Photo source: 203 Street Pedestrian Bridge over the Nicomekl River, City of Langley, November 15, 2021

Nicomekl River Floodplain Mapping

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EGBC Permit to Practice # 1003221

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CREDITS AND ACKNOWLEDGEMENTS

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We would also like to thank the City of Surrey and Township of Langley for their roles in flood assessment and planning and data collection in the Nicomekl River watershed over the previous decades.

The following NHC personnel participated in the project:

• Hydrologic analysis	Derek Stuart
• Hydraulic modelling	Nayyar Asif Minhaj
• Project hydrotechnical engineer	Jason Kindrachuk
• Hydraulic model advisory and review	Natalia Leon-Barrios, Vanessa McMaster
• Channel / bridge / culvert survey	Logan Ashall, Dawson Meier
• Mapping and GIS	Joe Drechsler, Sarah North
• Floodplain map review	Neil Peters
• Project management / senior review	Monica Mannerström

EXECUTIVE SUMMARY

Overview

Northwest Hydraulic Consultants Ltd. (NHC) was engaged by the City of Langley (the City) to develop and update floodplain mapping for the Nicomekl River, Logan Creek, and Murray Creek within the City's boundaries.

A hydraulic model of the Nicomekl River system was built using HEC-RAS 2D to assess flood potential under the 200-year return period flood event for existing and future land use and climate change scenarios. Flows used in the model were derived from a hydrologic model created as part of previous work for the City of Surrey. The hydraulic model was calibrated to observed data collected during the recent November 15, 2021 flood event that caused widespread flooding across southwest BC and northwest Washington. The model calibrated well to observed data; additional model runs were completed to test the sensitivity to assumptions including Manning's roughness, downstream water levels, and blockages at the 203 St bridge from debris or sediment.

Flood Mapping

Flood depth maps are provided in Appendix A, showing the computed depth of flooding for the 200-year return period event under existing conditions. The maps also show the increase in flood extents for the 200-year return period event under future conditions. Results shown on the flood depth maps are based on output from the hydraulic model, with no freeboard added.

Floodplain maps are provided in Appendix B. The floodplain maps include flood construction level (FCL) contour lines, which are based on the output from the hydraulic model for the 200-year return period flood event plus a 0.6 m freeboard allowance. Maps are provided for both existing (Figure B.1) and future (Figure B.2) conditions. Based on discussions with the City of Langley, the intention is to apply the FCLs from the future scenario to new development within the City.

Under existing conditions, flooding in the area adjacent to Logan Creek upstream of Glover Road is dependent on the storm drainage system, and local road elevations that contribute to ponding, and so conventional floodplain mapping is not applicable, and FCL contours cannot be drawn. For future conditions, the flooding in this region is sufficiently extensive that FCL contours can be drawn. Detailed discussion is provided in Section 5.2.2.

Flooding along small tributaries (Baldi Creek, Brydon Creek, Pleasantdale Creek, Muckle Creek and Langley Creek) has not been modelled. Each tributary is quite small, and act more as extensions of the storm drainage network than as channels with floodplains. For development adjacent to these tributaries, we recommend the Provincial Flood Hazard Area Land Use Management Guidelines for '*smaller streams*' be followed, with a minimum FCL of 1.5 m above the natural boundary of the watercourse. Refer to Section 5.2.3 for details.

The future climate scenario is based on a single, preliminary assessment of changes to flows based on a 'moderate' end-of-century precipitation increase described in Section 4.3.2. These flows are routed through the existing Nicomekl River system, including the existing bridge and culvert infrastructure. Changes to the floodplain, river and creek crossings between now and the end-of-century will affect the flood extents and FCLs. Further, as noted in Section 4.5.3, consistently higher flows associated with climate change may reshape the channel, and result in flood profiles different from those shown.

Updating the floodplain maps at least every 15 years is necessary to capture infrastructure and morphology changes, and projected impacts of climate change.

Flood Mitigation

Previous flood risk management studies had found that a structural (non-regulatory approach consisting of flood barriers / dikes, ground improvements, piping, pumping, and road crossing improvements) was not preferred due to cost. If a structural approach is to be reconsidered in the future, additional work is needed to confirm that the approach would not contribute to added flooding in areas not captured by the floodplain maps. Instead, a non-structural (regulatory) approach was recommended.

Based on the results from this study, alternative cost-effective structural mitigation measures may include enhancing channel capacity, bridge and culvert capacity, strategic road raising, and increasing floodplain storage in collaboration with adjacent jurisdictions. For non-structural flood protection, the following minimum requirements should be maintained:

- Preserve the floodplain, retain in-channel and off-channel storage.
- Flood proof new and retrofit existing development by meeting FCL requirements and implementing flood proofing strategies where applicable.
- Regular review and updates to the Floodplain Bylaw.
- Periodic revision of floodplain maps to reflect newer versions of software, changes in channel / floodplain geometry, and latest scientific information on climate impacts.
- Communication and public education.
- Emergency response planning.

Recommendations

Additional work is recommended to implement the findings of this study, and improve the City's understanding of flood risk within its boundaries. Recommendations include:

- Update the Floodplain Bylaw to include the revised FCLs.
- During future large floods, exceeding about the 15-20 year return period, collect high water marks on the Nicomekl River including on Logan Creek, to facilitate better model validation.
- Survey all City water level gauges to CGVD2013 datum and develop rating curves for these.
- Resurvey the channel roughly every 15 years to update the hydraulic model and fine-tune the floodplain mapping.
- Review bank erosion and stabilize the banks as necessary to reduce sediment input.
- Evaluate alternative climate change scenarios to better define the changing risk profile, and to allow flood mitigation solutions to better consider adaptation, either during initial construction or through the ability for additions to be easily made in the future.

- With City of Surrey, explore the potential for improving the flow capacity of the Nicomekl channel / floodplain downstream of the City boundary as this could reduce upstream flood levels. With Township of Langley, explore opportunities for increased flow retention to reduce flood peaks within the City.
- Consider improving the flow conveyance of the bridges at the 200 St, 203 St, 51B Ave, Fraser Highway and 56 Ave crossings. This could significantly increase their climate change resilience, or ability to convey future increased flood flows. Similarly, upgrade culvert sizing along Logan Creek and improve inlet/outlet conditions at Glover Rd, two sets of railway culverts, Maple Leaf and Highway 10 / Langley Bypass.
- As a non-structural flood mitigation measure, avoid development within floodplain areas. Even relatively small reductions in flow conveyance area may significantly increase upstream flood levels. The impacts of any future developments within the floodplain should be tested in the hydraulic model before implementation.

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APPENDICES

1 INTRODUCTION

1.1 Background Information

Northwest Hydraulic Consultants Ltd. (NHC) was engaged by the City of Langley (the City) to develop and update floodplain maps for the Nicomekl River, Logan Creek, and Murray Creek within the City's boundaries.

The project uses a hydrologic model developed as part of previous work for the City of Surrey to generate inflows to a 2D hydraulic model of the Nicomekl River, Logan Creek, and Murray Creek. The results of the model are used to assess flood depths, inundation extents, and water levels and to develop official floodplain maps with Flood Construction Levels (FCLs) to be used when development is considered in flood-prone areas.

1.1.1 Study Area

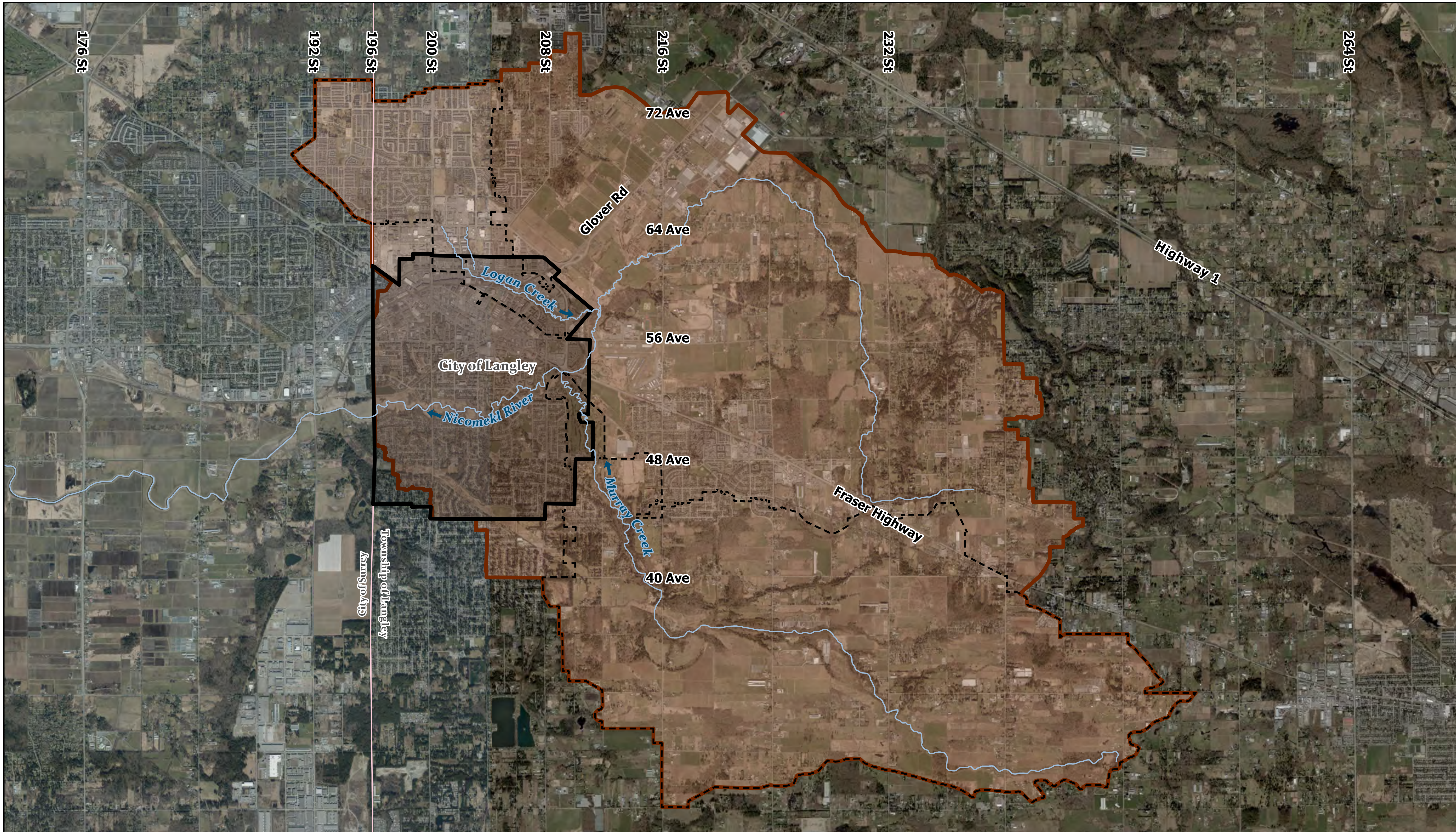
The portion of the upper Nicomekl River watershed, upstream of the City of Langley – City of Surrey border at 196 St, is approximately 7,550 ha; 85% of the basin is located in the Township of Langley and 15% in the City of Langley (Figure 1.1).

Two major watercourses flow through the City and contribute flows to the Nicomekl River upstream of 208 St. These are Logan Creek from the north and Murray Creek from the south. The total watershed areas of Logan Creek (including Jeffries Brook) and Murray Creek are approximately 630 ha and 2,760 ha, respectively. Together they comprise roughly 45% of the upper Nicomekl River watershed area.

Downstream of 208 St, several smaller creeks and lowland ditches contribute flows to the Nicomekl River. These creeks primarily receive flow from the storm systems built in the City's developed areas and include Pleasantdale Creek, Langley Creek, Muckle Creek, Brydon Creek and Baldi Creek.

The City is primarily developed with urban and residential land use, and few natural undisturbed areas remain. Development has encroached on the banks of Logan Creek and many of the smaller tributaries. While development around the Nicomekl River is generally set back from the river, several residential developments are within the floodplain and prone to flooding due to their proximity to the river and low elevation. Within the floodplain, an extensive trail network has been developed by the City, and several roads cross the floodplain. Future development is anticipated to be primarily densification and re-development in and around the downtown core; however, some development and re-development may be expected around the Nicomekl River, as guided by the City's Nicomekl River District Neighbourhood Plan (City of Langley, 2021).

The current study focuses on the portion of the Nicomekl River, Logan Creek (including Jeffries Brook), and Murray Creek within the City's administrative boundary.



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STUDY AREA (CITY OF LANGLEY BORDER)
LOGAN AND MURRAY CREEK WATERSHEDS
UPPER NICOMEKL RIVER WATERSHED
WATERCOURSES

DATA SOURCES: ESRI WORLD IMAGERY; CITY OF LANGLEY; BC FRESHWATER ATLAS

SCALE - 1:50,000
0 2 KM
N

Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES; Vertical Datum: CGVD2013

Job: 3006708 *Date: 17-MAY-2022*

NICOMEKL RIVER FPM STUDY AREA

FIGURE 1.1

1.1.2 Previous Studies

Several studies outlined in the following sections have been conducted by the City of Langley, the City of Surrey, and the Township of Langley that provide context and supporting information to the current project.

1.1.2.1 2004 Upper Nicomekl Flood Control Strategy

In 2004, the City of Surrey, City of Langley, and Township of Langley jointly completed the Upper Nicomekl Flood Control Strategy for the Langley Area (UMA, 2004). The study included hydrologic and hydraulic modelling of the upper Nicomekl River with a focus on assessing agricultural drainage criteria (ARDSA). The hydrologic model was built using XP-SWMM, and the hydraulic model was a 1D model built using DHI's Mike11 software.

1.1.2.2 2007 City of Langley Floodplain Bylaw and Maps

In 2007, the City produced Designated Flood Plain maps showing Designated Flood Levels (DFLs) and Flood Construction Levels (FCLs) for Murray Creek, Logan Creek, and the Nicomekl River within the City's boundary (Urban Systems, 2007). DFLs used on those maps appear to be based on the previous 1D Mike11 model with the flood levels extended away from the channel based on topography. FCLs are based on 0.6 m freeboard applied to the DFL. The maps also delineate the area of the City where the FCL requirements apply.

1.1.2.3 2008 Upper Nicomekl Surrey Lowland Functional Plan

In 2008, the City of Surrey completed the Upper Nicomekl Surrey Lowland Functional Plan / Nicomekl River Large Flood Strategy (UMA and KWL, 2008), which focused on flood mitigation planning for the reach of the Nicomekl River immediately downstream of the City of Langley border. The previous hydrologic and hydraulic models were used for this study.

1.1.2.4 2012 Serpentine, Nicomekl, and Campbell Rivers Climate Change Floodplain Review Phase 1

The City of Surrey completed a study of the Serpentine, Nicomekl, and Campbell River floodplains in 2012 (NHC, 2012). This work included ocean, hydrologic, and hydraulic modelling to assess the potential for future flooding within the drainage basins to assess present-day conditions and potential future flood impacts due to climate change within the City of Surrey. Long-term continuous simulations were used to develop recurrence intervals of floodplain flooding that include the joint effects of rainfall, watershed response, and ocean levels in Mud Bay. Relevant to the current Nicomekl River floodplain mapping study, this project included the development of a hydrologic model of the Nicomekl River basin using Hydrologic Simulation Program Fortran (HSPF).

1.1.2.5 2015 Serpentine and Nicomekl River Climate Change Floodplain Review Phase 2

The second phase of the Serpentine and Nicomekl River Climate Change Floodplain Review was completed by the City of Surrey in 2015 (NHC, 2015). This work involved refinement of the models developed in Phase 1, including the hydrologic model, and additional analysis.

1.1.2.6 2015 Flood Risk Management Strategy Review

The City of Langley completed a qualitative review of their Flood Risk Management Strategy in 2015 (Urban Systems, 2015). The study evaluated implementation of structural flood solutions, including flood barriers, pumping, and road improvements. The estimated cost for those works was in the range of $50M to $100M. Based on that review and discussions with City staff at the time, the study did not recommend pursuing structural solutions, and instead recommended to continue with a non-structural strategy (regulatory approach) to flood protection.

1.1.2.7 2017 Upper Nicomekl River Integrated Stormwater Management Plan

The City and Township of Langley jointly completed an Integrated Stormwater Management Plan (ISMP) of the Upper Nicomekl River in 2017 (KWL, 2017). The ISMP included development of a PCSWMM model of the drainage network, and also extended and updated the existing Mike11 model, but did not include the reach of Logan Creek upstream of CP railway. The model was run for existing conditions and future land use and climate scenarios. Discussion of the results focused on the increased extents under climate change, to guide the area where FCL applications may be required, but does not provide updated floodplain maps or FCLs, as this information is beyond the scope of a typical ISMP.

1.1.2.8 2021 City of Langley Official Community Plan

The City of Langley's Official Community Plan (OCP) outlines plans and policies for long-term development within the City. Policy 5.7 within the OCP includes a policy to "identify floodplain hazards and impacts to infrastructure, including transportation, water, and economic. In particular, ensure habitable space and storage in the floodplain is at or above the flood construction levels and update flood construction levels to account for the impacts of climate change" (City of Langley, 2021).

Among the major development plans for the next 10 to 20 years is the City's Nicomekl River District, which surrounds the Nicomekl River from the Fraser Highway downstream to the City of Langley / City of Surrey border. One of the major concerns in this area is regular flooding from the Nicomekl River, and part of the purpose of the plan is to promote responsible and safe development of the area.

1.2 Project Objectives

The objectives of the current project are to support safe and responsible development in flood-prone areas, and specifically to:

1. Develop official floodplain maps.
2. Establish flood construction levels.

3. Evaluate flood depths under the 200-year return period (0.5% annual exceedance probability or AEP).
4. Assess potential increases to inundation extents and the flood profile associated with future land use and climate change.
5. Review tentative flood mitigation approaches.

Assessment of additional climate scenarios listed in the proposal (2050 moderate and extreme; 2100 extreme) was removed from the scope and replaced with additional model runs and calibration associated with the occurrence of the flood event in November 2021. The climate scenario modelled (2100 moderate) was selected as the most relevant to flood modelling and floodplain mapping for the City's planning objectives.

1.3 Study Limitations

This study is subject to the general limitations outlined below. These should be carefully reviewed prior to use of the information provided:

- The hydrologic and hydraulic models are based on data sets which have inherent uncertainty (lidar, survey, hydrometric measurements, etc.) and are limited by the accuracy of the available data and assumptions implicit in the models.
- The accuracy of the analysis is limited by the resolution of the hydrologic model and the 2D hydraulic models, input data, software, and model capabilities and assumptions.
- Reasonable efforts have been made by NHC to QA/QC the data and model outputs; however, there may be some discrepancies in the data and software used that have not been identified.
- Channel and overbank geometry used in the models is assumed to be fixed, and are based on a snapshot in time corresponding to when the data was collected.
- Potential increases to flood extents due to bank erosion, channel migration, aggradation, degradation, or debris are not included in the analysis, except for limited sensitivity analyses described in Section 4.4.
- Residual risk (i.e. greater than that shown in this report) exists. A more extreme event, or sequence of events (larger recurrence interval, infrastructure damage, etc.) could result in higher flood levels and greater flood inundation than that mapped.
- Under present-day conditions, flooding along Logan Creek upstream of Glover Road is a function of the available storm drainage system capacity to intercept overbank flows, and development of FCLs based on open channel flow (conventional floodplain mapping) is not feasible in this area. Instead, an approach applying a freeboard allowance to downstream road levels or surrounding ground is recommended. Under future conditions, flood extents increase such that FCL contour lines can C be developed (see Section 5.2 for details).
- Future land use assumptions used in the hydrologic model are based on available development plans. Future climate conditions are based on one of a range of plausible future scenarios. Actual future climatic conditions are not known.

This document should be read and understood in its entirety before applying the maps, models, or other findings or results from this study. It is recommended that any site-specific flood assessments be completed by a Qualified Professional, with consideration of the assumptions, uncertainties, and limitations inherent to this type of study.

2 SPATIAL DATA

2.1 Lidar Data

Lidar data used in this study was collected by Airborne Imaging for the City of Langley in December 2020. Data was collected for a 10.3 km^2 area over the City, using a dual scanner with a point density exceeding 20 points / m^2. The lidar vertical data accuracy was reported to be 6.7 cm for non-vegetated areas, and 7.2 cm for vegetated areas at a 95% confidence interval (Airborne Imaging, 2021). The vertical datum of the lidar is CGVD2013.

2.2 Channel Survey

NHC conducted a survey on October 12 to 14, 2021. Due to budget constraints, the survey focused on obtaining channel cross sections and collecting key information at major bridge and culvert crossings on Logan Creek and the Nicomekl River within the City's border.

2.3 GIS Data

GIS data, used to support the project, was downloaded from the City of Langley, City of Surrey, and Township of Langley open data websites in 2021.

2.4 Vertical Datum

The vertical datum used for this project is CGVD2013.

Lidar and channel survey data were collected in CGVD2013 datum. Elevations from the City's survey during the November 2021 floods and available hydrometric stations were converted to CGVD2013 datum. Some culvert invert information was supplemented with the City's online GIS data, but were not converted to CGVD2013; this only applies to five culverts on Logan Creek, and checks made during hydraulic model development show this assumption affects water levels on Logan Creek by less than 1 cm, and so was considered acceptable.

3 HYDROLOGIC ANALYSIS

3.1 Overview

As part of previous work for the City of Surrey's Climate Change Floodplain Review (CCFR), NHC had built, calibrated, and run a hydrologic model of the Nicomekl River watershed using the US EPA's Hydrologic Simulation Program Fortran (HSPF). The work included running a continuous hydrologic simulation for the period from October 1962 to March 2014, allowing flood recurrence intervals to be estimated at multiple locations within the system. Additional simulations representing various land use and climate scenarios were also run, and frequency analysis conducted on the results. Refer to the CCFR Phase 1 and 2 reports for additional detail on the development of the hydrologic model (NHC, 2012, 2015).

To support the current floodplain mapping study, some minor updates were made to the existing HSPF model before it was applied to generate flood frequency quantiles and input hydrographs at 10 locations along Logan Creek, Murray Creek, and the Nicomekl River for input into the hydraulic model. The updates included:

- Subcatchment boundaries and flow reporting locations are shown in Figure 3.1.
- Land use was updated from the CCFR work to better match that used in the Nicomekl River ISMP (KWL, 2017).
- Precipitation inputs from the "TOL Rain" gauge operated by the Township of Langley were extended through the November 2021 flood to allow for validation of the hydrology model and to provide flow inputs for the hydraulic model calibration event. Three rainfall zones were used to scale the input rainfall by factors of 0.9, 1.0, and 1.1, with higher factors applied to areas with higher rainfall, and lower factors in areas of lower rainfall relative to the rain gage. The resulting model performance metrics are summarized in Table 3.1. The model is biased 16% high on flood volume and 7% high on flood peaks. Post-2009 floods were intentionally selected for model validation due to changes in the WSC rating curve that were identified in the CCFR. Further improvement to the hydrologic model could be achieved by refining the scaling factors, but for the purposes of floodplain mapping, the slightly conservative results are considered reasonable.

Table 3.1 HSPF model validation to observed flows at 203 St for four recent large floods

Flood Event	Volume (mm)			1-hour Averaged Peak (m^3/s)		
	Gauged	Simulated	% Difference	Gauged	Simulated	% Difference
January 2013	73	82	11%	46	50	9%
January 2014	59	73	23%	49	54	11%
February 2020	63	73	15%	64	66	3%
November 2020	130	147	13%	76	79	4%
Average			**16%**			**7%**

3.2 Design Flood Flows and Hydrographs

Given the floodplain topography and Nicomekl River channel gradient, the use of steady-state inflows in the hydraulic model would produce unrealistic results. Therefore, we reviewed the output from the HSPF model to identify a representative flood hydrograph shape. The October 2003 flood event was found to have a similar magnitude to the estimated 200-year return period event. By applying small scaling factors to runoff simulated for each of the 10 subcatchment inflows applied to the hydraulic model, the routed flows were adjusted to match the 200-year return period flows in the mainstem (identified through flood frequency analysis of peak annual discharges simulated for the 1962 to 2014 period). The applied scaling factors varied from 0.95 to 1.1.

3.3 Future Land Use and Climate Change

The CCFR Phase 2 study included a model scenario that accounts for anticipated future land use and climate change to the year 2100. As described in the CCFR Phase 2 report, two alternative synthetic time series of hourly precipitation were developed to be consistent with the projections of a particular global climate model (GCM) run. The approach consisted of the following steps (NHC, 2015):

- GCM precipitation projections downscaled by the Pacific Climate Impacts Consortium (PCIC) were obtained and analyzed. Data from twelve GCMs were available from PCIC, nearly all of which project future increases in daily precipitation intensity accompanied by declines in the mean number of precipitation days in a year.
- Two GCM runs were identified that represented, in the context of all the PCIC projections, an ‘extreme’ scenario and a ‘moderately high’ scenario, in terms of flood risk.
- The observed historical time series of hourly precipitation at the Surrey Municipal Hall rain gauge was altered to create two new hourly time series, representative of projected precipitation regimes toward the end of the 21st century, one of which is statistically consistent with the ‘moderately high’ GCM run, and the other representing a ‘severe’ scenario, situated between the ‘moderately high’ and ‘extreme’ GCM runs.

Each future precipitation time series was then created by modifying the historical time series to reduce the number of precipitation days, and then adjusting the daily precipitation totals. Both steps were done to be consistent with the GCM projections. The methodology above results in a 5% reduction of average wet days per year, and a 33% increase to the 200-year return period daily precipitation under the ‘moderate’ scenario (NHC, 2015).

For the current project, the HSPF model results from the ‘moderate’ precipitation increase scenario were used.

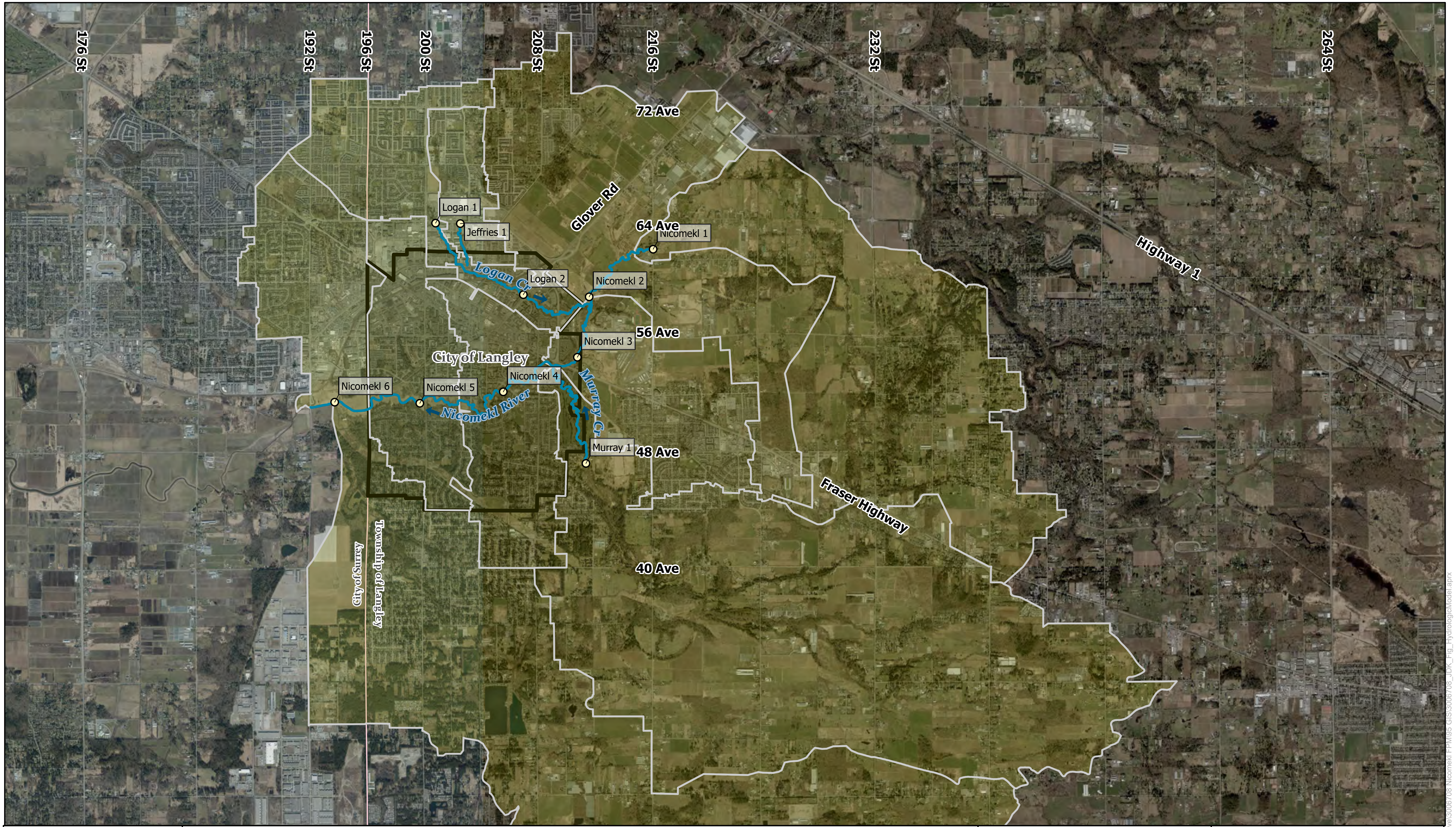
The peak instantaneous 200-year return period (0.5% AEP) estimates for existing (i.e. present day) and future scenarios at each subcatchment location are given in Table 3.2. The October 2003 flood event hydrograph shape was also used for the future scenario, with inflow scaling factors ranging from 1.02 to 1.19 to match the 200-year mainstem flood flows.

Note that the future land use and precipitation translates to a 77% increase in flow, on average. The soils modelled in the calibrated HSPF model are relatively thin, and increasing the rainfall input produces a significant response in runoff. Given uncertainty in climate projections, we anticipate that the adoption of the ‘moderate’ precipitation increase provides a reasonable scenario to support flood assessment and mitigation planning for the City of Langley. It does not reflect an accurate estimate.

Table 3.2 Instantaneous peak 200-year return period flow by location

ID[1]	Location	200-year Return Period Incremental Flow[2] (m^3/s)	
		Existing Conditions	Future Conditions
J1	Jeffries Brook at 64 Ave	3.9	8.1
L1	Logan Creek at 64 Ave	7.5	14.1
L2	Logan Creek at Glover Rd	2.9	4.8
M1	Murray Creek at 46A Ave	41.6	71.1
N1	Nicomekl River at 216 St	23.2	40.2
N2	Nicomekl River upstream of Logan Creek	19.4	33.7
N3	Nicomekl River upstream of Murray Creek	10.3	17.8
N4	Nicomekl River at 51B Ave	9.7	16.0
N5	Nicomekl River at 200 St	9.4	15.8
N6	Nicomekl River at Anderson Creek (west of 196 St)	42.4	82.3

Notes:
1. Refer to Figure 3.1 for catchment boundaries and reference ID locations: N = Nicomekl River; J = Jeffries Brook; L = Logan Creek; M = Murray Creek.
2. “Incremental flow” refers to the peak flow (unrouted) applied to the hydraulic model at each location.



Langley City THE PLACE TO BE

nhc northwest hydraulic consultants

STUDY AREA (CITY OF LANGLEY BORDER)
HYDROLOGIC MODEL BASINS
HYDROGRAPH OUTPUT LOCATIONS
MODELLED REACHES (HYDRAULIC MODEL)

DATA SOURCES: ESRI WORLD IMAGERY; CITY OF LANGLEY; BC FRESHWATER ATLAS

SCALE - 1:50,000
0 2 KM
N

Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES; Vertical Datum: CGVD2013

Job: 3006708 Date: 17-MAY-2022

NICOMEKL RIVER FPM
HYDROLOGIC MODEL OVERVIEW

FIGURE 3.1

4 HYDRAULIC ANALYSIS

4.1 Hydraulic Model Development

The Nicomekl River is a winding channel with low gradient which, during floods conveys significant flows in the overbanks. The City's previous model was a 1D Mike11 model. 1D models have certain limitations, and their usability is generally less preferable for meandering channels, as the predominant flow direction must be estimated by the modeller. They provide a single value of water depth, velocity, and flow rate at a given cross section, and extension of these results over the floodplain is based on topography alone, not hydraulics. In contrast, a two-dimensional model (2D) computes the hydraulics based on the terrain in each model cell. This allows varying depths, velocities, and flow rates to be computed for each cell within the channel and overbank, and provides more realistic hydraulic calculations. This detailed information is vital for the development of floodplain maps and to assess the spatial variation of depths and velocities.

The hydraulic model development included the following steps:

1. Model software selection;
2. Development of a digital elevation model (DEM) to represent channel and overbank geometry;
3. Selection of model domain, including mesh generation, application of inflow hydrographs, and development of downstream boundary conditions;
4. Representation of bridges and culverts in the model; and,
5. Inclusion of any flood bypass systems.

Following the model development, additional tasks included:

1. Model calibration and validation to observed events to assess the performance of the model;
2. Model simulations and review of results;
3. Testing of model sensitivity to input parameters and modelling assumptions;
4. Preparation of model results for floodplain map production; and
5. Assessment of model limitations and uncertainties.

4.1.1 Model Software Selection

NHC developed a hydraulic model of the Nicomekl River, Logan Creek (including Jeffries Brook) and Murray Creek using HEC-RAS 2D (v.6.1). HEC-RAS 2D is a free software developed by the US Army Corps of Engineers (USACE). The software is capable of performing 1D, 2D, or combined 1D-2D hydraulic calculations for channel networks. The model includes well-established routines for bridges, culverts, weirs, and spillways and can simulate both steady and unsteady flow conditions. The most recent releases of HEC-RAS include capabilities for modelling bridges and culverts directly within the 2D model domain, which overcomes previous limitations on its applicability to floodplain mapping where these structures are present.

4.1.2 Digital Elevation Model

A digital elevation model (DEM) was developed for this project to represent the channel and overbank geometry within the study area.

The base DEM was developed by combining the 2021 bare-earth lidar (i.e. vegetation and buildings removed) provided by the City of Langley (Airborne Imaging, 2021), and the 2021 channel survey conducted by NHC. Due to survey budget restrictions, cross sections were collected at major bridges and culverts only, and were interpolated along the remainder of the channel.

Buildings were then added directly to the DEM by extruding the surface based on the City of Langley's GIS layer of building outlines. This allows the model to account for the hydraulic impacts of building obstructions within wetted areas. Refer to Section 2 for additional information on the data sources.

4.1.3 Model Domain and Boundary Conditions

4.1.3.1 Hydraulic Model Domain

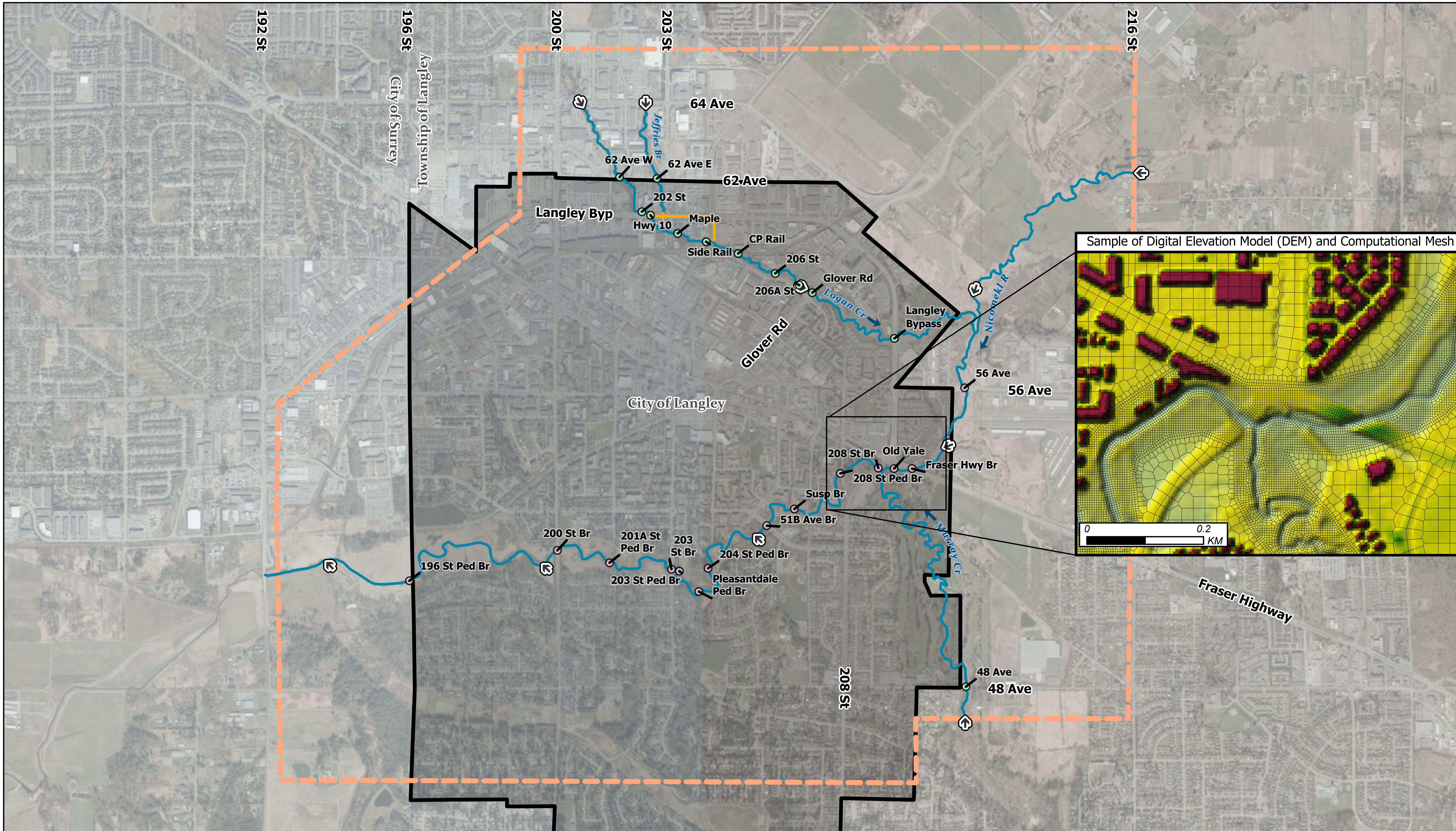
The hydraulic model domain is shown in Figure 4.1. Although the study area is limited to the area within the City of Langley's administrative boundary, the hydraulic model extends upstream and downstream beyond the City's border to limit the influence of boundary condition assumptions on the results.

The modelled reaches are as follows:

- Nicomekl River from 216 Street to 192 Street;
- Jeffries Brook from 64 Ave to its confluence with Logan Creek;
- Logan Creek from 64 Ave to its confluence with the Nicomekl River;
- Murray Creek from 46A Ave to its confluence with the Nicomekl River.

Other smaller creeks, tributaries, and the storm drainage network were not modelled.

The cell size used for the mesh is 4x4 m in the channel and adjacent floodplain, increasing to 20x20 m away from the channel. Local refinements to the mesh were made where necessary to adequately capture the important hydraulic processes. A sample of the model mesh is shown on Figure 4.1.



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STUDY AREA (CITY OF LANGLEY BORDER)
HYDRAULIC MODEL DOMAIN
HYDROGRAPH INPUT LOCATIONS
MODELLED REACHES

MODELLED STRUCTURES
BRIDGE
CULVERT
PIPED FLOOD BYPASS SYSTEM

DATA SOURCES: ESRI WORLD IMAGERY; CITY OF LANGLEY; BC FRESHWATER ATLAS

SCALE - 1:20,000
0 0.5 KM
N

Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES; Vertical Datum: CGVD2013

Job: 3006708 | Date: 16-MAY-2022

NICOMEKL RIVER FPM

HYDRAULIC MODEL DOMAIN

FIGURE 4.1

4.1.3.2 Manning's Roughness

Roughness parameters (Manning's n) were applied to the model based on land use. Initial estimates of roughness were refined based on model calibration and validation. The final Manning's n values used in the model are listed in Table 4.1. Note that the roughness values for the floodplain are higher than those used in previous studies (KWL, 2017; UMA, 2004). However, the roughness values used are within the range of literature values for floodplains with similar characteristics, and produce water levels in good agreement with observed data during the model calibration and validation process. The sensitivity of the profiles to Manning's n variations is described in Section 4.4.

Table 4.1 Final roughness (Manning's n) values by land use

Land cover type	Manning's n
Nicomekl River channel	0.060
Logan Creek, Murray Creek, Jeffries Brook channel	0.060
Residential land use	0.060
Commercial land use	0.060
Grass (maintained)	0.035
Forest	0.150
Heavy floodplain brush	0.130
Wetlands	0.080
Ponds	0.030
Roads	0.020

4.1.3.3 Inflow Boundary Conditions

Inflow hydrographs used in the hydraulic model were generated based on the output from the HSPF model (see Section 3) and applied at 10 locations across the model domain as shown in Figure 4.1.

4.1.3.4 Downstream Boundary Conditions

The downstream extent of the hydraulic model is at 192 Street in the City of Surrey. At this location, water levels are based on the combined effects of rainfall-runoff, ocean levels in Mud Bay, and the operation of the Nicomekl Sea Dam in the City of Surrey. Previous work done for the City of Surrey's CCFR included long-term hydrologic-hydraulic modelling, including ocean modelling, to establish the 200-year return period water levels under existing and future conditions (NHC, 2015). Values from that study at 192 Street were directly applied to the current hydraulic model for the existing and future scenarios (Table 4.2).

Table 4.2 Downstream boundary conditions: 200-year return period water levels at 192 Street

Scenario	Peak water level (El. m, CGVD2013)
Existing conditions	4.18
Future land use and climate change	5.05

Notes:

1. 200-year return period water levels at 192 Street are based on hydraulic modelling done by NHC for the City of Surrey (NHC, 2015)

4.1.4 Bridges and Culverts

A total of 14 bridges and 14 culverts (including the piped flood bypass system at Highway 10 and 203 St) were included in the hydraulic model. A list of the structures is given in Table 4.3, with locations shown in Figure 4.1.

Table 4.3 Modelled bridges and culverts

NHC Survey ID	Watercourse	Crossing
N02	Nicomekl River	196 St Pedestrian Bridge
N03	Nicomekl River	200 St Bridge
N04	Nicomekl River	201A St Pedestrian Bridge
N05	Nicomekl River	203 St Bridge
N06	Nicomekl River	203 St Pedestrian Bridge
N07	Nicomekl River	Pleasantdale Pedestrian Bridge
N08	Nicomekl River	204 St Pedestrian Bridge
N09	Nicomekl River	51B Ave Bridge
N10	Nicomekl River	Suspension Bridge
N11	Nicomekl River	208 St Pedestrian Bridge
N12	Nicomekl River	208 St Bridge
N13	Nicomekl River	Old Yale Bridge
N14	Nicomekl River	Fraser Hwy Bridge
N15	Nicomekl River	56 Ave Bridge
L01[1]	Logan Creek	Langley Bypass Culvert
L02	Logan Creek	Glover Rd Culvert
L03[1]	Logan Creek	206A St Culvert
L04	Logan Creek	206 St Culvert
L05[1]	Logan Creek	CP Rail Culvert

NHC Survey ID	Watercourse	Crossing
L06[2]	Logan Creek	Side Rail Culvert
n/a[2]	Logan Creek	Maple Culvert
L07-1	Logan Creek	Hwy 10 Culvert
L07-2[1]	Logan Creek	Hwy 10 Culvert (Flood Bypass)[5]
n/a[3]	Logan Creek	202 St Culvert
L08	Logan Creek	62 Ave Culvert
n/a[4]	Jeffries Brook	62 Ave Culvert
n/a[4]	Jeffries Brook	Hwy 10 Culvert (Flood Bypass)
M02	Murray Creek	48 Ave Culvert

Notes:
1. City GIS data used to supplement survey information.
2. Not surveyed; dimensions assumed based on upstream and downstream culverts
3. Not surveyed; dimensions approximated based on scaling from photos
4. Not surveyed; City GIS data used
5. Refer to Section 4.1.5 for discussion on the Logan Creek / Jeffries Brook flood bypass system.

4.1.5 Flood Bypass System

A piped flood bypass system was constructed in 2009 to address known flooding issues from Logan Creek and Jeffries Brook (Figure 4.1). Because of its role in flood management, we considered it important to include in the hydraulic model.

Details of the system were derived from the City of Langley's GIS data. The bypass is a 485 m long 1650 mm diameter concrete pipe that runs beneath Highway 10 (Langley Bypass) from Logan Creek at 202 Street, east to 204 Street, and then south along the 204 Street alignment to discharge back into Logan Creek. A portion of Jeffries Brook is diverted into the bypass system at Highway 10.

HEC-RAS has limited capabilities for modelling long pipes and junctions. For this project, we modelled the bypass system in HEC-RAS as a series of culverts, and adjusted the DEM locally at the junction with Jeffries Brook to allow flow to enter and leave the system.

To confirm the applicability of the modelling technique, we developed a small PCSWMM model of the bypass system to compare results. PCSWMM generally does a better job at handling pipe networks and complex junctions. Using the flows from the calibration event (discussed in Section 4.2), we compared the results of the PCSWMM and HEC-RAS models in terms of the proportion of flow through the bypass pipe versus Logan Creek. The PCSWMM model showed 53% of the total flow conveyed through the bypass, whereas the HEC-RAS model showed 48% of the total flow conveyed through the bypass. Based on the results, the methodology used to model the bypass in HEC-RAS produces reasonable results for the purposes of floodplain mapping. If the model were to be used for more detailed hydraulics in the vicinity of the bypass, refinement of the modelling approach would be warranted.

4.2 Model Calibration and Validation

Model calibration is a critical step of hydraulic model development. It involves the gradual refinement of model parameters to ensure simulated water levels match observed water levels for a particular flood event. Once the model has been calibrated, the model is used to simulate a second independent flood event to validate that the calibrated model is suitable for events other than just the calibrated event.

For the Nicomekl River, Logan Creek and Murray Creek, the amount, spatial extent, and accuracy of flow and water level data from past floods somewhat limit the model calibration and validation candidate events. Calibration efforts on the previous Mike11 model used the October 2003 event for calibration, but the model had difficulty matching water levels (UMA, 2004). Part of these discrepancies were attributed to local channel variations, including the presence of beaver dams on the system.

To select an event for model validation, we reviewed data available from the following sources:

- Water Survey of Canada (WSC) station Nicomekl River at 203 Street (WSC ID: 08MH155). This station is actively maintained, and the record includes flow data since 1985 and stage data since 2011
- Stage data from the City of Langley for 62 Ave, Glover Road, and 208 Street from 2008 to present. The data is in a local vertical datum, with no conversion to geodetic available, and therefore could not be used for model validation.
- Stage data from the City of Surrey's FlowWorks system for 192 Street South on the Nicomekl River. The location of this station corresponds to the downstream boundary condition of the hydraulic model, and is used as a model input for the calibration and validation, rather than a check against simulated water levels.

While this study was underway, two large flood events occurred across southwest BC and northwest Washington state (around November 15 and 28, 2021). The November 15 event was greater in magnitude; during that event, City staff were able to survey peak water levels at 9 locations on the Nicomekl River and 1 location on Logan Creek. The City also received several reports of flooding from residents. This event provided the most comprehensive collection of observed data, and so was used for model calibration.

For model validation, the January 11, 2014 flood event was selected. The October 2003 event was considered as an alternative, but was not selected because of missing or erroneous observational data, high likelihood that channel morphology has changed, and because it preceded the flood bypass system on Logan Creek constructed in 2009.

4.2.1 Calibration

Around November 15, 2021, prolonged heavy rainfall from a significant 'atmospheric river' event caused widespread flooding across much of southwestern BC and northwestern Washington State.

Comparing recorded rainfall data with the IDF curve at Surrey Municipal Hall suggests the event was roughly a 2-year return period for rainfall durations from 5-minute to 6-hours; 5-year return period for the 12-hour duration rainfall; and between a 25 and 50-year return period for the 24-hour duration rainfall amount. The Township of Langley Municipal Hall recorded similar rainfall amounts, with less than 2-year return period for the 1-hour duration rainfall; and between a 25 and 50-year return period for the 24-hour duration rainfall amount. The WSC measured a peak discharge of 76.8 m^3/s at the 203 Street hydrometric station on the Nicomekl River (WSC ID 08MH155). This equates to approximately a 5- to 10-year return period in terms of peak instantaneous flow on the Nicomekl River.

To calibrate the Nicomekl River model, recorded rainfall data from the Township of Langley was applied to the existing HSPF model. The resulting runoff time series was then applied to the hydraulic model. A time series of water levels recorded at the City of Surrey 192 Street South hydrometric station was used as the model downstream boundary condition. Iterations were completed, adjusting the roughness (Manning's n) values until suitable agreement between simulated and observed levels was achieved. To limit the risk of underestimating design water levels, roughness values that produced slightly higher maximum water levels than the observed data were preferred.

A comparison of simulated and observed water levels for the event is given in Table 4.4.

Table 4.4 Comparison of simulated and observed water levels for the November 15, 2021 calibration event

Point ID	Location	Water Level (El. m, CGVD2013)		Difference (Simulated – Observed, m)
		Observed[1]	Simulated[2]	
GS0001	20871 Fraser Hwy	7.45	7.66	0.21
GS0002	208 St South of Douglas Cr	7.18	7.28	0.10
GS0003	20600 53A Ave	6.56	6.62	0.06
GS0004	Upstream of 203 St, North Floodplain	5.32	5.49	0.17
GS0005	Downstream of 203 St, South Floodplain	5.02	5.03	0.01
GS0006	201A St, South Floodplain	4.83	4.87	0.04
GS0007	201A St, North Floodplain	4.7	4.83	0.13
GS0008	Brydon Lagoon Path	3.84	3.81	-0.03
GS0009	Brydon Lagoon Path	3.87	3.83	-0.04
GS0010	Logan Creek, 206 St and Duncan Way	9.31	9.36	0.05
WSC0001	WSC Station at 203 St (08MH155)	5.32	5.38	0.06

Notes:
1. Observed values are based on survey by City of Langley staff, converted to CGVD2013 except for WSC0001, taken from preliminary data from WSC station Nicomekl River at 203 St Langley, ID 08MH155.
2. Simulated values are taken from the nearest cell in the 2D model domain and so differ in some locations from the water surface profiles, which are taken at the channel centerline.

Comparisons between the model results and observed data are given in Figure 4.2 through Figure 4.5 on pages 20 to 22. Their agreement is considered sufficiently accurate. No observed data was available for Murray Creek. Figure 4.6 on page 23 shows the locations where observed data for the event was available, and also shows the modelled inundation extents relative to the locations where the City received reports of flooding during the event.

In general, the model produces a good match with observed data from the calibration event:

- Out of the 11 locations where observed data was available, 8 of them had a difference in water level of 10 cm or less, considered an excellent agreement. The largest overprediction was 21 cm (GS0001, near 20871 Fraser Highway), suggesting the model is somewhat conservative in this location but still within acceptable limits. The general area is complex, with the presence of Fraser Highway, Old Yale, and 208 Street bridges, the Murray Creek confluence, and overtopping of the Fraser Highway / Langley Bypass. The largest underprediction was 4 cm (GS0009, near Brydon Lagoon).
- The modelled inundation extents match very well with the surveyed high water marks, and with most of the flood reports received from residents. We attempted to filter out flood reports that were obviously due to backed up storm systems, and not from river / creek flooding; however, some of the reported flooding may be influenced by backed up or clogged storm systems, which are not modelled.
- One location that received multiple reports of flooding calls from residents was at 53A Ave and 205 Street (highlighted area downstream of GS0003 on Figure 4.6). The model shows some flooding of the road, but does not reflect the number of calls the City received. The location is just upstream of the 51B Ave bridge, near the junction between two storm drainage systems that may have been backed up by the Nicomekl River. It should be emphasized that the model cannot simulate debris blockages or storm system backup / overflow unless specifically programmed in the model.
- As noted in Section 4.1.3.2, the final roughness values from the calibration process are higher than estimated in previous reports, but remain within the range of literature values for similar channels / floodplains, and are well supported by the observed data.
- The water surface profiles show realistic head losses across the bridges and culverts:
  - The water level difference between GS0004 and GS0005 was measured as 30 cm, whereas the model shows a difference of 47 cm. Note that these points were taken on opposite sides of the floodplain, and not in the main channel.
  - The water level difference between GS0006 and GS0007 was measured as 13 cm, whereas the model shows a difference of only 4 cm. Note that these points were also taken on opposite sides of the floodplain, and not in the main channel.
  - Photos of the 203 Street pedestrian bridge show it submerged, with no visible head loss across it. Similarly, the model does not show a notable water level difference across it during the event peak.

- Data gaps on Logan and Murray Creek mean there is a higher degree of uncertainty in the model's capabilities on those tributaries. In particular, Logan Creek has several culvert crossings, some of which have multiple culverts, as well as the flood bypass system, which complicates the hydraulics; only one data point is available for comparison. However, very few reports of flooding were received for Logan Creek and none for Murray Creek during the November 15, 2021 event; similarly, photos of Logan Creek at 62 Ave show it contained within the channel, and so the model results seem reasonable.

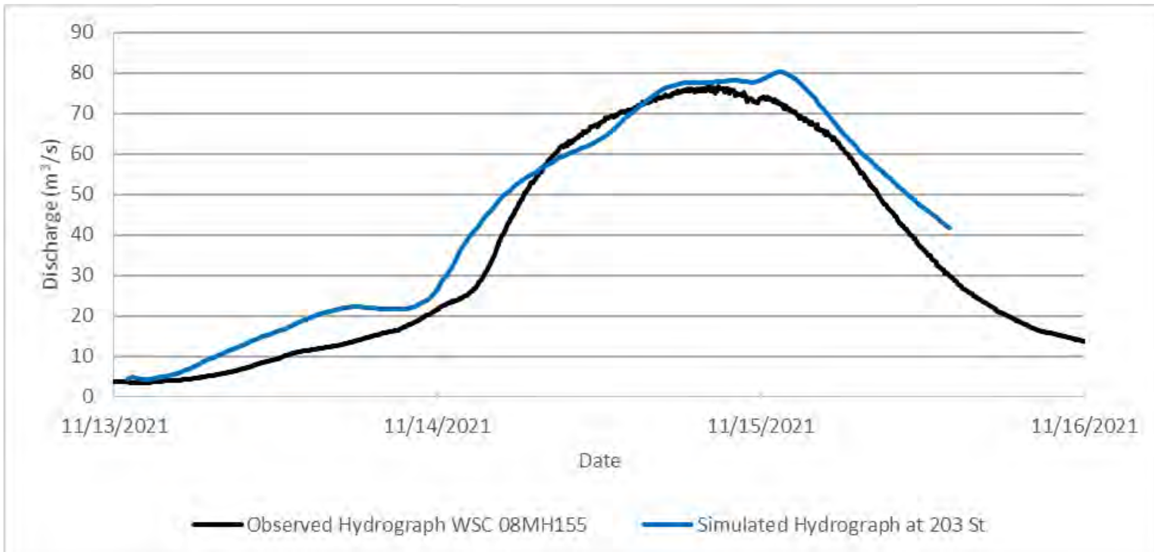


Figure 4.2 Simulated and observed discharge time series at 203 Street for the November 15, 2021 calibration event

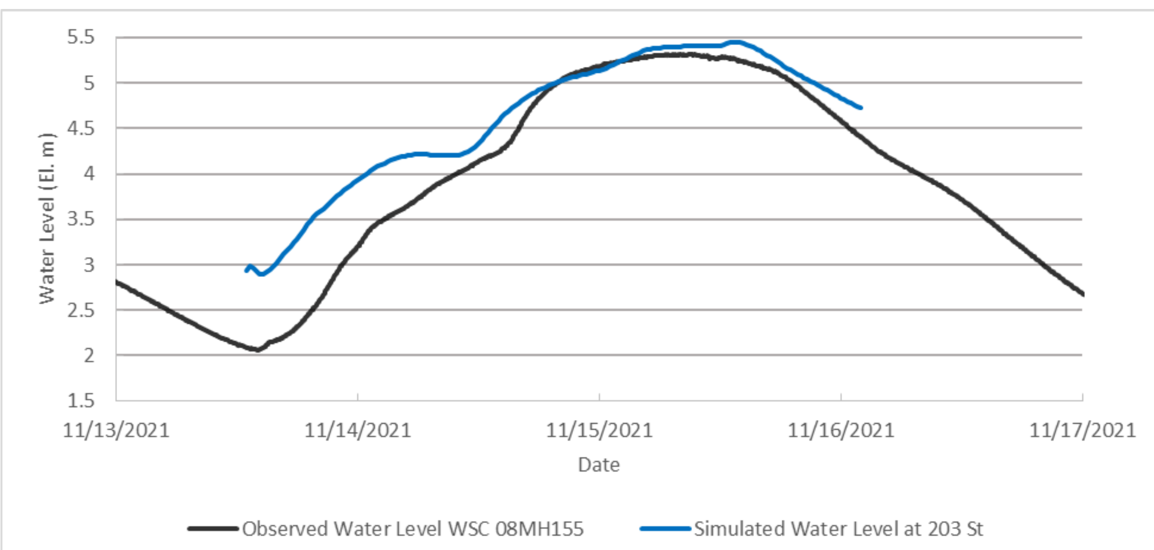


Figure 4.3 Simulated and observed stage time series at 203 Street for the November 15, 2021 calibration event

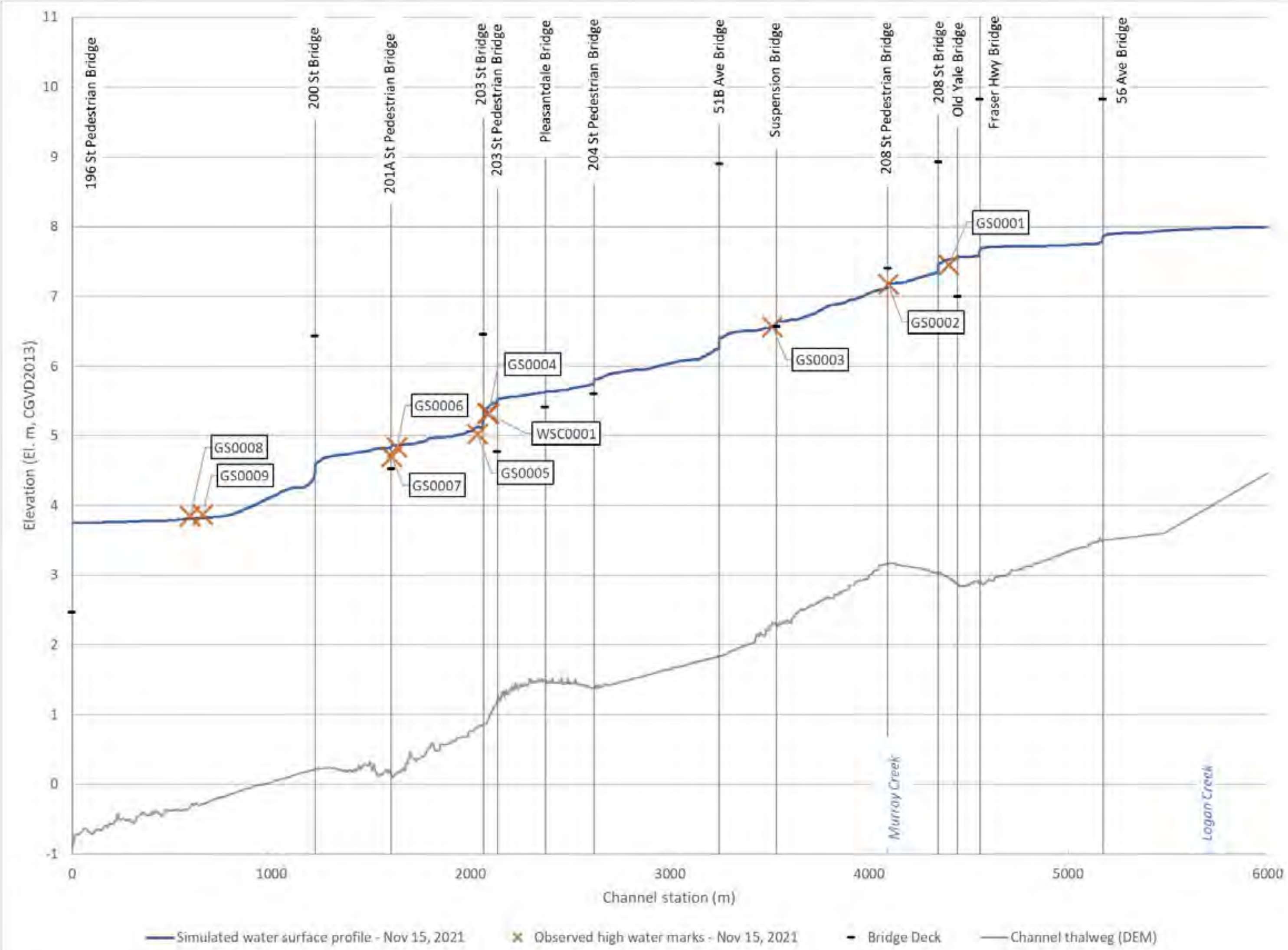


Figure 4.4 Simulated and observed water levels from the November 15, 2021 calibration event, Nicomekl River

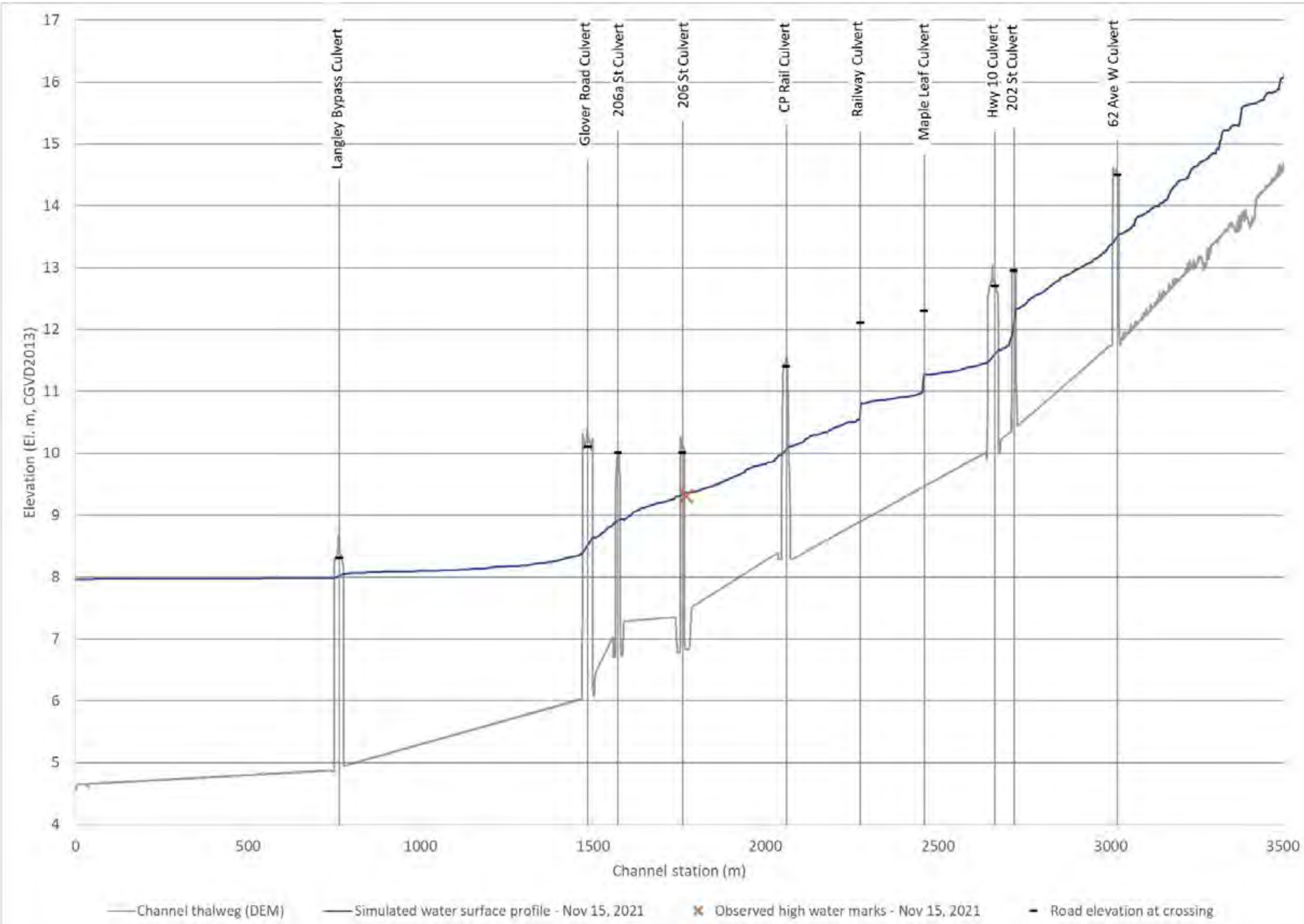
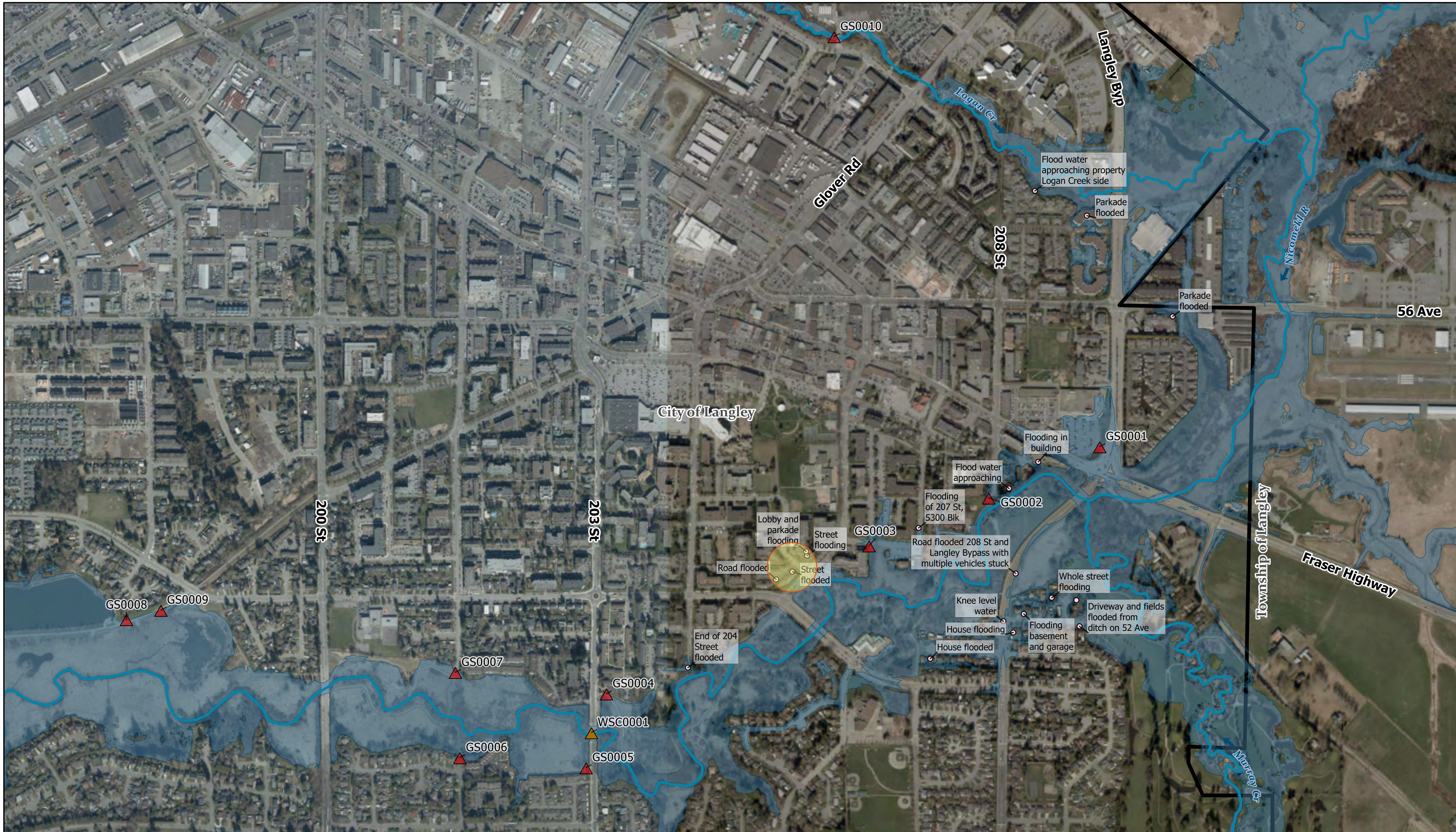


Figure 4.5 Simulated and observed water levels from the November 15, 2021 calibration event, Logan Creek



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STUDY AREA (CITY OF LANGLEY BORDER)
MODELLED REACHES
NOV 15, 2021 REPORTS OF FLOODING
SIMULATED INUNDATION, NOV 15, 2021 CALIBRATION EVENT

OBSERVED DATA

CITY OF LANGLEY SURVEYED HIGH WATER MARKS
WATER SURVEY OF CANADA HYDROMETRIC STATION

DATA SOURCES: ESRI WORLD IMAGERY; CITY OF LANGLEY; BC FRESHWATER ATLAS

SCALE - 1:8,500
0 0.25 KM
N

Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES; Vertical Datum: CGVD2013

Job: 3006708 Date: 17-MAY-2022

NICOMEKL RIVER FPM
MODEL CALIBRATION QUALITATIVE FLOOD REPORT COMPARISON

FIGURE 4.6

4.2.2 Validation

The January 11, 2014 event was selected for model validation. The event has the highest recorded peak at the 203 Street WSC station in the last 10 years with the exception of the November 2021 events. The peak flow recorded was 52.5 m^3/s, which is approximately a 2-year return period.

Flow hydrographs for the event were taken from the existing HSPF model and applied to the hydraulic model. The downstream water level time series was taken from hydraulic model simulations completed as part of the CCFR (NHC, 2015).

A comparison of the modelled water level and discharge time series near 203 St with that recorded at the WSC station (08MH155) is shown in Figure 4.7. Observed data from other City of Langley hydrometric stations (62 Ave, Glover Rd, Langley Bypass and 208 St) was reviewed, but each were in local datum with no conversion to geodetic available and so could not be used.

Limited data was available for model validation, but the model simulated a maximum water level 5 cm higher than the observed data, which is similar in magnitude to the findings from the calibration event. The shape of the hydrograph rise and peak is reasonably close the observed data, however, the recession limb remains elevated for a longer period of time than the observed data suggests.

Based on the model calibration and validation, the hydraulic model is expected to produce reasonable results for the purposes of floodplain mapping. If the model is to be used for other applications where the shape of the hydrograph, or detailed hydraulics around structures (culverts and bridges) is required, the model should be revisited and verified for those applications.

During future large floods, exceeding about the 15-20 year return period, additional high water marks should be collected on the Nicomekl River including on Logan Creek, to facilitate better model validation in the future. It is also recommended that the City’s water level gauge levels be surveyed to CGVD2013 datum and that rating curves be developed for these.

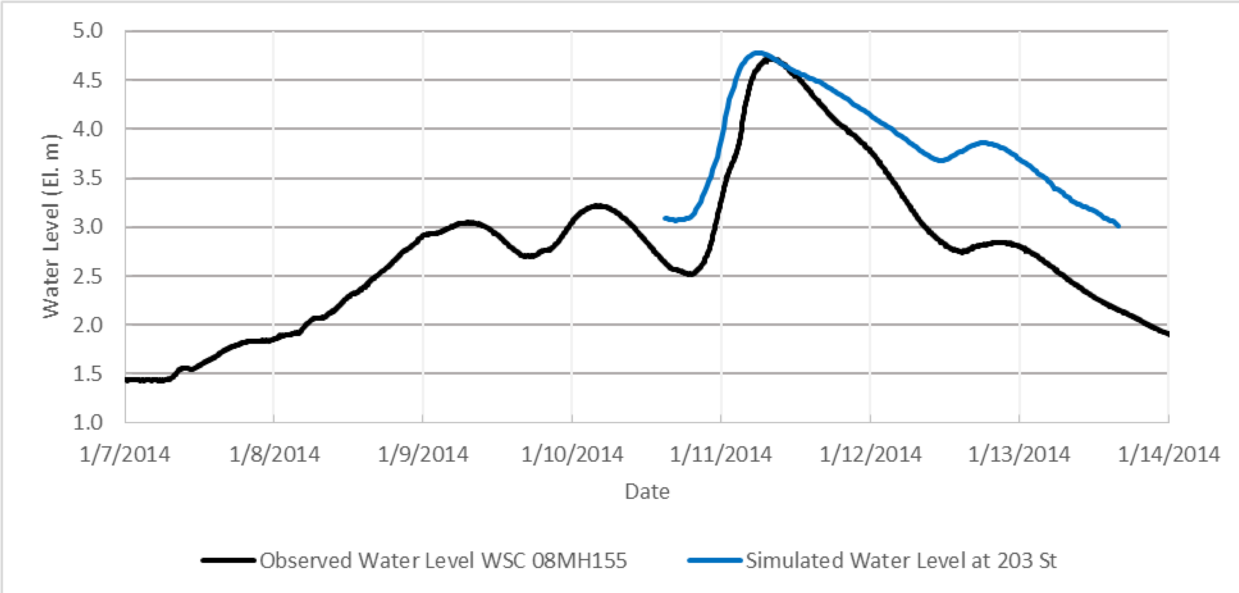

Figure 4.7 Simulated and observed stage time series at 203 Street for the January 11, 2014 validation event

4.3 Model Simulations and Results

4.3.1 Base Scenario Simulations

The base scenarios that were modelled for this project were the 200-year return period event under present-day conditions (200-year 'existing') and the 200-year return period event under future land use and climate change (200-year 'future').

The 200-year 'existing' scenario forms the basis of the floodplain maps, while the 200-year 'future' scenario was used to assess the change to the flood profile and inundation extents under one possible land use and climate change scenario reflecting the year 2100.

Refer to Section 3.2 and 3.3 for detail on the hydrologic inputs, and Section 4.1.3 for the water levels applied to the downstream boundary for each scenario.

The water surface profiles for the Nicomekl River, Logan Creek, and Murray Creek for the 200-year return period existing and future scenarios are shown in Figure 4.8 to Figure 4.10.

4.3.2 Comparison of Existing and Future Water Surface Profiles

Figure 4.11 summarizes the differences in maximum water level between the 200-year return period existing and future scenarios on the Nicomekl River, Logan Creek, and Murray Creek. Under future land use and climate change, the highest increases to maximum water levels tend to be due to downstream boundary conditions (influenced by sea level rise), and local influences of bridges and culverts which do not have the hydraulic capacity to handle the increased flows. In particular, increases to the maximum water level along each profile are as follows:

- On the Nicomekl River, the median increase is 0.50 m; however, the increases are not uniformly distributed: upstream of 208 Street, water level increases are 0.40 m or less, while increases are up to 0.93 m downstream of 208 Street.
- On Logan Creek, the median increase is 0.38 m, but is strongly influenced locally by culvert crossings, which cause a maximum increase of 1.08 m.
- On Murray Creek, the median increase is 0.24 m, but is strongly influenced by the 48 Ave culvert, which causes a maximum increase of 1.06 m.

These results provide a general understanding of the increases to maximum water levels that may be expected under future land use and climate change.

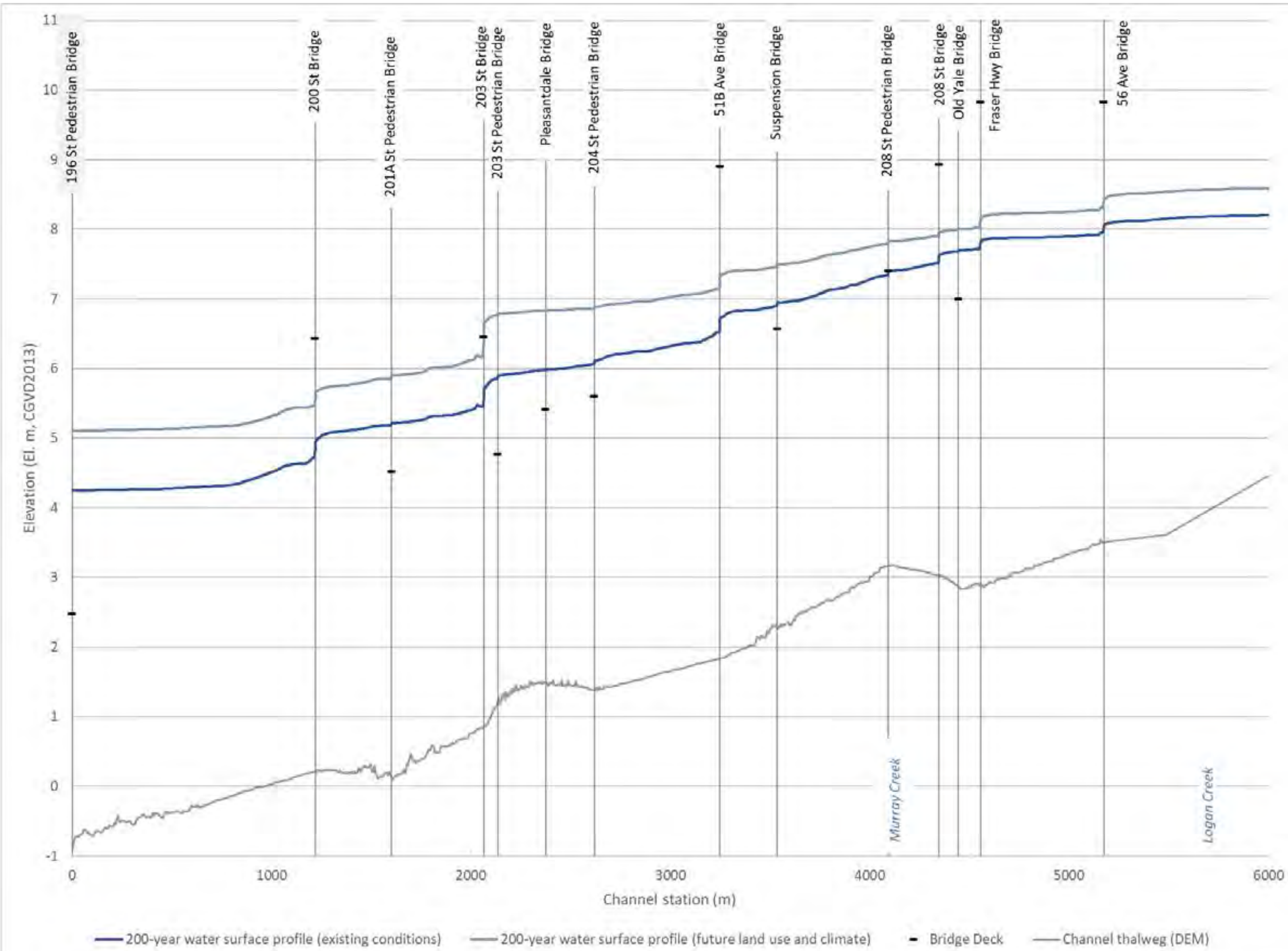

Figure 4.8 Nicomekl River flood profile: 200-year return period, existing and future conditions

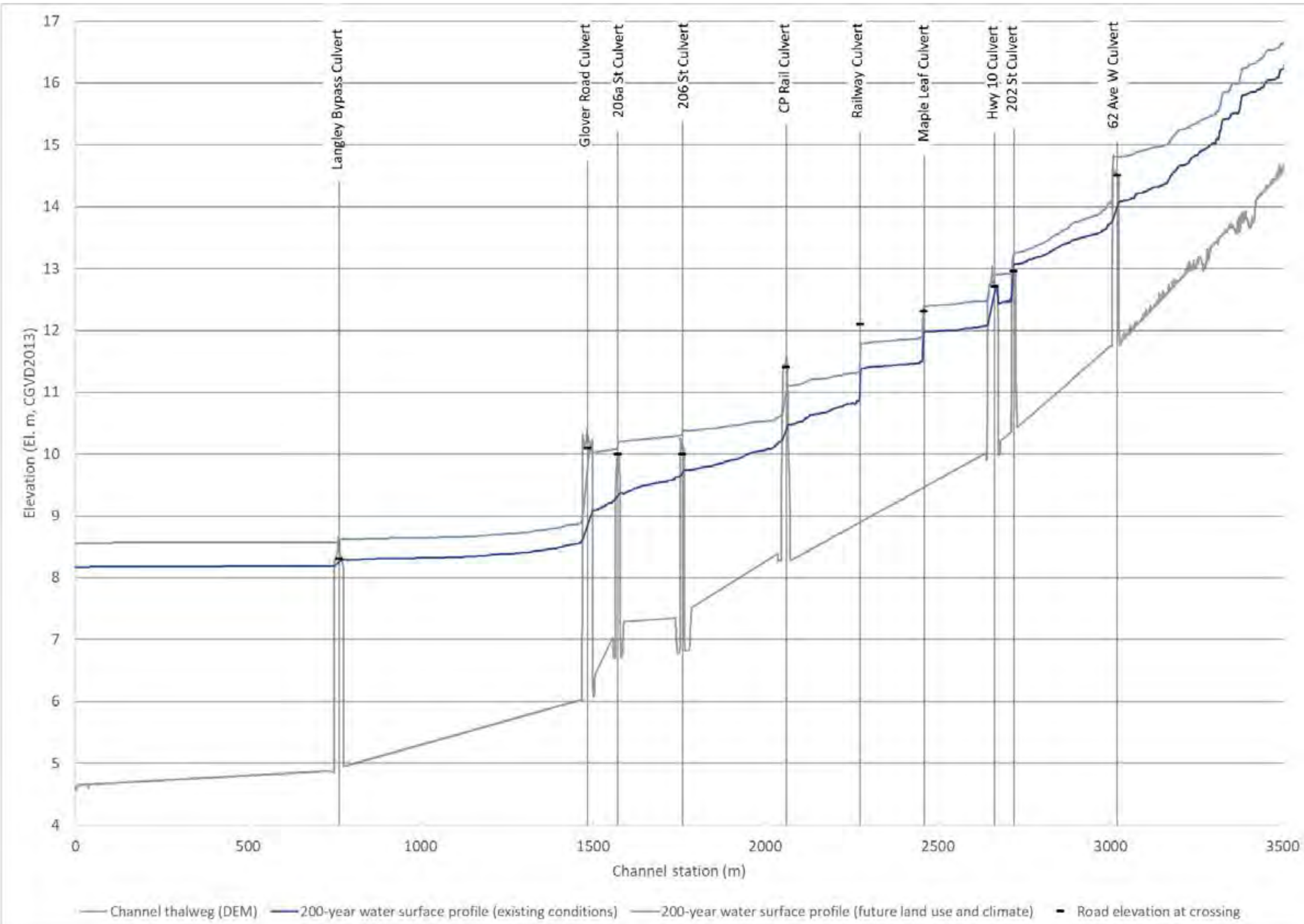

Figure 4.9 Logan Creek flood profile: 200-year return period, existing and future conditions

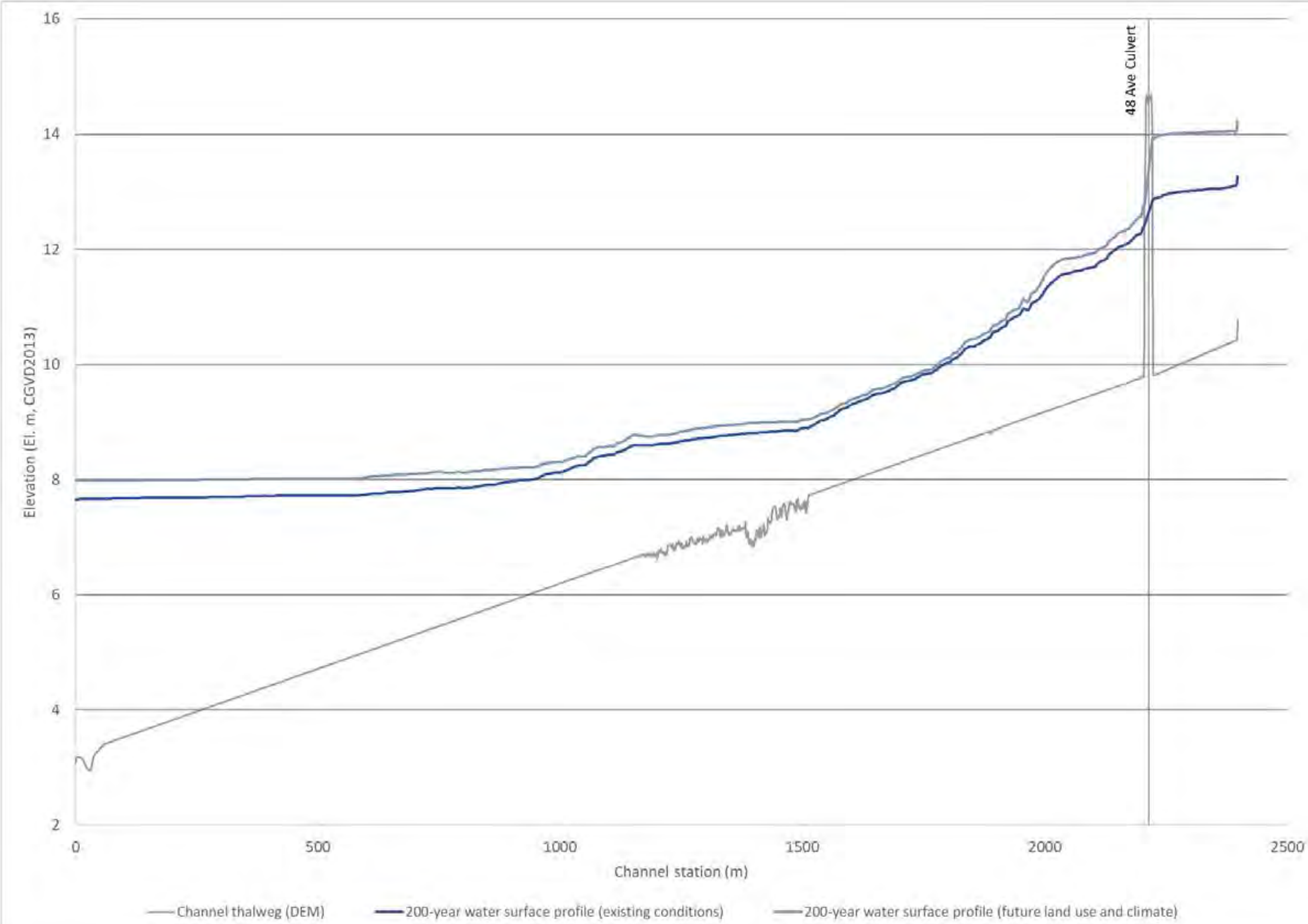

Figure 4.10 Murray Creek flood profile: 200-year return period, existing and future conditions

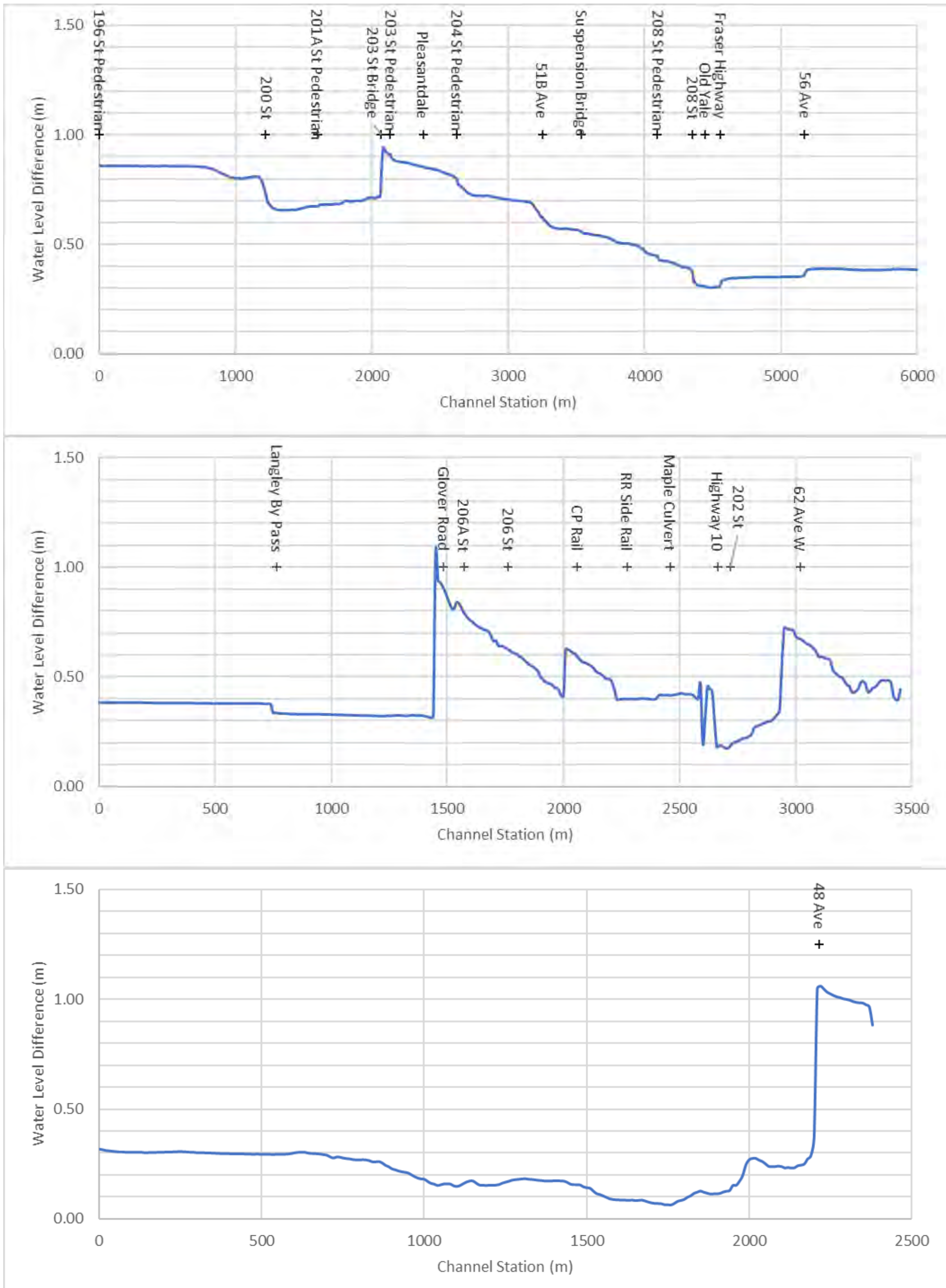

Figure 4.11 Differences in maximum water level between the 200-year return period 'existing' and 'future' conditions for Nicomekl River (top), Logan Creek (middle), and Murray Creek (bottom)

4.4 Sensitivity Testing

4.4.1 Sensitivity Runs

The results of the hydraulic model are influenced by the availability and quality of input data, the model software, and assumptions made during the model development process.

The sensitivity of the model results was assessed by adjusting the model parameters and comparing the results. The following modifications were made, using the 200-year existing scenario as the baseline for comparison:

1. 20% increase in Manning's n
2. 20% decrease in Manning's n
3. 1 m increase in the downstream boundary water level at 192 Street
4. 1 m decrease in the downstream boundary water level at 192 Street
5. Reduction of the hydraulic opening of the 203 Street bridge to represent a blockage caused by floating woody debris during a flood. This was done by lowering the bridge soffit by 1 m.
6. 1 m increase in the channel bed elevation in the vicinity of the 203 Street bridge to represent accumulation of sediment that reduces the channel capacity.

4.4.2 Sensitivity Results

The water surface profiles for each of the sensitivity runs are given in Figure 4.12 through Figure 4.14. Sensitivity testing was done relative to the 200-year existing scenario; the 200-year future profile is included on the figures as a reference.

Key findings from the sensitivity testing are summarized below:

- The variation in roughness (Manning's n) causes the water surface profile to vary by +/- 0.08 m, on average, with maximum variations of +0.14 m and -0.17, occurring on the Nicomekl River near the 51B Ave bridge. A summary of the average and maximum water level variations is given in Table 4.5.
- The effect of changing the downstream boundary water level extends upstream to the 208 Street bridge. This finding is roughly in line with sensitivity testing conducted in the City's recent ISMP, which found that a boundary water level of 5.5 m at the border influenced the profile as far as the Fraser Highway Bridge (KWL, 2017).
- Lowering the 203 Street bridge soffit by 1 m to represent a blockage caused by floating debris causes a local increase in water levels of up to 0.37 m immediately upstream of the bridge. The backwater effect from this scenario extends 1.5 km upstream of the 203 Street bridge, to approximately the Nicomekl River suspension bridge upstream of 51B Ave. Similar impacts may be expected at other crossings if debris build-up during a flood reduces the hydraulic opening.

- Raising the channel bed elevation by 1 m to represent sediment accumulation near the 203 Street bridge results in a local increase in water levels for approximately 600 m upstream of the bridge, to the 204 Street pedestrian bridge. The maximum water level increase is 0.16 m. This increase is less severe than the floating debris scenario, likely due to the relatively small size of the channel to the overall floodplain. For Logan Creek, for example, the impacts of sediment accumulation in the channel may lead to considerably greater impacts to water levels.
- Overall, none of the sensitivity testing scenarios produce water surface profiles approaching those of the 200-year return period scenario where future climate change and land use is considered. This suggests that the sensitivity to flow is greater than roughness, downstream water level, and channel blockages, and underscores the potential impact on flood risk in the Nicomekl River and its tributaries due to climate change. Refer to Section 4.5.2 for additional discussion on uncertainties related to the climate allowances.

Table 4.5 Sensitivity of water surface profiles to changes in roughness (Manning's n)

	Average Water Level Difference (m)		Maximum Water Level Difference (m)	
	20% Rougher	20% Smoother	20% Rougher	20% Smoother
Nicomekl River	0.08	-0.09	0.14	-0.17
Logan Creek	0.07	-0.07	0.10	-0.11
Murray Creek	0.05	-0.05	0.10	-0.10

Notes:
1. Water level differences are given relative to the 200-year return period existing conditions scenario.

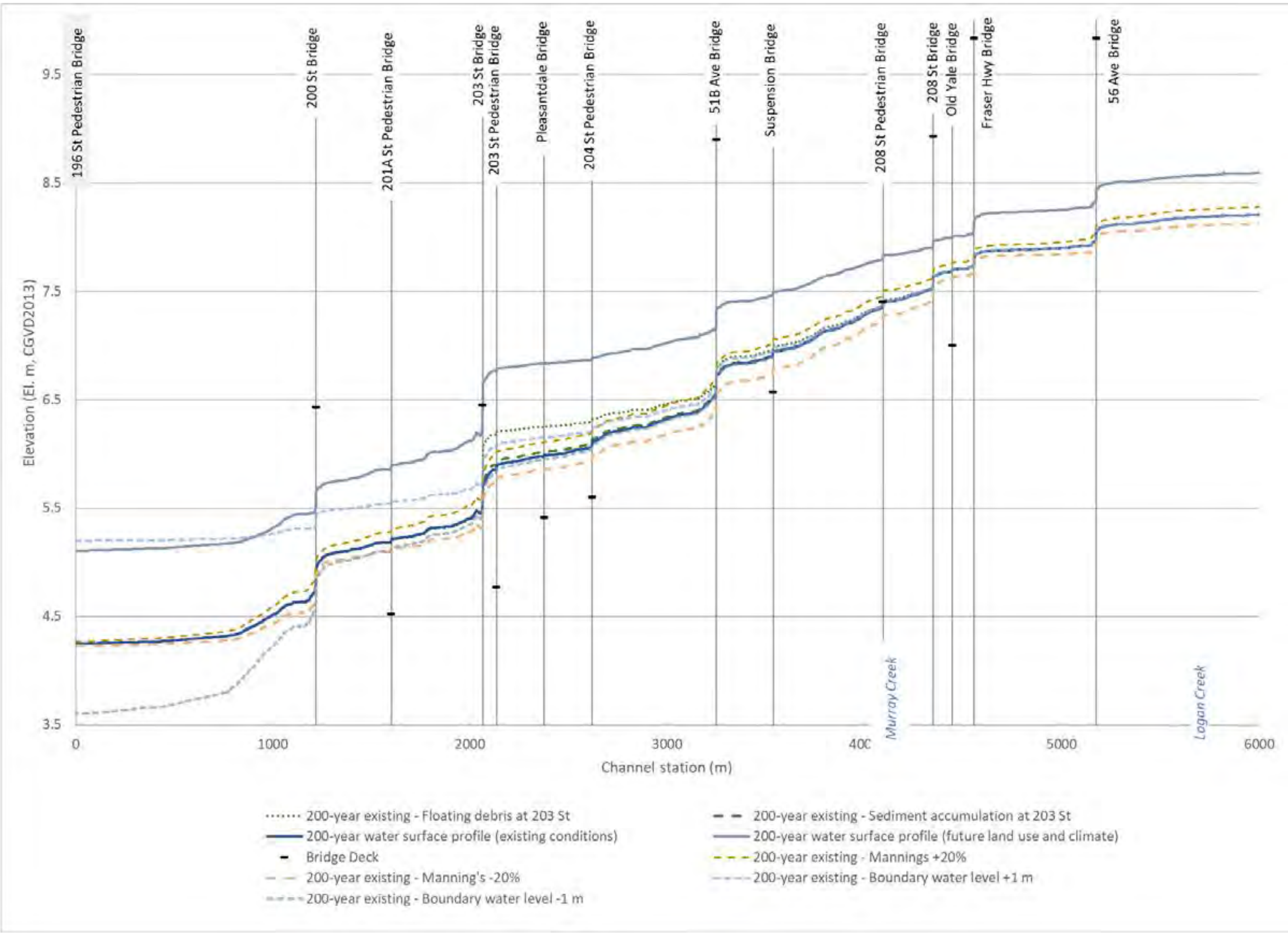

Figure 4.12 Model sensitivity – Nicomekl River water surface profile

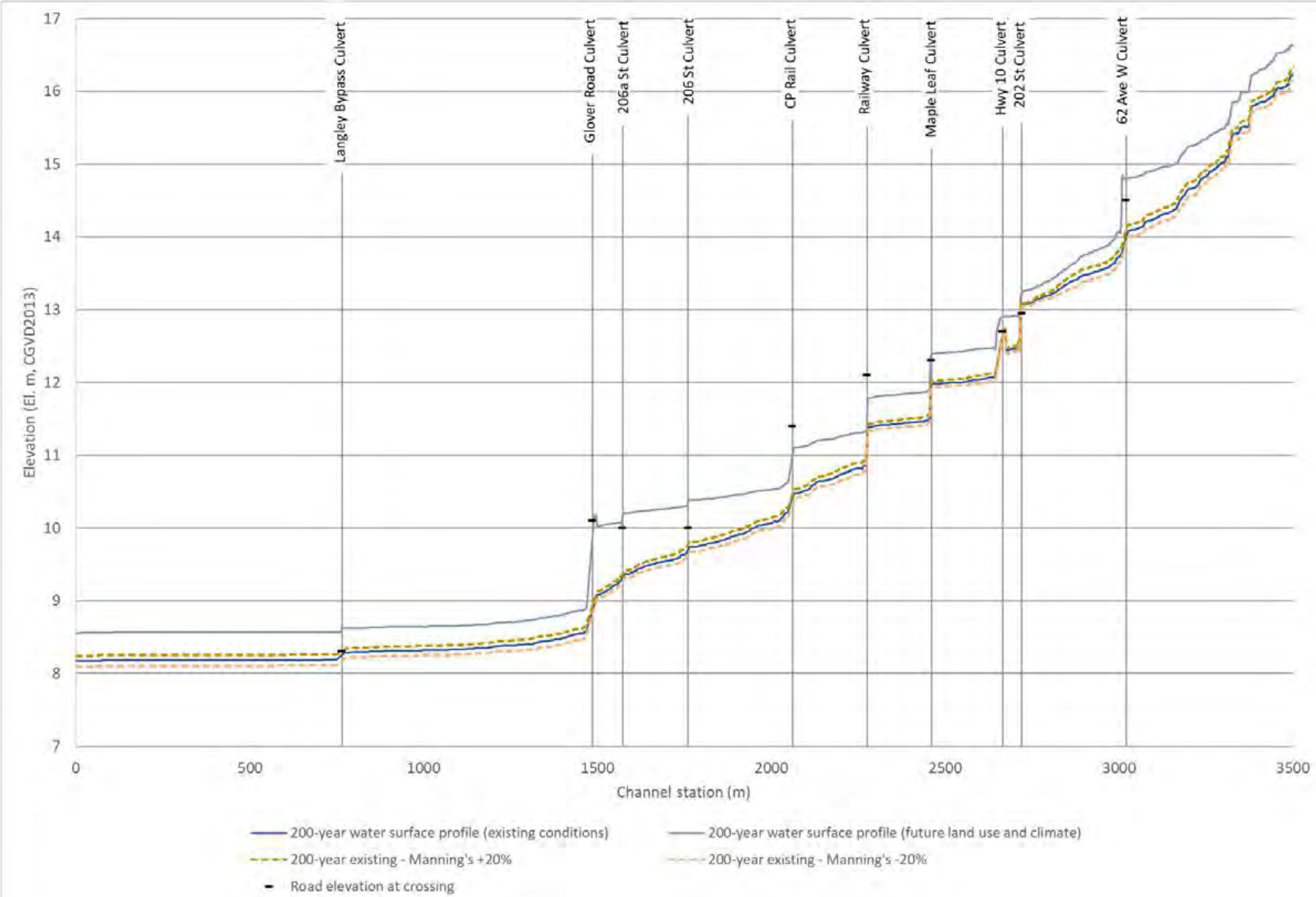

Figure 4.13 Model sensitivity – Logan Creek water surface profile

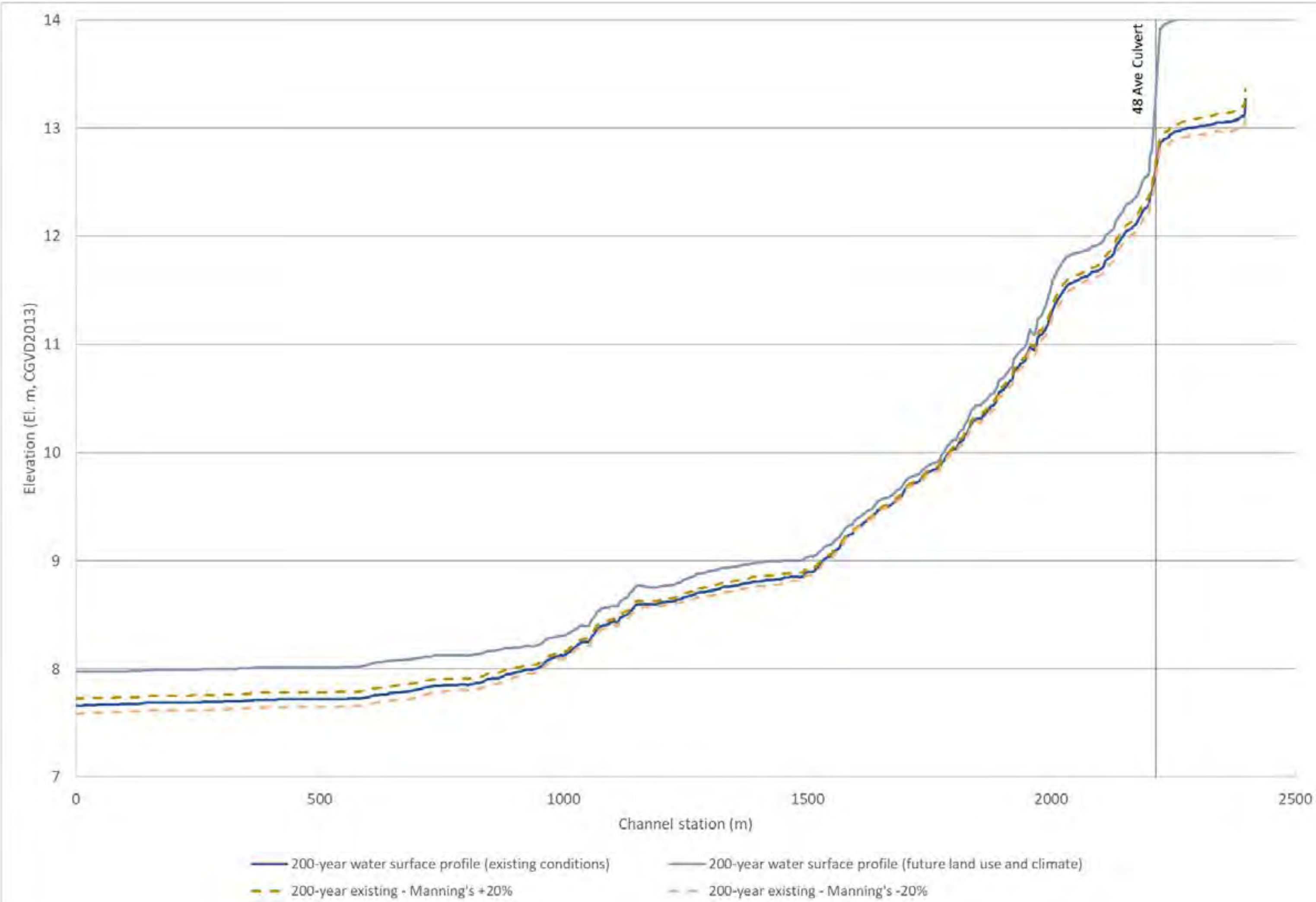

Figure 4.14 Model sensitivity – Murray Creek water surface profile

4.5 Model Limitations / Uncertainties and Geomorphic Changes

4.5.1 Model Limitations / Uncertainties

The HEC-RAS 2D model developed for the Nicomekl River floodplain mapping is useful to help understand flood hazards and inform flood management. However, as with any model, certain limitations and uncertainties exist that should be understood when reviewing and applying the results.

- Although the lidar used to develop the DEM was specified to contain bare-earth data, some artifacts and interpolation errors can be expected, especially in areas where the vegetation is dense. This can create some unrealistic 'dry spots' for some floodplain areas. Channel geometry is based on limited survey, interpolated between structures. Local variations in the channel bathymetry, including bars, are not captured.
- The floodplain includes several side channels and off-channel ponds, including Brydon Lagoon. Bathymetry of these features was not available, and the DEM represents the water surface at the time the lidar data was collected.
- Buildings were added to the DEM by extruding them from the lidar surface locally, based on the City's building outlines GIS layer.
- The 2D model was developed to simulate regional flooding, and therefore does not include local details such as drainage culverts, ditches, curbs, road barriers, guard rails that may influence flood extents and depths. Similarly, the model represents clear water flow conditions, without sediment or debris.
- Other than the Logan Creek and Murray Creek, tributaries were not modelled. Flows from the tributaries, predicted by the hydrologic model were introduced at point locations along the main channels. It is recommended that tributaries be surveyed and included in the model.
- The storm drainage system was not modelled. River overflows in certain areas (e.g. Logan Creek) may be partially captured by the City's storm system and conveyed below ground back to the primary watercourses; conversely, backwater effects from the primary watercourses may cause the storm systems to surcharge.
- Future land subsidence or uplift has not been included in the results.

4.5.2 Uncertainty in Future Precipitation Projections

The hydrologic and hydrologic modelling conducted for this study includes an assessment of potential future land use and climate change, as described in Section 3.3. As described in NHC's previous work for the City of Surrey (NHC, 2015), while there is a need to provide quantitative information for flood risk management planning, the underlying projections of climate change are subject to large and unquantifiable uncertainty (see e.g. Kundewicz and Stakhiv, 2013).

The main sources of uncertainty are unknown greenhouse gas emissions, unknown response of the global climate to increases in the emissions, and how these global changes will vary regionally. Additional uncertainties include downscaling of climate variables from the global climate models (GCMs) to local scales, validity of frequency analyses in non-stationary climate, and disaggregation from future daily precipitation to hourly scales.

For this project, a single scenario representing a 'moderate' precipitation increase was used. The results should therefore be considered as an indication of one potential future climate scenario, based on currently available scientific information, intended to inform planning-level decisions within the City of Langley. The actual change in precipitation and flow regimes on the Nicomekl River, Logan Creek, and Murray Creek will differ from the scenario used for this study, and may be greater or less than the differences projected in this work. Periodic reassessment of local climate projections and their potential influence on future flood levels should be undertaken in the coming decades based on new and emerging scientific information, with comparison to historical precipitation and flows.

4.5.3 Geomorphic Changes

The hydraulic model DEM represents the channel and floodplain geometry at the time of lidar capture and ground surveys. The configuration of the channel may change as a result of long-term aggradation / degradation, gradual horizontal changes in river meander configurations or more sudden alterations caused by the localized collapse of river banks due to erosion or sudden cut-offs / avulsions. Floodplain changes are generally human-made, stemming from the construction of roads, bridge abutments and new development.

A rough comparison with historic maps (Watt, 2017) dating back to the 1870's shows that the Nicomekl River general configuration within the City has remained relatively unchanged. However, after about 1954, there was a notable change in floodplain land use from mainly agricultural to industrial / commercial along Logan Creek and residential densification along the Nicomekl (UMA, 2004).

The Nicomekl River banks are unstable in a number of locations and erosion protection has been placed in areas where development could be affected. In the undeveloped floodplain, the river banks have slumped, causing a gradual build-up of the channel bed. Other sources of material are the tributary creeks, particularly those that run through steep ravines. Over time, it is anticipated that material depositions will raise the design flood profile.

The end-of-century design profile, estimated based on future climate and land use conditions, is not representative of future channel conditions. As flood flows gradually increase, they will reshape the channel resulting in potentially quite different flood water levels. Updating of the floodplain maps should be undertaken at least every 15 years or so.

5 FLOOD MAPPING

5.1 Flood Depth Maps

Maps showing predicted flood depths under the 200-year return period event for present-day conditions are included in Appendix A. These maps are based on the hydraulic model results, and do not include freeboard. Additional inundation extents from the 200-year return period event under future land use and climate change are also shown on the maps for reference.

Note that the results of the model for Logan Creek upstream of Glover Rd are distinct from those downstream of Glover Rd, including the Nicomekl River and Murray Creek. Upstream of Glover Road, 200-year return period flows under present-day conditions are mostly contained within the channel banks; however, if the capacity of any culvert is exceeded, large areas adjacent to Logan Creek become exposed to flooding.

As shown on the maps, these capacity exceedances may arise due to climate change, but they may also occur because of channel or culvert obstructions. In these instances, flood levels and extents will depend on the elevation and grade of the roads, and the ability of the storm drainage network (piped or overland) to intercept these flows.

5.2 Designated Floodplain Maps

5.2.1 Flood Construction Levels

Two sets of floodplain maps for the Nicomekl River, Logan Creek, and Murray Creek are included in Appendix B:

1. Figure B.1 shows the 200-year return period event under existing (present-day) conditions;
2. Figure B.2 shows the 200-year return period event under future (end-of-century) climate conditions, as described in Section 3.3.

The floodplain maps include a standard freeboard of 0.6 m, and show flood construction level (FCL) contour lines for each scenario. Except where noted below on Logan Creek under existing conditions, the existing 'Application Zone for Flood Construction Level' may be replaced with the extents of the floodplain shown on the maps.

Notable features of the floodplain maps are described below.

5.2.2 Logan Creek

5.2.2.1 Logan Creek - Existing Conditions

Under existing conditions (Figure B.1), conventional floodplain mapping is not applicable to Logan Creek upstream of Glover Road. This is because flood levels and extents in this area are governed by road elevations and the capacity of the storm drainage system, as described in Section 5.1. In the likely event that the culverts on Logan Creek become blocked, flood levels due to local ponding would exceed FCLs set based on creek levels / hydraulic modelling. Because of the nature of the flood exposure, typical FCL isolines cannot be drawn for this area. We recommend instead the City retains the existing 'Application Zone for Flood Construction Level' from the 2007 Designated Floodplain Map, and set FCLs for all new buildings within this zone to the higher of the following:

- 0.6 m above the crest of the downstream road / rail embankment that could cause ponding (see for current elevations); or
- At least 0.3 m above adjacent roads and grades surrounding the building.

The existing road / rail elevations and the corresponding minimum proposed FCLs are shown on Figure B.1. At each location, the road / rail grades at the creek crossings were checked against the results from the hydraulic model, and are confirmed to be the governing flood levels under present-day conditions.

5.2.2.2 Logan Creek - Future Conditions

Under future conditions (Figure B.2), the increase in flows associated with climate change exceed the capacity of the Logan Creek channel and contribute to widespread flooding upstream of Glover Rd. The limit of floodplain mapping south of the channel was set at Logan Ave.

5.2.3 Tributaries

Flooding along small tributaries (Baldi Creek, Brydon Creek, Pleasantdale Creek, Muckle Creek and Langley Creek) has not been modelled. Each tributary is quite small, and act more as extensions of the storm drainage network than as channels with floodplains.

For development outside of the Nicomekl River floodplain, but adjacent to tributaries, we recommend that the Provincial Flood Hazard Area Land Use Management Guidelines (MFLNRORD, 2018) be applied.

In our opinion, Baldi, Brydon, Pleasantdale, Muckle, and Langley Creeks may be classified as *'smaller streams'* per the guidelines. Under this designation, the FCL is 1.5 m above the natural boundary of the watercourse. Refer to the guidelines for definition of the natural boundary. For channel setback requirements, also refer to the guidelines.

The land use guidelines do not presently incorporate climate change allowances. As peak flows increase it would be prudent to increase both the distance above the natural boundary of the watercourse and the recommended set-back by a minimum of 20%.

5.2.4 Climate Change

The future climate scenario is based on a single, preliminary assessment of changes to flows based on a 'moderate' end-of-century precipitation increase described in Section 4.3.2. These flows are routed through the existing Nicomekl River system, including the existing bridge and culvert infrastructure. Changes to the river and creek crossings between now and the end-of-century will affect the flood extents and FCLs. Further, as noted in Section 4.5.3, consistently higher flows associated with climate change may reshape the channel, and result in flood profiles different from those shown.

Updating the floodplain maps at least every 15 years is necessary to capture infrastructure and morphology changes, and projected impacts of climate change.

5.3 Comparison to Previous Floodplain Mapping

Appendix C compares the updated floodplain map extents with the previous floodplain mapping for both existing and future conditions. The previous FCLs were extracted from Schedule A of the City's floodplain bylaw (Urban Systems, 2007), and converted to CGVD2013 to match the vertical datum of the current project.

For the most part, the differences between the previous and updated FCLs for existing conditions are relatively small and vary irregularly. In the Nicomekl reach, roughly between the Murray Creek and Logan Creek confluences, the updated FCLs (without a climate allowance) are lower. The differences are not surprising considering the variations in topographic data and modelling approach. The updated inundation extents are wider as they are based on more detailed topography derived from lidar.

FCLs under the future conditions model are in general considerably higher than the previous FCLs from 2007, due to the inclusion of climate change, but the differences vary between a 37 cm decrease to a 95 cm increase.

6 TENTATIVE FLOOD MITIGATION

The City of Langley previously conducted a study on flood risk management strategies (Urban Systems, 2015). As part of that study, a structural flood protection scheme was developed, consisting of a combination of flood barriers / dikes, ground improvements, pumping, piping, and road crossing improvements. The total estimated cost of the scheme was between $50M and $105M, not including land acquisition. At that time, based on discussions with the City, the structural approach was not recommended, and instead it was suggested that the City continue with a non-structural (regulatory) approach to flood risk management.

While non-structural flood risk management is an important component of the City's overall strategy, and can guide safe development, it is not sufficient to address flood risk to existing properties.

A considerable risk associated with a structural flood protection approach such as that outlined in the City's flood management study (Urban Systems, 2015) is that the confinement of the floodway and loss of flood storage will increase water levels beyond those on the updated floodplain maps, and potentially contribute to added flooding in areas not captured by the maps. Therefore, if a structural flood protection approach is re-considered by the City in the future, further analysis should be conducted to incorporate climate change adaptation, technical feasibility and impacts on water levels, and economic benefits.

Given the challenges of constructing and maintaining a diking system, alternative cost-effective structural mitigation measures may include enhancing channel capacity, bridge and culvert capacity, strategic road raising, and increasing floodplain storage in collaboration with adjacent jurisdictions. Collaboration with the City of Surrey may include improving the flow capacity of the Nicomekl channel / floodplain downstream of the City of Langley's boundary, and with Township of Langley may include exploring opportunities for increased flow retention upstream to reduce flood peaks.

For non-structural flood protection, the following minimum requirements should be maintained:

- Preserve the floodplain, retain in-channel and off-channel storage.
- Flood proof new and retrofit existing development by meeting FCL requirements and implementing flood proofing strategies where applicable.
- Regular review and updates to the Floodplain Bylaw.
- Periodic revision of floodplain maps to reflect newer versions of software, changes in channel / floodplain geometry and latest scientific information on climate impacts.
- Communication and public education.
- Emergency response planning.

7 SUMMARY AND RECOMMENDATIONS

This study included hydrologic modelling and the development and sensitivity testing of a 2D hydraulic model of the Nicomekl River, Logan Creek including Jeffries Brook, and Murray Creek. The model was calibrated to the November 2021 flood and good agreement between observed and simulated water levels was obtained for the Nicomekl River. The hydraulic model was used to develop updated floodplain maps and FCLs. The new results are more detailed than the 2007 information by Urban Systems and include FCL isolines and flood extents incorporating freeboard for both present-day and future conditions. A comparison of the updated FCLs with the previous work from 2007 showed somewhat irregular differences.

We understand that the City intends to require developments to adhere to the FCLs presented on the future floodplain maps (Figure B.2).

Additional work is recommended to implement the findings of this study, and improve the City's understanding of flood risk within its boundaries. Recommendations include:

- Update the Floodplain Bylaw to include the revised FCLs.
- During future large floods, exceeding about the 15-20 year return period, collect high water marks on the Nicomekl River including on Logan Creek, to facilitate better model validation.
- Survey all City water level gauges to CGVD2013 datum and develop rating curves for these.
- Resurvey the channel roughly every 15 years to update the hydraulic model and fine-tune the floodplain mapping.
- Review bank erosion and stabilize the banks as necessary to reduce sediment input.
- Evaluate alternative climate change scenarios to better define the changing risk profile, and to allow flood mitigation solutions to better consider adaptation, either during initial construction or through the ability for additions to be easily made in the future.
- With City of Surrey, explore the potential for improving the flow capacity of the Nicomekl channel / floodplain downstream of the City boundary as this could reduce upstream flood levels. This may involve widening bridge openings, setting back dikes and not raising overflow spillways. With Township of Langley, explore opportunities for increased flow retention to reduce flood peaks within the City.
- Consider improving the flow conveyance of the bridges at the 200 St, 203 St, 51B Ave, Fraser Highway and 56 Ave crossings. This could significantly increase their climate change resilience, or ability to convey future increased flood flows. Similarly, upgrade culvert sizing along Logan Creek and improve inlet/outlet conditions at Glover Rd, two sets of railway culverts, Maple Leaf and Highway 10 / Langley Bypass.
- As a non-structural flood mitigation measure, avoid development within floodplain areas. Even relatively small reductions in flow conveyance area may significantly increase upstream flood levels. The impacts of any future development within the floodplain should be tested in the hydraulic model before implementation, including those in the Nicomekl Neighbourhood Plan.

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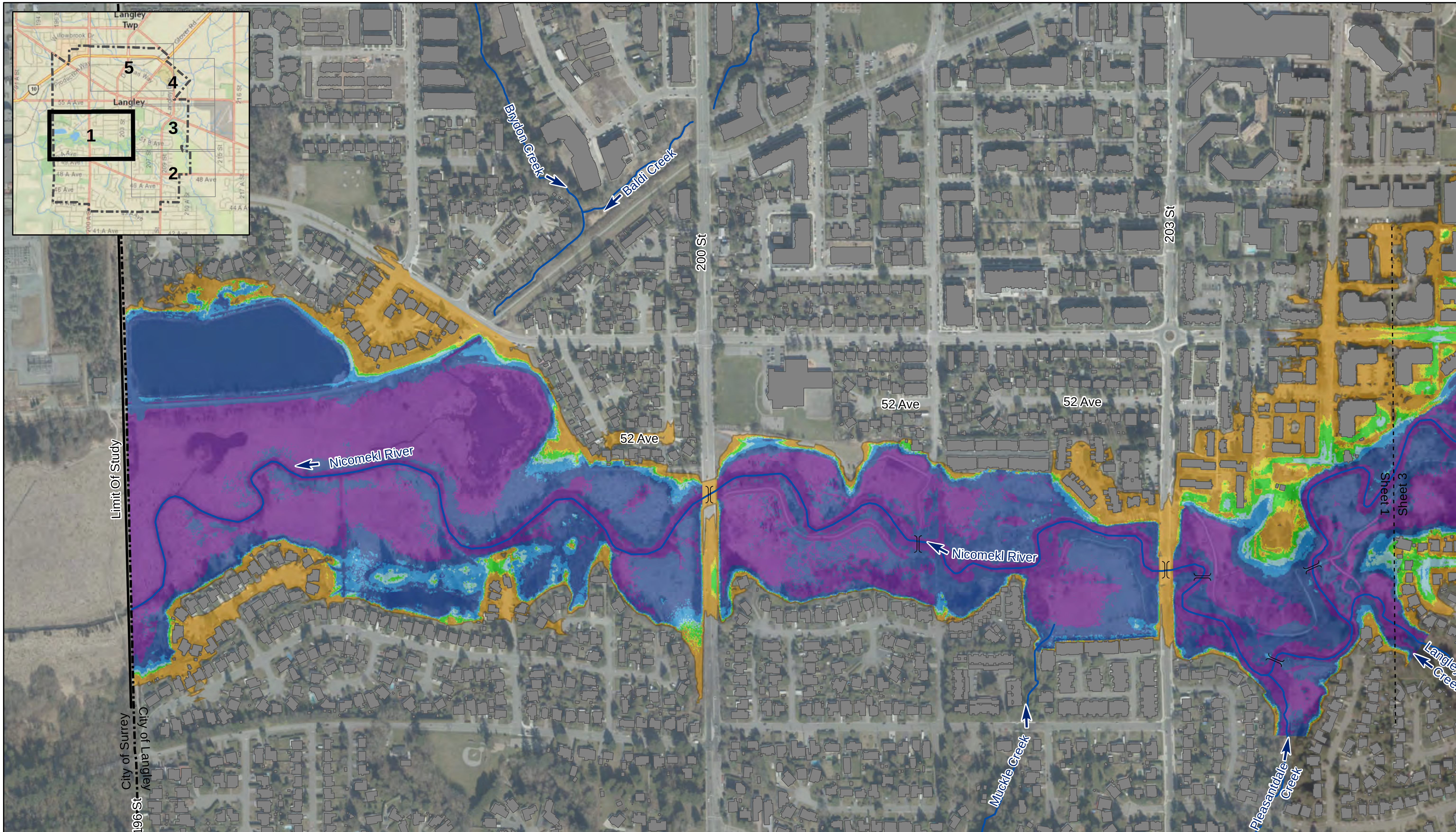
APPENDIX A
FLOOD DEPTH MAPS



Langley City
THE PLACE TO BE

nhc
northwest hydraulic consultants

200YR DEPTH (EXISTING)
UNITS (M)
- > 2.0
- 1.0 - 2.0
- 0.5 - 1.0
- 0.3 - 0.5
- 0.1 - 0.3
- < 0.1

- BRIDGES
- CULVERTS
- STREAMS
- LANGLEY CITY BOUNDARY
- BUILDINGS

200YR INUNDATION EXTENTS
- 2100 LAND USE AND CLIMATE

DATA SOURCES: BACKGROUND - ESRI WORLD IMAGERY, INSET – NATIONAL GEOGRAPHIC

NOTES:
1. DEPTHS SHOWN ARE BASED ON THE 200-YEAR RETURN PERIOD EVENT WITH EXISTING CLIMATE AND LAND USE, ***NO FREEBOARD INCLUDED****. ADDITIONAL INUNDATED AREA DUE TO LAND USE AND CLIMATE CHANGE IS SHOWN IN ORANGE*
2. EXCEPT FOR MURRAY CREEK, LOGAN CREEK, AND JEFFRIES BROOK, TRIBUTARIES HAVE NOT BEEN MODELLED AND DEPTHS SHOWN ARE DUE TO BACKWATER FROM THE NICOMEKL RIVER ONLY
3. ASSUMES UNBLOCKED, FREE FLOW CONDITIONS
4. DEPTHS SHOWN THROUGH SUBMERGED BRIDGE OPENINGS ARE RELATIVE TO THE CHANNEL BED, NOT THE BRIDGE DECKS. DEPTHS SHOWN THROUGH SUBMERGED CULVERT CROSSINGS ARE RELATIVE TO ROAD ELEVATIONS.

SCALE - 1:5,000
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Coordinate System: NAD 1983 CSRS UTM ZONE 10N
Units: METRES

Job: 3006708 *Date: 20-MAY-2022*

NICOMEKL RIVER FPM
DEPTH MAP
200 YR
PAGE 1 OF 5

FIGURE A.1

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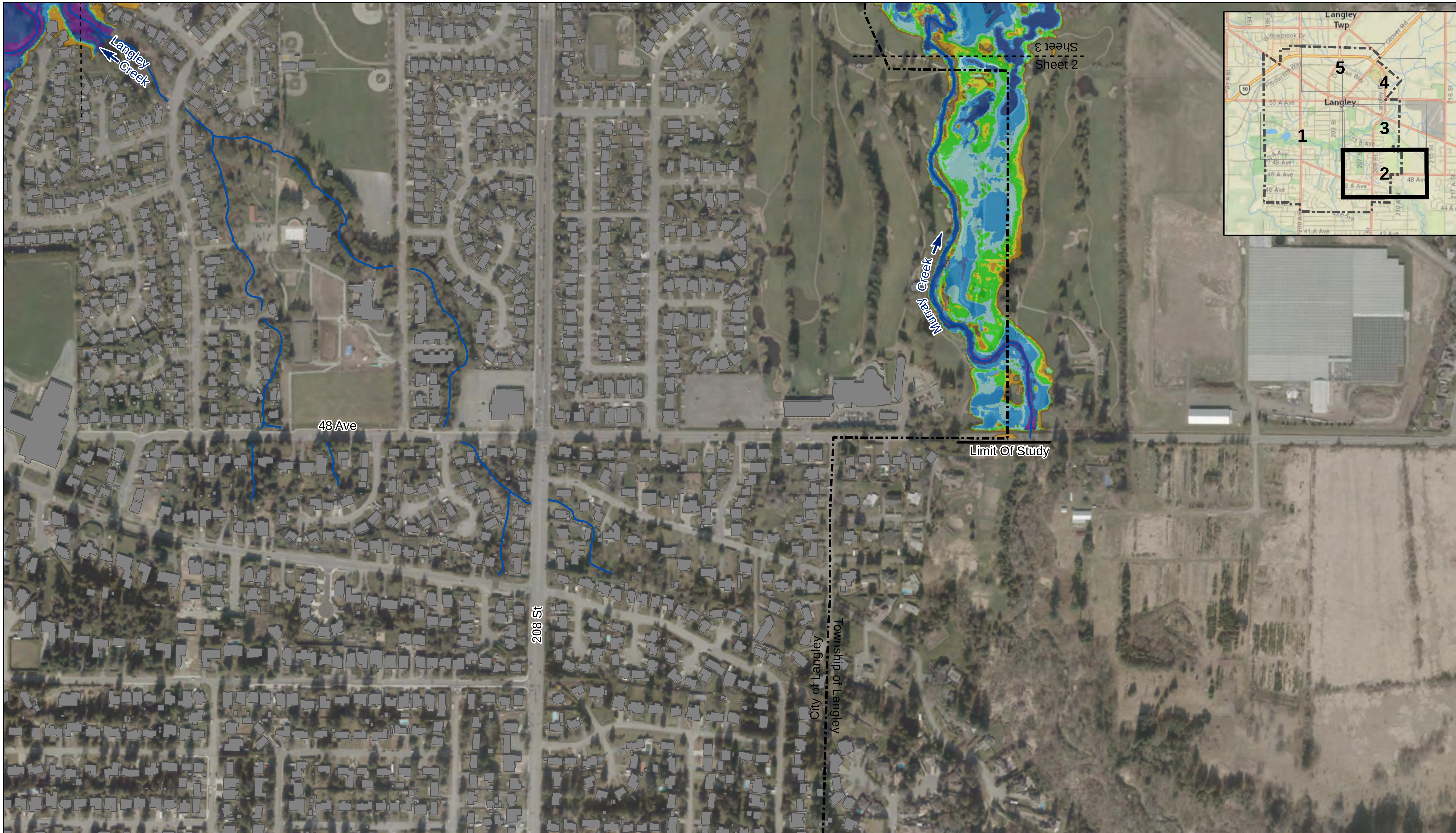

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Job: 3006708 *Date: 20-MAY-2022*

NICOMEKL RIVER FPM
DEPTH MAP
200 YR
PAGE 2 OF 5

FIGURE A.1

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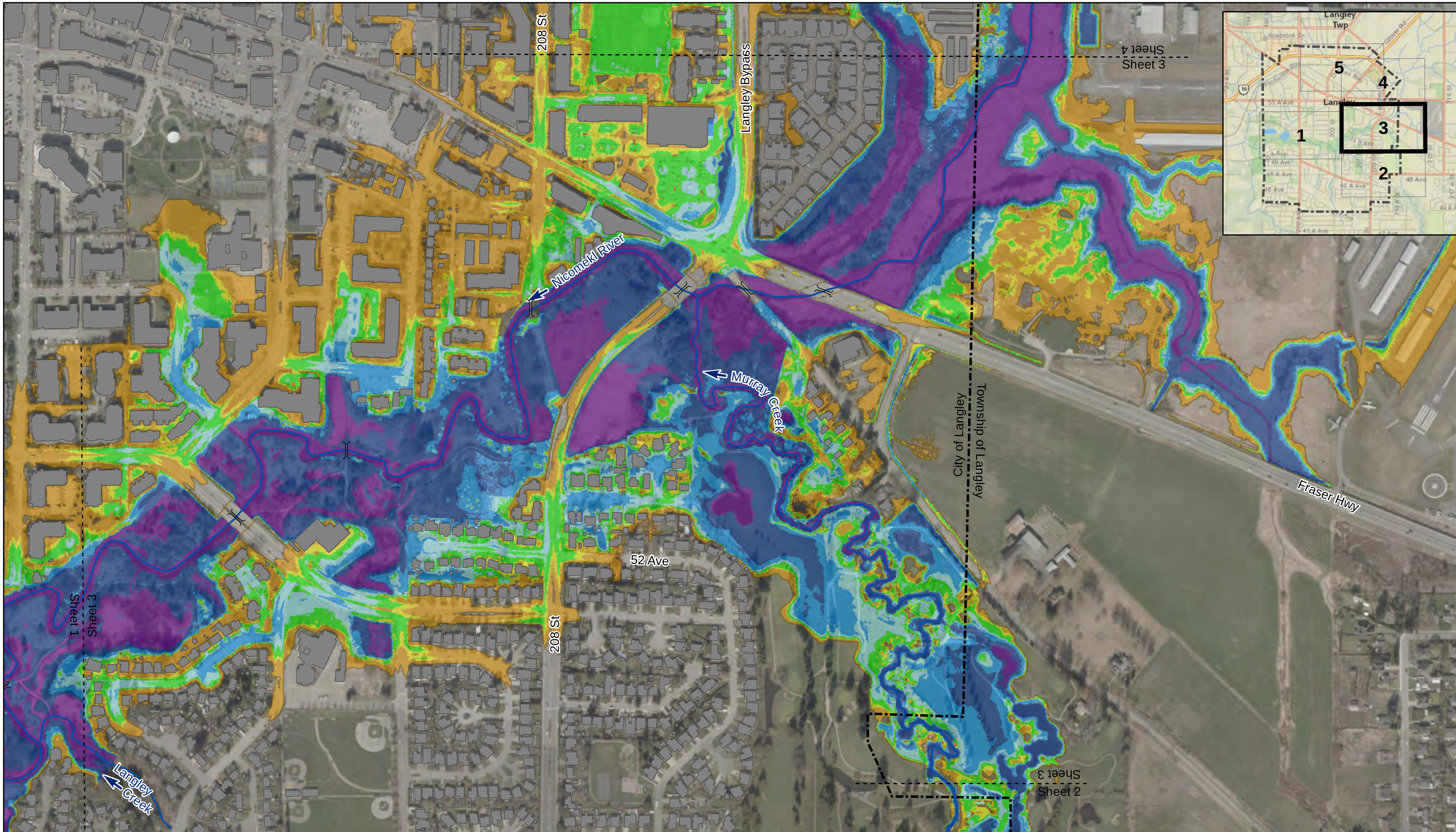

Langley City THE PLACE TO BE

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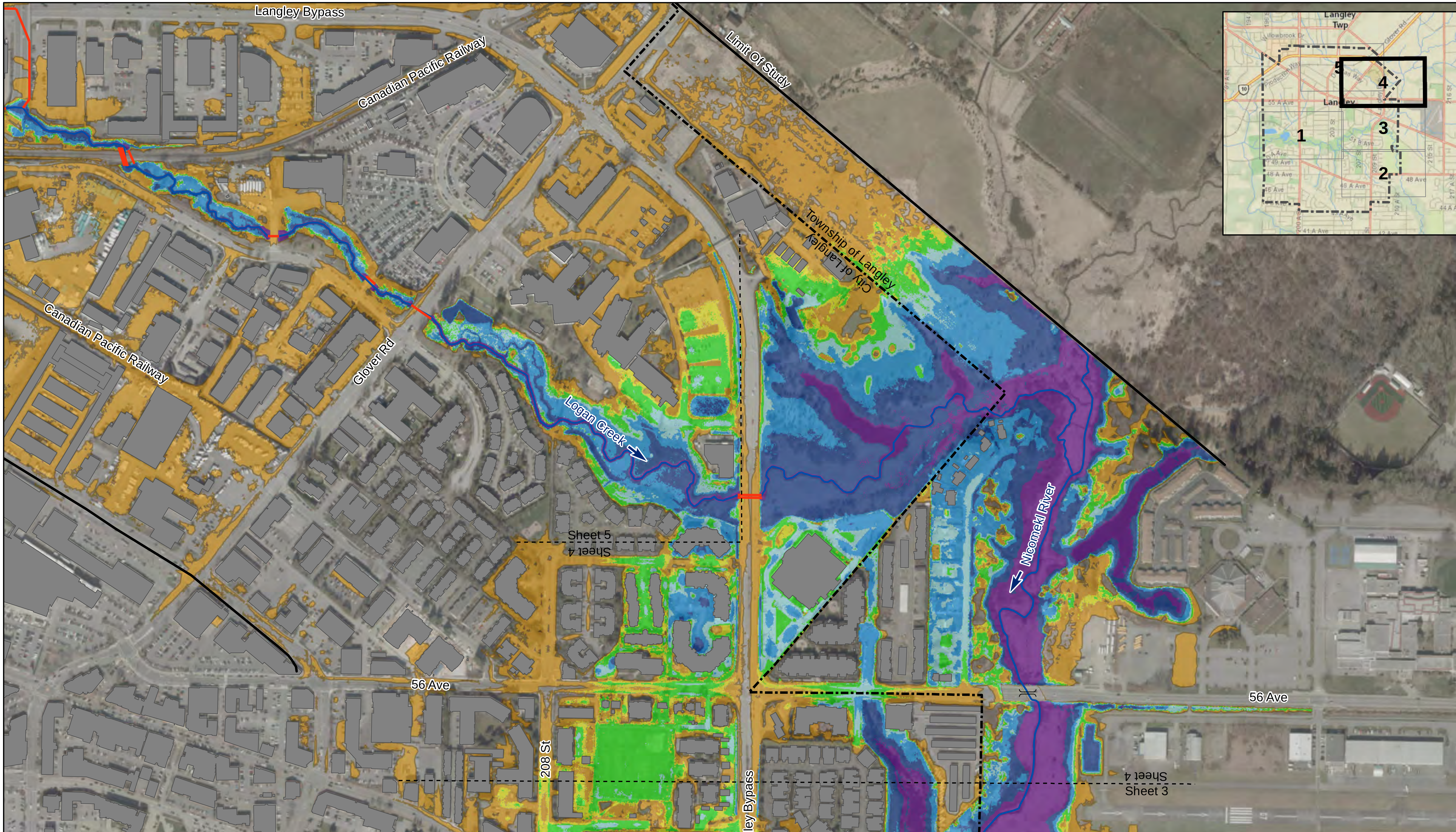
Coordinate System: NAD 1983 CSRS UTM ZONE 10N
Units: METRES

Job: 3006708 *Date: 20-MAY-2022*

NICOMEKL RIVER FPM
DEPTH MAP
200 YR
PAGE 3 OF 5

FIGURE A.1



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Job: 3006708 | *Date: 20-MAY-2022*

NICOMEKL RIVER FPM
DEPTH MAP
200 YR
PAGE 4 OF 5

FIGURE A.1

Langley City
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200YR DEPTH (EXISTING)
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- 0.5 - 1.0
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Job: 3006708 Date: 20-MAY-2022

NICOMEKL RIVER FPM
DEPTH MAP
200 YR
PAGE 5 OF 5

FIGURE A.1

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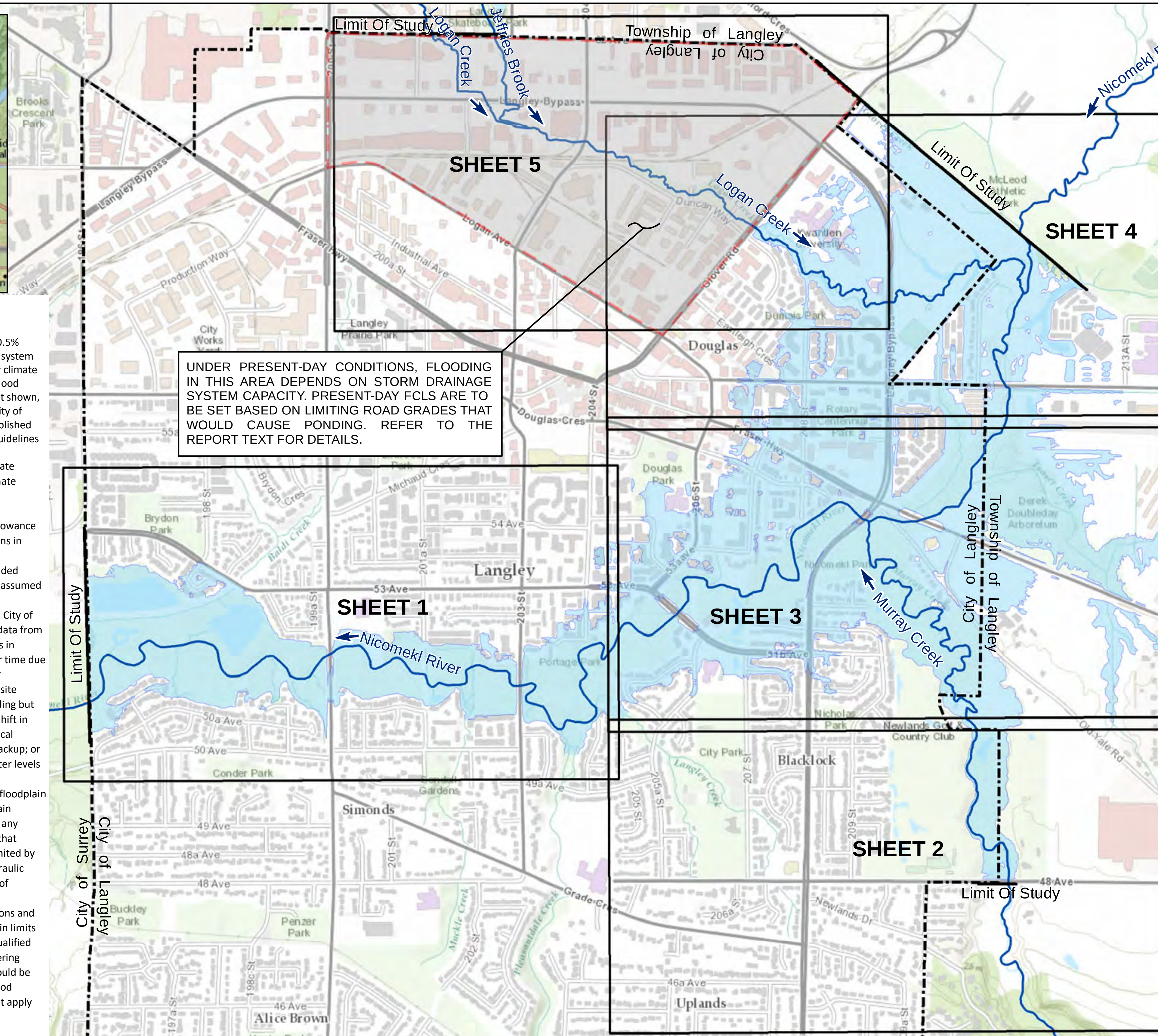
APPENDIX B

FLOODPLAIN MAPS



General Notes

1. These maps delineate the potential for flooding under conditions caused by a 200-year return period event (0.5% Annual Exceedance Probability) on the Nicomekl River system within the City of Langley under predicted present-day climate and land use conditions, as described in NHC (2022). Flood inundation from tributaries or the storm network is not shown, except for Logan Creek and Murray Creek within the City of Langley border. FCLs for other tributaries shall be established using the Flood Hazard Area Land Use Management Guidelines (MWLAP, 2018).
2. These flood maps do not include an allowance for climate change. FCLs based on a projected end-of-century climate change scenario are included as a separate map sheet (Appendix B.2).
3. Flood construction levels (FCLs) include a freeboard allowance (margin of safety) of 0.6 m to account for local variations in water level and uncertainty in the underlying data and modelling. FCLs within the freeboard areas were extended based on digital elevation map (DEM) topography and assumed water level isolines.
4. The hydraulic analysis and mapping are based on 2020 City of Langley lidar data, 2021 survey by NHC, and 2021 GIS data from the City of Langley (see data sources below). Variations in geometry may occur during a flood event and / or over time due to vegetation growth, channel erosion, aggradation, or degradation. The maps do not provide information on site specific hazards that may influence water levels, including but not limited to: land erosion; land subsidence; sudden shift in watercourse alignment; debris accumulation / jams; local stormwater inflows or drainage; stormwater system backup; or groundwater. These have the potential to increase water levels and extents beyond those mapped.
5. Industry best practices were followed to generate the floodplain maps. Flooding may occur outside the defined floodplain boundary. The City of Langley and NHC do not assume any liability for variations of flood levels and extents from that shown. The accuracy of flood levels and extents are limited by the input data; assumptions and limitations in the hydraulic model and design flow; and the digital representation of topography. Floodplain maps should be considered an administrative tool indicating anticipated flood elevations and floodplain boundaries for a designated flood. Floodplain limits are not established on the ground by legal survey. A qualified professional is to be consulted for site-specific engineering analysis, and building and floodproofing elevations should be based on field survey and established benchmarks. Flood extents and FCLs are for City of Langley only and do not apply beyond the City boundary.

Data Sources

1. The digital elevation model (DEM) used to develop the **hydraulic** model and **floodplain** mapping is based on survey by NHC in October 2021; City of Langley lidar data collected by Airborne Imaging in December 2020 (Airborne Imaging, 2021); and GIS data (e.g. building footprints) from the City of Langley in 2021. Channel geometry is based on cross sections taken at major bridge / culvert crossings and interpolated between survey points. A detailed channel survey was not conducted.
2. Water levels are calculated by a 2D numerical model developed by NHC using HEC-RAS (v.6.1) software. Model development, design flood details, and mapping inputs are described in NHC (2022).
3. Administrative boundaries from Data BC.
4. Application Zone for Flood Construction Level upstream of Glover Road is from previous floodplain designation (Urban Systems, 2007).

References

Airborne Imaging (2021). City of Langley LiDAR Project - Final Report. Airborne Imaging for City of Langley.

BC Ministry of Water, Land and Air Protection (2018). Flood Hazard Area Land Use Management Guidelines. Amended by Ministry of Forests, Lands, Natural Resource Operations and Rural Development January 1, 2018.

NHC (2022). Nicomekl River Floodplain Mapping. Northwest Hydraulic Consultants Ltd. for City of Langley.

Urban Systems (2007). Schedule A of City of Langley Floodplain Elevation Bylaw No. 2768 - Designated Flood Plain for the Nicomekl River, Murray Creek, Logan Creek, and Jeffries Brook. Urban Systems for City of Langley.

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STREAMS
LANGLEY CITY BOUNDARY
APPLICATION ZONE FOR FLOOD CONSTRUCTION LEVEL
PRESENT-DAY 200YR FLOODPLAIN INCLUDING 0.6 m FREEBOARD

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:15,000

0 200 400 600 M

N

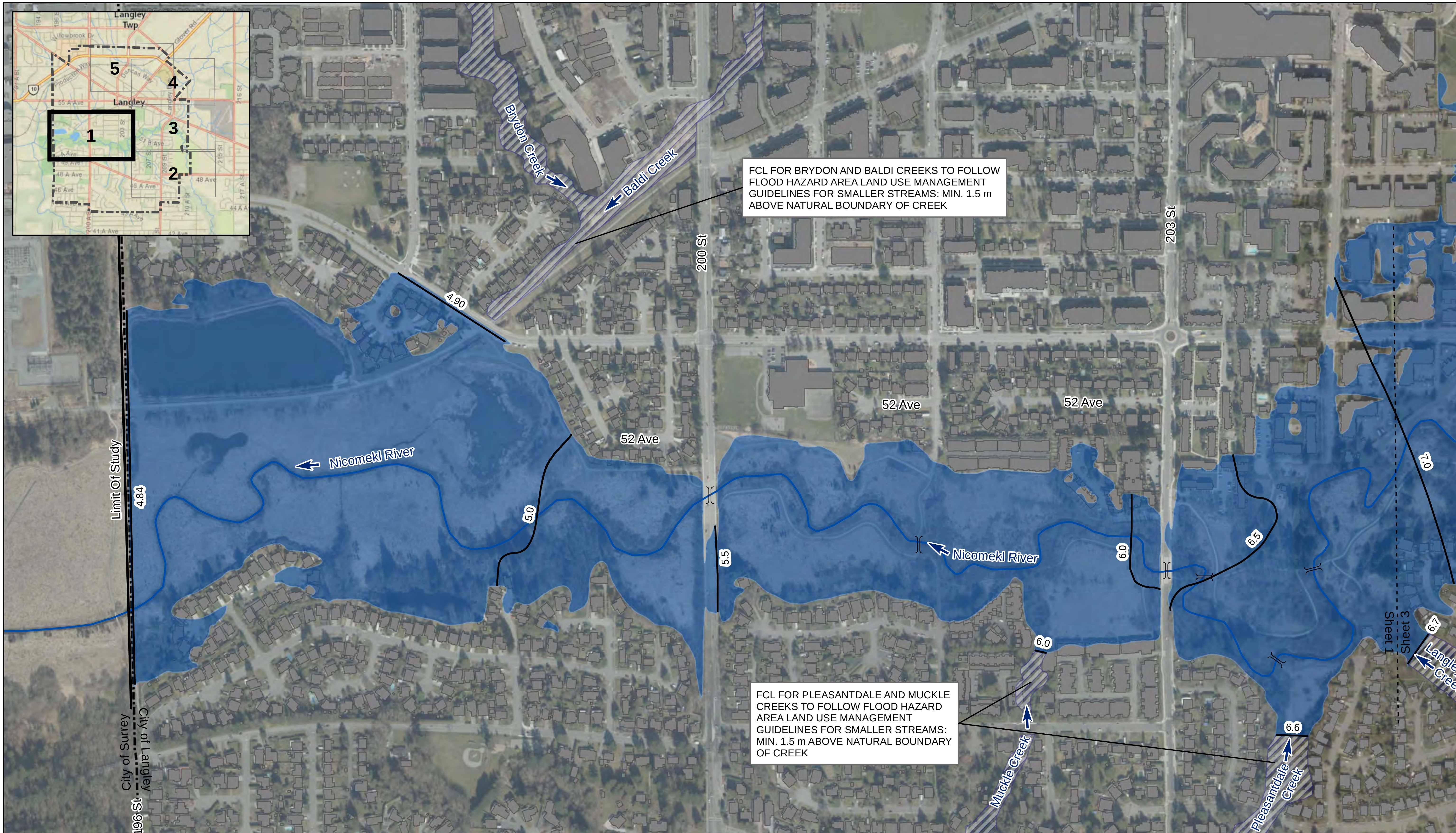
Coordinate System: NAD 1983 CSRS UTM ZONE 10N
Units: METRES

Job: 3006708 Date: 20-MAY-2022

NICOMEKL RIVER FLOODPLAIN MAP - PRESENT-DAY CONDITIONS MAP INDEX

FIGURE B.1

JXD, \\vanfile-van\Projects\Active\3006708 Nicomekl FPM\95 GIS\3006708_Fig_MapIndex1_B1.mxd



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- STREAMS
- CULVERTS
- BRIDGES
- FLOOD CONSTRUCTION LEVEL (EL. M)
- APPLICATION ZONE FOR FLOOD CONSTRUCTION LEVEL
- 200-YR (PRESENT-DAY) FLOOD EXTENTS WITH FREEBOARD
- LANGLEY CITY BOUNDARY
- BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

N

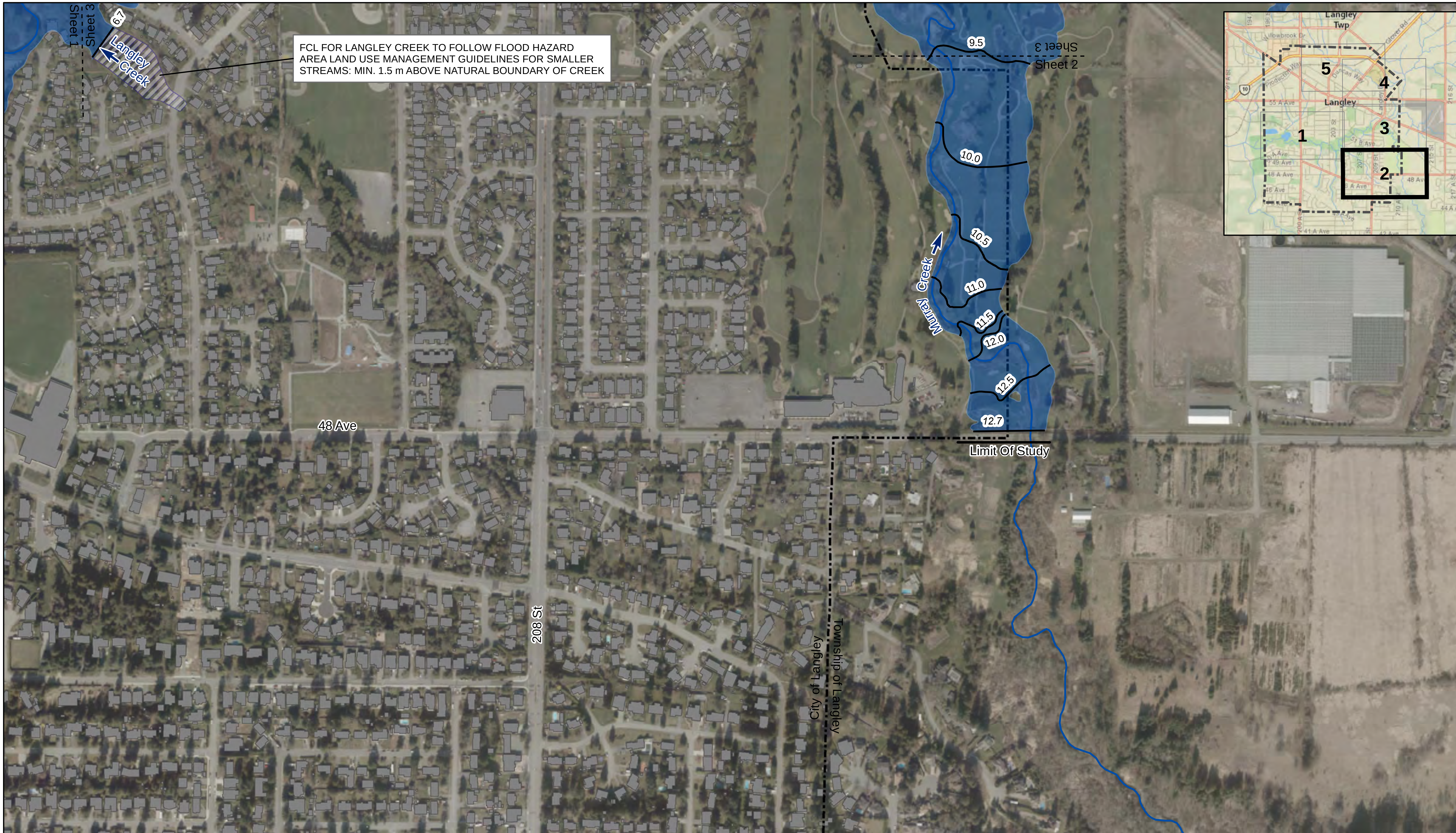
Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 Date: 17-MAY-2022

NICOMEKL RIVER FLOODPLAIN MAP 200 YR PRESENT-DAY WITH FREEBOARD PAGE 1 OF 5

FIGURE B.1

JXD, \\nhc\Projects\Active\3006708 Nicomekl FPM\95 GIS\3006708_Fig_200yrFloodMap1.mxd



STREAMS
CULVERTS
BRIDGES
FLOOD CONSTRUCTION LEVEL (EL. M)
APPLICATION ZONE FOR FLOOD CONSTRUCTION LEVEL
200-YR (PRESENT-DAY) FLOOD EXTENTS WITH FREEBOARD
LANGLEY CITY BOUNDARY
BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 Date: 17-MAY-2022

NICOMEKL RIVER FLOODPLAIN MAP 200 YR PRESENT-DAY WITH FREEBOARD PAGE 2 OF 5

FIGURE B.1

Langley City THE PLACE TO BE

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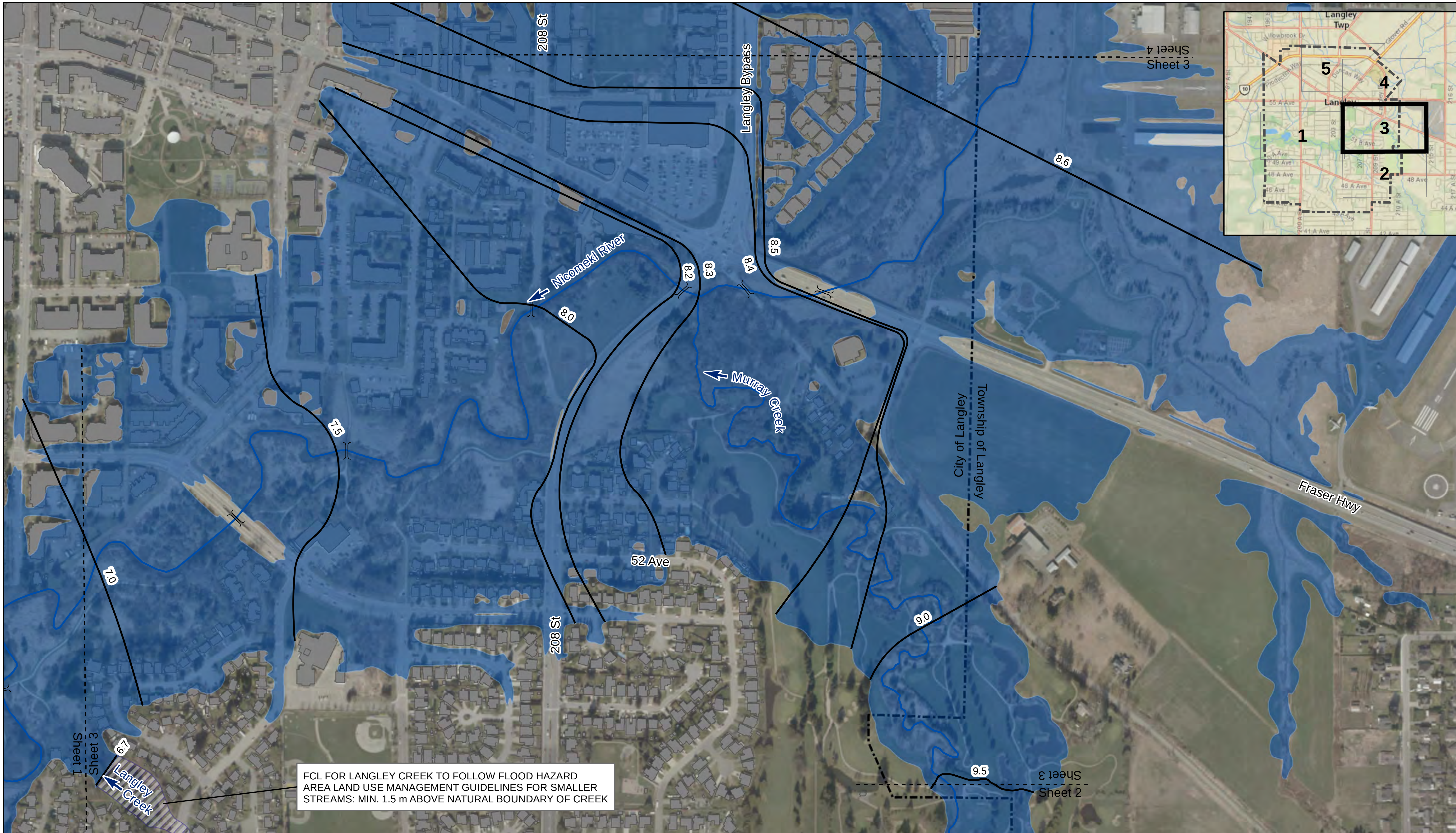
JXD, \\nhaintile-van\Projects\Active\3006708 Nicomekl FPM\95 GIS\3006708_Fig_200yrFloodMap1.mxd



Langley City THE PLACE TO BE

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- STREAMS
- CULVERTS
- BRIDGES
- FLOOD CONSTRUCTION LEVEL (EL. M)
- APPLICATION ZONE FOR FLOOD CONSTRUCTION LEVEL
- 200-YR (PRESENT-DAY) FLOOD EXTENTS WITH FREEBOARD
- LANGLEY CITY BOUNDARY
- BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

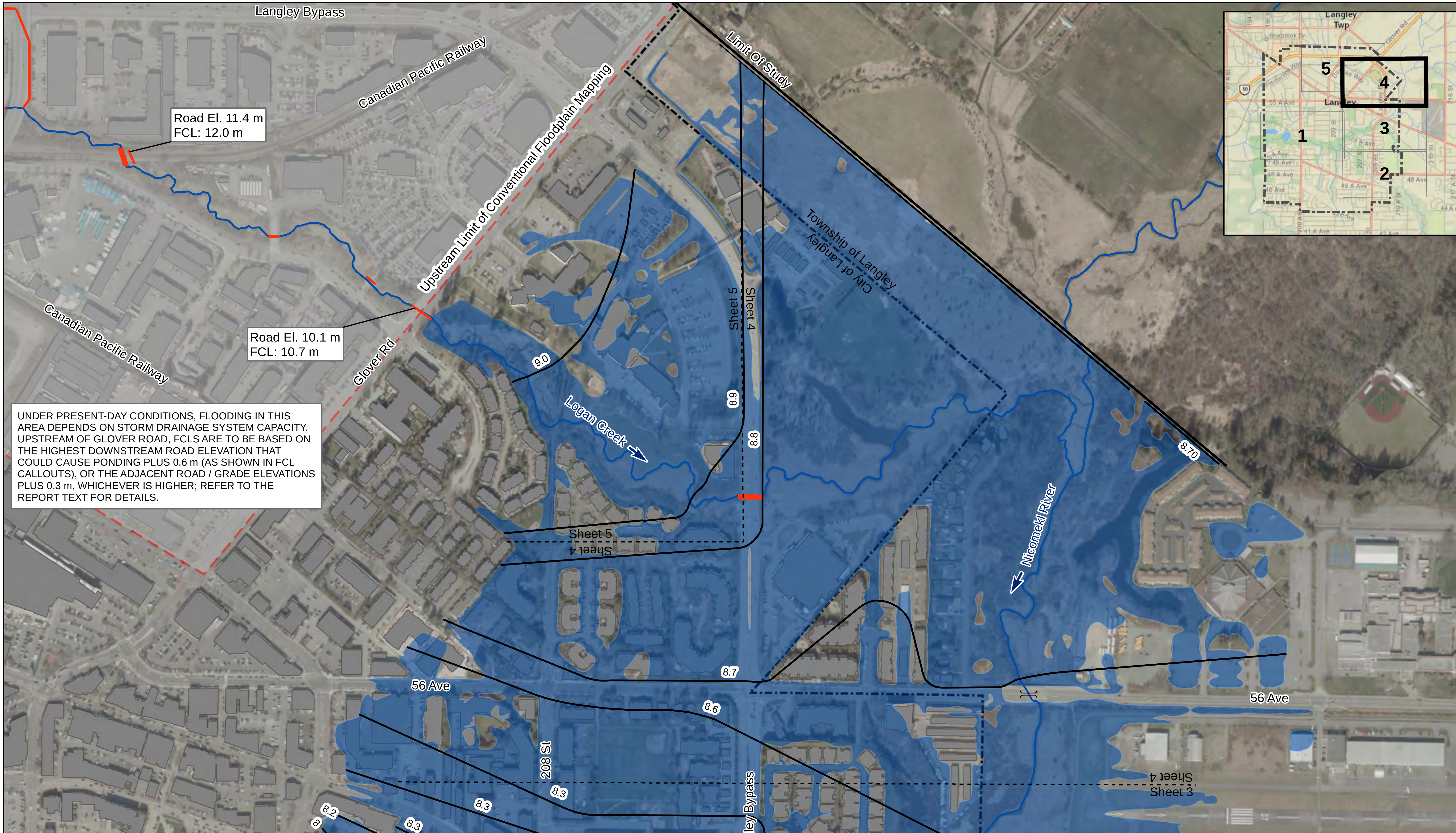
N

Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 *Date: 17-MAY-2022*

NICOMEKL RIVER FLOODPLAIN MAP 200 YR PRESENT-DAY WITH FREEBOARD PAGE 3 OF 5

FIGURE B.1



STREAMS
CULVERTS
BRIDGES
FLOOD CONSTRUCTION LEVEL (EL. M)
APPLICATION ZONE FOR FLOOD CONSTRUCTION LEVEL
200-YR (PRESENT-DAY) FLOOD EXTENTS WITH FREEBOARD
LANGLEY CITY BOUNDARY
BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 Date: 17-MAY-2022

NICOMEKL RIVER FLOODPLAIN MAP
200 YR PRESENT-DAY WITH FREEBOARD PAGE 4 OF 5

FIGURE B.1

Langley City THE PLACE TO BE

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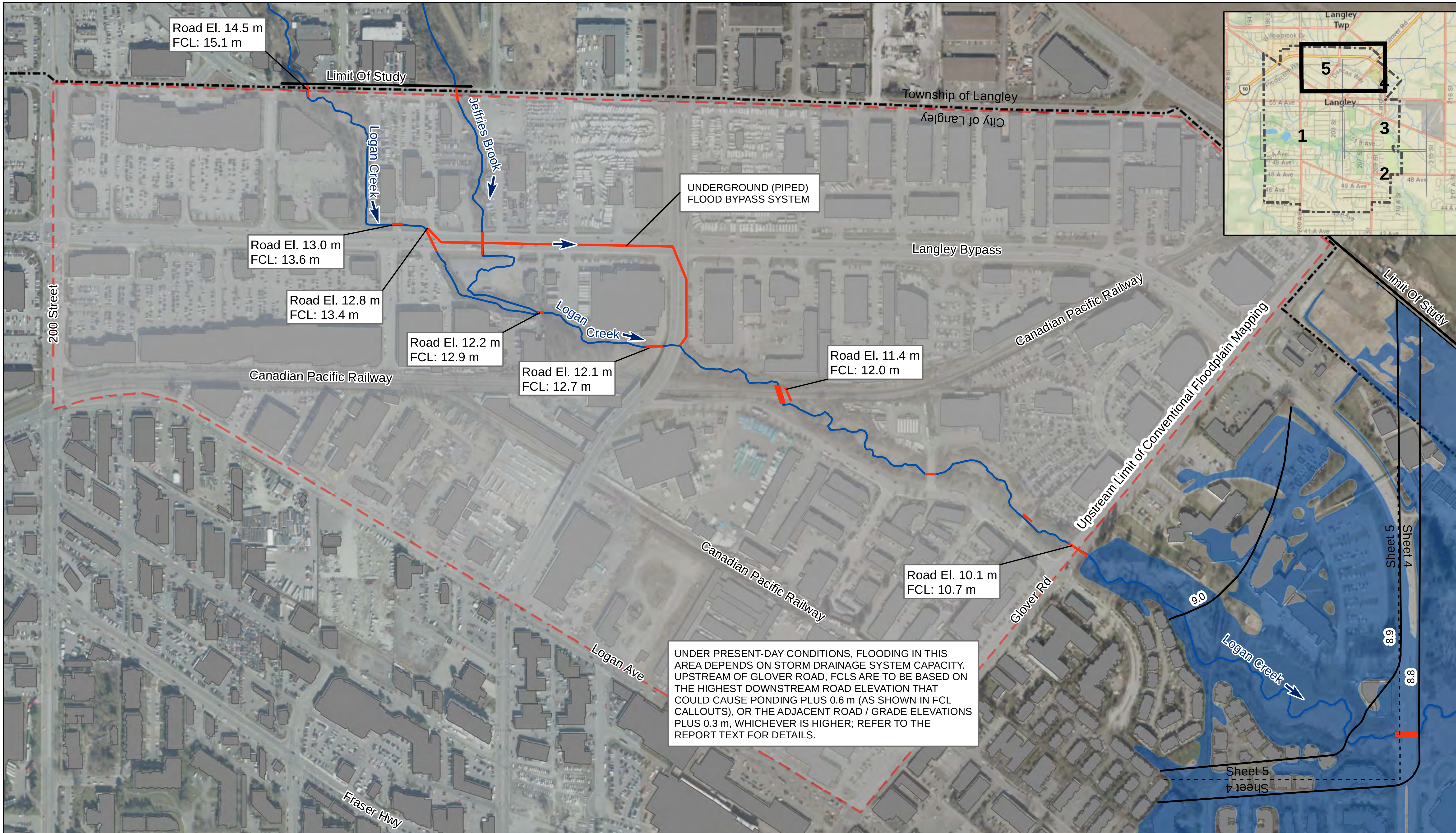

Langley City
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STREAMS
CULVERTS
BRIDGES
FLOOD CONSTRUCTION LEVEL (EL. M)
APPLICATION ZONE FOR FLOOD CONSTRUCTION LEVEL
200-YR (PRESENT-DAY) FLOOD EXTENTS WITH FREEBOARD
LANGLEY CITY BOUNDARY
BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

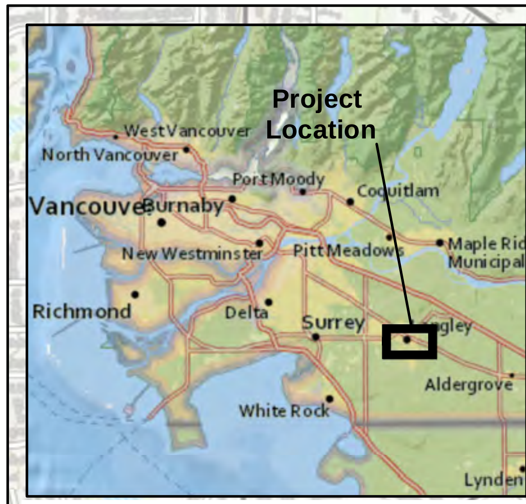
SCALE - 1:5,000
0 50 100 150 200 M
N

Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 *Date: 17-MAY-2022*

NICOMEKL RIVER FLOODPLAIN MAP 200 YR PRESENT-DAY WITH FREEBOARD PAGE 5 OF 5

FIGURE B.1



General Notes

1. These maps delineate the potential for flooding under conditions caused by a 200-year return period event (0.5% Annual Exceedance Probability) on the Nicomekl River system within the City of Langley under predicted future climate and land use conditions to the year 2100, as described in NHC (2022). Flood inundation from tributaries or the storm network is not shown, except for Logan Creek and Murray Creek within the City of Langley border. FCLs for other tributaries shall be established using the Flood Hazard Area Land Use Management Guidelines (MWLAP, 2018).
2. These flood maps include an allowance for climate change based on a projected end-of-century climate change scenario, as described in NHC (2022). FCLs based on present-day conditions are included as a separate map sheet (Appendix B.1).
3. Flood construction levels (FCLs) include a freeboard allowance (margin of safety) of 0.6 m to account for local variations in water level and uncertainty in the underlying data and modelling. FCLs within the freeboard areas were extended based on digital elevation map (DEM) topography and assumed water level isolines.
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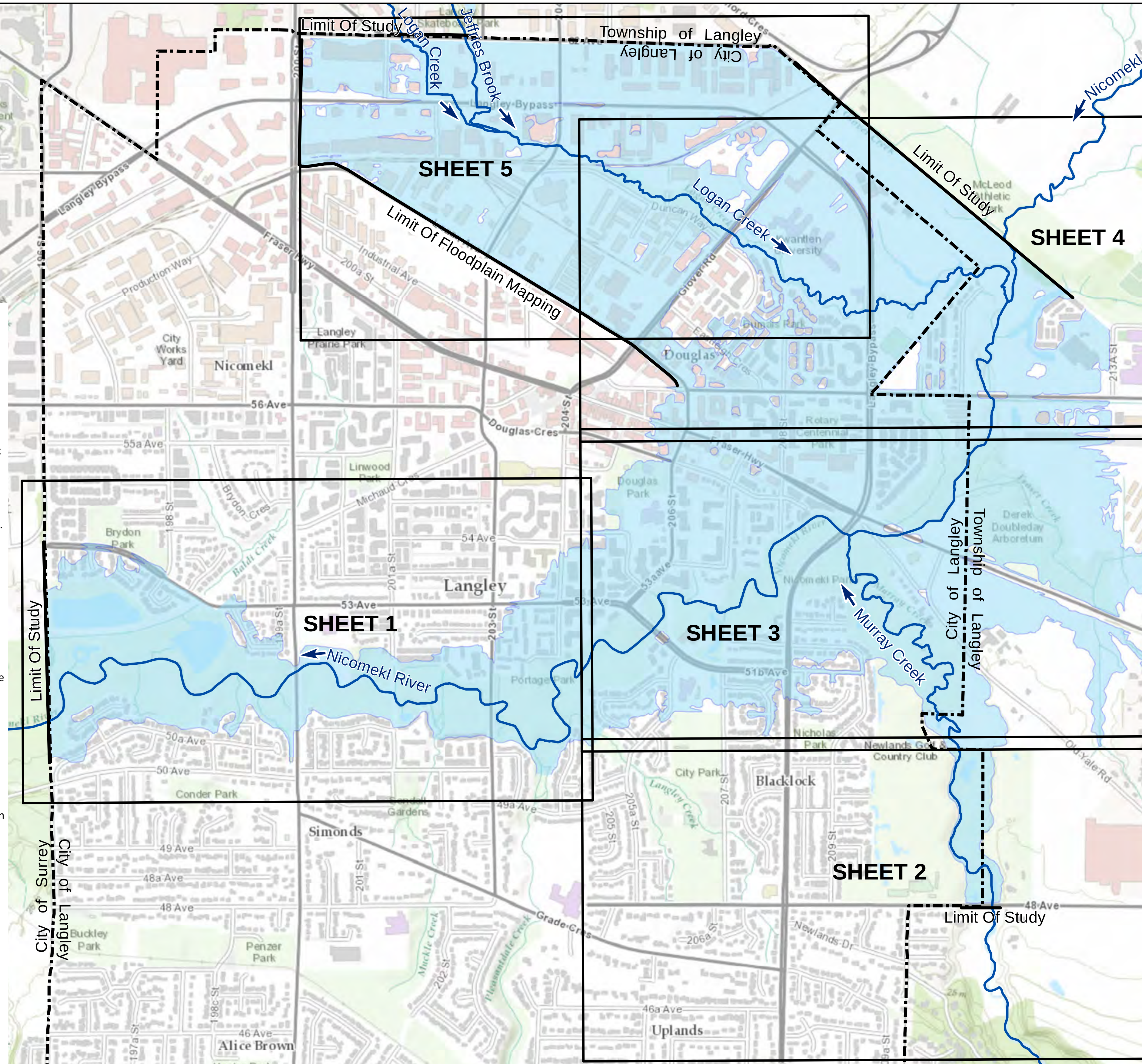

Data Sources

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References

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STREAMS
LANGLEY CITY BOUNDARY
FUTURE 200YR FLOODPLAIN INCLUDING 0.6 m FREEBOARD

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:15,000

0 200 400 600 M

N

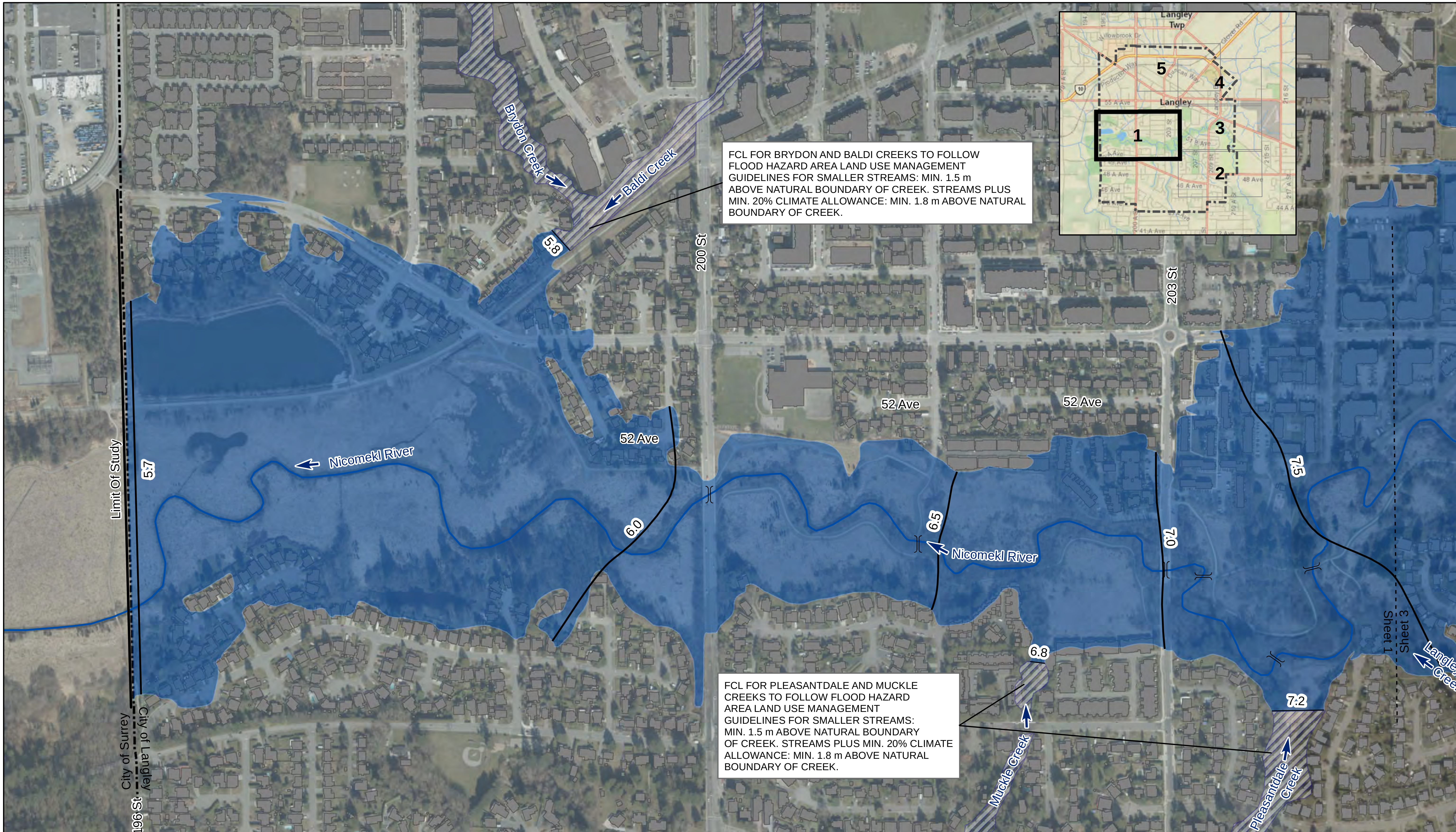
Coordinate System: NAD 1983 CSRS UTM ZONE 10N
Units: METRES

Job: 3006708

Date: 20-MAY-2022

NICOMEKL RIVER FLOODPLAIN MAP - FUTURE CONDITIONS MAP INDEX

FIGURE B.2



BRIDGES
FLOOD CONSTRUCTION LEVEL, FUTURE CONDITIONS (EL. m)
CULVERTS
STREAMS
200YR (FUTURE) WITH FREEBOARD
LANGLEY CITY BOUNDARY
BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

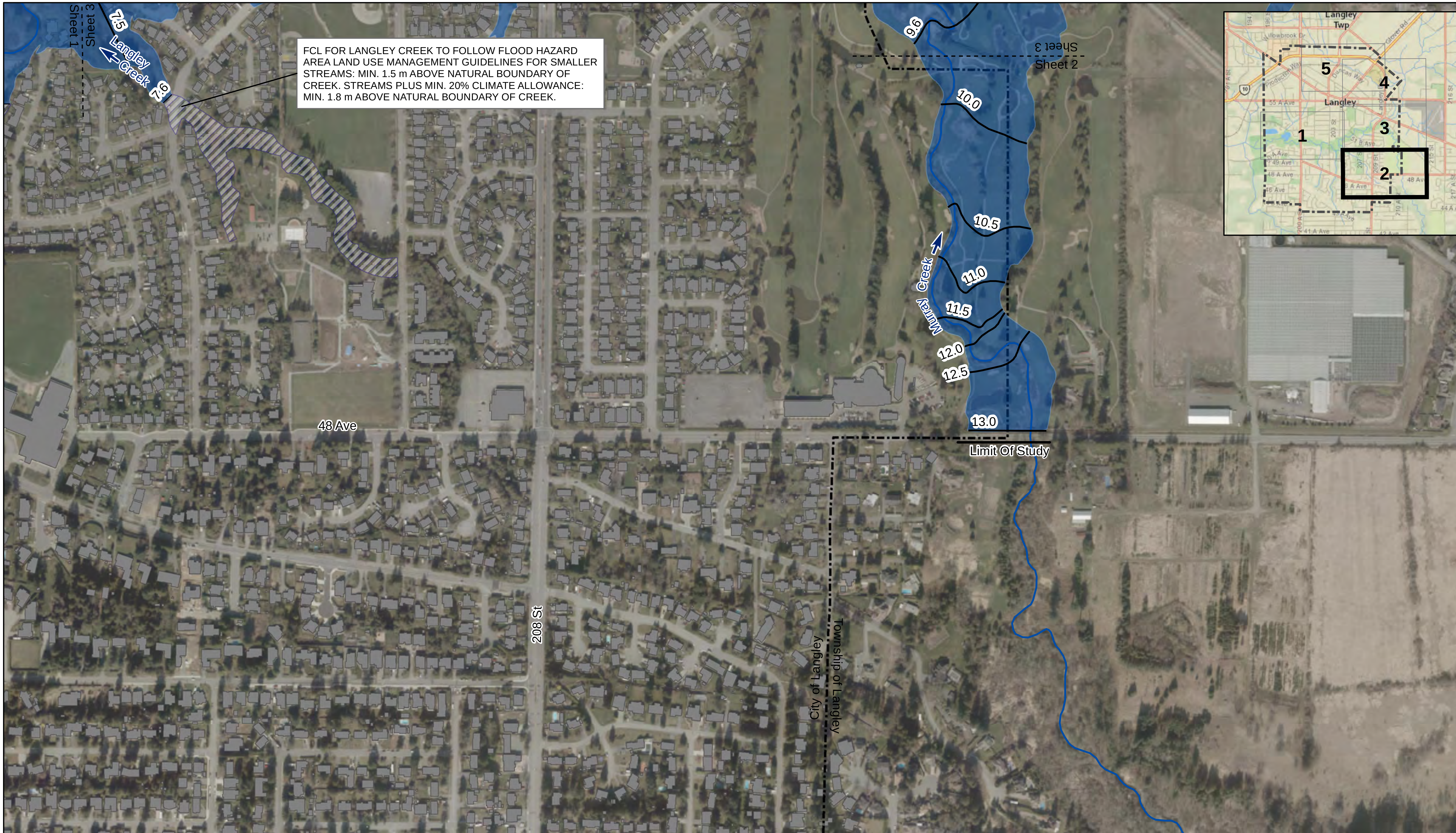
N

Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 Date: 20-MAY-2022

NICOMEKL RIVER FLOODPLAIN MAP 200 YR FUTURE WITH FREEBOARD PAGE 1OF 5

FIGURE B.2



BRIDGES
FLOOD CONSTRUCTION LEVEL, FUTURE CONDITIONS (EL. m)
CULVERTS
STREAMS
200YR (FUTURE) WITH FREEBOARD
LANGLEY CITY BOUNDARY
BUILDINGS

Langley City THE PLACE TO BE

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DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 Date: 20-MAY-2022

NICOMEKL RIVER FLOODPLAIN MAP 200 YR FUTURE WITH FREEBOARD PAGE 2OF 5

FIGURE B.2

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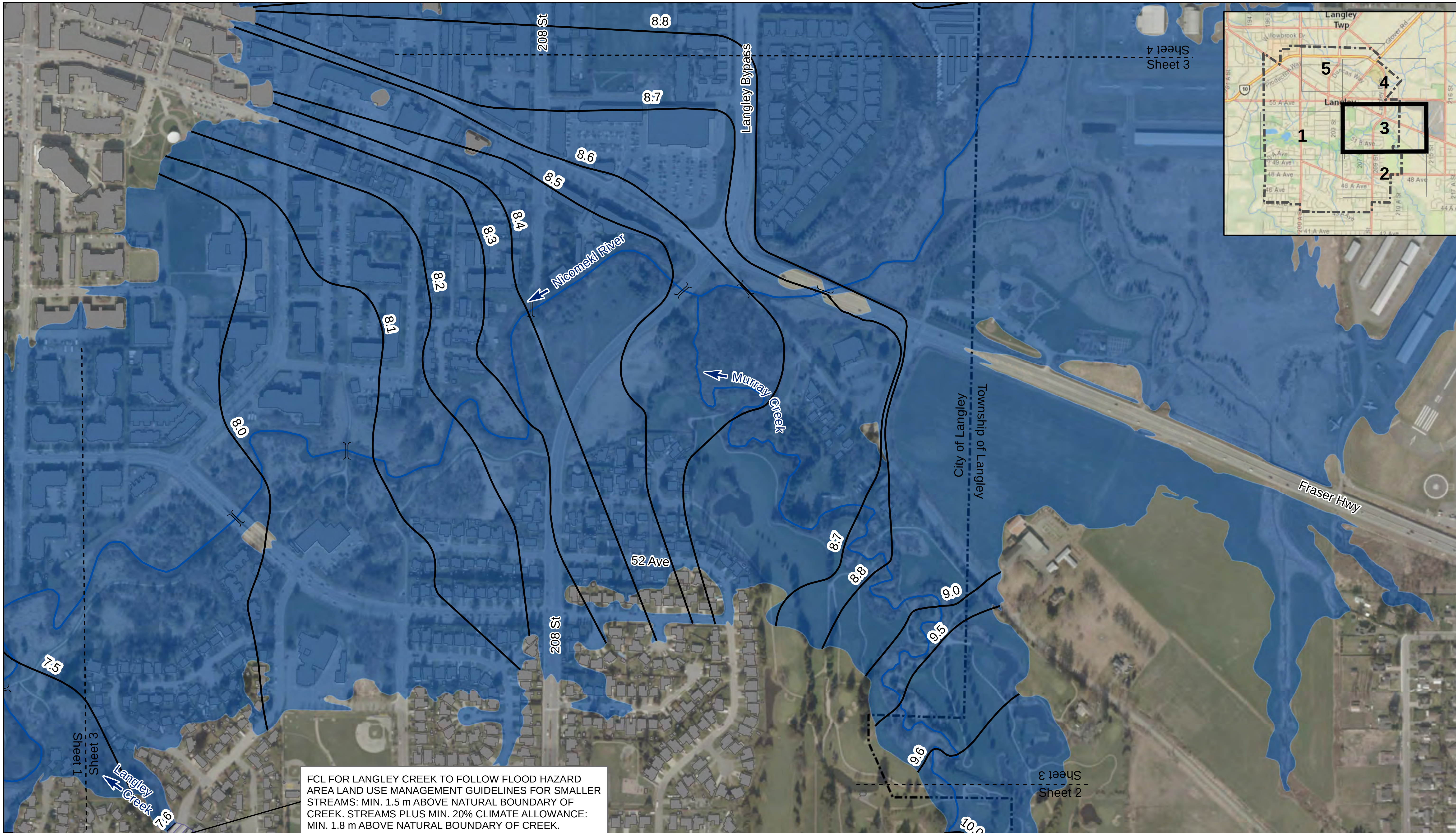

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- BRIDGES
- FLOOD CONSTRUCTION LEVEL, FUTURE CONDITIONS (EL. m)
- CULVERTS
- STREAMS
- 200YR (FUTURE) WITH FREEBOARD
- LANGLEY CITY BOUNDARY
- BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

N

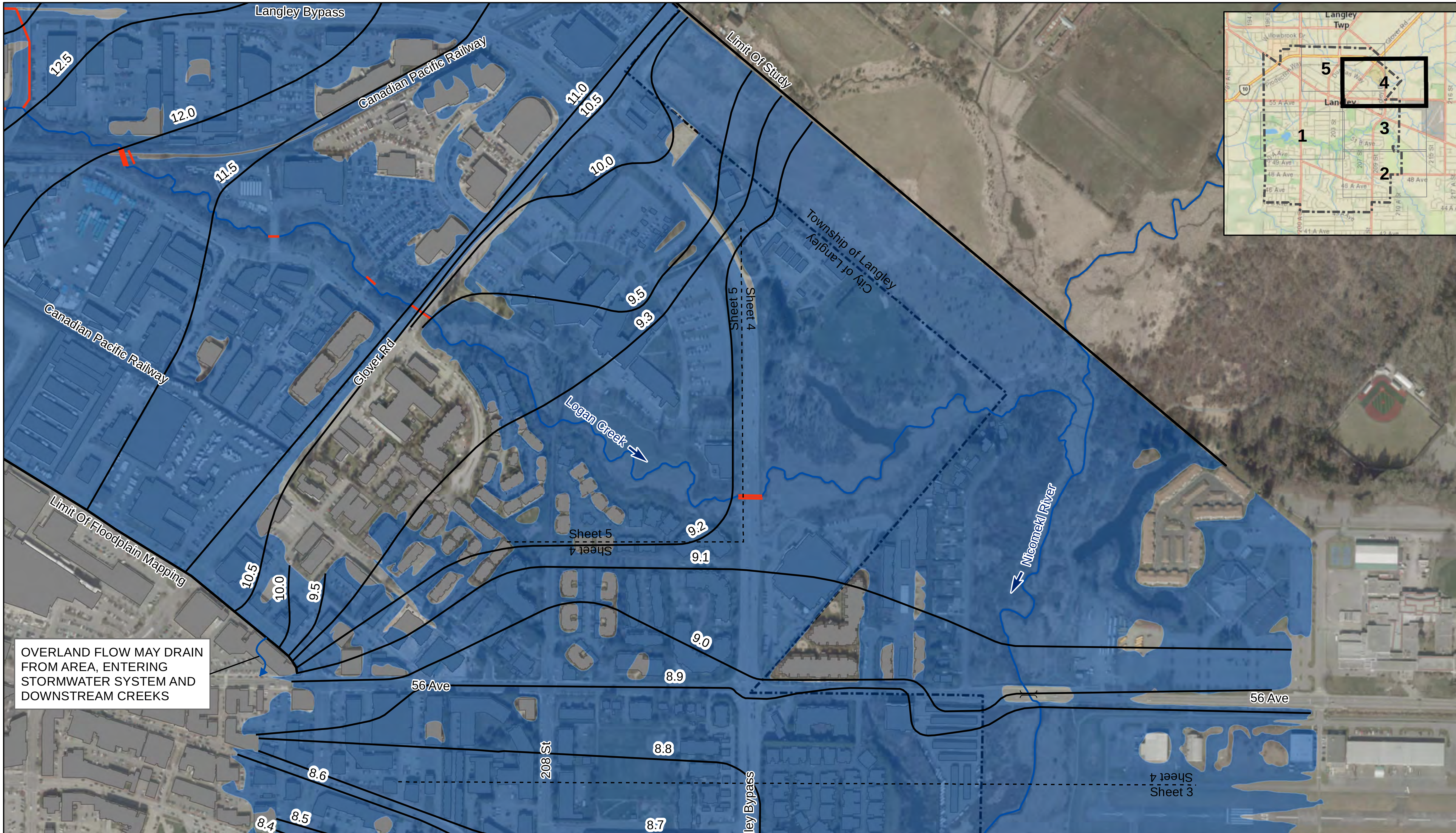
Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 *Date: 20-MAY-2022*

NICOMEKL RIVER FLOODPLAIN MAP 200 YR FUTURE WITH FREEBOARD PAGE 3OF 5

FIGURE B.2

JXD, \\nhc-van\Projects\Active\3006708 Nicomekl FPM\95 GIS\3006708_Fig_200yrFutureFloodMap1.mxd



Langley City THE PLACE TO BE

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BRIDGES
FLOOD CONSTRUCTION LEVEL, FUTURE CONDITIONS (EL. m)
CULVERTS
STREAMS
200YR (FUTURE) WITH FREEBOARD
LANGLEY CITY BOUNDARY
BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

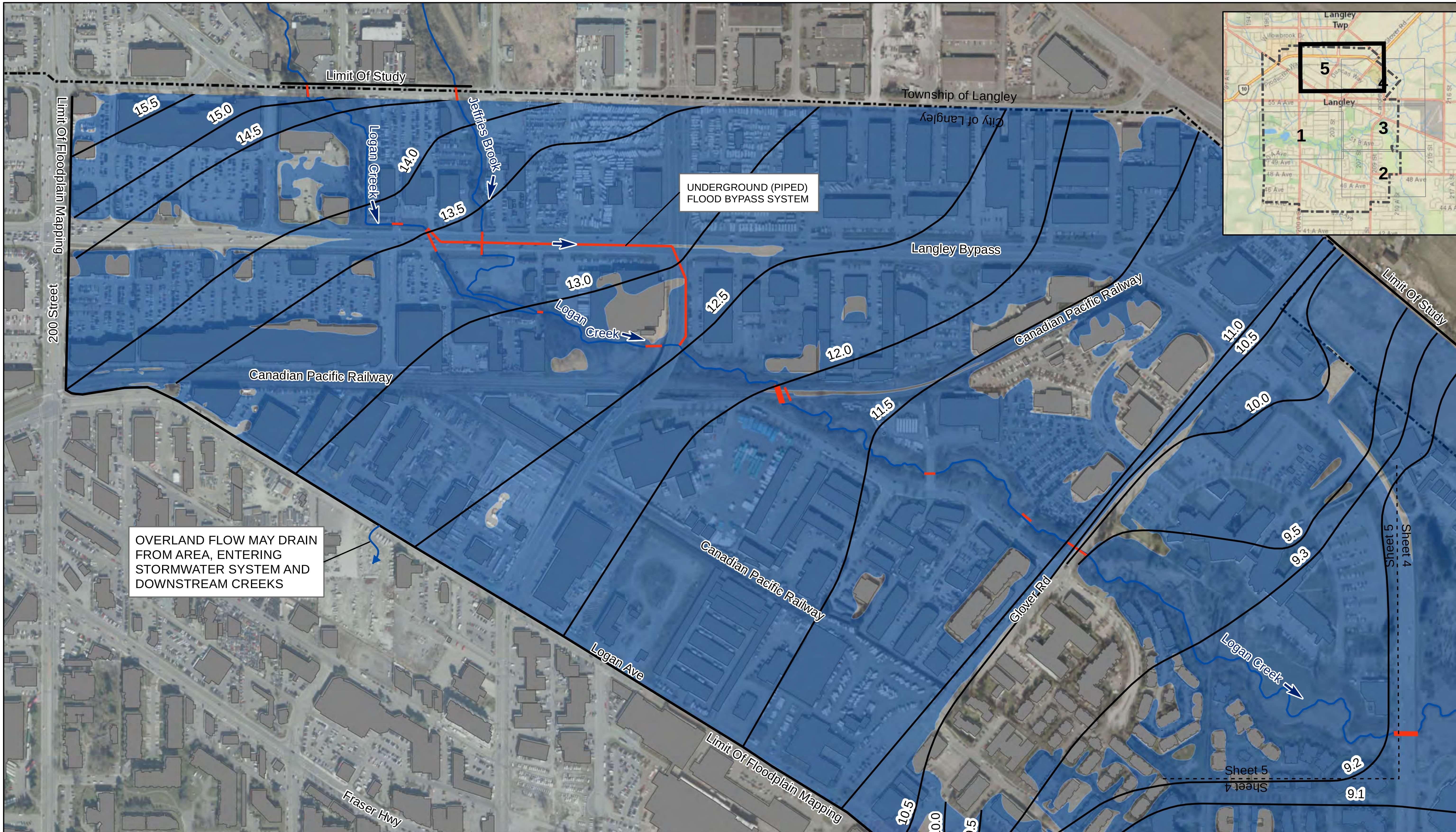
N

Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 | Date: 20-MAY-2022

NICOMEKL RIVER FLOODPLAIN MAP 200 YR FUTURE WITH FREEBOARD PAGE 4 OF 5

FIGURE B.2



Langley City THE PLACE TO BE

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BRIDGES
FLOOD CONSTRUCTION LEVEL, FUTURE CONDITIONS (EL. m)
CULVERTS
STREAMS
200YR (FUTURE) WITH FREEBOARD
LANGLEY CITY BOUNDARY
BUILDINGS

DATA SOURCES AND NOTES: SEE INDEX

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS UTM ZONE 10N; CGVD2013 Units: METRES

Job: 3006708 *Date: 20-MAY-2022*

NICOMEKL RIVER FLOODPLAIN MAP 200 YR FUTURE WITH FREEBOARD PAGE 5 OF 5

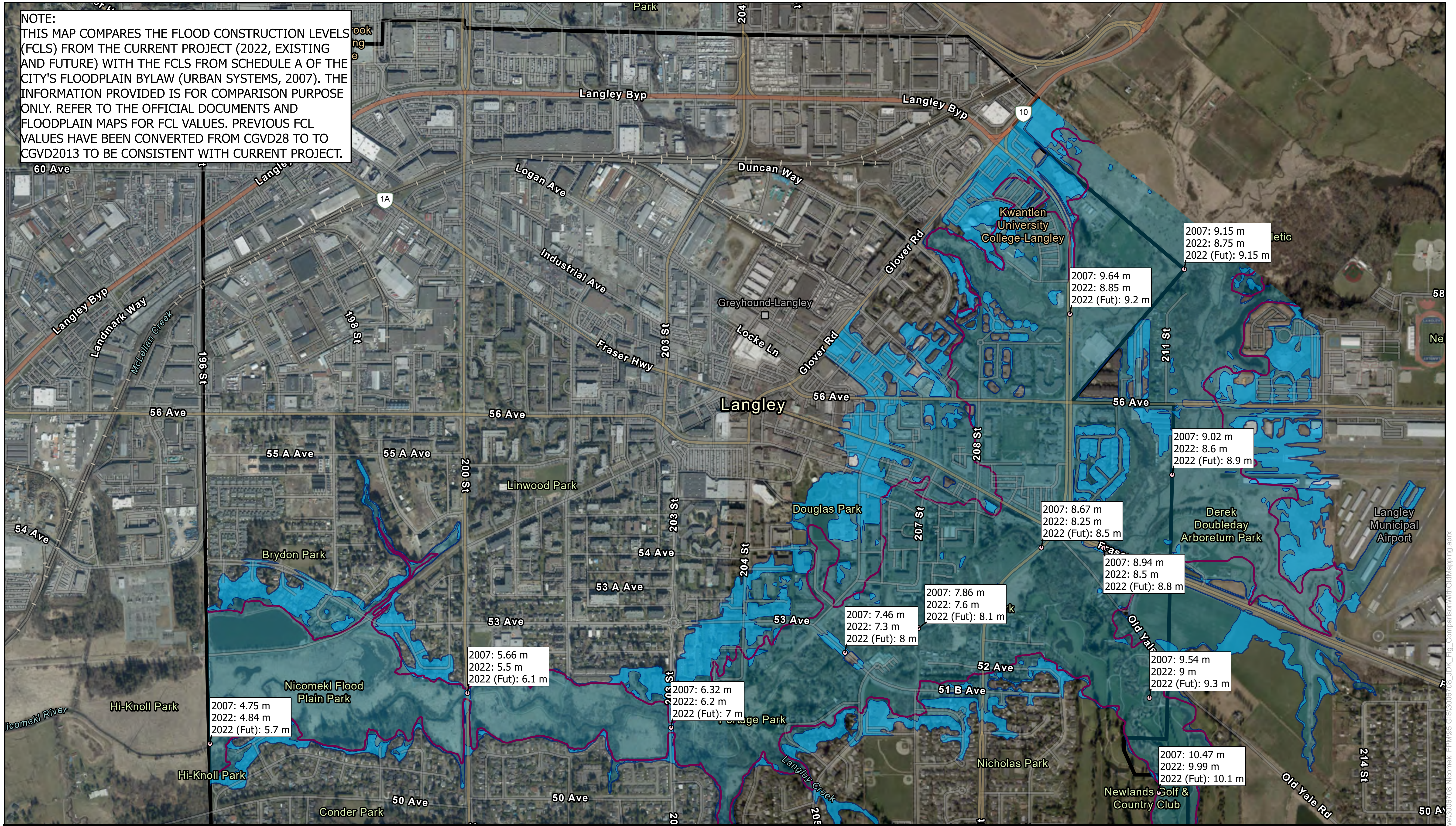
FIGURE B.2

JXD, \\nhaifile-van\Projects\Active\3006708 Nicomekl FPM\95 GIS\3006708_Fig_200yrFutureFloodMap1.mxd

APPENDIX C

COMPARISON TO PREVIOUS FLOODPLAIN MAPPING

NOTE:
THIS MAP COMPARES THE FLOOD CONSTRUCTION LEVELS (FCLS) FROM THE CURRENT PROJECT (2022, EXISTING AND FUTURE) WITH THE FCLS FROM SCHEDULE A OF THE CITY'S FLOODPLAIN BYLAW (URBAN SYSTEMS, 2007). THE INFORMATION PROVIDED IS FOR COMPARISON PURPOSE ONLY. REFER TO THE OFFICIAL DOCUMENTS AND FLOODPLAIN MAPS FOR FCL VALUES. PREVIOUS FCL VALUES HAVE BEEN CONVERTED FROM CGVD28 TO TO CGVD2013 TO BE CONSISTENT WITH CURRENT PROJECT.



	STUDY AREA (CITY OF LANGLEY BORDER)
	PREVIOUS 200-YEAR FLOODPLAIN BOUNDARY, 2007 FLOODPLAIN BYLAW
	CURRENT PROJECT FLOODPLAIN MAPPING EXTENTS, INCLUDING FREEBOARD
	CURRENT PROJECT FLOODPLAIN MAPPING EXTENTS (FUTURE), INCLUDING FREEBOARD

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DATA SOURCES: ESRI WORLD IMAGERY; CITY OF LANGLEY; BC FRESHWATER ATLAS

SCALE - 1:11,000
0 0.25 KM
N

Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES; Vertical Datum: CGVD2013

Job: 3006708 Date: 19-MAY-2022

NICOMEKL RIVER FPM

COMPARISON TO PREVIOUS FLOOD MAPPING

FIGURE C.1

JDK \\manfile-van\Projects\Active\3006708 Nicomekl FPM\05 GIS\3006708_JDK_Fig_ComparisonWithOldMapping.aprx