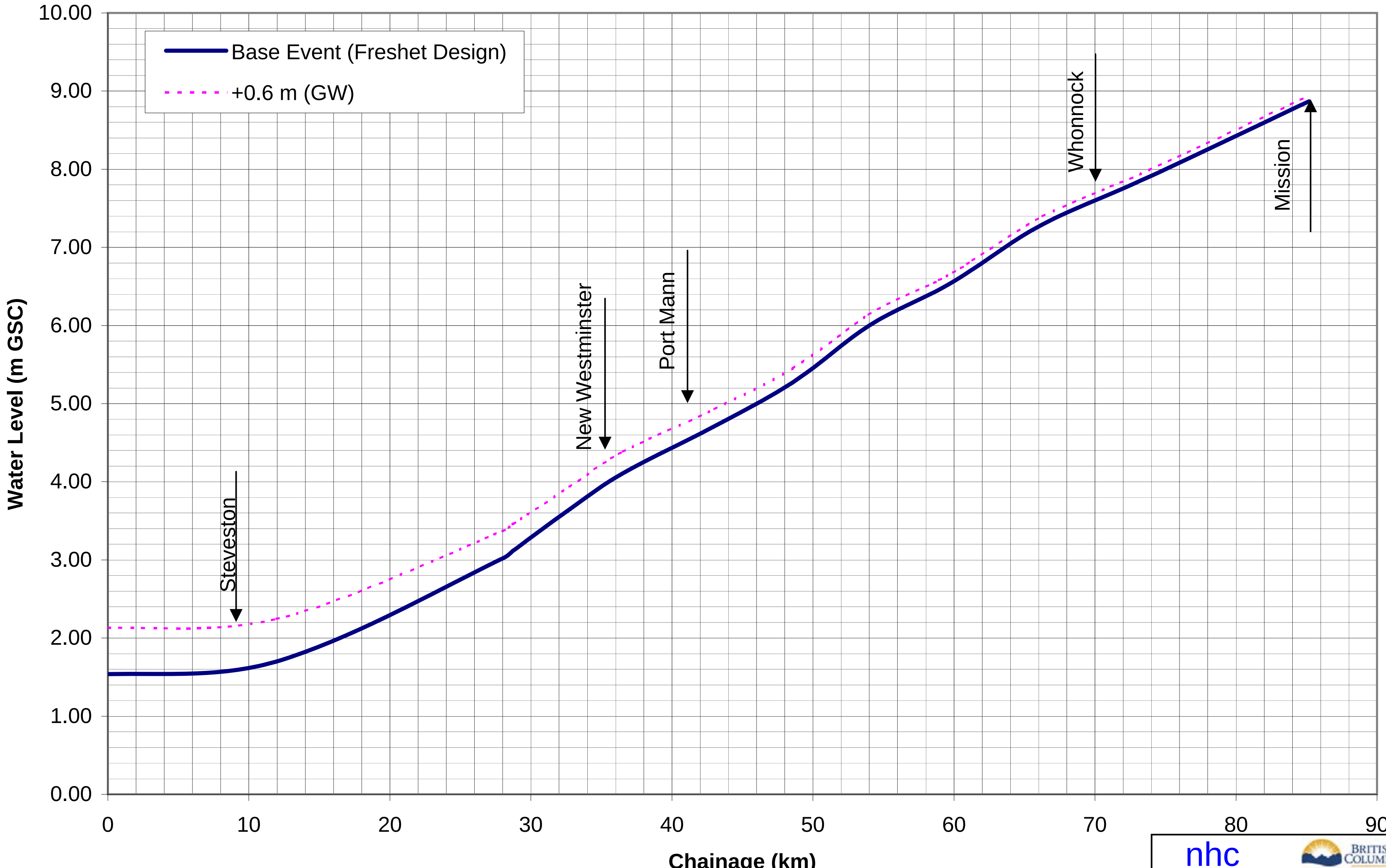
Inflow Sensitivity
Lower Model

March 2008 | Figure E.2



nhc

BRITISH COLUMBIA

Ocean Level Sensitivity
Lower Model

March 2008	Figure E.3

APPENDIX F

SENSITIVITY ANALYSES FOR UPPER MODEL

(TABLES AND CHARTS)

Tables			Charts	
Number	Name		Number	Name
F-1	Roughness Sensitivity		F-1	Roughness Sensitivity
F-2	Inflow Sensitivity		F-2	Inflow Sensitivity
F-3	Downstream Boundary Sensitivity		F-3	Downstream Boundary Sensitivity

Table F.1: Roughness Sensitivity for Upper Model

Municipality/Diking District	Location	MIKE 11 Chainage		Base Model (m GSC)	+10% n Diff. (m)	+20% n Diff. (m)	-10% n Diff. (m)
North Fraser							
District of Mission	Mission Bridge	FRASER_R	85400	8.87	0.00	0.00	0.00
	FVRD Electoral Area G border	FRASER_R	89872	9.38	0.10	0.21	-0.09
FVRD Electoral Area G	Mission border	FRASER_R	89872	9.38	0.10	0.21	-0.09
	Downstream end Nicomen Island	FRASER_R	95540	9.99	0.19	0.40	-0.18
	FVRD Electoral Area C border	FRASER_R	107234	11.01	0.30	0.59	-0.30
FVRD Electoral Area C	FVRD Electoral Area G border	FRASER_R	107234	11.01	0.30	0.59	-0.30
	District of Kent border (Harrison River)	FRASER_R	117387	13.73	0.30	0.60	-0.31
	Harrison Lake	HARRISON_R	17845	13.93	0.31	0.61	-0.31
District of Kent	FVRD Electoral Area C border	FRASER_R	117387	13.73	0.30	0.60	-0.31
	Hammersley Pump Station	FRASER_R	124155	15.87	0.39	0.76	-0.41
	Upstream of Agassiz Bridge	FRASER_R	131184	18.67	0.37	0.73	-0.38
	Maria Slough	MARIA_S	0	20.33	0.34	0.66	-0.35
Seabird First Nation	Maria Slough	MARIA_S	0	20.33	0.34	0.66	-0.35
	Upstream end Seabird Island	FRASER_R	147935	26.88	0.36	0.67	-0.41
FVRD Electoral District C	Upstream end Seabird Island	FRASER_R	147935	26.88	0.36	0.67	-0.41
	Laidlaw	FRASER_R	154447	31.72	0.38	0.73	-0.41
South Fraser							
City of Abbotsford	Mission Bridge	FRASER_R	85400	8.87	0.00	0.00	0.00
	FVRD Electoral Area H border	FRASER_R	92864	9.69	0.15	0.31	-0.14
FVRD Electoral Area H	Abbotsford border	FRASER_R	92864	9.69	0.15	0.31	-0.14
	Chilliwack border	FRASER_R	99944	10.48	0.25	0.51	-0.24
City of Chilliwack	FVRD Electoral Area H border	FRASER_R	99944	10.48	0.25	0.51	-0.24
	Minto Landing	MINTO_C	3073	13.06	0.35	0.69	-0.37
	FVRD Electoral Area D border	SC_122760L	6322	18.54	0.34	0.68	-0.35
FVRD Electoral Area D	Chilliwack border	SC_122760L	6322	18.54	0.34	0.68	-0.35
	Upstream of Agassiz Bridge	FRASER_R	131184	18.67	0.37	0.73	-0.38
	FVRD Electoral Area B border	FRASER_R	145700	25.65	0.30	0.57	-0.34
FVRD Electoral Area B	FVRD Electoral Area D border	FRASER_R	145700	25.65	0.30	0.57	-0.34
	Laidlaw	FRASER_R	154447	31.72	0.38	0.73	-0.41

Notes:
1. Difference is calculated as scenario model less base model water level.
2. Percentage increases in roughness refer to a global increase to Manning's n.
3. All boundary conditions the same as for base design profile.

Table F.2: Inflow Sensitivity for Upper Model

Municipality/Diking District	Location	MIKE 11 Chainage		Base Model (m GSC)	+10% Global Diff. (m)	-10% Global Diff. (m)	+50% Harrison Diff. (m)	-50% Harrison Diff. (m)
North Fraser								
District of Mission	Mission Bridge	FRASER_R	85400	8.87	0.00	0.00	0.00	0.00
	FVRD Electoral Area G border	FRASER_R	89872	9.38	0.11	-0.10	0.04	-0.03
FVRD	Mission border	FRASER_R	89872	9.38	0.11	-0.10	0.04	-0.03
Electoral Area G	Downstream end Nicomen Island	FRASER_R	95540	9.99	0.21	-0.20	0.07	-0.07
	FVRD Electoral Area C border	FRASER_R	107234	11.01	0.35	-0.31	0.13	-0.10
FVRD	FVRD Electoral Area G border	FRASER_R	107234	11.01	0.35	-0.31	0.13	-0.10
Electoral Area C	District of Kent border (Harrison River)	FRASER_R	117387	13.73	0.43	-0.44	0.17	-0.17
	Harrison Lake	HARRISON_R	17845	13.93	0.44	-0.44	0.38	-0.30
District of Kent	FVRD Electoral Area C border	FRASER_R	117387	13.73	0.43	-0.44	0.17	-0.17
	Hammersley Pump Station	FRASER_R	124155	15.87	0.42	-0.43	0.05	-0.05
	Upstream of Agassiz Bridge	FRASER_R	131184	18.67	0.38	-0.38	0.01	-0.01
	Maria Slough	MARIA_S	0	20.33	0.38	-0.39	0.00	0.00
Seabird First Nation	Maria Slough	MARIA_S	0	20.33	0.38	-0.39	0.00	0.00
	Upstream end Seabird Island	FRASER_R	147935	26.88	0.33	-0.36	0.00	0.00
FVRD	Upstream end Seabird Island	FRASER_R	147935	26.88	0.33	-0.36	0.00	0.00
Electoral District C	Laidlaw	FRASER_R	154447	31.72	0.40	-0.42	0.00	0.00
South Fraser								
City of Abbotsford	Mission Bridge	FRASER_R	85400	8.87	0.00	0.00	0.00	0.00
	FVRD Electoral Area H border	FRASER_R	92864	9.69	0.16	-0.15	0.05	-0.05
FVRD	Abbotsford border	FRASER_R	92864	9.69	0.16	-0.15	0.05	-0.05
Electoral Area H	Chilliwack border	FRASER_R	99944	10.48	0.28	-0.27	0.09	-0.09
City of Chilliwack	FVRD Electoral Area H border	FRASER_R	99944	10.48	0.28	-0.27	0.09	-0.09
	Minto Landing	MINTO_C	3073	13.06	0.43	-0.42	0.14	-0.13
	FVRD Electoral Area D border	SC_122760L	6322	18.54	0.38	-0.39	0.01	-0.01
FVRD	Chilliwack border	SC_122760L	6322	18.54	0.38	-0.39	0.01	-0.01
Electoral Area D	Upstream of Agassiz Bridge	FRASER_R	131184	18.67	0.38	-0.38	0.01	-0.01
	FVRD Electoral Area B border	FRASER_R	145700	25.65	0.33	-0.36	0.00	0.00
FVRD	FVRD Electoral Area D border	FRASER_R	145700	25.65	0.33	-0.36	0.00	0.00
Electoral Area B	Laidlaw	FRASER_R	154447	31.72	0.40	-0.42	0.00	0.00

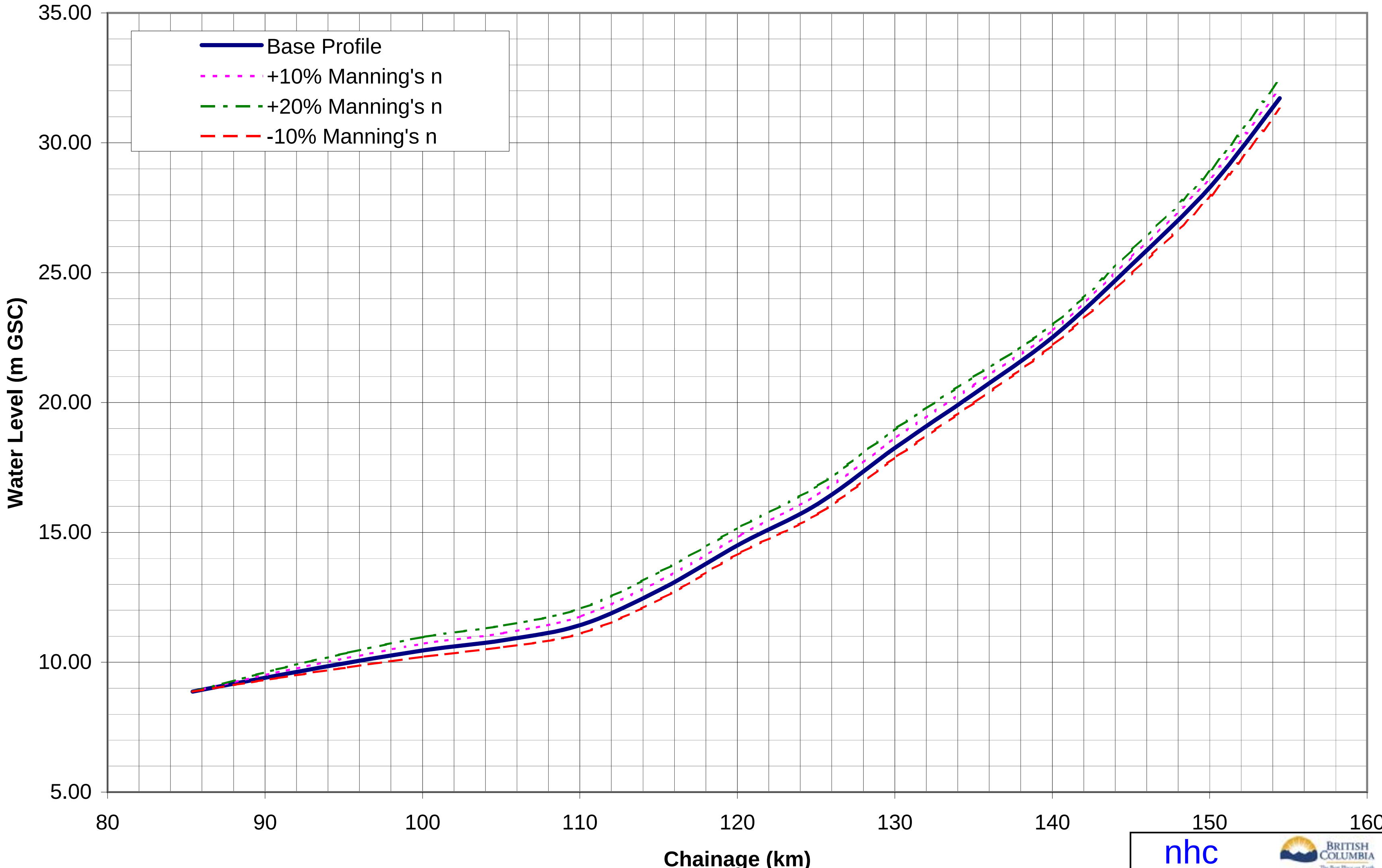
Notes:

1. Difference is calculated as scenario model less base model water level.
2. For global scenarios percentage increases in flow refer to global increases to all inflow boundaries.
3. For Harrison scenarios percentage increases in flow refer to increase in Harrison Lake inflow only.
4. Downstream boundary condition and roughness values the same as for base design profile.

Table F.3: Downstream Boundary Condition Sensitivity for Upper Model

Municipality/Diking District	Location	MIKE 11 Chainage		Base Model (m GSC)	+1m @ Mission Diff. (m)	-1m @ Mission Diff. (m)
North Fraser						
District of Mission	Mission Bridge	FRASER_R	85400	8.87	1.00	-1.00
	FVRD Electoral Area G border	FRASER_R	89872	9.38	0.92	-0.90
FVRD Electoral Area G	Mission border	FRASER_R	89872	9.38	0.92	-0.90
	Downstream end Nicomen Island	FRASER_R	95540	9.99	0.81	-0.76
	FVRD Electoral Area C border	FRASER_R	107234	11.01	0.63	-0.50
FVRD Electoral Area C	FVRD Electoral Area G border	FRASER_R	107234	11.01	0.63	-0.50
	District of Kent border (Harrison River)	FRASER_R	117387	13.73	0.22	-0.14
	Harrison Lake	HARRISON_R	17845	13.93	0.21	-0.13
District of Kent	FVRD Electoral Area C border	FRASER_R	117387	13.73	0.22	-0.14
	Hammersley Pump Station	FRASER_R	124155	15.87	0.08	-0.04
	Upstream of Agassiz Bridge	FRASER_R	131184	18.67	0.02	-0.01
	Maria Slough	MARIA_S	0	20.33	0.00	0.01
Seabird First Nation	Maria Slough	MARIA_S	0	20.33	0.00	0.01
	Upstream end Seabird Island	FRASER_R	147935	26.88	0.00	0.00
FVRD Electoral District C	Upstream end Seabird Island	FRASER_R	147935	26.88	0.00	0.00
	Laidlaw	FRASER_R	154447	31.72	0.00	0.00
South Fraser						
City of Abbotsford	Mission Bridge	FRASER_R	85400	8.87	1.00	-1.00
	FVRD Electoral Area H border	FRASER_R	92864	9.69	0.86	-0.82
FVRD Electoral Area H	Abbotsford border	FRASER_R	92864	9.69	0.86	-0.82
	Chilliwack border	FRASER_R	99944	10.48	0.72	-0.65
City of Chilliwack	FVRD Electoral Area H border	FRASER_R	99944	10.48	0.72	-0.65
	Minto Landing	MINTO_C	3073	13.06	0.28	-0.18
	FVRD Electoral Area D border	SC_122760L	6322	18.54	0.02	-0.01
FVRD Electoral Area D	Chilliwack border	SC_122760L	6322	18.54	0.02	-0.01
	Upstream of Agassiz Bridge	FRASER_R	131184	18.67	0.02	-0.01
	FVRD Electoral Area B border	FRASER_R	145700	25.65	0.00	0.00
FVRD Electoral Area B	FVRD Electoral Area D border	FRASER_R	145700	25.65	0.00	0.00
	Laidlaw	FRASER_R	154447	31.72	0.00	0.00

Notes:
1. Difference is calculated as scenario model less base model water level.
2. Upstream boundary conditions and roughness values the same as for base design profile.



nhc

BRITISH COLUMBIA
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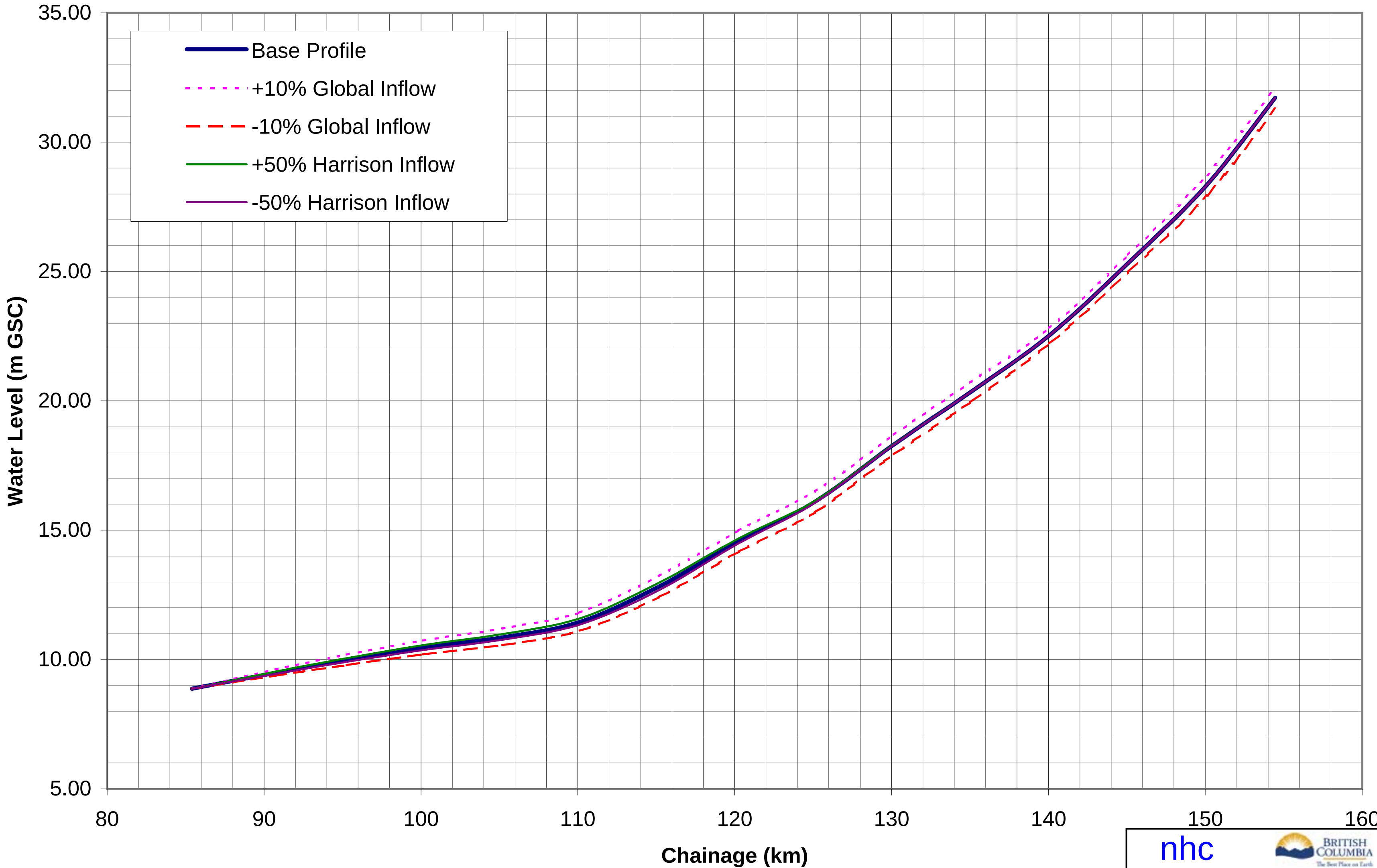
Roughness Sensitivity
Upper Model

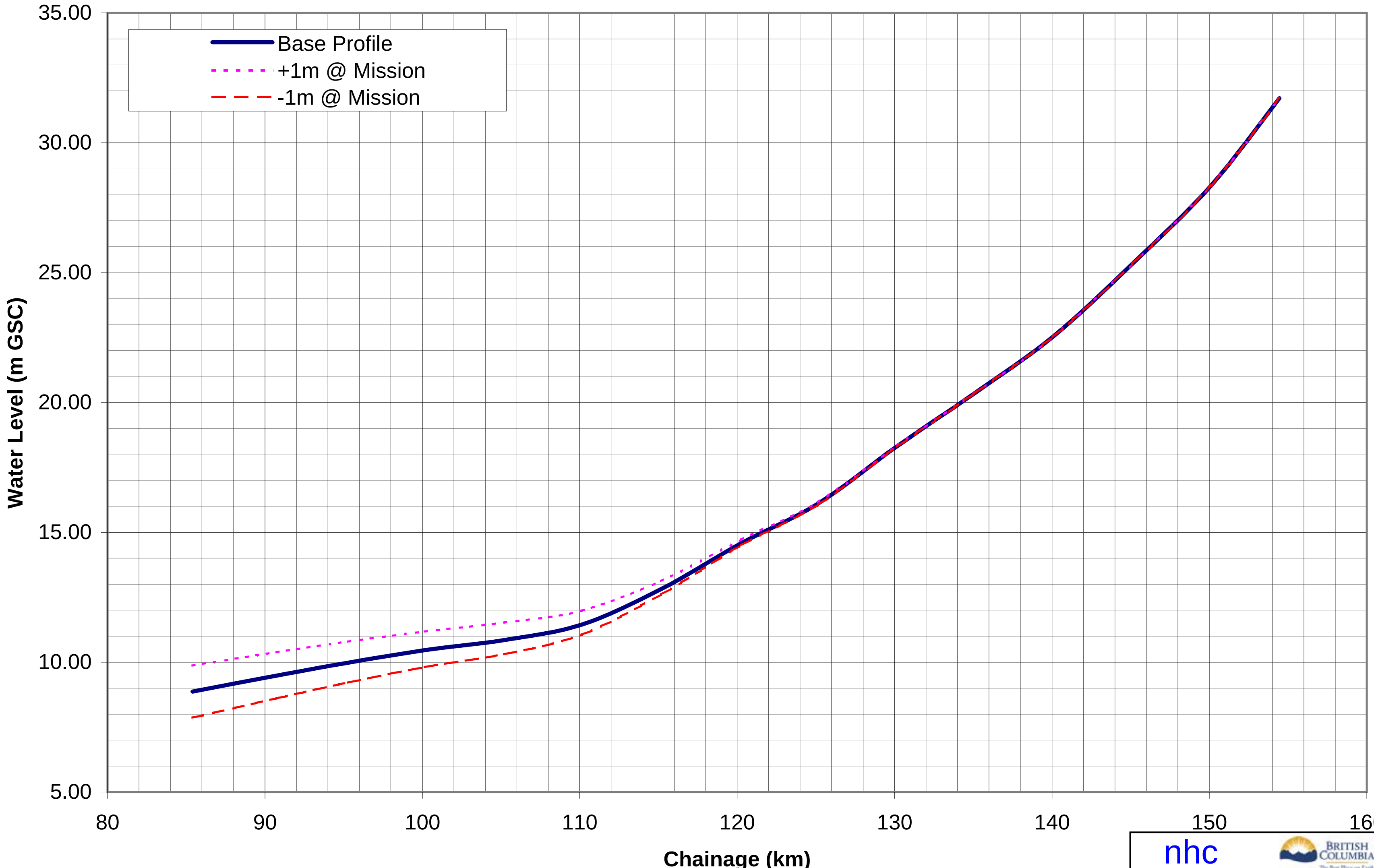
March 2008	Figure F.1



nhc

Inflow Sensitivity
Upper Model

March 2008 | Figure F.2



nhc

Downstream Boundary Sensitivity
Upper Model

March 2008	Figure F.3

APPENDIX G

RAILWAY EMBANKMENT BREACH AT SEABIRD ISLAND

nhc
memorandum

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From:	**Tamsin Lyle, Monica Mannerström (nhc)**	**No. Pages:**	2
CC:		**Project No.:**	34743
		Ref. No.:	

Re: **Fraser River Hydraulic Model Update**
Railway Embankment Breach at Seabird Island

1 INTRODUCTION

Seabird Island is located near the upstream end of the MIKE11 model, and is bounded by the Fraser River on the east side and by Maria Slough on the west side. The island is divided along its length by a CPR railway embankment which acts as a dike. There is concern that if a breach of this embankment were to occur, water levels on the land side near the downstream end of the island could be higher than on the river side. UMA (2000) modelled several breach scenarios, of which one was presented in their report. Breach modelling was not undertaken as part of the 2007-2008 model update. However, the risk of flood levels exceeding computed Fraser River design levels was briefly reviewed as outlined below.

2 BACKGROUND

Embankment breach scenarios on Seabird Island were initially studied by Hay&Company (1992) as part of a study carried out for INAC to develop flood construction levels for Seabird Island I.R.0. Hay&Company modelled a breach at the upstream end of the island causing water to pond behind the embankment at the downstream end, as a result of Fraser River backwater and flow blockage at the Highway #7 and CPR Bridge openings near the exit of Maria Slough. The modelled water level (ponded elevation) for this scenario was 22.4 m GSC and was based on a 200-year design flow of 15,400 m^3/s at Hope.

The UMA 2000 work showed that as a result of a breach, water levels in Maria Slough upstream of the Highway #7 Bridge could be approximately 0.5 m higher in the slough than water levels resulting from local inflow to the Slough and backwater from the Fraser.

In March 2006, **nhc** completed a flood construction level assessment for the Seabird Island band for a new subdivision on the Island. Previous reporting was reviewed and a physical assessment of the embankment was made. The report concluded that a breach at the upstream end of the island was unlikely to occur. However, some spilling over the embankment could result if Fraser River water levels ever exceeded the top of railroad elevation.

3 BREACH ASSESSMENT

According to the updated model, the Maria Slough design water level at Station 0+000 of Kent A Dike is 21.2 m. (The crest elevation of the dike in this location is 21.5 m). The dike starts at the Highway 7 Bridge, downstream of the CPR crossing. The top-of-railway elevation at the Maria Slough crossing is 21.9 m.

If, in the unlikely event, a major breach of the embankment were to occur at some upstream location on Seabird Island, it is conceivable that water levels on the land side of the embankment could be higher than those on the river side if the CPR and Highway 7 Bridge openings became severely blocked and could not be cleared out. The same could potentially happen in other locations in the Fraser Valley where dikes or embankments may trap water on the land side, raising flood levels beyond those modelled for the main or side channels.

Detailed breach modelling typically requires two-dimensional modelling along with extensive topographic data of the floodplain and detailed surveys of dikes and embankments. This work was outside the scope of the present study and breach modelling was not undertaken.

REFERENCES

Hay&Company 1992. *Fraser River Floodplain Mapping Seabird Island I.R. and Peters Island IR. 1 and 2.* Prepared for Indian and Northern Affairs Canada.

nhc 2006. *Sebird Island I.R. Flood Construction Level Assessment.* Prepared for Seabird Indian Band.

UMA 2000. *Fraser River Gravel Rreach Hydraulic Modelling Study*. Prepared for the City of Chilliwack.

APPENDIX H

MUNICIPAL WATER LEVEL REFERENCE TABLES

Table H.1: Typical Water Levels for Various Water Levels at Mission (Lower Model)

Municipality/Diking District	Location	MIKE 11 Chainage	Water Level at Mission	6 m		6.5 m		7 m		7.5 m		8 m		8.5 m		9 m	
			Corresponding Inflow	11200 cms		12350 cms		13725 cms		15050 cms		16450 cms		17800 cms		19225 cms	
			Tidal Condition	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
North Fraser																	
City of Vancouver	West end UBC	'NORTH ARM'	1238	-2.82	1.95	-2.82	1.95	-2.82	1.95	-2.82	1.95	-2.82	1.95	-2.82	1.95	-2.82	1.95
	Burnaby border	'NORTH ARM'	22157	-0.29	2.19	-0.06	2.26	0.23	2.34	0.53	2.46	0.84	2.59	1.14	2.72	1.42	2.86
City of Richmond	Sea Island: McDonald Slough	'NORTH ARM'	9913	-1.97	1.92	-1.88	1.92	-1.77	1.95	-1.66	1.96	-1.55	1.98	-1.44	2.01	-1.32	2.03
	Sea Island: West end at Middle Arm	'MIDDLE ARM'	6788	-1.27	1.91	-1.25	1.91	-1.20	1.91	-1.17	1.90	-1.11	1.90	-1.07	1.90	-1.02	1.90
	Middle and North Arm Confluence	'MIDDLE ARM'	14066	-0.97	1.99	-0.82	2.01	-0.61	2.05	-0.39	2.08	-0.18	2.12	0.02	2.18	0.21	2.23
	Terra Nova Park at Middle Arm	'MIDDLE ARM'	7834	-1.09	1.91	-1.03	1.90	-0.98	1.90	-0.92	1.90	-0.84	1.90	-0.77	1.89	-0.70	1.89
	New Westminster border	'NORTH ARM'	28105	0.23	2.32	0.49	2.44	0.82	2.58	1.18	2.74	1.57	2.95	1.92	3.13	2.27	3.34
City of Burnaby	Vancouver border	'NORTH ARM'	22157	-0.29	2.19	-0.06	2.26	0.23	2.34	0.53	2.46	0.84	2.59	1.14	2.72	1.42	2.86
	New Westminster border	'NORTH ARM'	28761	0.26	2.32	0.53	2.44	0.86	2.59	1.22	2.75	1.61	2.95	1.96	3.14	2.30	3.35
City of New Westminster	Burnaby border	'NORTH ARM'	28761	0.26	2.32	0.53	2.44	0.86	2.59	1.22	2.75	1.61	2.95	1.96	3.14	2.30	3.35
	Coquitlam border	'FRASER'	37528	1.15	2.56	1.49	2.73	1.93	3.00	2.37	3.26	2.80	3.58	3.21	3.89	3.63	4.21
City of Coquitlam	Burnaby border	'FRASER'	37528	1.15	2.56	1.49	2.73	1.93	3.00	2.37	3.26	2.80	3.58	3.21	3.89	3.63	4.21
	Port Coquitlam border	'FRASER'	42617	1.79	2.79	2.16	3.03	2.62	3.36	3.06	3.70	3.52	4.06	3.94	4.43	4.38	4.78
City of Port Coquitlam	Coquitlam border	'FRASER'	42617	1.79	2.79	2.16	3.03	2.62	3.36	3.06	3.70	3.52	4.06	3.94	4.43	4.38	4.78
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	1.93	2.83	2.30	3.09	2.76	3.43	3.19	3.77	3.65	4.14	4.06	4.51	4.47	4.88
	Pitt River at De Bouville Slough	'PITT'	7342	2.03	2.78	2.37	3.04	2.80	3.39	3.23	3.73	3.67	4.11	4.08	4.47	4.43	4.85
District of Pitt Meadows	Pitt River at Sheridan Hill	'PITT'	10817	2.04	2.80	2.38	3.06	2.81	3.39	3.23	3.74	3.66	4.12	4.07	4.48	4.44	4.86
	Pitt and Fraser Rivers confluence	'DOUGLAS'	2988	1.93	2.83	2.30	3.09	2.76	3.43	3.19	3.77	3.65	4.14	4.06	4.51	4.47	4.88
	Maple Ridge border	'FRASER'	53954	3.09	3.69	3.53	4.04	4.02	4.45	4.49	4.86	4.99	5.30	5.43	5.73	5.82	6.13
District of Maple Ridge	Pitt Meadows border	'FRASER'	53954	3.09	3.69	3.53	4.04	4.02	4.45	4.49	4.86	4.99	5.30	5.43	5.73	5.82	6.13
	Whonnock Creek	'FRASER'	71256	4.42	4.79	4.92	5.22	5.41	5.67	5.91	6.13	6.42	6.65	6.88	7.11	7.34	7.59
	Mission border	'FRASER'	73842	4.78	5.10	5.29	5.57	5.80	6.04	6.32	6.52	6.84	7.06	7.32	7.54	7.80	8.04
District of Mission	Maple Ridge border	'FRASER'	73842	4.78	5.10	5.29	5.57	5.80	6.04	6.32	6.52	6.84	7.06	7.32	7.54	7.80	8.04
	Silverdale Creek	'FRASER'	80578	5.20	5.49	5.73	5.98	6.25	6.46	6.79	6.96	7.32	7.53	7.82	8.03	8.32	8.54
	Mission bridge	'FRASER'	85182	5.74	6.00	6.30	6.50	6.82	7.00	7.34	7.50	7.87	8.00	8.32	8.50	8.81	9.00

Table H.1 (Continued): Typical Water Levels for Various Water Levels at Mission (Lower Model)

Municipality/Diking District	Location	MIKE 11 Chainage	Water Level at Mission	6 m		6.5 m		7 m		7.5 m		8 m		8.5 m		9 m	
			Corresponding Inflow	11200 cms		12350 cms		13725 cms		15050 cms		16450 cms		17800 cms		19225 cms	
			Tidal Condition	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
South Fraser																	
Corporation of Delta	Roberts Bank at Canoe Pass	'CANOE'	8065	-1.34	1.96	-1.28	1.96	-1.21	1.96	-1.15	1.96	-1.09	1.95	-1.02	1.94	-0.94	1.94
	Massey Tunnel	'FRASER'	18117	-0.69	2.10	-0.51	2.13	-0.34	2.18	-0.18	2.26	0.00	2.34	0.18	2.41	0.40	2.51
	Surrey border	'FRASER'	31926	0.64	2.39	0.92	2.54	1.27	2.73	1.64	2.95	2.06	3.19	2.44	3.44	2.82	3.70
	Westham Island: Roberts Bank at Can	'CANOE'	8065	-1.34	1.96	-1.28	1.96	-1.21	1.96	-1.15	1.96	-1.09	1.95	-1.02	1.94	-0.94	1.94
	Westham Island: Reifel Island at Ladne	'FRASER'	9650	-1.54	1.94	-1.42	1.94	-1.32	1.94	-1.23	1.95	-1.15	1.96	-1.06	1.96	-0.96	1.97
	Westham Island: Upstream end	'LADNER'	4506	-1.04	2.05	-0.89	2.06	-0.74	2.08	-0.61	2.11	-0.47	2.14	-0.33	2.17	-0.16	2.21
City of Richmond	Steveston, Garry Point Park	'FRASER'	7589	-1.70	1.91	-1.60	1.91	-1.52	1.91	-1.44	1.91	-1.37	1.91	-1.30	1.91	-1.22	1.91
	Massey Tunnel	'FRASER'	18117	-0.69	2.10	-0.51	2.13	-0.34	2.18	-0.18	2.26	0.00	2.34	0.18	2.41	0.40	2.51
	New Westminster Border	'ANNACIS'	3136	0.26	2.29	0.50	2.39	0.83	2.54	1.15	2.73	1.49	2.94	1.84	3.13	2.19	3.34
City of New Westminster	City of Richmond Border	'ANNACIS'	3136	0.26	2.29	0.50	2.39	0.83	2.54	1.15	2.73	1.49	2.94	1.84	3.13	2.19	3.34
	Trifurcation	'FRASER'	34089	0.65	2.40	0.94	2.55	1.32	2.75	1.72	2.97	2.14	3.23	2.52	3.48	2.91	3.74
City of Surrey	Delta border	'FRASER'	31926	0.64	2.39	0.92	2.54	1.27	2.73	1.64	2.95	2.06	3.19	2.44	3.44	2.82	3.70
	Township of Langley border	'BARNSTON'	6011	2.84	3.51	3.27	3.84	3.76	4.24	4.23	4.63	4.71	5.05	5.15	5.46	5.53	5.85
Barnston Diking District	Barnston Island: downstream end	'BARNSTON'	0	0.77	2.42	1.06	2.58	1.43	2.78	1.82	3.02	2.24	3.28	2.63	3.54	3.01	3.81
	Barnston Island: upstream end	'BARNSTON'	7446	2.97	3.60	3.41	3.94	3.89	4.35	4.37	4.75	4.86	5.18	5.30	5.60	5.68	6.00
Township of Langley	Surrey border	'BARNSTON'	6011	2.84	3.51	3.27	3.84	3.76	4.24	4.23	4.63	4.71	5.05	5.15	5.46	5.53	5.85
	Jacob-Haldi Bridge	'MCMILLAN'	2644	3.86	4.33	4.36	4.76	4.89	5.22	5.41	5.71	5.98	6.29	6.44	6.72	6.95	7.25
	Abbotsford border	'FRASER'	70804	4.47	4.84	4.98	5.29	5.49	5.75	6.00	6.22	6.52	6.75	6.99	7.23	7.46	7.71
City of Abbotsford	Langley border	'FRASER'	70804	4.47	4.84	4.98	5.29	5.49	5.75	6.00	6.22	6.52	6.75	6.99	7.23	7.46	7.71
	Mission Bridge	'FRASER'	85182	5.74	6.00	6.30	6.50	6.82	7.00	7.34	7.50	7.87	8.00	8.32	8.50	8.81	9.00

Notes:

1. All water levels estimated using MIKE11 model.
2. Inflow boundary condition at Mission estimated from MIKE11 rating curve for Mission.
3. Downstream boundary condition based on highest recorded tide level from June 24th, 1982.
4. Maximum and Minimum expected water levels shown for 24.6 hour tidal cycle around the June 24th peak.
5. Roughness values for New Westminster to Mission reach vary linearly for flows between calibration flow (12000 cms) and design flow (18900 cms)

Caution:

This data is provided for planning purposes only and is subject to variation related to actual inflows and tide levels and to local changes to the river.
This data does not replace water level estimates from real-time modelling.

Table H.2: Typical Water Levels for Various Water Levels at Mission (Upper Model)

Municipality/Diking District	Location	MIKE 11 Chainage		Water Level at Mission	6 m	6.5 m	7 m	7.5 m	8 m	8.5 m	9 m
				Corresponding Inflow at Hope	9750 cms	10750 cms	12000 cms	13225 cms	14525 cms	15775 cms	17125 cms
North Fraser											
District of Mission	Mission Bridge	FRASER_R	85400		6.00	6.50	7.00	7.50	8.00	8.50	9.00
	FVRD Electoral Area G border	FRASER_R	89872		6.31	6.84	7.38	7.91	8.45	8.97	9.50
FVRD	Mission border	FRASER_R	89872		6.31	6.84	7.38	7.91	8.45	8.97	9.50
Electoral Area G	Downstream end Nicomen Island	FRASER_R	95540		6.78	7.33	7.90	8.45	9.01	9.55	10.10
	FVRD Electoral Area C border	FRASER_R	107234		8.04	8.52	9.05	9.55	10.07	10.57	11.09
FVRD	FVRD Electoral Area G border	FRASER_R	107234		8.04	8.52	9.05	9.55	10.07	10.57	11.09
Electoral Area C	District of Kent border (Harrison River)	FRASER_R	117387		11.36	11.76	12.18	12.57	12.97	13.36	13.76
	Harrison River at Lake	HARRISON_F	17845		11.83	12.20	12.57	12.91	13.26	13.60	13.96
District of Kent	FVRD Electoral Area C border	FRASER_R	117387		11.36	11.76	12.18	12.57	12.97	13.36	13.76
	Hammersley Pump Station	FRASER_R	124155		13.76	14.09	14.47	14.82	15.18	15.52	15.88
	Upstream of Agassiz Bridge	FRASER_R	131184		16.72	17.04	17.42	17.75	18.07	18.36	18.67
	Maria Slough	MARIA_S	0		18.35	18.68	19.05	19.39	19.72	20.02	20.33
Seabird First Nation	Maria Slough	MARIA_S	0		18.35	18.68	19.05	19.39	19.72	20.02	20.33
	Upstream end Seabird Island	FRASER_R	147935		25.00	25.31	25.66	25.98	26.30	26.59	26.88
FVRD	Upstream end Seabird Island	FRASER_R	147935		25.00	25.31	25.66	25.98	26.30	26.59	26.88
Electoral District C	Laidlaw	FRASER_R	154447		29.40	29.78	30.24	30.64	31.04	31.38	31.72
South Fraser											
City of Abbotsford	Mission Bridge	FRASER_R	85400		6.00	6.50	7.00	7.50	8.00	8.50	9.00
	FVRD Electoral Area H border	FRASER_R	92864		6.55	7.09	7.64	8.18	8.73	9.26	9.80
FVRD	Abbotsford border	FRASER_R	92864		6.55	7.09	7.64	8.18	8.73	9.26	9.80
Electoral Area H	Chilliwack border	FRASER_R	99944		7.20	7.76	8.34	8.90	9.47	10.02	10.57
City of Chilliwack	FVRD Electoral Area H border	FRASER_R	99944		7.20	7.76	8.34	8.90	9.47	10.02	10.57
	Minto Landing	MINTO_C	3073		10.59	10.98	11.42	11.84	12.26	12.67	13.10
	FVRD Electoral Area D border	SC_122760L	6322		16.59	16.91	17.28	17.61	17.93	18.23	18.55
FVRD	Chilliwack border	SC_122760L	6322		16.59	16.91	17.28	17.61	17.93	18.23	18.55
Electoral Area D	Upstream of Agassiz Bridge	FRASER_R	131184		16.72	17.04	17.42	17.75	18.07	18.36	18.67
	FVRD Electoral Area B border	FRASER_R	145700		23.78	24.10	24.45	24.77	25.08	25.37	25.66
FVRD	FVRD Electoral Area D border	FRASER_R	145700		23.78	24.10	24.45	24.77	25.08	25.37	25.66
Electoral Area B	Laidlaw	FRASER_R	154447		29.40	29.78	30.24	30.64	31.04	31.38	31.72

Notes:
1. All water levels estimated using MIKE11 model.
2. Inflow boundary condition at Hope based on total expected flow at Mission from rating Curve.
3. Downstream boundary condition based on scenario.
4. Maximum and Minimum expected water levels shown for 24.6 hour tidal cycle around the June 24th peak.

Caution:
This data is provided for planning purposes only and is subject to variation related to actual inflows and tide levels and to local changes to the river.
This data does not replace water level estimates from real-time modelling.

Table H.3: Typical Water Levels at Gauge Locations for Various Water Levels at Mission by Gauge

Gauge Name (Downstream to Upstream)	**Gauge Type**	**MIKE 11 Chainage**	**Water Level at Mission**	**6 m**	**6.5 m**	**7 m**	**7.5 m**	**8 m**	**8.5 m**	**9 m**
			Corresponding Inflow at Hope	9750	10750	12000	13225	14525	15775	17125
			Corresponding Inflow at Mission	11200	12350	13725	15050	16450	17800	19225
Bath Slough	Continuous	'NORTH ARM'	18172	2.10	2.14	2.21	2.31	2.41	2.51	2.62
Fraser River at Byrne Creek	Continuous	'NORTH ARM'	23736	2.22	2.30	2.40	2.52	2.65	2.80	2.94
Queensborough	Continuous	'NORTH ARM'	26666	2.30	2.41	2.53	2.68	2.87	3.04	3.22
CNW Fraser River Pile and Dredge	Staff	'NORTH ARM'	29537	2.35	2.49	2.63	2.82	3.03	3.24	3.47
Fraser R. at Steveston - 08MH028	Continuous	'FRASER'	9163	1.94	1.93	1.94	1.94	1.95	1.95	1.96
3395 River Road	Continuous	'CANOE'	10617	2.01	2.02	2.05	2.07	2.08	2.11	2.16
Elliot & River Road	Continuous	'LADNER'	7584	2.08	2.11	2.16	2.21	2.27	2.33	2.40
62B & River Road	Continuous	'FRASER'	18117	2.10	2.13	2.18	2.26	2.34	2.41	2.51
No. 6 Road	Continuous	'FRASER'	19322	2.13	2.18	2.25	2.34	2.44	2.55	2.67
Nelson Road	Continuous	'FRASER'	24152	2.21	2.28	2.38	2.53	2.69	2.84	3.00
9600 River Road	Continuous	'FRASER'	29120	2.27	2.39	2.54	2.72	2.92	3.11	3.32
Carter PS (Queensborough)	Staff	'ANNACIS'	4845	2.31	2.46	2.61	2.81	3.03	3.24	3.46
New Westminster	Continuous	'FRASER'	35451	2.48	2.66	2.90	3.16	3.46	3.75	4.05
Manson	Continuous	'FRASER'	34655	2.45	2.62	2.84	3.09	3.37	3.64	3.93
CNW Quayside	Staff	'FRASER'	34655	2.45	2.62	2.84	3.09	3.37	3.64	3.93
CNW Winvan	Staff	'SAPPERTON'	1206	2.58	2.78	3.05	3.34	3.67	3.99	4.32
Fraser R. at Port Mann PS - 08MH126	Continuous/Staff	'FRASER'	41158	2.64	2.87	3.16	3.46	3.81	4.15	4.49
Pitt River at Argue St	Continuous	'DOUGLAS'	1973	2.81	3.05	3.38	3.72	4.09	4.45	4.80
Kennedy Slough PS	Staff	'PITT'	2760	2.84	3.09	3.43	3.77	4.15	4.52	4.88
Coquitlam, Gauge on outlet structure	Staff	'PITT'	7714	2.78	3.05	3.39	3.74	4.11	4.47	4.85
Baynes Road	Continuous	'FRASER'	50737	3.27	3.58	3.96	4.33	4.74	5.14	5.52
192nd Street	Continuous	'BARNSTON'	5613	3.47	3.80	4.20	4.58	5.01	5.41	5.80
Yorkson	Staff	'BARNSTON'	6772	3.56	3.89	4.29	4.69	5.12	5.53	5.93
GEB Burnco	Continuous	'FRASER'	53954	3.69	4.04	4.45	4.86	5.30	5.73	6.13
Salmon River Confluence	Continuous	'MCMILLAN'	1016	4.21	4.62	5.07	5.51	5.98	6.46	6.86
Salmon River PS	Staff	'MCMILLAN'	1669	4.25	4.66	5.11	5.54	6.00	6.49	6.87
Albion Ferry Dock	Staff	'FRASER'	63234	4.25	4.66	5.10	5.55	6.05	6.51	6.97
Glen Valley PS	Staff	'CRESCENT'	381	4.88	5.33	5.79	6.27	6.80	7.28	7.76
Fraser R. at Whonnock - 08MH044	Continuous	'FRASER'	70006	4.79	5.23	5.69	6.16	6.68	7.15	7.63
Silverdale PS	Staff	'FRASER'	76811	5.23	5.70	6.17	6.66	7.20	7.68	8.18
McLennan Creek PS	Staff	'MATSQUI'	4284	5.60	6.11	6.61	7.12	7.69	8.20	8.72
Matsqui Slough Discharge	Continuous	'MATSQUI'	5620	5.74	6.24	6.73	7.23	7.80	8.30	8.81
Fraser R. at Mission - 08MH024	**Continuous/Staff**	**'FRASER'**	**85182**	**6.00**	**6.50**	**7.00**	**7.50**	**8.00**	**8.50**	**9.00**
Dewdney PS	Continuous	FRASER_R	90676	6.37	6.91	7.45	7.99	8.53	9.07	9.60
Robson PS	Staff	STRAWBERRY_S	372	6.79	7.34	7.91	8.47	9.04	9.59	10.14
McGillivray Slough PS	Staff	SUMAS_R	3050	7.23	7.79	8.37	8.94	9.51	10.08	10.63
Collinson PS	Staff	VEDDER_R	2828	7.30	7.84	8.42	8.97	9.53	10.11	10.66
Quaamitch Slough	Staff	SC_102218R	1677	7.62	8.15	8.72	9.26	9.81	10.34	10.88
Chilliwack Creek PS (Wolfe Road)	Staff	SKWAY_IR5	0	8.35	8.81	9.31	9.80	10.31	10.80	11.31
Bell Dam	Staff	SC_110122R	0	8.75	9.17	9.65	10.10	10.58	11.04	11.52
Hope Slough at Young St.	Staff	HOPE_S	3060	8.86	9.27	9.73	10.19	10.65	11.11	11.58
Minto Landing Area (Bell Slough)	Staff	MINTO_C	3073	10.59	10.98	11.42	11.84	12.26	12.67	13.10
Harrison R. at Harrison Mills - 08MG014	Continuous/Staff	HARRISON_R	1084	11.39	11.78	12.20	12.59	12.99	13.38	13.77
Duncan Bateson PS	Staff	HARRISON_R	4627.8	11.49	11.89	12.31	12.69	13.09	13.46	13.85
Harrison R. below Morris Creek - 08MG022	Continuous	HARRISON_R	9248.8	11.58	11.97	12.37	12.74	13.12	13.49	13.87
Carey Point	Staff	GREYELL_S	45.1	13.06	13.40	13.79	14.16	14.54	14.90	15.27
Hammersley PS	Staff	FRASER_R	124155	13.76	14.09	14.47	14.82	15.18	15.52	15.88
Limbert Road	Staff	FP_124155R	1943	14.21	14.52	14.88	15.21	15.56	15.88	16.22
915m West of Gill Road	Staff	GREYELL_S	3931	13.58	13.91	14.28	14.64	15.01	15.39	15.79
650m West of Gill Road	Staff	GREYELL_S	4368	14.72	15.04	15.40	15.74	16.11	16.43	16.76
Chip (Camp-Hope) Intake	Staff	SC_122760L	5713	16.28	16.59	16.95	17.28	17.60	17.91	18.22
Agassiz-Rosedale Bridge	Staff	FRASER_R	131022	16.63	16.92	17.27	17.58	17.88	18.17	18.47
Tranmer Plant	Staff	AGASSIZ_CHEAM	4590	17.80	18.11	18.40	18.67	18.96	19.24	19.53
Wahleach Powerhouse	Continuous	SC_132593L	2210	17.59	17.93	18.31	18.65	18.98	19.28	19.59
Maria Slough	Staff	MARIA_S	1648	18.75	19.11	19.65	20.10	20.49	20.81	21.15
Cuthbert Road	Staff	MARIA_S	3097	18.75	19.11	19.66	20.11	20.50	20.82	21.17
Herrling Island	Staff	SC_132593L	8029	20.26	20.51	20.79	21.03	21.27	21.50	21.74
Seabird Island	Staff	FRASER_R	142256	21.68	21.93	22.22	22.49	22.75	22.99	23.23
Johnson Slough	Staff	SC_149184R	1093	26.47	26.81	27.21	27.59	27.97	28.31	28.65
Wahleach (Jones) Creek	Staff	FRASER_R	150935	26.63	26.94	27.31	27.66	28.01	28.33	28.65

Notes:

1. All water levels estimated using MIKE11 model.
2. Inflow boundary condition at Mission estimated from MIKE11 rating curve for Mission. Inflow boundary condition at Hope based on total expected flow at Mission from rating Curve. Reported in cms.
3. Downstream boundary condition based on highest recorded tide level from June 24th, 1982.
4. Maximum and Minimum expected water levels shown for 24.6 hour tidal cycle around the June 24th peak.
5. If there are both staff and continous gauges at a location, only one gauge is reported.
6. All flows reported in m^3/s and all water levels reported in m GSC.
7. Roughness values for New Westminster to Mission reach vary linearly for flows between calibration flow (12000 cms) and design flow (18900 cms).

Caution:

This data is provided for planning purposes only and is subject to variation related to actual inflows and tide levels and to local changes to the river.
This data does not replace water level estimates from real-time modelling.

APPENDIX I

DESIGN WATER LEVELS LISTED BY GAUGE

Table I.1: Design Profile for Lower Model by Gauge

Gauge (Downstream to Upstream)	Gauge Type	MIKE 11 Chainage		Design Profile (m GSC)
Bath Slough	Continuous	'NORTH ARM'	18172	2.96
Fraser River at Byrne Creek	Continuous	'NORTH ARM'	23736	3.06
Queensborough	Continuous	'NORTH ARM'	26666	3.12
CNW Fraser River Pile and Dredge	Staff	'NORTH ARM'	29537	3.25
Fraser R. at Steveston - 08MH028	Continuous	'FRASER'	9163	2.84
3395 River Road	Continuous	'CANOE'	10617	2.87
Elliot & River Road	Continuous	'LADNER'	7584	2.90
62B & River Road	Continuous	'FRASER'	18117	2.92
No. 6 Road	Continuous	'FRASER'	19322	2.94
Nelson Road	Continuous	'FRASER'	24152	3.00
9600 River Road	Continuous	'FRASER'	29120	3.17
Carter PS (Queensborough)	Staff	'ANNACIS'	4845	3.47
New Westminster	Continuous	'FRASER'	35451	3.99
Manson	Continuous	'FRASER'	34655	3.89
CNW Quayside	Staff	'FRASER'	34655	3.89
CNW Winvan	Staff	'SAPPERTON'	1206	4.18
Fraser R. at Port Mann PS - 08MH126	Continuous/Staff	'FRASER'	41158	4.54
Pitt River at Argue St	Continuous	'DOUGLAS'	1973	4.82
Kennedy Slough PS	Staff	'PITT'	2760	4.92
Coquitlam, Gauge on outlet structure	Staff	'PITT'	7714	4.92
Baynes Road	Continuous	'FRASER'	50737	5.56
192nd Street	Continuous	'BARNSTON'	5613	5.79
Yorkson	Staff	'BARNSTON'	6772	5.90
GEB Burnco	Continuous	'FRASER'	53954	6.00
Salmon River Confluence	Continuous	'MCMILLAN'	1016	6.79
Salmon River PS	Staff	'MCMILLAN'	1669	6.85
Albion Ferry Dock	Staff	'FRASER'	63234	6.94
Glen Valley PS	Staff	'CRESCENT'	381	7.70
Fraser R. at Whonnock - 08MH044	Continuous	'FRASER'	70006	7.59
Silverdale PS	Staff	'FRASER'	76811	8.16
McLennan Creek PS	Staff	'MATSQUI'	4284	8.61
Matsqui Slough Discharge	Continuous	'MATSQUI'	5620	8.70
Fraser R. at Mission - 08MH024	Continuous/Staff	'FRASER'	85182	8.87

Notes:
1. Modelled water levels are based on smoothed profile.
2. Water levels below chainage 28369 are based on winter design condition (200-year, 95% confidence tide event)
3. Water levels above chainage 28369 are based on freshet design condition (reoccurance of 1894 event).

Table I-2: Design Profile for Upper Model by Gauge

Gauge Name (Downstream to Upstream)	Gauge Type	MIKE 11 Chainage		Design Flood (m GSC)
Dewdney PS	Continuous	FRASER_R	90676	9.49
Robson PS	Staff	STRAWBERRY_S	372	10.06
McGillivray Slough PS	Staff	SUMAS_R	3050	10.54
Collinson PS	Staff	VEDDER_R	2828	10.56
Quaamitch Slough	Staff	SC_102218R	1677	10.78
Chilliwack Creek PS (Wolfe Road)	Staff	SKWAY_IR5	0	11.27
Bell Dam	Staff	SC_110122R	0	11.47
Hope Slough at Young St.	Staff	HOPE_S	3060	11.55
Minto Landing Area (Bell Slough)	Staff	MINTO_C	3073	13.23
Harrison R. at Harrison Mills - 08MG014	Continuous/Staff	HARRISON_R	1084	13.78
Duncan Bateson PS	Staff	HARRISON_R	4627.8	13.82
Harrison R. below Morris Creek - 08MG022	Continuous	HARRISON_R	9248.8	13.84
Carey Point	Staff	GREYELL_S	45.1	15.27
Hammersley PS	Staff	FRASER_R	124155	15.90
Limbert Road	Staff	FP_124155R	1943	16.45
915m West of Gill Road	Staff	GREYELL_S	3931	16.79
650m West of Gill Road	Staff	GREYELL_S	4368	16.96
Chip (Camp-Hope) Intake	Staff	SC_122760L	5713	18.25
Agassiz-Rosedale Bridge	Staff	FRASER_R	131022	18.73
Tranmer Plant	Staff	AGASSIZ_CHEAM	4590	19.87
Wahleach Powerhouse	Continuous	SC_132593L	2210	19.58
Maria Slough	Staff	MARIA_S	1648	21.15
Cuthbert Road	Staff	MARIA_S	3097	21.17
Herrling Island	Staff	SC_132593L	8029	21.73
Seabird Island	Staff	FRASER_R	142256	23.30
Johnson Slough	Staff	SC_149184R	1093	28.95
Wahleach (Jones) Creek	Staff	FRASER_R	150935	28.65