Okanagan Floodplain Mapping Standards

Prepared for:

Okanagan Basin Water Board (OBWB)

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Photo credits of the 2017 flood, clockwise from top: District of Summerland, District of Lake Country, City of Kelowna (2) - Michael Hintringer.
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OKANAGAN MAINSTEM FLOODPLAIN MAPPING PROJECT

OKANAGAN FLOODPLAIN MAPPING STANDARDS

Prepared for:

Okanagan Basin Water Board
Kelowna, BC

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1 INTRODUCTION

This Okanagan Valley Flood Mapping Standards document has been prepared on behalf of the Okanagan Basin Water Board ("OBWB") and is intended as a standard for reference by local governments and consultants undertaking flood(plain) mapping in the Okanagan Valley. Consistent standards provide for results that can be compared and combined throughout the valley, which streamlines their application to flood emergency preparedness, emergency response, risk assessments, and other valley-wide efforts.

The main components of a flood mapping study are (APEGBC, 2017):

- Data gathering / Field survey
- Digital elevation model (DEM) development
- Hydrologic modelling
- Hydraulic modelling
- Determination of design flood event
- Mapping
- Reporting
- Data delivery

These standards provide details on Okanagan Valley-specific requirements for Mapping and Data Delivery, but do not include information on other components of a flood mapping study.

According to the Engineers and Geoscientists British Columbia (EGBC), "there are three main types of flood maps in use currently…." These are: inundation maps, flood hazard maps, and flood risk maps. Inundation (or flood extent) maps show the extent of flood water. Hazard maps provide "information on the hazards associated with … flood events" and may include depth and hazard rating maps. "Risk maps reflect the potential damages that could occur as a result of … (flooding)." (APEGBC, 2017)[1] A subset of the inundation maps or possibly hazard maps is the official floodplain map, sometimes referred to as the designated floodplain map or flood construction map. The official floodplain map is typically the map used by local authorities to define specific flood hazard bylaws requirements, such as flood construction level and occasionally set back.

These standards are for flood inundation mapping, hazard mapping, and official floodplain maps. This document does not include information on how to prepare flood risk mapping.

Flood maps, such as a community's official floodplain maps, may be presented as conventional maps in paper or digital (e.g., PDF or JPEG) format. Information may also be presented as part of an interactive

[1] APEGBC (Association of Professional Engineers and Geoscientists of British Columbia) changed their name to EGBC (Engineers and Geoscientists of BC) in 2017.

online mapping application, which allows the user to turn flood map layers on and off and zoom in to areas of interest. Some of the information covered in this standards document applies no matter what presentation format is used (e.g., hazard mapping approach; coordinate system and datum; metadata) while other information is specifically relevant to the production of conventional maps (e.g., map scale; map elements; layers and symbology).

1.1 Applicable Flood Mapping Guidelines

This standards document provides information specific to Okanagan Valley mapping requirements, building on existing guidelines where appropriate.

The following guidelines were considered in the development of this document:

- Flood Mapping in BC – Professional Practice Guidelines (APEGBC, 2017).
- Legislated Flood Assessments in a Changing Climate in BC – Professional Practice Guidelines (EGBC, 2018).
- Flood Hazard Area Land Use Management Guidelines (FLNRORD, 2018).
- Coastal Floodplain Mapping – Guidelines and Specifications (MFLNRO, 2011)
- Guidelines for Management of Coastal Flood Hazard Land Use (Ausenco-Sandwell, 2011)
- The Canadian Federal Flood Mapping Guidelines Series (currently under development). There are several documents already published in this series. Of particular relevance to mapping standards are the Geomatics Guidelines for Flood Mapping (Natural Resources Canada, 2019).

2 MAPPING

2.1 Base Mapping

Base map layers include some combination of the following:

- Orthophotos
- Terrain hillshade
- Contours with labelling of index contours
- Terrain spot elevations
- Road lines with labels
- Rail lines with labels
- Property boundaries
- Building footprints
- Administrative boundaries with labels
- Hydrography (i.e. water bodies) with labels and stream flow direction
- Critical infrastructure with labels

Other reference layers may also be relevant, such as municipal Development Permit Areas (DPAs), emergency access, or evacuation routes.

For online interactive maps, most or all of these base map layers can be included, and the user can turn layers on and off as required.

For conventional maps, base map layers required for the Okanagan Valley Flood Mapping Standards are:

- Orthophotos
- Ground elevation contours with labelling of index contours
- Dike lines
- Road labels (but no road lines)
- Rail lines with labels
- Administrative boundaries with labels (e.g., municipal, regional district, and First Nation reserve boundaries)
- Water body names and flow direction arrows

2.2 Flood Mapping

Flood maps include inundation maps and hazard maps. Inundation maps show flood extents for a defined flood event. Inundation maps are a type of hazard map, but they are typically distinguished from other hazard maps which show information such as water depth, velocity, and possibly duration (APEGBC, 2017). These standards provide specifications for inundation mapping, hazard mapping based on depth, and hazard mapping based on depth and velocity.

Flood construction levels (FCLs) are generally used to provide a minimum level (elevation) for future construction of homes and commercial space to reduce risk of flood damage. The FCLs represent the maximum water level associated with the design flood event plus freeboard. Freeboard is a vertical distance added to the calculated design flood level to account for the uncertainty in hydrologic and hydraulic estimates, and local water level variations (i.e. standing waves, superelevation, or flow over minor local obstruction).

Inundation mapping depicts the flooded area as solid colours representing inundation extents without freeboard.

OBWB's official floodplain map is an inundation map for the design flood event that illustrates flood extent without and with freeboard and presents the FCLs as a series of isolines and where applicable spot elevations.

There are several approaches to creating hazard maps. In these standards, hazard maps will primarily be based on water depth and velocity, as described in more detail below.

Depending on the hydraulic modelling approach used for flood mapping, velocity information may not be available. In that case, hazard maps showing only depth may be created. Depth maps show the depth of flooding above ground level throughout the flooded area, based on the maximum water level associated with the design event being mapped. If hazard maps are to be used as official floodplain maps then depth maps include freeboard. OBWB hazard maps are not official floodplain maps, and do not include freeboard.

2.2.1 Flood Inundation Mapping

Flood inundation maps are typically produced in a Geographic Information System (GIS) from flood depths, which are calculated by subtracting ground elevations in the form of a digital elevation model (DEM) from the flood level or imported directly from results of a two-dimensional (2D) hydraulic model.

Inundation Extents: The extent of inundation is shown with bounding polygons with inundated area colour shaded. Inundation extents are based on the water surface elevation results from hydraulic model simulation of the design flood. Inundation extents typically do not include freeboard unless the maps are to be used as official floodplain maps.

Mapping based on one-dimensional (1D) modelling may result in isolated areas, or inundation polygons that are not connected to direct inundation. Filtering is used to remove isolated areas smaller than 100 m^2. Holes in the inundation extent with areas less than 100 m^2 are also removed.

Inundation Extents – Alternative Design Events: Despite official floodplain maps often being based on inundation maps, inundation maps for alternative design events may be desired. Alternative design events could include events with alternative probability (i.e. alternative average recurrence interval (ARI)), alternative climate change scenarios, dike breach scenarios, or potential obstructions. Inundation extents corresponding to these alternative design events may be shown on maps or provided as additional GIS layers.

GIS layers for flood inundation mapping are as follows:

- Flood depth rasters – not shown on maps, but created as part of the mapping process and included with GIS deliverables
- Flood extent polygons – polygons for extents without freeboard, with isolated areas specifically indicated

2.2.2 Flood Depth Mapping

Flood depth is typically determined in GIS by subtracting a DEM from the modelled water level or imported directly from results of a 2D hydraulic model. Depths are represented by data stored in raster (grid) format, with the raster horizontal resolution matching that of the input DEM data. If multiple scenarios are modelled, the maximum depth values from all scenarios may be used for mapping. Data descriptions must indicate whether depth includes freeboard or not.

Flood extents are represented with depth rasters, so extents are not smoothed. As a result, extents may look slightly different from inundation mapping extents, which are generalized and smoothed.

GIS layer for flood depth mapping:

- Flood depth raster

2.2.3 Flood Velocity Mapping

Flood velocity data are typically output from a 2D hydraulic model. Data can be in the format of points, with each point representing the velocity magnitude and direction. If multiple scenarios a modelled, the maximum velocity values from all scenarios may be used for mapping.

GIS layer for flood velocity mapping:

- Flood velocity points

2.2.4 Official Floodplain Map

Official floodplain maps are generally based on inundation maps, but could include components of other maps. They are typically produced in GIS from flood depths, which are calculated by subtracting ground elevations from the flood level or imported directly from results of a 2D hydraulic model.

Design Event: The design event for the official floodplain map is generally based on consideration of the range of potential hazards, such as flow, debris, lake or ocean water level, and waves versus the use of the map. Previous iterations of official floodplain maps included 20-year and 200-year ARI floods. The 200-year event was used for buildings and the 20-year for locating septic systems. Contemporary official floodplain maps in BC are generally based on the 200-year ARI event projected to some future date based on potential impacts of climate change. In some instances where there is record of larger, more extreme floods, the largest flood recorded (referred to as the flood of record) has been used. In addition, where flood levels are expected to be impacted by debris, sediment, or channel or crossing blockage by ice or debris, then such conditions may also be incorporated into the design event. Potential design events are suggested by the qualified professional, but typically agreed upon by the local community based on societal acceptance of risk.

Freeboard: Freeboard is often related to the design event. In BC, the minimum standard freeboard applied to official floodplain maps has been selected based on the greater of 0.3 m over an instantaneous peak flood level and 0.6 m over the daily maximum flood level. Contemporary official floodplain maps in BC have generally used 0.6 m over the instantaneous peak flood level. Freeboard should be suggested by the qualified professional based on confidence in the assessment, expectation for local water level variations, and consequence of exceeding the design event, and then agreed upon by the local community based on societal acceptance of risk.

Inundation Extents: Inundation extents must include freeboard for the official floodplain map. Freeboard can easily be added to 1D model results, if not already included in model output. 2D model results do not include freeboard, so this must be added in GIS as part of post-processing.

Mapping based on 1D modelling may result in isolated areas, or inundation polygons that are not connected to direct inundation. Filtering is used to remove isolated areas smaller than 100 m^2. Holes in the inundation extent with areas less than 100 m^2 are also removed. Isolated areas larger than 100 m^2 are retained for mapping if they are within 40 metres of direct inundation or within 40 metres of other retained polygons. Alternately, isolated areas can be reviewed individually to determine if they should be retained. This processing is conducted following the addition of freeboard.

Different colours may be used to differentiate the additional inundation extent resulting from addition of freeboard versus extents that do not include freeboard. Alternatively, different colours may be used to differentiate floodway from flood fringe. Floodway is the area of the flood path that conveys the majority of flow, and is sometimes defined by velocity (> 1m/s), depth (> 1m), or effect of encroachment (water level increases by 0.3 m or more if flow confined beyond this point). Flood fringe is the inundated area that does not substantially contribute to flow conveyance. Typically the inundated flood fringe area has low velocity (< 1m/s) and is shallow (<1 m) or isolated.

The OBWB official floodplain maps use different colours to differentiate between with and without freeboard.

Flood Construction Levels: On river floodplains, FCLs are generally shown on the map as isolines, perpendicular to the flow. The FCL may be a single value for a lake or other large area where a similar flood level is expected. Values are shown in metres and include freeboard. Depending on the slope and map scale, FCL isolines are typically shown every metre to every 0.1 metre. The upstream point or face of a structure or area is the location used to determine the FCL for a particular structure or area. Where this is located between two FCL isolines, the FCL can be determined either as the FCL represented by the next upstream isoline or by linearly interpolating between the surrounding FCL isolines.

Wave Effect Flood Construction Zone and Inundation Flood Construction Zone:

Flooding from the lakes is identified in the mapping through the characterization of two hazards – lake inundation and wave effects. Lake inundation is developed through modelling of the flood elevation for each lake, called the 'still-water' level. On top of this still-water level, wind-setup (increase in water level due to the effect of the wind pushing the water in a direction) and freeboard are added. This elevation is projected on the DEM surface to identify the flood extents. The FCLs for the lake inundation zones are comprised of the modelled still-water level, wind setup, and freeboard.

Along the shorelines of lakes, additional flooding is expected due to the effects of waves. To show this hazard, a wave effect zone (area which may be impacted by waves) is developed through the following steps. A generalized shoreline (where the lake edge typically meets the land) is used as the lakeward edge of the wave effect zone. To characterize the waves, a wave model was run with a design event to determine wave heights and calculate runup. A wave breaking line was determined where wave heights are equal to 0.3 meters[2]. This wave height line was then offset 40 metres inland to define the landward edge of the wave effect zone in flat areas that had extensive inland flooding from the shoreline. For steep shorelines, the wave effects zone is narrower and limited to expected area of wave runup. The line was subsequently smoothed and reviewed to ensure appropriate representation of likely wave effects on the shoreline. That said, due to the size and scale of the project this was not performed for a property by property level analysis.

To determine the height of the FCL for lakeshore zones, estimated wave runup was added to the lake inundation FCL elevation. See FCL components in Figure 2-1.

[2] In some areas, the accuracy of the wave breaking line was compromised due to poor bathymetry resolution for the lakes and the resolution of the wave model and conservative estimates of wave breaking zones were estimated from the shoreline DEM. Individual property level assessments will benefit from improved bathymetry data at the property sites.

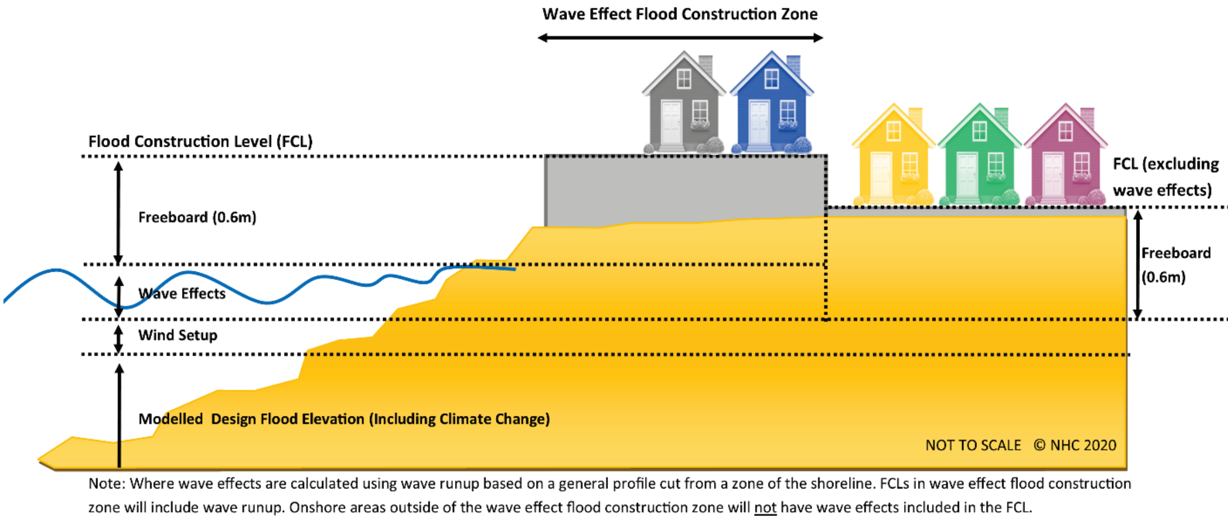


Figure 2-1 Flood construction level schematic for lakes.

GIS layers for flood inundation mapping are as follows:

- Flood depth rasters – not shown on maps, but created as part of the mapping process and included with GIS deliverables
- Flood extent polygons – polygons for extents with and without freeboard, with isolated areas specifically indicated
- FCL isolines and areas, attributed with FCL values

2.3 Map Layout

Some of the information in this section applies to the production of conventional maps in paper or digital (e.g., PDF or JPEG) format, but may not apply to online interactive maps.

2.3.1 Detailed Maps

Detailed flood maps are required. Required scale for flood maps is 1:5,000.

The detailed map series is to be oriented north-up. The map sheet layout will be optimized to cover the study area, and does not need to follow an existing map grid (e.g., does not need to follow a British Columbia Geographic System map grid).

A 1:5,000 scale map sheet layout for the entire Okanagan Valley floodplain is shown in Appendix A. This is the layout for the OBWB Okanagan Mainstem Flood Mapping Project, and is based on a 24” x 36” page size. Other flood studies may use a different map sheet layout and page size.

2.3.2 Index Map

An index map is required when flood mapping covers multiple sheets. The index map shows the general location of the study area, the detailed map sheet layout, and the map notes (described below).

If there is no index map, the detailed map sheet will include a general location map and the map notes.

2.3.3 Map Elements

Maps must include the following elements:

- Flood extents, as described above. Design flood parameters, including ARI and whether or not freeboard is included, must be clearly stated on the maps.
- Study limit boundaries.
- Base map layers, as described above.
- Title block, legend, north arrow, and scale.
- Description of coordinate system, horizontal datum, and vertical datum.
- Map notes.

All benchmarks and monuments are to be shown on maps or described in map notes or survey report text.

Maps must include detailed notes. Sample notes are provided in Appendix B. Notes should also be provided for digital data layers provided separately from conventional maps. These notes will differ from the map notes if the digital data layers do not match the conventional map layers. Sample digital data notes are also provided in Appendix B.

2.3.4 Map Templates

Templates for the Index and Detailed maps are to include the map elements listed above. Examples from the OBWB Okanagan Mainstem Flood Mapping Project are included in Appendix A. Other flood studies may use different templates as long as the key elements are included.

2.4 Accuracy

Flood maps are to be based on topographic mapping that meets federal and provincial mapping guidelines. Table 2-1, extracted from the federal guidelines, provides recommended LiDAR accuracies for flood mapping.

- High Flood Risk Category: All urban areas and rural areas that are protected by diking;
- Medium Flood Risk Category: All other rural areas that include settlements and agricultural lands;

- Low Flood Risk Category: Sparsely populated areas.

Table 2-1 Recommended approximate LiDAR data accuracy and density for flood mapping applications[3].

	Flood Risk Category		
	High	Medium	Low
Vertical Accuracy (open, level, hard surfaces			
Non-vegetated Vertical Accuracy (NVA) – Vertical Root Mean Square Error ($RMSE_z$)	≤ 5.0 – 7.5 cm	7.5 – 10.0 cm	15 cm
Non-vegetated Vertical Accuracy (NVA) – 95% confidence level (≈ 1.96 * $RMSE_z$)	≤ ±10 – 15 cm	±15 – 20 cm	±30 cm
Horizontal Accuracy (open, level, hard surfaces)			
Horizontal Root Mean Square Error ($RMSE_r$)	≤ 11 – 15 cm	30 – 45 cm	60 cm
Horizontal Accuracy – 95% confidence level (≈ 1.7308 * $RMSE_r$)	≤ ±20 – 25 cm	±50 – 75 cm	±100 cm
Data Density			
Aggregate nominal point density (ANPD) for DSM (first return) and DEM (last return)	≥ 4 – 10 pts/m^2	2 – 4 pts/m^2	1 – 2 pts/m^2

Raster DEMs should have a minimum horizontal resolution of 1 m.

2.5 Coordinate System and Datum

Coordinate system, horizontal datum, and vertical datum must be documented on maps and in reporting.

The following will be used for Okanagan Valley flood mapping:

- Coordinate system: Universal Transverse Mercator (UTM) Zone 11. Coordinates in metres.
- Horizontal datum: NAD 83 (CSRS).
- Vertical datum: Geodetic – CGVD2013.

[3] Table B2, Appendix 2, Federal Airborne LiDAR Data Acquisition Guidelines (Natural Resources Canada and Public Safety Canada, 2018)

The horizontal datum for BC is North American Datum of 1983 (NAD83). For the most accurate positioning, the Canadian Spatial Reference System (CSRS) realization of NAD 83 is used (NAD83(CSRS)).

Canadian Geodetic Vertical Datum 2013 (CGVD2013) is a new vertical datum for Canada, gradually being adopted across the country.[4] The Province of BC is developing a transition plan and tools to support migration to CGVD2013.[5] CGVD2013 will replace the older CGVD28 HTv2.0_2002 vertical datum. Conversion between the two datums can be done with spot heights inputted into Natural Resources Canada's (NRCan's) online tool GPS-H[6], or through development of an in-house conversion grid.

Changes in the elevations between the two vertical datums for representative locations in the Okanagan Valley are shown below in Figure 2-2 and Table 2-2. Values were calculated using the NRCan GPS-H tool. Differences range from 19.0 cm to 33.2 cm.

[4] Natural Resources Canada (2017). Height Reference System Modernization, https://www.nrcan.gc.ca/earth-sciences/geomatics/geodetic-reference-systems/9054

[5] Government of British Columbia. Vertical (Height) Reference System, https://www2.gov.bc.ca/gov/content/data/geographic-data-services/georeferencing/vertical-reference-system

[6] Natural Resources Canada (2019). GPS-H, http://webapp.geod.nrcan.gc.ca/geod/tools-outils/gpsh.php?locale=en

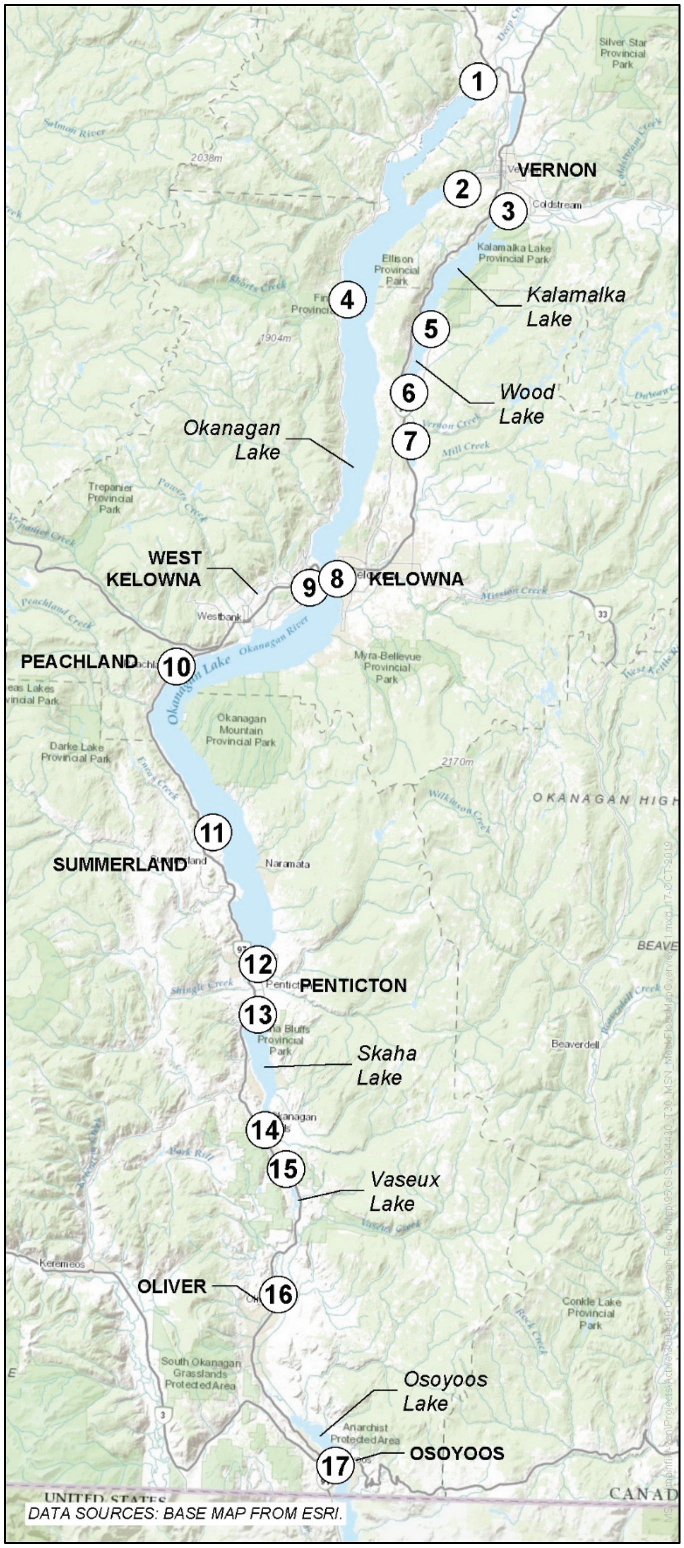


Figure 2-2 Representative points for vertical datum comparison.

Table 2-2 Changes in elevation between vertical datums at representative locations[1].

ID	Location	Latitude	Longitude	Elevation (m, CGVD28 HTv2.0)	Elevation (m, CGVD2013)	Difference in Elevation (m)[2]
1	north end Okanagan Lake	50° 20' 57" N	119° 18' 43" W	343.229	343.561	0.332
2	Vernon Regional Airport	50° 14' 47" N	119° 19' 49" W	345.859	346.157	0.298
3	north end Kalamalka Lake (Coldstream)	50° 13' 35" N	119° 15' 41" W	393.259	393.551	0.292
4	Fintry, west shore Okanagan Lake	50° 8' 16" N	119° 29' 40" W	344.973	345.279	0.306
5	Oyama, south end Kalamalka Lake	50° 6' 43" N	119° 22' 14" W	412.775	413.046	0.271
6	south end Wood Lake	50° 3' 3" N	119° 23' 57" W	394.027	394.295	0.269
7	north end Ellison Lake (Duck Lake Reserve)	50° 0' 18" N	119° 23' 40" W	427.924	428.188	0.264
8	Kelowna, east shore Okanagan Lake	49° 52' 18" N	119° 29' 45" W	343.478	343.722	0.244
9	West Kelowna, west shore Okanagan Lake	49° 51' 45" N	119° 32' 12" W	369.042	369.259	0.217
10	Peachland, west shore Okanagan Lake	49° 46' 58" N	119° 43' 38" W	344.470	344.687	0.217
11	Crescent Beach, west shore Okanagan Lake (Summerland)	49° 37' 35" N	119° 39' 55" W	344.533	344.723	0.190
12	Penticton, south end Okanagan Lake	49° 30' 11" N	119° 35' 37" W	344.275	344.486	0.211
13	Penticton, north end Skaha Lake	49° 27' 17" N	119° 35' 27" W	339.125	339.365	0.240
14	south end Skaha Lake	49° 20' 43" N	119° 34' 29" W	343.872	344.150	0.278
15	north end Vaseux Lake	49° 18' 32" N	119° 32' 31" W	333.043	333.322	0.279
16	Oliver	49° 11' 23" N	119° 32' 48" W	296.284	296.581	0.297
17	Osoyoos	49° 1' 42" N	119° 27' 22" W	280.231	280.468	0.238

[1] Data in this table is provided as an example only. These data points should not be used to transform elevations. Refer to conversion tools such as NRCan's GPS-H tool.
[2] Changes are from CGVD28 HTv2.0_2002 to CGDV2013.

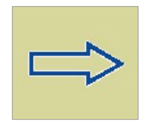
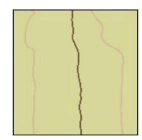
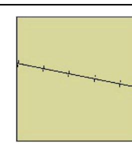
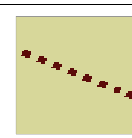
2.6 Layers and Symbology

Symbology specifications for flood maps are provided in tables on the following pages:

- Table 2-3 Base map layers
- Table 2-4 Inundation map layers
- Table 2-5 Depth categories and symbols
- Table 2-6 Velocity categories and symbols

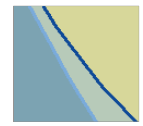
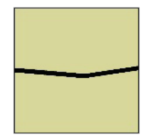
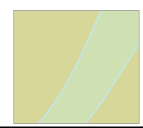
These specifications refer primarily to conventional maps. This information does not necessarily apply when flood map layers are being presented as part of an online interactive map.

Table 2-3 Base map layers[7].

	Style	Colour (RGB)	Example
Orthophotos			
Transparency	30% transparent	NA	NA
Flow Direction			
Symbol	ESRI Cartography Latin-1 Supplement Unicode 172, 26 pt, 0.5 pt halo (blue)	0/77/168 (blue)	
Symbol (halo)	ESRI Cartography Latin-1 Supplement Unicode 172, 26 pt, 1.3 pt halo (white)	255/255/255 (white)	
Label	Arial, 12 pt, bold, italic, 1 pt halo (white)	0/77/168 (blue)	
Major Contours (e.g., 5 m interval)			
Line	Solid, 1 pt	128/110/82 (dark brown)	
Label	Arial, 6 pt, bold, 1 pt halo (white)	0/0/0 (black)	
Minor Contour (e.g., 1 m interval)			
Line	Solid, 1 pt	215/194/158 (light brown)	
Label	NA		
Rail Lines			
Line	Solid, 0.5 pt	0/0/0 (black)	
Line (hash)	Solid 0.4 pt, length – 4.0 pt long, angle - 90°, spacing – 7.0 pt	0/0/0 (black)	
Dikes			
Line	Dashed, 3 pt, spacing – 4 pt	115/0/0 (dark brown)	

[7] Suggested symbology is adapted from internal standards used by Alberta Environment and Parks for inundation mapping and federal guidelines (Natural Resources Canada, 2019).

Table 2-4 Inundation map layers[8].

	Style	Colour (RGB)	Example
Inundation Extent Polygons – design extent without freeboard			
Line	Solid, 2 pt	115/178/255 (light blue)	
Fill	Solid, 70% transparent	0/77/168 (dark blue)	
Inundation Extent Polygons – design extent with freeboard			
Line	Solid, 2 pt	0/77/168 (dark blue)	
Fill	Solid, 70% transparent	115/178/255 (light blue)	
Flood Construction Level Isolines			
Line	Solid, 1.5 pt	0/0/0 (black)	
Shoreline Flood Construction Level Zone			
Line	Solid, 2 pt	190/255/232 (light green)	
Fill	Solid, 70% transparent	190/255/232 (light green)	

[8] Suggested symbology is adapted from internal standards used by Alberta Environment and Parks for inundation mapping , examples such as Maple Ridge Alouette Rivers floodplain maps (NHC, 2016) and City of Vancouver coastal flood maps (NHC, 2014), and federal guidelines (Natural Resources Canada, 2019).

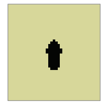
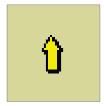
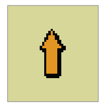
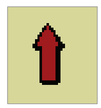
Table 2-5 Depth categories and symbols[9].

Depth (m)	Description	Colour (RGB)	Example
< 0.1	Most buildings expected to be dry; underground infrastructure and basements may be flooded.	Yellow (255/255/0)	
0.1 – 0.3	Water may enter buildings at grade, but most expected to be dry; walking in moving water or driving is potentially dangerous; underground infrastructure and basements may be flooded.	Green (8/255/0)	
0.3 – 0.5	Water may enter ground floor of buildings; walking in moving or still water or driving is dangerous; underground infrastructure and basements may be flooded.	Light Blue (115/178/255)	
0.5 – 1.0	Water on ground floor; underground infrastructure and basements flooded; electricity failed; vehicles are commonly carried off roadways.	Medium Blue (0/112/255)	
1.0 – 2.0	Ground floor flooded; residents and workers evacuate.	Dark Blue (0/38/115)	
> 2.0	First floor and often higher levels covered by water; residents and workers evacuate.	Purple (76/0/115)	

Depths are mapped from the depth raster, using 30% transparency so that the underlying orthophoto is visible.

[9] Categories and colours adapted from (EXCIMAP, 2007) and (Flood Control Division, River Bureau, Ministry of Land, Infrastructure and Transport (MLIT), 2005).

Table 2-6 Velocity categories and symbols.

Velocity (m/s)	Colour (RGB)	Example
< 0.25	Black (0/0/0)	
0.25 – 0.50	Yellow (255/255/0)	
0.50 – 1.00	Orange (230/152/0)	
> 1.00	Dark Red (168/0/0)	

Velocity points can be mapped as arrows based on magnitude and direction. One method for doing this in ArcMap is outlined below:

- Ensure that the point layer has attributes for velocity “magnitude” and “direction”
  - “Geographic” angles in ArcMap have east = 0 degrees and north = 90 degrees
- Go to Layer Properties – Symbology – Quantities – Graduate Symbols
- Specify Value = magnitude
- Template = an arrow symbol, for example Template – Edit Symbol
  - Type = Character Marker Symbol
  - Font = ESRI Cartography
  - Subset = Latin-1 Supplement
  - Unicode = 173
  - Color = choose any colour
  - Mask – Halo = 1 pt (black)
  - Size = 20 (e.g.)
- Advanced – Rotation
  - = direction field
  - Specify Geographic (if this matches the data)
- Classify
  - Classes = 4
  - Set categories as noted in Table 2.7
- Symbol Size
  - Specify a range, e.g., 10 to 24
- Colour – select colour for each arrow symbol as noted in Table 2-6

3 DATA DELIVERY

3.1 Digital Map PDF Formats

All maps are to be supplied in PDF format. High-resolution PDFs (e.g., 300 dpi) are required for printing maps and low-resolution PDFs are required for inclusion in electronic documents.

Recommended settings for high-resolution PDFs exported from the ArcMap Desktop Export Map dialog are as follows:

- General
    - 300 dpi
    - Output Image Quality (Resample Ratio): Best (1:1)
- Format
    - Destination Colorspace: RGB
    - Compress Vector Graphics: TRUE
    - Image Compression: Adapative
    - JPEG Quality: 80%
    - Picture Symbol: Rasterize layers with bitmap markers/fills
    - Convert Marker Symbols to Polygons: FALSE
    - Embed All Document Fonts: TRUE
- Advanced
    - Layers: either None or Export PDF Layers Only, depending on user preferences
    - Export Map Georeference Information: TRUE

Similar settings are to be used for PDFs exported from other mapping software. High resolution maps can be printed from these PDFs or directly from the mapping software.

Lower resolution PDFs can also be created using Adobe Acrobat (Standard or Professional), via File – Save As Other – Reduced Size PDF (default settings are acceptable).

3.2 Spatial Data File Formats

For work completed on behalf of OBWB, deliverables must include mapping data files. Relevant files are listed in section 2.2, above.

The preferred format is GIS data in Esri file geodatabase or shapefile format, but other GIS and CAD formats are acceptable if accompanied by detailed documentation. All file and layer names are to be descriptive in nature and non-cryptic to be easily understood. All data delivered include descriptions of file formats and versions.

3.3 Metadata

All data must be clearly documented in accompanying metadata. Metadata should include:

- Data layer names and descriptions;
- Date of data creation;
- Time period the data is relevant for;
- Contact person and organization responsible for creation and/or maintenance of the data;
- Data use and access limitations and constraints;
- Horizontal and vertical reference system (coordinate system and datums); and
- Information about source data used in creating the data.

Some of this information is found in map notes (see section 2.3.3).

4 REFERENCES

APEGBC (2017). *Flood Mapping in BC, APEGBC Professional Practice Guidelines, V1.0*. The Association of Professional Engineers and Geoscientists of British Columbia, Burnaby, BC. 54 pp.

Ausenco-Sandwell (2011). *Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use: Guidelines for Management of Coastal Flood Hazard Land Use*. Report prepared by Ausenco-Sandwell for BC Ministry of Environment. 45 pp.

EGBC (2018). *Legislated Flood Assessments in a Changing Climate in BC, Version 2.1*. Engineers & Geoscientists British Columbia, Burnaby, BC. 192 pp.

EXCIMAP (2007). Flood mapping: a core component of flood risk management - Atlas of Flood Maps: Examples from 19 Countries, USA and Japan. European Commission - Environment.

FLNRORD (2018). *Flood Hazard Area Land Use Management Guidelines, originally Ministry of Water, Land and Air Protection, Province of British Columbia, May 2004, amended January 2018 by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD)*. Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Flood Control Division, River Bureau, Ministry of Land, Infrastructure and Transport (MLIT) (2005). *Flood Hazard Mapping Manual in Japan*. Ministry of Land, Infrastructure and Transport. 87 pp.

MFLNRO (2011). *Coastal Floodplain Mapping - Guidelines and Specifications*. Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). 91 pp.

Natural Resources Canada (2019). *Federal Geomatics Guidelines for Flood Mapping, Version 1.0* (General Information Product 114e). Government of Canada. 59 pp.

Natural Resources Canada, and Public Safety Canada (2018). *Federal airborne LiDAR data acquisition guideline, Version 2.0* (General Information Product 117e). Government of Canada. 64 pp.

NHC (2014). *City of Vancouver Coastal Flood Risk Assessment* (300227). Report prepared by Northwest Hydraulic Consultants for City of Vancouver. 143 pp.

NHC (2016). *North Alouette and South Alouette Rivers Additional Floodplain Analysis: Phase 2 - Technical Investigations Completion Report*. Report prepared by NHC for the City of Maple Ridge. 46 pp.

5 APPENDIX A – SAMPLE MAPS

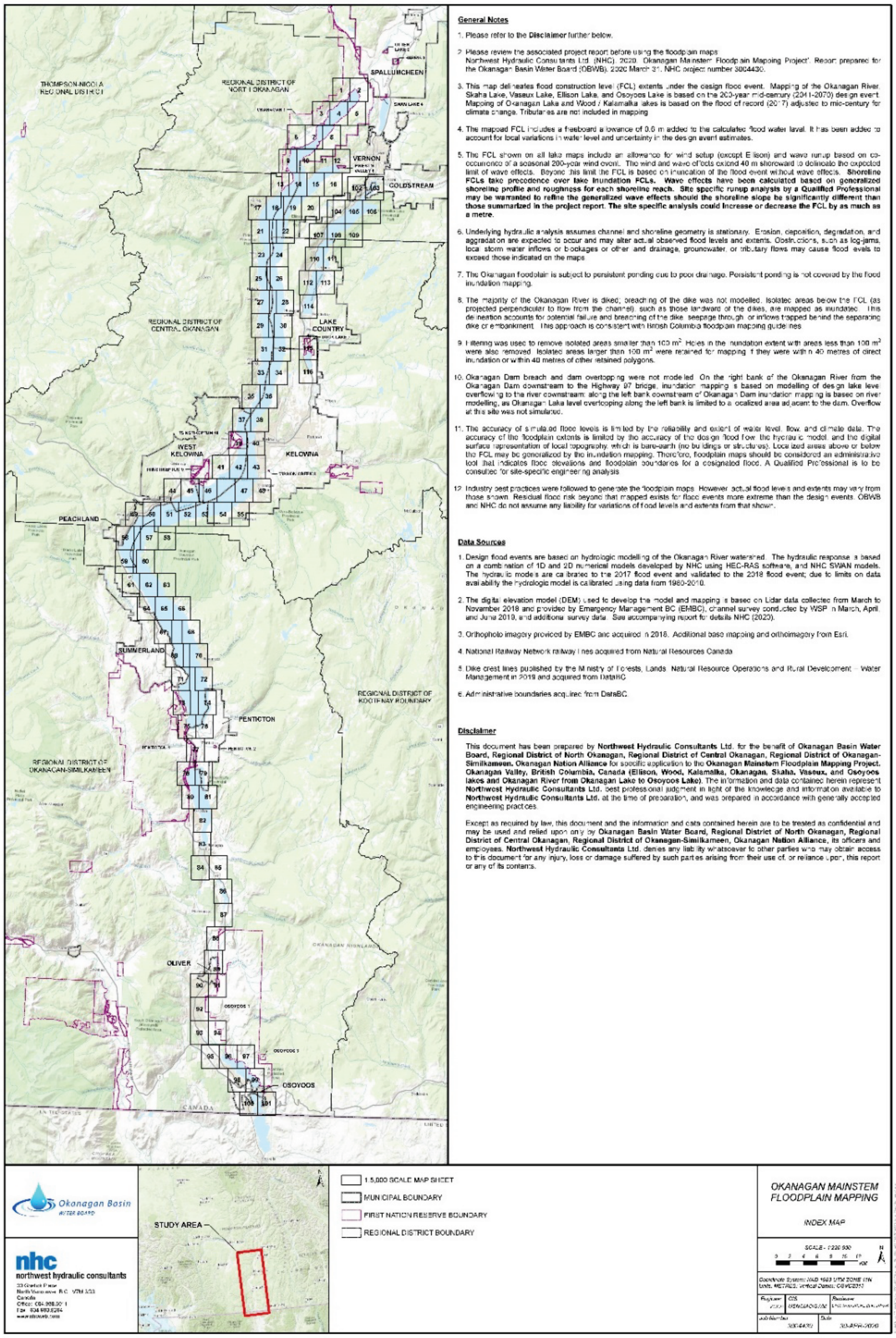


Figure 5-1 Index map for Okanagan mainstem flood mapping (24" x 36" page size)

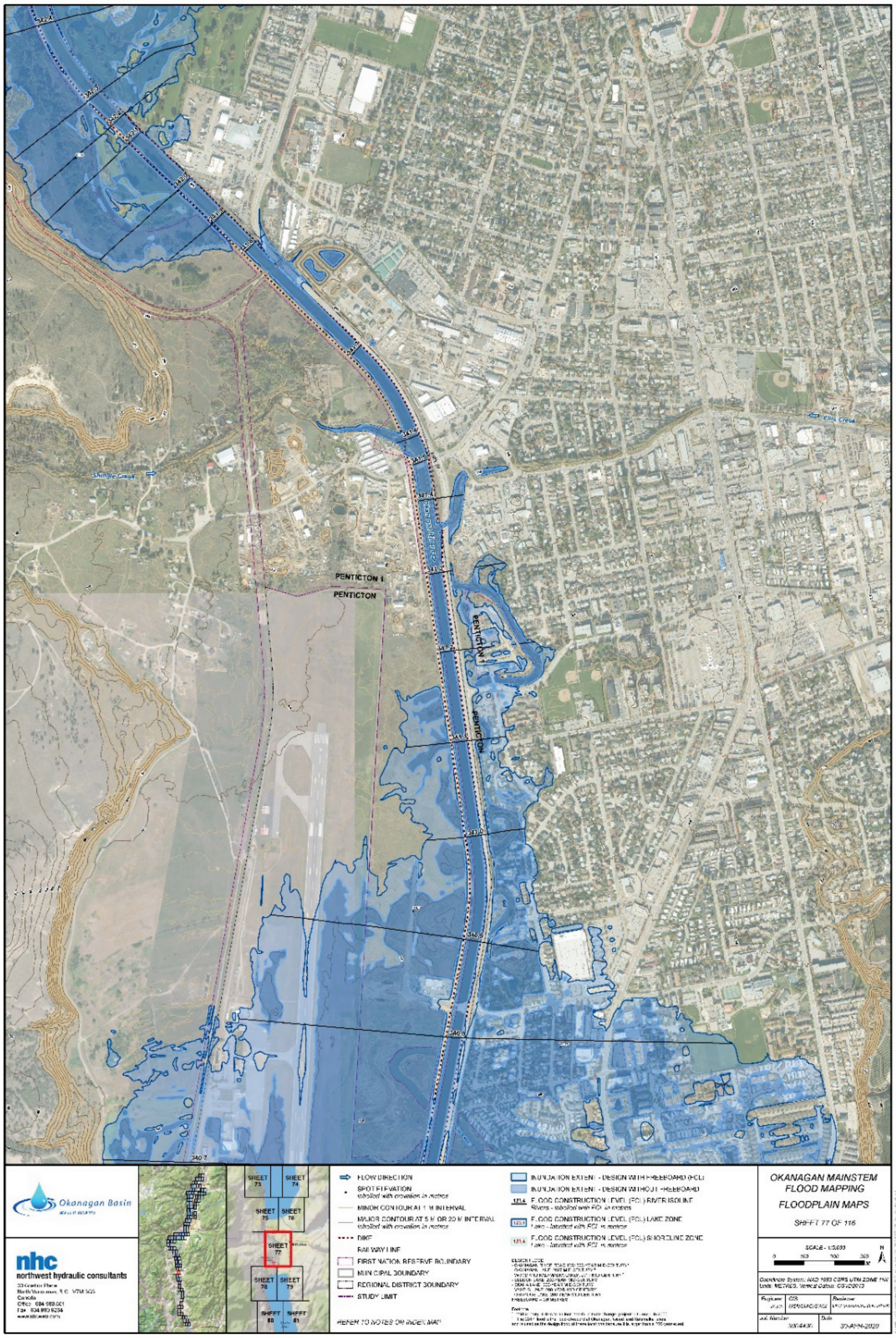


Figure 5-2 Flood map template for Okanagan mainstem flood mapping (24" x 36" page size)

6 APPENDIX B – SAMPLE MAP AND DATA NOTES

Table 6-1 Map notes.

Map Notes
General Notes

1. Please refer to the **Disclaimer** further below.
2. Please review the associated project report before using the floodplain maps: Northwest Hydraulic Consultants Ltd. (NHC). 2020. 'Okanagan Mainstem Floodplain Mapping Project'. Report prepared for the Okanagan Basin Water Board (OBWB). 2020 March 31. NHC project number 3004430.
3. This map delineates flood construction level (FCL) extents under the design flood event. Mapping of the Okanagan River, Skaha Lake, Vaseux Lake, Ellison Lake, and Osoyoos Lake is based on the 200-year mid-century (2041-2070) design event. Mapping of Okanagan Lake and Wood / Kalamalka lakes is based on the flood of record (2017) adjusted to mid-century for climate change. Tributaries are not included in mapping.
4. The mapped FCL includes a freeboard allowance of 0.6 m added to the calculated flood water level. It has been added to account for local variations in water level and uncertainty in the design event estimates.
5. The FCL shown on all lake maps include an allowance for wind setup (except Ellison) and wave runup based on co-occurrence of a seasonal 200-year wind event. The wind and wave effects extend 40 m shoreward to delineate the expected limit of wave effects. Beyond this limit the FCL is based on inundation of the flood event without wave effects. **Shoreline FCLs take precedence over lake inundation FCLs. Wave effects have been calculated based on generalized shoreline profile and roughness for each shoreline reach. Site specific runup analysis by a Qualified Professional may be warranted to refine the generalized wave effects should the shoreline slope be significantly different than those summarized in the project report. The site specific analysis could increase or decrease the FCL by as much as a metre.**
6. Underlying hydraulic analysis assumes channel and shoreline geometry is stationary. Erosion, deposition, degradation, and aggradation are expected to occur and may alter actual observed flood levels and extents. Obstructions, such as log-jams, local storm water inflows or blockages or other land drainage, groundwater, or tributary flows may cause flood levels to exceed those indicated on the maps.
7. The Okanagan floodplain is subject to persistent ponding due to poor drainage. Persistent ponding is not covered by the flood inundation mapping.
8. The majority of the Okanagan River is diked; breaching of the dike was not modelled. Isolated areas below the FCL (as projected perpendicular to flow from the channel), such as those landward of the dikes, are mapped as inundated. This delineation accounts for potential failure and breaching of the dike, seepage

Map Notes

through, or inflows trapped behind the separating dike or embankment. This approach is consistent with British Columbia floodplain mapping guidelines.

9. Filtering was used to remove isolated areas smaller than 100 m^2. Holes in the inundation extent with areas less than 100 m^2 were also removed. Isolated areas larger than 100 m^2 were retained for mapping if they were within 40 metres of direct inundation or within 40 metres of other retained polygons.
10. Okanagan Dam breach and dam overtopping were not modelled. On the right bank of the Okanagan River from the Okanagan Dam downstream to the Highway 97 bridge, inundation mapping is based on modelling of design lake level overflowing to the river downstream; along the left bank downstream of Okanagan Dam inundation mapping is based on river modelling, as Okanagan Lake level overtopping along the left bank is limited to a localized area adjacent to the dam. Overflow at this site was not simulated.
11. The accuracy of simulated flood levels is limited by the reliability and extent of water level, flow, and climate data. The accuracy of the floodplain extents is limited by the accuracy of the design flood flow, the hydraulic model, and the digital surface representation of local topography, which is bare-earth (no buildings or structures). Localized areas above or below the FCL may be generalized by the inundation mapping. Therefore, floodplain maps should be considered an administrative tool that indicates flood elevations and floodplain boundaries for a designated flood. A Qualified Professional is to be consulted for site-specific engineering analysis.
12. Industry best practices were followed to generate the floodplain maps. However, actual flood levels and extents may vary from those shown. Residual flood risk beyond that mapped exists for flood events more extreme than the design events. OBWB and NHC do not assume any liability for variations of flood levels and extents from that shown.

Data Sources:

1. Design flood events are based on hydrologic modelling of the Okanagan River watershed. The hydraulic response is based on a combination of 1D and 2D numerical models developed by NHC using HEC-RAS software, and NHC SWAN models. The hydraulic models are calibrated to the 2017 flood event and validated to the 2018 flood event; due to limits on data availability the hydrologic model is calibrated using data from 1980-2010.
2. The digital elevation model (DEM) used to develop the model and mapping is based on Lidar data collected from March to November 2018 and provided by Emergency Management BC (EMBC), channel survey conducted by WSP in March, April, and June 2019, and additional survey data. See accompanying report for details NHC (2020).
3. Orthophoto imagery provided by EMBC and acquired in 2018. Additional base mapping and orthoimagery from Esri.

Map Notes
4. National Railway Network railway lines acquired from Natural Resources Canada. 5. Dike crest lines published by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development – Water Management in 2019 and acquired from DataBC. 6. Administrative boundaries acquired from DataBC.
Disclaimer This document has been prepared by **Northwest Hydraulic Consultants Ltd.** for the benefit of **Okanagan Basin Water Board, Regional District of North Okanagan, Regional District of Central Okanagan, Regional District of Okanagan-Similkameen, Okanagan Nation Alliance** for specific application to the **Okanagan Mainstem Floodplain Mapping Project, Okanagan Valley, British Columbia, Canada (Ellison, Wood, Kalamalka, Okanagan, Skaha, Vaseux, and Osoyoos lakes and Okanagan River from Okanagan Lake to Osoyoos Lake).** The information and data contained herein represent **Northwest Hydraulic Consultants Ltd.** best professional judgment in light of the knowledge and information available to **Northwest Hydraulic Consultants Ltd.** at the time of preparation, and was prepared in accordance with generally accepted engineering practices. Except as required by law, this document and the information and data contained herein are to be treated as confidential and may be used and relied upon only by **Okanagan Basin Water Board, Regional District of North Okanagan, Regional District of Central Okanagan, Regional District of Okanagan-Similkameen, Okanagan Nation Alliance**, its officers and employees. **Northwest Hydraulic Consultants Ltd.** denies any liability whatsoever to other parties who may obtain access to this document for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

Table 6-2 Digital data notes.

Map Notes
General Notes 1. Please refer to the **Disclaimer** further below. 2. Please review the associated project report before using the floodplain maps: Northwest Hydraulic Consultants Ltd. (NHC). 2020. ‘Okanagan Mainstem Floodplain Mapping Project’. Report prepared for the Okanagan Basin Water Board (OBWB). 2020 March 31. NHC project number 3004430. 3. These floodplain mapping layers delineate flood inundation extents under the specific flood events. Tributaries are not included in mapping.

Map Notes

4. The mapped inundation is based on the calculated water level. Freeboard, wind effects, and wave effects have been added to the calculated water level where noted.
5. Where noted, a freeboard allowance of 0.6 m has been added to the calculated flood water level. It has been added to account for local variations in water level and uncertainty in the underlying data and modelling.
6. Where noted, the FCL included in lake mapping layers includes an allowance for wind setup and wave runup based on co-occurrence of the seasonal 200-year wind event. The wind and wave effects extend 40 m shoreward to delineate the expected limit of wave effects. Beyond this limit the FCL is based on inundation of the flood event without wave effects. Wave effects have been calculated based on generalized shoreline profile and roughness for each shoreline reach. Site specific runup analysis by a Qualified Professional may be warranted to refine the generalized wave effects shown, which could increase or decrease the FCL by as much as a metre.
7. Underlying hydraulic analysis assumes channel and shoreline geometry is stationary. Erosion, deposition, degradation, and aggradation are expected to occur and may alter actual observed flood levels and extents. Obstructions, such as log-jams, local storm water inflows or other land drainage, groundwater, or tributary flows may cause flood levels to exceed those indicated on the maps.
8. The Okanagan floodplain is subject to persistent ponding due to poor drainage. Persistent ponding is not covered by the flood inundation mapping.
9. For flood level maps (water level and inundation extents):
    a. Layers for each flood scenario describe inundation extents, water surface elevations, and depths.
    b. The calculated water level has been extended perpendicular to flow across the floodplain; thus mapping inundation of isolated areas regardless of likelihood of inundation; whether it be from dike failure, seepage, or local inflows. Distant isolated areas may be conservatively mapped as inundated. Site specific judgement by a Qualified Professional is required to determine validity of isolated inundation.
    c. Filtering was used to remove isolated areas smaller than 100 m^2. Holes in the inundation extent with areas less than 100 m^2 were also removed. Isolated areas larger than 100 m^2 are included in GIS data layers and are shown on maps if they are within 40 metres of direct inundation or within 40 metres of other retained polygons.
    d. Okanagan Dam breach and dam overtopping were not modelled. Inundation downstream of the Okanagan Dam on the left bank floodplain is based on river modelling with the assumption that Okanagan Lake levels will not overtop Lakeshore Drive and adjacent high ground. For the design flood scenarios, inundation mapping on the right bank of the Okanagan River from the Okanagan Dam downstream to the Highway 97 bridge and Burnaby

Map Notes

Avenue is based on additional lake and river modelling. For other flood scenarios, river and lake inundation has been mapped separately and has not been integrated on the right bank. Inundation mapping on the right bank is based on river modelling as far as the most upstream modelled river cross section.

10. For flood hazard maps (depth and velocity):
    a. Layers describe flood water depths and velocities. Depths and velocities are based on the maximum values from three modelled scenarios: all dikes removed, left bank dikes removed, and right bank dikes removed. Depths do not include freeboard.
    b. All hazard layers were modelled with the same parameters and boundary conditions as the design flood.
11. The accuracy of simulated flood levels is limited by the reliability and extent of water level, flow, and climatic data. The accuracy of the floodplain extents is limited by the accuracy of the design flood flow, the hydraulic model, and the digital surface representation of local topography. Localized areas above or below the mapped inundation maybe generalized. Therefore, floodplain maps should be considered an administrative tool that indicates flood elevations and floodplain boundaries for a designated flood. A qualified professional is to be consulted for site-specific engineering analysis.
12. Industry best practices were followed to generate the floodplain maps. However, actual flood levels and extents may vary from those shown. OBWB and NHC do not assume any liability for variations of flood levels and extents from that shown.

Data Sources:

1. Design flood events are based on hydrologic modelling of the Okanagan River watershed. The hydraulic response is based on a combination of 1D and 2D numerical models developed by NHC using HEC-RAS software, and NHC SWAN models. The hydraulic models are calibrated to the 2017 flood event and validated to the 2018 flood event; due to limits on data availability the hydrologic model is calibrated using data from 1980-2010.
2. The digital elevation model (DEM) used to develop the model and mapping is based on Lidar data collected from March to November 2018 and provided by Emergency Management BC (EMBC), channel survey conducted by WSP in March, April, and June 2019, and additional survey data. See accompanying report for details NHC (2020).
3. Orthophoto imagery provided by EMBC and acquired in 2018. Additional base mapping and orthoimagery from Esri.
4. National Railway Network railway lines acquired from Natural Resources Canada.

Map Notes

5. Dike crest lines published by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development – Water Management in 2019 and acquired from DataBC.
6. Administrative boundaries acquired from DataBC.

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