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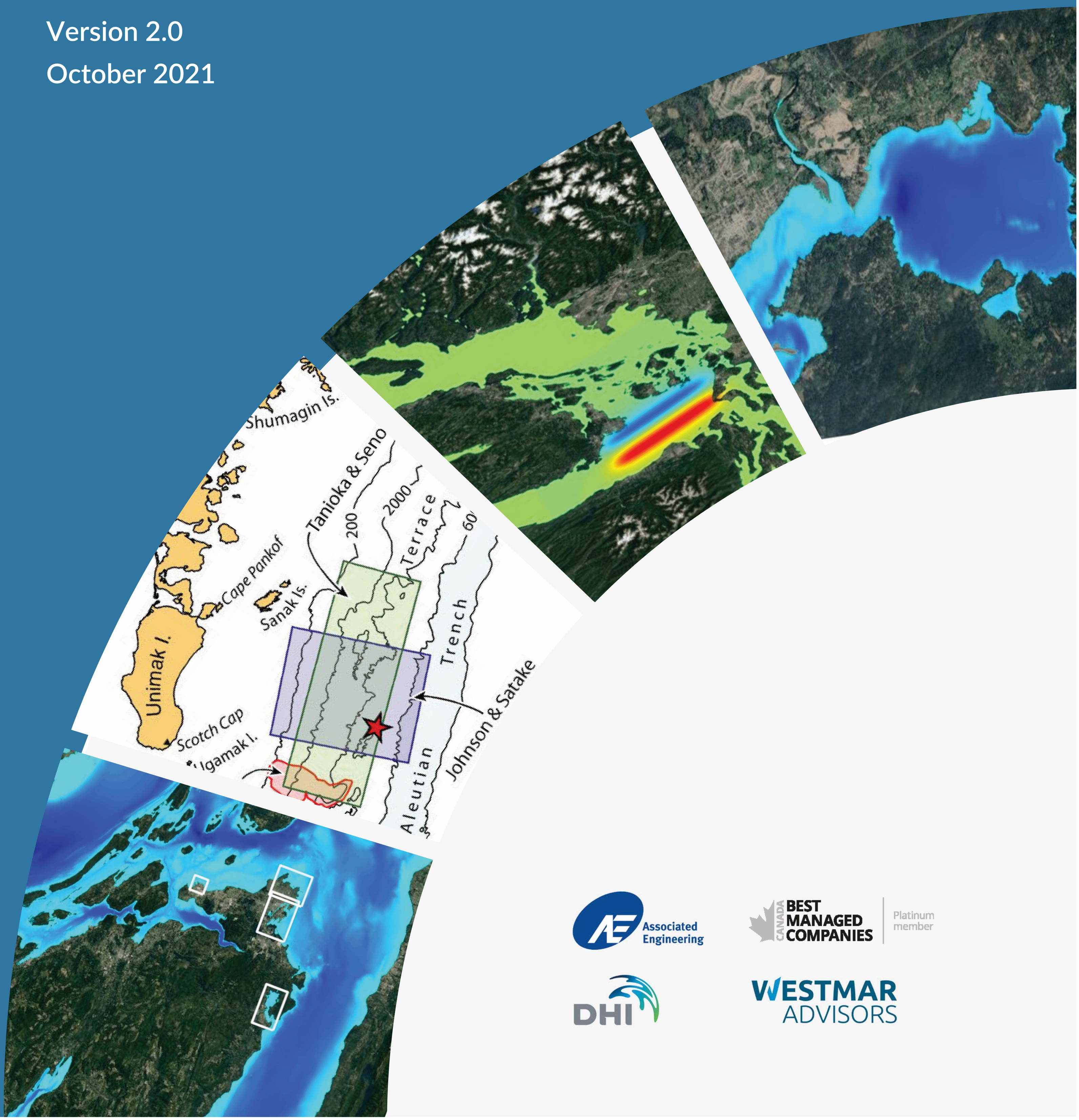
Task 3 – Tsunami Modelling and Mapping Report

Capital Region Coastal Flood Inundation Mapping Project

Version 2.0

October 2021



Associated Engineering

CANADA BEST MANAGED COMPANIES Platinum member

DHI

WESTMAR ADVISORS

EXECUTIVE SUMMARY

PROJECT CONTEXT

In recent years, scientific studies and measured observations have demonstrated that Climate Change is causing global mean sea levels to increase at an accelerated rate. Communities located along the British Columbia coastline have the potential to be negatively impacted in the coming years as flood events become more frequent and intensive in both depth and extent. This risk is compounded by the fact that BC is located within a seismologically-active zone, with a demonstrated history of tsunami hazard from a number of potential sources including the Cascadia Subduction Zone, the Alaska-Aleutian Subduction Zone and local shallow crustal faults. As such, the Capital Regional District (CRD) and its project partners recognised the need for detailed inundation mapping from both Sea Level Rise and Tsunamis for the capital region, on southern Vancouver Island; thereby commissioning the Capital Region Coastal Flood Inundation Mapping Project.

The purpose of this project is to help inform the CRD, its local governments, First Nations, and other interested stakeholders of the risk of coastal flooding due to sea level rise and tsunamis, and the subsequent impacts as a result of inundation. The results of this project should be used to develop flood construction policy in the region's respective local governments, as well as informed emergency mitigation and evacuation plans.

This particular report is the third report of three as part of this overarching Coastal Flood Inundation Mapping Project; the complete collection of reports is as follows:

- Task 1 – DEM Development Report
- Task 2 – Sea Level Rise Modelling and Mapping Report
- Task 3 – Tsunami Modelling and Mapping Report

This report summarises the work performed by the project team in pursuit of meeting objectives defined for 'Task 3 – Tsunami Modelling and Mapping'. The project team consists of Associated Engineering (AE), DHI and Westmar Advisors. Working under DHI, Dr James Kirby, Edward C. Davis Professor of Civil Engineering at the University of Delaware, and Dr. Fengyan Shi, Research Professor at the University of Delaware's Center for Applied Coastal Research were the tsunami modelling specialists for this project. Working under Westmar Advisors, Dr. John Clague (Simon Fraser University) and Peter Acton supplemented the project team and offered expert guidance in the selection of appropriate tsunami generation sources and port / harbour risk analyses respectively.

Version 2.0 of this Tsunami Modelling and Mapping Report replaces the previous Version 1.0 report, published in June 2020. The project team and the CRD produced an FAQ memo for municipal partners that summarises the key differences between each Version.

PROJECT OBJECTIVES

The primary objective of this task (Task 3 – Tsunami Modelling and Mapping) was to assess the risk of tsunami inundation along the capital region coastline. A secondary objective of this report was to assess, qualitatively, the risk to harbours/marinas / docks within the capital region as a result of tsunami waves and currents hitting these vulnerable facilities.

SUMMARY OF TECHNICAL APPROACH

Early in the project, it was decided by the project team, in concert with the project stakeholders, that the study would focus on as many different sources as possible. In addition, emergency managers indicated a desire to model a spread of magnitudes to inform how lower-order events may impact the capital region. Based on these criteria, the project team, under the guidance of Dr. John Clague, reviewed applicable scientific literature to select appropriate tsunami generating sources. A combination of Cascadia Subduction Zone (CSZ) events, far-field events and local crustal fault events was preferred. The candidate tsunami sources were shortlisted to 11, to ensure that modelling could be completed within the project schedule. As such, **Table ES-1** shows the finalised list of sources modelled for this study. For all tsunami events, magnitude is coincident and proportional with probability (i.e. the greater the magnitude, the more remote the probability).

Table ES-1
Summary of Tsunami Sources in this Project

Source	Abbrv.	Magnitude	Probability	Comment
Cascadia Subduction Zone - L1 Source	CSZ-L1	9.1 - 9.2	2500-yr. return period	Worst-case earthquake scenario (L1)
Cascadia Subduction Zone - Northern Segment	CSZ-NS	8.5 - 9.0	500 - 600 yr. return period	Rupture of northern segment
Cascadia Subduction Zone - Central Segment	CSZ-CS	8.5	500 - 600 yr. return period	Rupture of central segment (southern Washington, northern Oregon), identified by Wang et al., 2013
Alaskan 1964	AL	9.2	500 - 1000 yr. return period	Same as 1964 earthquake
Aleutian Trench	UN	8.6	unknown	1946 Aleutian Trench earthquake, off Unimak Island
Haida Gwaii	HG1	7.7	unknown	2012 earthquake
South of Haida Gwaii	HG2	7.5	unknown	Hypothetical event spanning between Haida Gwaii failure and Nootka fault
Devil's Mountain Fault Mw 7.5	DM1	7.5	2000-yr. return period	Worst-case earthquake – Long transpressive rupture (>50 km)
Devil's Mountain Fault Mw 6.5	DM2	6.5	<2000-yr. return period	Middle length transpressive rupture (<50 km)
Southern Whidbey Island Fault Mw 7.5	SW1	7.5	2000-yr. return period	Worst-case earthquake – Long transpressive rupture (>50 km)
Southern Whidbey Island Fault Mw 6.5	SW2	6.5	<2000-yr. return period	Shorter transpressive rupture (<50 km)

Hydrodynamic modelling and mapping for each tsunami source was completed as per the US National Tsunami Hazard Mitigation Program (NTHMP) guidelines[1]. The NTHMP program is a federal-state partnership, founded by the National Oceanic and Atmospheric Administration (NOAA), whose objective is to plan for and reduce tsunami risk to US coastal communities. The tsunami modelling program used in this study was FUNWAVE-TVD, a Boussinesq wave model, developed at the University of Delaware. This program has been successfully benchmarked against the standards adopted by the NTHMP.

As per NTHMP modelling guidelines, the initial water level used for tsunami modelling was the Higher High-Water Mean Tide (HHWMT). HHWMT is defined as the average from all the higher high waters from an 18.6 year tide cycle. It is important to note there are higher tides possible at the project location like the Highest Astronomical Tide (HAT) or Higher High-Water Large Tide (HHWLT, defined as the average of the annual maximum series for an 18.6 year tide cycle). However, the statistical probability of these initial tide levels occurring at the same time as an extreme tsunami event results in a joint-probability far more remote that the actual return period of the tsunami event being modelled. Therefore, the choice of HHWMT is a technically robust selection, incorporating an acceptable level of conservatism. (Refer to **Appendix N** for further information on conversion between HHWMT and elevations reported to CGVD2013).

The FUNWAVE-TVD tsunami model was constructed using a multi-grid nesting technique. Five areas in the capital region were selected for detailed modelling. These areas were chosen to complement the detailed sea level rise inundation areas examined in Task 2 (see Task 2 - Sea Level Rise Modelling and Mapping Report), as well as communities within Juan de Fuca Strait that have greater exposure to the Cascadia Subduction Zone. There were two types of hydrodynamic modelling resolution used in this project to deliver the resulting inundation mapping:

- The entire capital region was modelled using a minimum cell resolution of 30 m (specifically, 1 arc-second) i.e. Grid D.
- Victoria / Esquimalt, Saanich / Oak Bay, Sidney, Sooke, and Port Renfrew were modelled using a detailed grid; a cell resolution of 4 m.

KEY FINDINGS & RECOMMENDATIONS

A summary of average modelled maximum water surface elevation for each local government and electoral area is given in Table ES2. A summary of tsunami travel times (i.e. the amount of time for an event to travel from a generating source to a particular location, in minutes) is given in Table ES-3. All deliverables that reference elevation produced as part of this project are referenced to CGVD2013 geodetic datum unless otherwise stated. A summary of the key findings and recommendations of this Task is given below:

- The performance of the hydrodynamic model was compared against the recent 2012 Haida Gwaii earthquake event (see **Section 3**). It was found that the model was able to replicate the observed response satisfactorily and compared favourably against a cross-reference model developed in MIKE 21 software.
- As hypothesized at project outset, the CSZ-L1 source as used by the State of Washington is the most extreme event modelled here when examining the results, with a return period of 2,500 years. Large surface elevations of over 10 m occur at the entrance to Juan de Fuca Strait (see **Sections 2.1.1** and **4.3.1**).
- Results contained within this report may inform the flood construction level (FCL) in tsunami-prone areas. Specifically, the project team recommends that project stakeholders use the Cascadia Subduction Zone Northern Segment (CSZ-NS) as the flood construction standard event, when comparing to Relative Sea Level

[1] https://nws.weather.gov/nthmp/documents/1inundationmodelingguidelines.pdf

Rise FCLs (see Section 6.4 for further information). This is due to the relative return period of this event (approximately 500 - 600 year), in comparison to the more remote CSZ L1 scenario (2,500-year return period). (see Section 6, in 'Task 2- Sea Level Rise Modelling and Mapping Report' for further information).

- It is also recommended to revisit these modelling efforts in the short-medium term (5 - 10 years), as understanding of tsunami generation sources and mechanisms continue to deepen in academia; as well as the ability for modelling software to represent the complicated hydraulics that describe a tsunami wave.

Table ES-2
Summary of Modelled Average Water Surface Elevations (m CGVD 2013)

Tsunami Source / Local Government or Electoral Area	CSZ-L1 (*CSZ - L1 Source*)	CSZ-NS (*CSZ - Northern Segment*)	CSZ-CS (*CSZ - Central Segment*)	AL (*Alaskan 1964*)	UN (*Aleutian Trench*)	HG1 (*Haida Gwaii*)	HG2 (*South of Haida Gwaii*)	DM1 (*Devil's Mountain Mw 7.5*)	DM2 (*Devil's Mountain Mw 6.5*)	SW1 (*Southern Whidbey Mw 7.5*)	SW2 (*Southern Whidbey Mw 6.5*)
Central Saanich	4.21	3.26	1.42	1.37	Event used for calibration purposes only. Effects in capital region minimal.	Effects in capital region minimal.	3.30	1.30	2.36	1.27	3.30
Colwood	6.93	4.64	1.09	1.03			3.53	0.88	2.39	0.88	3.53
Esquimalt	6.82	4.48	1.08	1.04			3.57	0.87	2.38	0.88	3.57
Highlands	3.54	2.94	1.41	1.37			1.97	1.25	1.72	1.24	1.97
Juan de Fuca Electoral Area	7.68	5.09	1.49	1.37			1.78	1.16	1.94	1.16	1.78
Langford	3.60	3.06	1.42	1.39			2.58	1.31	2.05	1.28	2.58
Metchosin	5.25	3.51	1.04	0.95			2.10	0.85	1.75	0.85	2.10
North Saanich	3.92	2.77	1.40	1.34			2.51	1.29	1.98	1.26	2.51
Oak Bay	3.84	2.67	0.94	0.92			3.50	0.90	2.02	0.90	3.50
Saanich	3.53	2.55	0.96	0.90			3.32	0.91	1.84	0.84	3.32
Salt Spring Electoral Area	3.32	2.60	1.36	1.31			2.15	1.27	1.84	1.25	2.15
Sidney	4.78	3.01	1.42	1.38			3.42	1.31	2.26	1.27	3.42
Sooke	6.42	4.05	1.29	1.23			1.46	1.06	1.43	1.07	1.46
Southern Gulf Islands Electoral Area	3.11	2.37	1.35	1.32			2.03	1.26	1.75	1.25	2.03
Victoria	5.62	3.99	1.03	0.98			3.09	0.86	2.26	0.88	3.09
View Royal	8.46	6.27	1.18	1.14			4.54	0.96	3.65	0.97	4.54

Note that any gaps in the above table denote that the event in question has minimal effect on the location in question and results have accordingly not been provided.

Table ES-3
Summary of Approximate Arrival Time for Each Modelled Tsunami Event (min.)

Tsunami Source	CSZ-L1	CSZ-NS	CSZ-CS	AL	UN	HG1	HG2	DM1	DM2	SW1	SW2
Central Saanich	100	100	125	280	325	170	170	5	5	5	5
Colwood	75	75	100	255	300	145	145	5	5	5	5
Esquimalt	75	75	100	255	300	145	145	5	5	5	5
Highlands	120	120	145	300	345	190	190	30	30	30	30
Juan de Fuca Electoral Area	40	40	65	220	265	110	110	15	15	15	15
Langford	75	75	100	255	300	145	145	5	5	5	5
Metchosin	70	70	95	250	295	140	140	5	5	5	5
North Saanich	105	105	130	285	330	175	175	10	10	10	10
Oak Bay	85	85	105	265	310	155	155	5	5	5	5
Saanich	90	90	115	270	315	160	160	5	5	5	5
Salt Spring Electoral Area	115	115	135	290	340	180	180	15	15	15	15
Sidney	110	110	135	290	335	180	180	15	15	15	15
Sooke	60	60	85	240	285	130	130	15	15	15	15
Southern Gulf Islands Electoral Area	100	100	125	280	325	170	170	5	5	5	5
Victoria	80	80	105	260	305	150	150	5	5	5	5
View Royal	80	80	105	260	305	150	150	5	5	5	5

USES & LIMITATIONS

It is intended that this study will help planners and emergency response managers in adapting the capital region to the ever-present tsunami risk that exists for all communities in southern Vancouver Island and the Southern Gulf Islands. The findings in this report can be leveraged for a variety of different exercises and it is hoped that this project serves as a 'foundation stone' upon which further risk mitigation and education work can build.

This study has modelled the capital region in unprecedented detail, relative to previous studies. The resolutions adopted were selected to maximise the detail represented in this study, whilst balancing computational demands and an aggressive, compressed schedule.
However, particularly in areas included in the coarse grid domains (see **Sections 2.2**. and **2.3**), there are opportunities to improve on model resolution as computational power requirements and project scope allow. Like all computational modelling of hydrodynamic processes, minor, localised instabilities exist in the modelling as a result of the limitations

of the methodology selected. Users are asked to familiarise themselves with these limitations (see **Section 4.5**) to maximise their understanding of the derived results.

It is also important to note that no account for relative sea level rise (RSLR) was taken in the modelling. RSLR is an absolute increase in mean sea level, incorporating the effects of land subsidence or uplift. The reason for its omission was to maximise the number of tsunami sources and magnitudes modelled within the compressed project schedule. This could be the focus of future work.

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GLOSSARY

AE	Associated Engineering	
AEP	Annual Exceedance Probability	The probability of a specific event occurring, or being exceeded, in any given year.
CD	Chart Datum	The local datum for oceanographic measurements (e.g. tides) at a specific location, port or harbour.
CGVD1928	Canadian Geodetic Vertical Datum 1928	Vertical elevation reference system, which is to be superseded by CGVD2013.
CGVD2013	Canadian Geodetic Vertical Datum 2013	Vertical elevation reference system, which supersedes CGVD1928.
CHS	Canadian Hydrographic Service	
CRD	Capital Regional District	Regional government for 13 municipalities and three electoral areas on southern Vancouver Island and the Gulf Islands. 'Capital Region' refers to the specific geographic area within the CRD's jurisdictional boundaries.
CSRS	Canadian Spatial Reference System	
CSZ	Cascadia Subduction Zone	
DART®	Deep-ocean Assessment and Reporting of Tsunami Buoys	
DEM	Digital Elevation Model	
DTM	Digital Terrain Model	
DWT	Deadweight Tonnage	A measure of how much weight a ship can carry; is the sum of the weights of cargo, fuel, fresh water, ballast water, provisions, passengers, and crew.
FCL	Flood Construction Level	As per Provincial Guidelines, defined as the underside elevation of a wooden floor system, or the top elevation of a concrete slab, for habitable buildings.
FEMA	Federal Emergency Management Agency	
GIS	Geographic Information Systems	
GNSS	Global Navigation Satellite Systems	
HHWLT	Higher-High Water Large Tide	The average of the annual highest tides over the 18.6 year tide cycle.
HHWMT	Higher High Water Mean Tide	The average from all the higher high waters from an 18.6 year tide cycle.
LiDAR	Light Detection and Ranging	
MFLNRORD	BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development	
MWL	Mean Water Level	The average of all hourly water levels over the available period of record.
NAD83	North American Datum of 1983	

NCEP	National Centers for Environmental Protection	
NEIC	National Earthquake Information Center	
NOAA	National Oceanic and Atmospheric Administration	
RSLR	Relative Sea Level Rise	RSLR is an absolute increase in mean sea level, incorporating the effects of land subsidence or uplift.
SLR	Sea Level Rise	Sea level rise is the increase in mean sea level without incorporating an adjustment due to local land subsidence or uplift.
SWL	Still Water Level	
UTM	Universal Transverse Mercator	

1 INTRODUCTION

1.1 Project Background

Associated Engineering (AE), DHI Water & Environment Inc. (DHI) and Westmar Advisors (Westmar) were appointed by the Capital Regional District (CRD), as per an agreement executed on August 8, 2019, to undertake the "Capital Region Coastal Flood Inundation Mapping Project"; hereafter referred to as the "project" or the "study". It is important to define that the CRD refers to the regional government for 13 local governments and three electoral areas on southern Vancouver Island and the Gulf Islands. The term 'capital region' refers to the specific geographic area within the CRD's jurisdictional boundaries. These definitions are used throughout this report.

The project has been based on the overarching tasks summarised below:

- **Background Data Collection:** Gathering the available historic reports, analyses and geospatial data.
- **DEM Development:** Creation of a digital elevation model that can be used in hydraulic models to simulate coastal flooding.
- **Sea Level Rise (SLR) Flooding Analysis:** Development of coastal flood construction levels (FCLs) for the capital region using transect analyses; as well as detailed inundation modelling in select locations.
- **Tsunami Source Identification:** Review of available scientific literature and analyses to select appropriate tsunami-generating sources for modelling.
- **Tsunami Modelling:** Development of hydraulic models that can simulate tsunami wave propagation from source to inundation of the coast.
- **Mapping & Reporting:** Summarising the significant volume of technical work completed in concise reporting, accompanied by inundation and transect mapping.

Working under DHI, Dr James Kirby, Edward C. Davis Professor of Civil Engineering at the University of Delaware, and Dr. Fengyan Shi, Research Professor at the University of Delaware's Center for Applied Coastal Research were the tsunami modelling specialists for this project[2]. Their work informs the bulk of this report. Working under Westmar Advisors, Dr. John Clague (Simon Fraser University) and Peter Acton supplemented the project team and offered expert guidance in the selection of appropriate tsunami generation sources and port/harbour risk analyses respectively. Dr. Michael Isaacson (University of British Columbia) has provided senior review of this report.

The purpose of this report is to describe the methodology[3], data sources and results of this project's Tsunami Inundation Modelling & Mapping (Task 3). In addition, the 'Project Digital Elevation Model' (DEM) is a major input to the tsunami modelling and mapping. For further information on how the Project DEM was created, refer to Task 1 (DEM Development Report).

Version 2.0 of this Tsunami Modelling and Mapping Report replaces the previous Version 1.0 report, published in June 2020. The project team and the CRD produced an FAQ memo for municipal partners that summarises the key differences between each Version.

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[2] Dr James Kirby and Dr. Fengyan Shi were independent contractors working directly for DHI.
[3] This report follows the procedures agreed upon in the Finalized Project Methodology Technical Memorandum, submitted to the CRD in December 2019.

It is important to note that all deliverables produced for this project are referenced to Canadian Geodetic Vertical Datum 2013 (CGVD2013), unless otherwise stated. Readers of this report may be more familiar with the long-established CGVD28 vertical datum. However, this is currently being phased out in favour of the CGVD2013 datum. Refer to **Appendix N** for a more detailed explanation and further reference sources.

1.2 Study Area

The capital region is located on southern Vancouver Island, with an area of approximately 4900 km^2. The study's approximately 1300 km long coastline is bounded by Juan de Fuca Strait to the south-west, Haro Strait to the east and the Strait of Georgia to the north-east. The capital region also shares an international boundary with the US State of Washington. The study area is shown in **Figure 1-1**. There are many First Nations communities and lands within the capital region bounds, as shown in **Figure 1-2**.

The study coastline is extremely complex, varying between steep rocky bluffs, gently-sloping beaches and urban marinas / waterfronts. The coastline is well developed, particularly in its eastern extents, with numerous private residences, tourist amenities, commercial industries, transportation facilities and military installations.

The study area includes the Southern Gulf Islands, of which, Salt Spring Island, Galiano Island, Saturna Island, Mayne Island, North Pender Island and South Pender Island are the most notable. The CRD is the regional government for the southern portion of Vancouver Island, being comprised of 13 local governments and three (3) electoral areas. The region hosts a number of significant population centres, with greatest density being concentrated around Victoria and the Saanich Peninsula.

The study area is affected by coastal processes in the Strait of Georgia and Juan de Fuca Strait. These processes include large tidal variations, and moderate local waves and storm surge generated by strong local winds within both straits. The study area is also affected by potential tsunami hazards, including those generated:

- Locally within the Strait of Georgia, Juan de Fuca Strait and the Puget Sound,
- By a major earthquake within the Cascadia Subduction Zone, and
- Other tsunamis generated from other parts of the Pacific Ocean, e.g. Alaska.

1.3 Historical and Paleo-Tsunami Flood Record

The west coast of Canada is vulnerable to tsunamis generated by earthquakes beneath the Pacific Ocean. The largest tsunamis in British Columbia result from magnitude 8 (Mw 8.0) or larger earthquakes in the Cascadia Subduction Zone, where the oceanic Juan de Fuca plate moves underneath North America (Clague, 1997; Clague *et al*., 1999).

Space-based geodetic observations have shown that large parts of the Cascadia forearc (i.e. the region that overlies the subducting Juan de Fuca plate between the trench and the Cascade volcanic arc) in western Oregon and western Washington are migrating northward as a nearly rigid, independent block or microplate known as the Oregon Coast Block (**Figure 1-3**; Wells et al., 1998; Miller et al., 2001; Savage et al., 2001; Wells and Simpson, 2001; Svarc et al., 2002; McCaffrey et al., 2007). Geoscientists have characterized the motion of the Oregon Coast Block relative to stable North America as clockwise rotation about a Euler pole located somewhere in northeast Oregon or western Idaho (see **Figures 1-3 (a)** and **1-3 (b)**)

Coastal Flood Inundation Mapping Project
Figure 1-1
Study Area

Coastal Flood Inundation Mapping Project

Figure 1-2
First Nation Communities

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The last significant Cascadia Subduction Zone event occurred on January 26, 1700 and is documented in the Japanese record, where the resulting tsunami had a significant impact (Satake et al., 1996). The development of an understanding of the recurring nature and frequency of such events moved forward after the discovery and documentation of layered tsunami deposits in coastal wetlands, resulting from subsidence and then overwash by tsunami waves, and subsequently protected by burial under deposited muddy sediments. (Atwater, 1992; Atwater et al., 1995). **Figure 1-4** from Garrison-Laney and Miller (2017), shows such a history in the sediment record, taken in Discovery Bay, Washington. Similar deposits have been found at many sites along the Pacific coast from Vancouver Island south through Oregon, providing convincing evidence that large tsunamis have struck this coastline repeatedly over the last few thousand years (Clague, 1997; Clague et al., 1999).

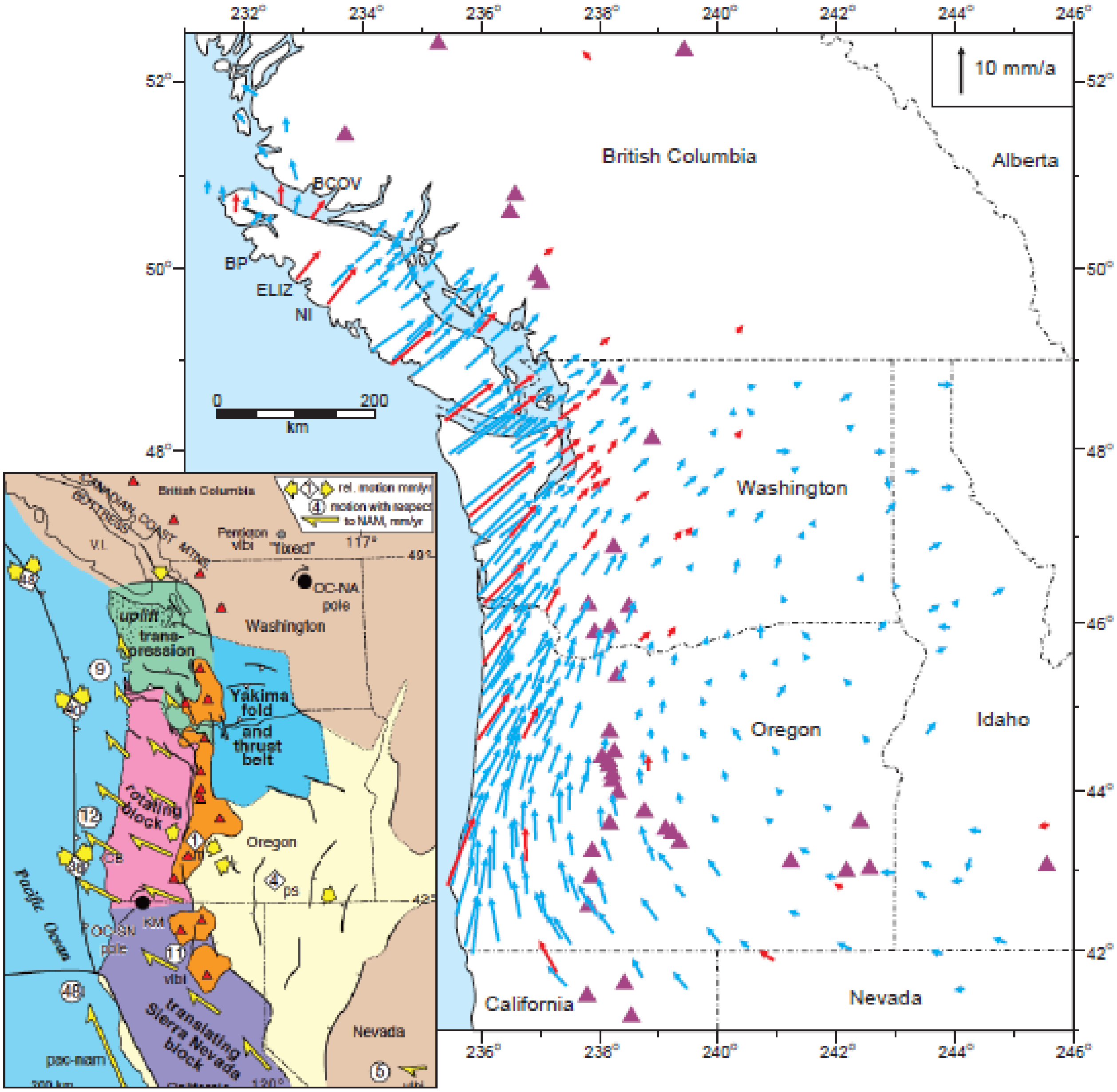

Figure 1-3

Figure 1-3 (a) Velocities of Cascadia GPS sites in North American reference frame. Figure 1-3 (b) Tectonic framework for velocity field.

Figure 1-3 (a): Velocities of Cascadia GPS sites in North American reference frame. Red vectors are derived from continuous GPS sites; blue from survey mode sites (McCaffrey et al., 2007, their figure 2). Error ellipses are at 70% confidence level. Triangles show locations of volcanoes. BP—Brooks Peninsula; NI—Nootka Island; ELIZ and BCOV are continuous GPS sites. **Figure 1-3 (b):** Tectonic framework for velocity field. The Oregon block (pink) is rotating in a clockwise direction about a Euler pole (OC-NA), here located in northeast Washington State (Wells et al., 1998, their figure 4). The north end of the Oregon block deforms the Washington forearc (green) against the buttress formed by the southern Coast Mountains in British Columbia, causing north-south compression, uplift, thrust faulting, and earthquakes. Rates derived from: very long baseline interferometry (vlbi), paleoseismology (ps), and Pacific–North America motion (pac-nam). NAM = North America motion. The British Columbia coast is also affected by tsunamis of more distant Pacific earthquakes. The largest tsunami to strike British Columbia in historical time was generated by the magnitude Mw 9.2 Alaska earthquake of March 27, 1964 (Plafker, 1969; Lander, 1996), simulated as one of four remote tsunami sources in the present study. A series of waves radiated outward from the earthquake rupture area off south-central Alaska and reached the outer coast of British Columbia, causing damage mainly to the Vancouver Island communities of Port Alberni, Hot Springs Cove, and Zeballos (Thomson, 1981). **Figure 1-4** shows tsunami deposits (sand layers bounded by silty clays) at Discovery Bay, WA. The tsunami deposits visible in the photo include an inferred AD 1700 sand layer that was later disturbed by marsh restoration projects, a sand layer dated at 630 to 560 radiocarbon years BP (Garrison-Laney and Miller, 2017), and two older sand layers beneath. The topmost mud layer was deposited in 2006, following marsh restoration.

The region around the southern end of Vancouver Island, including the San Juan Islands and water bodies such as the Juan de Fuca Strait, Salish Sea and Strait of Georgia are also possibly subject to the effects of local fault systems running through Vancouver Island and adjacent areas to the south and east. GPS data reveal that at least some of the northward motion of the Oregon Coast Block is accommodated by crustal shortening in northwest Washington and southwest BC (Wells et al., 1998; McCaffrey et al., 2007). Mazzotti et al. (2008) document a velocity gradient along the northern margin of the Oregon Coast Block in northwest Washington that is equivalent to several millimetres per year of north-south shortening in the Puget Lowland and northern Olympic Peninsula. The shortening in the GPS velocity field is consistent with observations of Holocene thrust and reverse-oblique faulting in Puget Sound at the latitude of Seattle (Johnson et al. 1994, 1996; Pratt et al. 1997). Possible local faulting associated with this crustal shortening is represented in the present study through two hypothetical events (with each represented with two different magnitudes) on the Devil’s Mountain Fault (Barrie and Greene, 2018) and the South Whidbey Island Fault (Johnson et al., 1996).

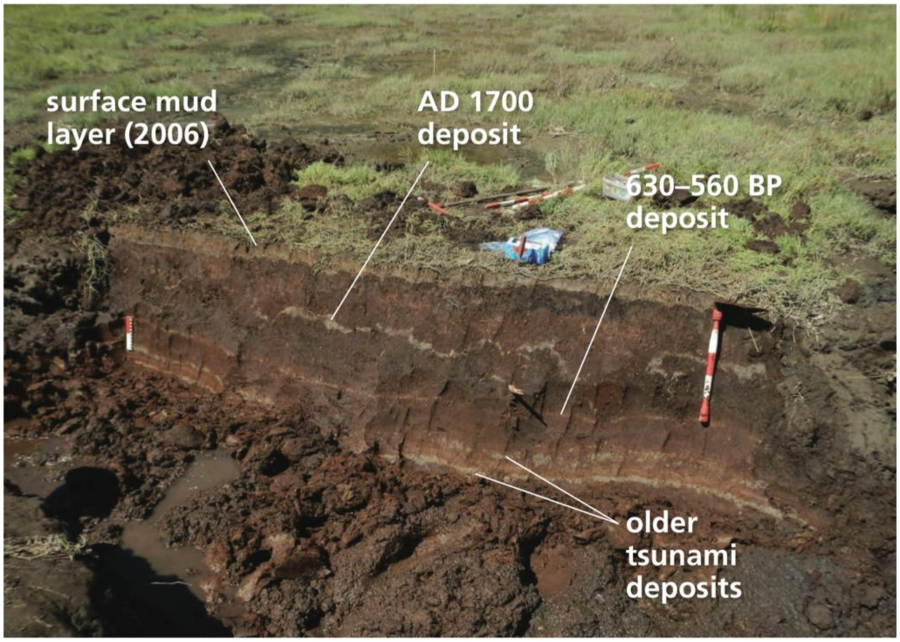

Figure 1-4
Photo of Tsunami Deposits at Discovery Bay, Washington[4]

1.4 Previous Tsunami Modelling Studies

Previous studies of tsunami hazard for the areas around the capital region have concentrated on potential events in the Cascadia Subduction Zone (CSZ). Among these are the following:

- Institute of Ocean Sciences and NOAA / Pacific Marine Environmental Laboratory (Cherniawsky et al., 2007);
- Capital Regional District (AECOM, 2013) 'Modelling of Potential Tsunami Inundation Limits and Run-Up' and;
- A recent study conducted by the State of Washington focusing on sites in the Juan de Fuca Strait (Eungard et al., 2018).

The source conditions used by Cherniawsky et al. (2007) and AECOM (2013) are comparable and lead to similar predictions of wave impact around Victoria, BC, while Eungard et al. (2018) use a much stronger source, repeated in this study and referred to as the "Washington" extended L1 (CSZ-L1) source. Previous studies considered here have used a range of CSZ sources but generally have not included any local sources or far-field events beyond the CSZ.

1.4.1 Cherniawsky et al. (2007) (IOS / NOAA Study)

Cherniawsky et al. (2007) considered three configurations of a CSZ source, referred to as *long-narrow*, *short-north* and *short-south*, each of which was intended to correspond to a return period of approximately 500 years. The source area encompassing the three cases followed from previous work by Wang et al (2001) and is shown in **Figure 1-5**. The first two cases were configured to have magnitudes Mw = 9.0, while the short-south source had a magnitude of Mw = 8.8. The boundary between north and south segments was taken to be 44.3° N.

[4] Photo by Carrie Garrison-Laney (Washington Sea Grant)

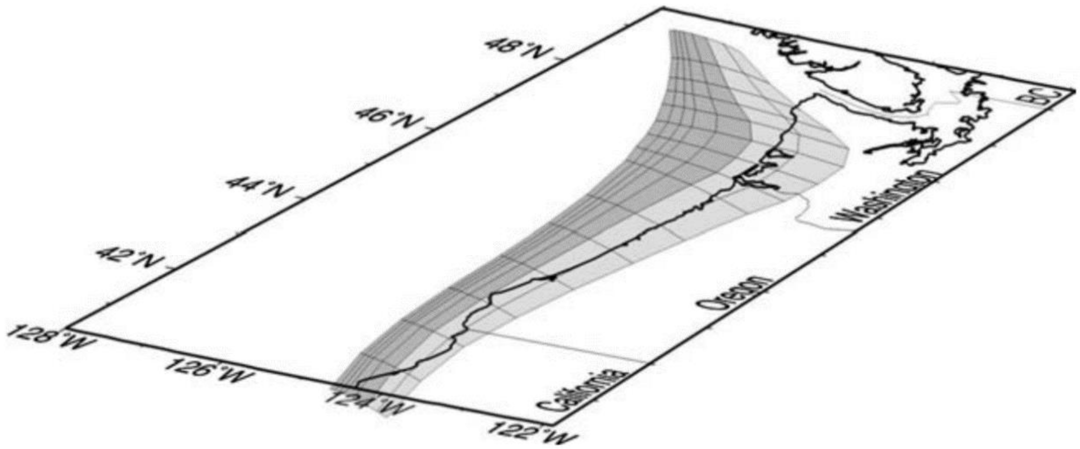

Figure 1-5
CSZ Source Region Used by Cherniawsky et al. (2007).

The long-narrow source covered the entire length of the region shown in **Figure 1-5** which extends from Cape Mendocino at 40.5° N to the Nootka fracture zone near 49.5° N. The Mw = 9.0 magnitude corresponded to a full-slip zone width of 48 km with a slip distance of 19 m. The short-north and short-south sources used the same assumed slip and full-slip zone widths of 56 km and 37 km with the same assumed slip of 19 m to get the target magnitudes of Mw = 9.0 and 8.8 respectively.

Cherniawsky et al. (2007) used the MOST-3 model (Titov and Synolakis, 1998), which solves the nonlinear shallow water equations and neglects the frequency dispersion effects included in later studies. This factor is probably not significant for the propagation distances considered. The presentation of results concentrated on open coastal response (where a significant trapped or edge-wave response is generated), the area around Ucluelet (which is significantly impacted by the long-narrow and short-north events) and the Victoria / Esquimalt harbours. The finest grid employed for Victoria / Esquimalt had a resolution of 6 x 10 m. Results for the long-narrow source indicate a concentrated maximum wave runup of approximately 4.2 m in the northern extreme of Esquimalt harbour, with significantly lower surface elevations in the order of 2 m in Victoria harbour. Predicted current speeds are quite strong, however, reaching 17.4 m/s in the entrance to Esquimalt harbour, with maximum values in the order of 5 m/s occurring in Victoria harbour. These results are summarized graphically in **Figures 1-6** and **1-7.**

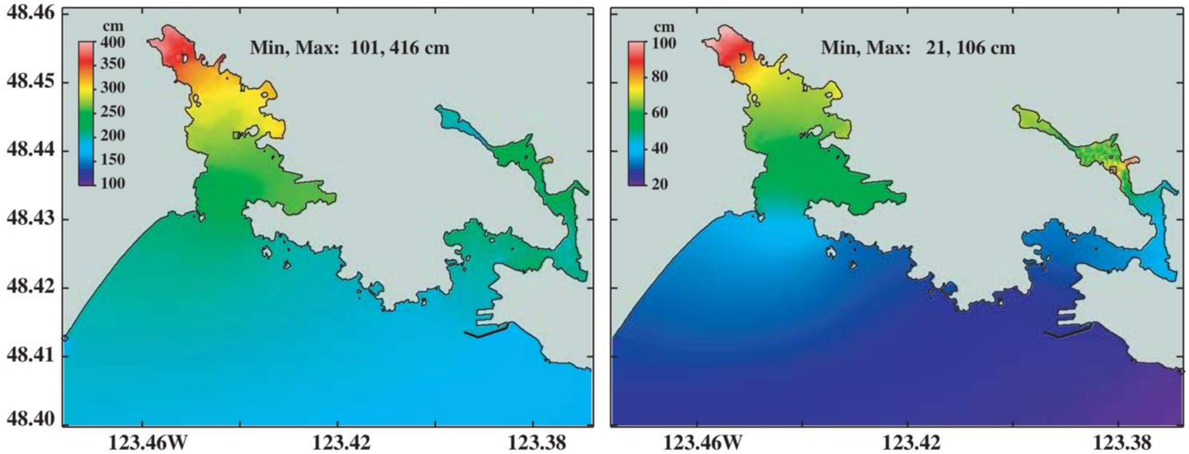

Figure 1-6
Maximum Tsunami Wave Elevation in Esquimalt and Victoria Harbours For Long-Narrow (left) and Short-South (right) Deformation Scenarios. (Cherniawsky et al. (2007), Figure 14.)

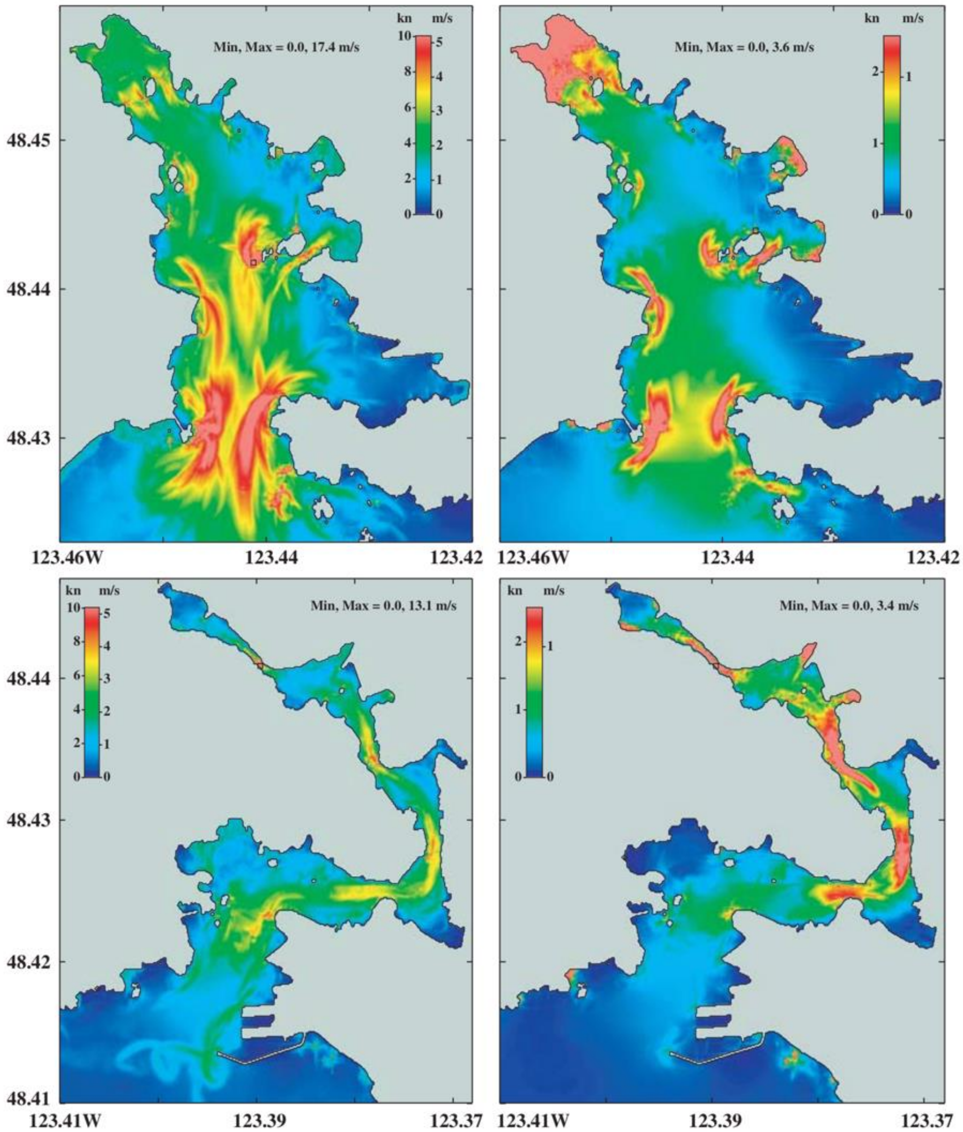

Figure 1-7
Maximum Current Speeds in Esquimalt Harbour (top) and Victoria Harbour (bottom) for Long-Narrow (left) and Short-South (right) Deformation Scenarios (Cherniawsky et al. (2007), Figure 15)

1.4.2 2013 AECOM 'Modelling of Potential Tsunami Inundation Limits and Run-Up' Report

The AECOM (2013) 'Modelling of Potential Tsunami Inundation Limits and Runup' Report is a detailed study of tsunami effects in Victoria and Esquimalt harbours, using a source with an intended return period of 500 years. The source is referred to as the GA source (for Global Analogs) and is illustrated in **Figure 1-8**. The parameters for the source are based on an assumed 428 years of accumulated strain and a magnitude of Mw = 9.0, leading to a slip of 15.4 m (compared to 19 m in the Cherniawsky et al. (2007) study) with a maximum uplift of 6.2 m along the trench, and a subsidence of about 1 m at Port Renfrew, decreasing to 0.2 m in Victoria.

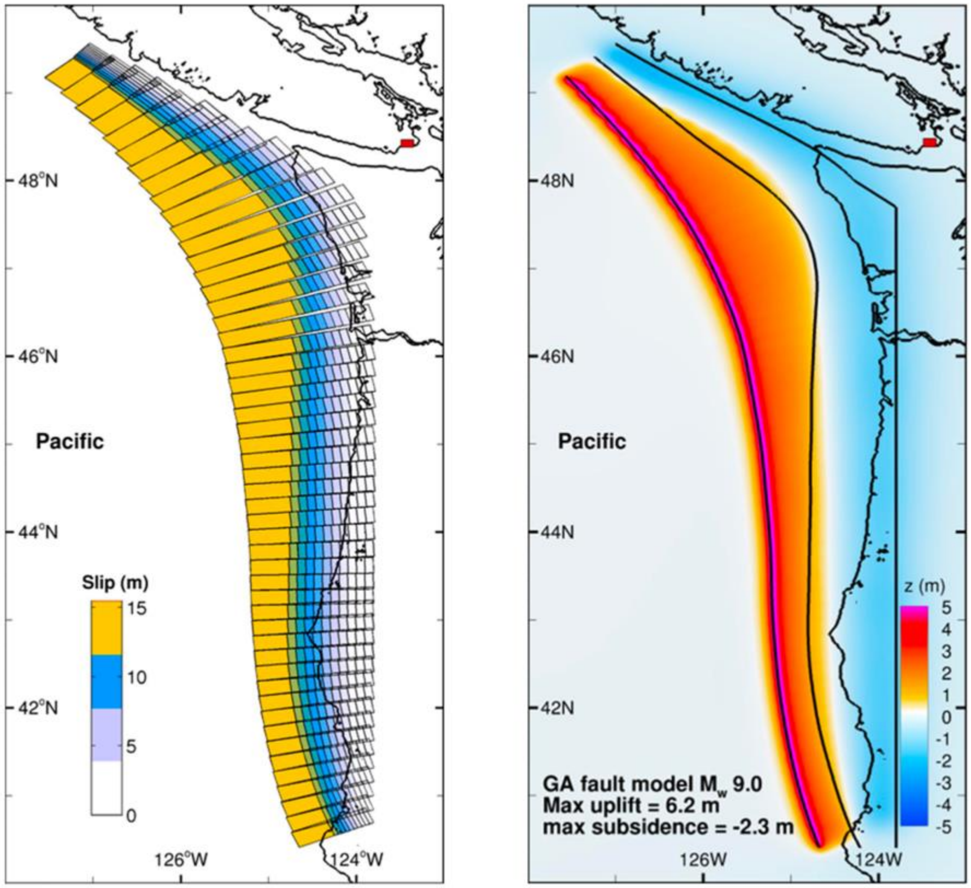

Figure 1-8
Slip Distribution at the Rupture Plane (left) and Vertical Displacement of the Earth Surface (right) for the GA Source (Figure 2.1 in AECOM (2013)).

The study employed the NEOWAVE model (Yamazaki et al, 2011), which is a depth-integrated, one-layer non-hydrostatic model which includes frequency dispersion effects at a level of accuracy comparable to the FUNWAVE-TVD model used in the present study. The simulations were run using a tidal datum of Higher High Water Mean Tide (HHWMT) and incorporating subsidence in the bathymetry. Five levels of grid nesting were used to get to a final resolution of 9 m in Victoria harbour and 18 m in Esquimalt harbour.

AECOM (2013) report maximum water levels in Esquimalt harbour which are very similar to the predictions of Cherniawsky et al. (2007). Predicted water levels in the main harbour area in Victoria are similar in the two studies, but AECOM (2013) predict a progressively higher water level with landward distance in Victoria harbour which is not seen in the earlier study. Results are shown in **Figure 1-9**. Both studies indicate that expected flooding in Victoria harbour would be minimal, with no overtopping of the cruise ship terminals. AECOM (2013) also report maximum flow speeds which are considerably lower in the entrance of Esquimalt harbour than predicted in the earlier study. This is a curious discrepancy between the two studies, as the build-up of water level in the northern extreme of the harbour would require the same amount of water entering at the harbour entrance. The difference could be due to variations in the time history of the tsunami wave form, which is not reported in any detail in the AECOM study.

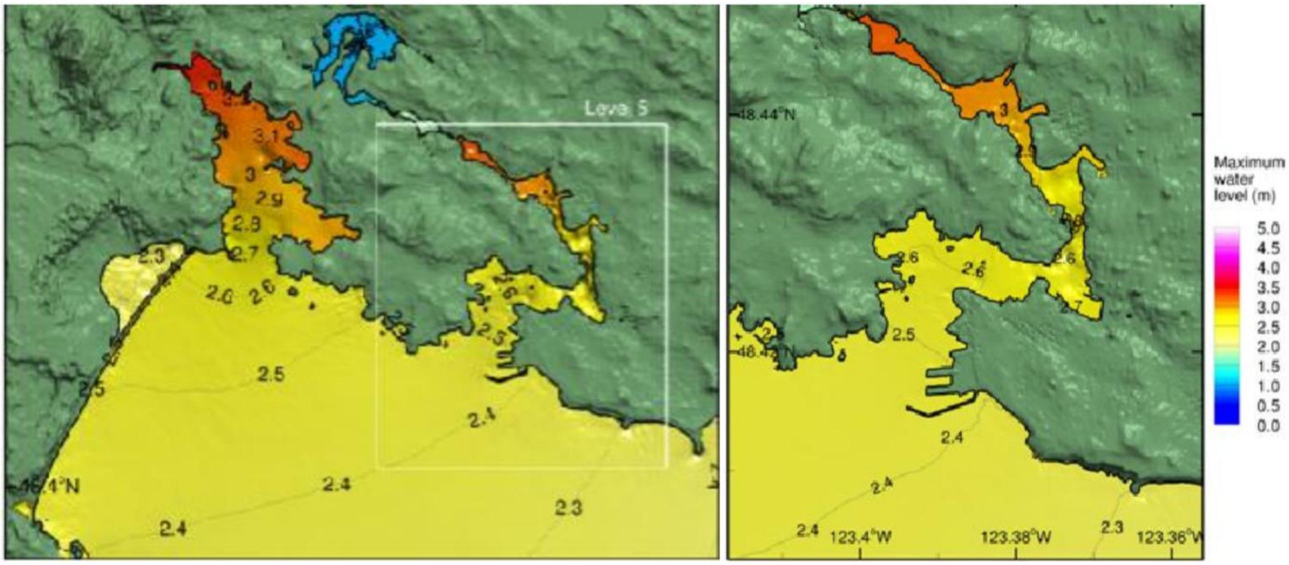

Figure 1-9
Maximum Surface Elevations in Esquimalt and Victoria Harbours for the GA Mw 9.0 Source (AECOM, 2013, Figure 5.1).

1.4.3 2018 Washington State

A more recent study of tsunami hazard in the Juan de Fuca Strait was carried out by the State of Washington Department of Natural Resources, as part of Washington's analysis of tsunami hazards within the U. S. National Tsunami Hazard Mitigation Program (NTHMP). The study is documented in Eungard et al. (2018). The study differs from the two prior studies in that it employs a CSZ source which represents an extreme case with an estimated return period of ~2,500 years, in contrast to the target of a 500-year return period used in the earlier study. The approach of using a maximum probable event as the basis of a hazard analysis is common in settings involving safety class infrastructure, such as nuclear power plants, and is presently fairly standard in the tsunami community.

The source configuration used by Washington has grown out of work done by Witter et al. (2011) and comparable sources developed for the State of Oregon, leading to a conservative source referred to as 'L1'. Eungard et al. (2018) point out that the L1 source provides a close approximation to the seismic design requirements for critical facilities in the Washington State building code. The Witter et al. L1 source has been subsequently modified by Walsh et al. (2016), with further undocumented modifications by the Pacific Marine Environmental Laboratory (PMEL), by extending the source further to the north, along Vancouver Island.

This final L1 source configuration, as utilized recently by the State of Washington, is adopted as the largest of three CSZ sources used in the present study. The source is considerably stronger than the 500-year return period source employed in the 2013 AECOM Report, and thus the tsunami effects described here are expected to be more severe than predicted in the earlier study.

Eungard et al. (2018) concentrated on tsunami predictions for regions around Port Angeles and Port Townsend in Washington. These communities are covered in Grid C of the present study's hierarchy of nested grids, and predictions for those communities are used in **Section 3** as a further check of the validity of the present modeling effort.

2 TSUNAMI MODELLING METHODOLOGY

The methodology for conducting a tsunami inundation modelling study consists of:

1. Developing a set of tsunami source scenarios which cover the range of probable events that are able to affect the study area.
2. Choose an appropriate numerical model which provides the needed physics to describe the problem, from initial wave generation in the source region, propagation towards the study site, and the inundation of the study site and associated maritime hazards.
3. Testing the performance of the numerical model using one or all of the following: recorded / observed wave data, previous tsunami modelling studies and an alternative software package.
4. Development of a high-quality map of topography and bathymetry and related model grids, which are usually used in a nested fashion in order to improve resolution from the source region down to resolutions needed to accurately represent overland flow and strong currents in harbours and waterways. Figure 2-1 shows this process graphically.

The set of sources used in the present study are described first, subsequently the nested set of model grids used and the subsequent limitations of the model outputs.

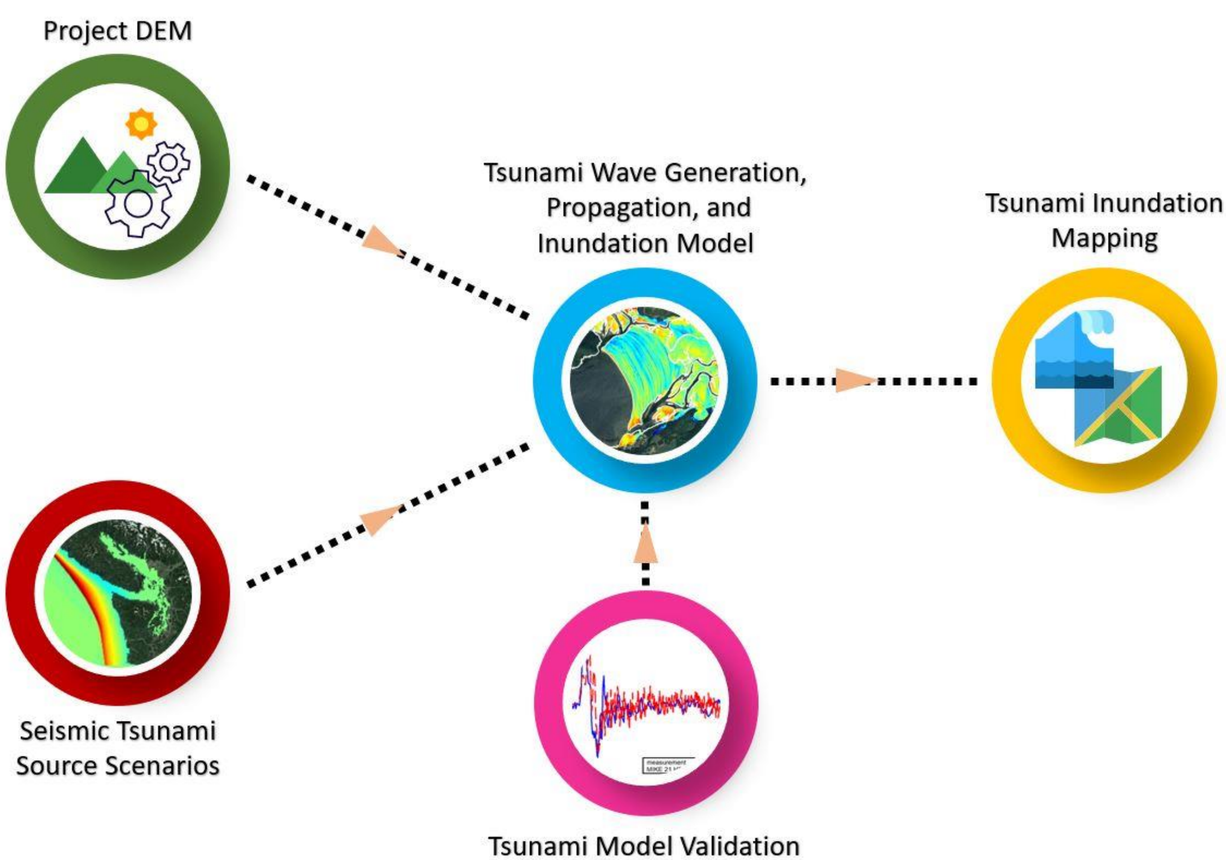

Figure 2-1
Overview of Tsunami Modelling and Mapping Methodology[5]

[5] Icons made by Freepik, SmashIcons and FreeIcons from www.flaticon.com and freeicons.io

2.1 Tsunami Generation Sources

The sources for tsunamis simulated for this project were either provided directly from agencies or experts leading tsunami inundations studies; or were constructed based on published literature. Details for each individual source are provided in this section. Seismic sources are constructed from single or multiple idealized slip planes arranged geographically to cover the desired source areas. **Figure 2-2** shows a definition sketch for a single source plane. The plane's geometry is defined in terms of Strike angle, defined as the angle between the downslope edge of the plane, the Rake angle (defined as the direction of slip motion measured perpendicular to the Strike), the Dip angle, or angle between the slip plane and the (ideally) local horizontal surface. The slip plane area is defined in terms of length L along the Strike and width W perpendicular to the Strike.

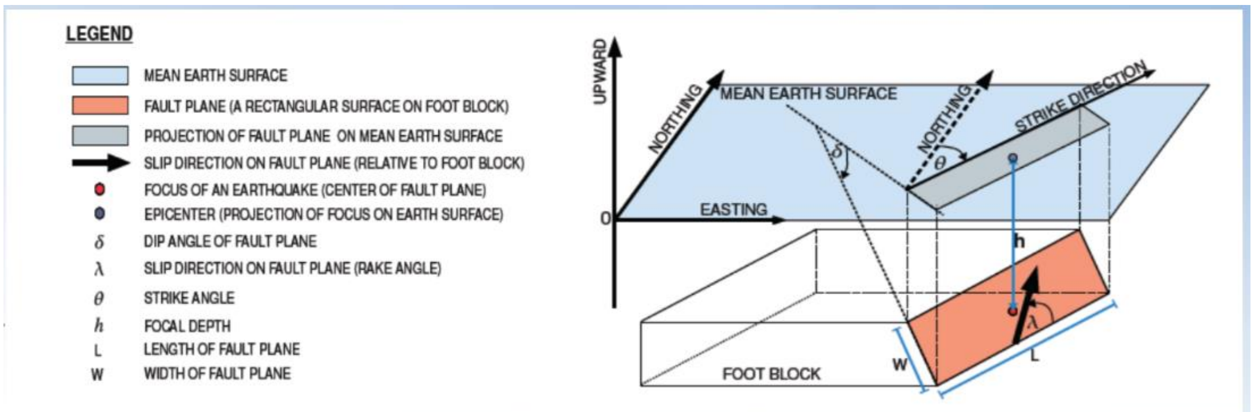

Figure 2-2
Definition Sketch for Source Geometry

Earthquake magnitude is proportional to the product of the slip magnitude, the basal slip area, and a constant that describes material properties in the region of the slip. Source configurations are often constrained first by an estimate of magnitude Mw, after which some iteration is required in order to arrive at a reasonable combination of width W, length L and amount of slip on the fault plane. The resulting configuration is then used together with estimates of the dip angle and the depth of the event to compute a resulting initial ground displacement, using the method of Okada (1985). Okada's method is based on a solution of the equations for elastic deformation in a semi-infinite region with an initially flat upper surface and an imposed dislocation corresponding to the fault plane shown in **Figure 2-2**, with the elastic deformation leading to a deformation of the initially flat upper surface. This approach is a standard means for determining ground displacements based on event magnitudes and estimates of the fault plane geometry.

Table 2-1 provide a list of the sources used for simulations in the present study. Three different configurations of the Cascadia Subduction Zone (CSZ) event are considered. These approximately correspond geographically to the full length, northern section and southern section versions of the source region, described by Cherniawsky et al. (2007) and subsequently refined by Wang et al (2013) and the State of Oregon Department of Geology and Mineral Industries (DOGAMI, information provided directly by Dr. Jonathan Allen, DOGAMI). The full length L1 source used in the present study corresponds to an enhancement of the DOGAMI source used by the State of Washington in tsunami inundation studies and corresponds to an estimated return period of 2500 years.

Four additional distant sources were considered. Two were based on historical events in Alaska: The 1964 Great Alaska earthquake, and the 1946 Aleutian event near Unimak Island, which had significant impact locally and at a number of distant sites in the Pacific basin. The remaining two are the historic 2012 Haida Gwaii earthquake event, and a hypothetical event based on a possible failure of the un-failed segment of the Queen Charlotte fault extending from the failed Haida Gwaii region south to the Nootka Fault triple junction.

Finally, this study is fairly unique in using two near-field faults with two configurations of each, to evaluate potential hazards from seismically active faults within the study site. The events are based on mapping of possible fault structures referred to as the Devil's Mountain fault (Barrie and Greene, 2018; Morell et al., 2018) and the southern Whidbey Island fault (Johnson et al., 1996).

Note that subaerial and submarine landslide-generated tsunamis were considered earlier in the project, however upon review of the applicable background literature and in communication with colleagues, the team (led by Dr. John Clague) deemed the risk of such events to the capital region was low, relative to the sources eventually selected for **Table 2-1**.

Table 2-1
Sources Used in the Present Study

Source	Abbrv.	Magnitude	Probability	Comment
Cascadia Subduction Zone - L1 Source	CSZ-L1	9.1 - 9.2	2500-yr. return period	Worst-case earthquake scenario (L1)
Cascadia Subduction Zone - Northern Segment	CSZ-NS	8.5 - 9.0	500 - 600 yr. return period	Rupture of northern segment
Cascadia Subduction Zone - Central Segment	CSZ-CS	8.5	500 - 600 yr. return period	Rupture of central segment (southern Washington, northern Oregon), identified by Wang et al., 2013
Alaskan 1964	AL	9.2	500 - 1000 yr. return period	Same as 1964 earthquake
Aleutian Trench	UN	8.6	unknown	1946 Aleutian Trench earthquake, off Unimak Island
Haida Gwaii	HG1	7.7	unknown	2012 earthquake
South of Haida Gwaii	HG2	7.5	unknown	Hypothetical event spanning between Haida Gwaii failure and Nootka fault
Devil's Mountain Fault Mw 7.5	DM1	7.5	2000-yr. return period	Worst-case earthquake – Long transpressive rupture (>50 km)
Devil's Mountain Fault Mw 6.5	DM2	6.5	<2000-yr. return period	Middle length transpressive rupture (<50 km)
Southern Whidbey Island Fault Mw 7.5	SW1	7.5	2000-yr. return period	Worst-case earthquake – Long transpressive rupture (>50 km)
Southern Whidbey Island Fault Mw 6.5	SW2	6.5	<2000-yr. return period	Shorter transpressive rupture (<50 km)

2.1.1 Cascadia Subduction Zone - L1 Source (CSZ-L1)

The description of this source was obtained from the State of Washington Geological Survey on January 21, 2020. The source has an associated return period of 2,500 years. This source was chosen to represent the 'worst-case' tsunami event for the study area, which will be useful for emergency managers / planners going forward. The source consists of a complex set of individual fault planes and is described as the L1 source in Witter et al. (2011), with undocumented additions to extend the source to the northern end of Vancouver Island added by NOAA PMEL. The source was provided as a map of resulting ground deformation, which was used directly as model input in FUNWAVE-TVD. This source is employed by the State of Washington as their worst-case scenario for local inundation studies under the NTHMP program, such as the study by Eungard et al. (2018) mentioned above. The spatial distribution of initial vertical ground displacement is shown in **Figure 2-3**. Earthquake parameters including dip, slip and strike angles, depth, lat-lon of epicenter and Lame coefficient, can be found in Witter et al (2011). A description of the modification of the Witter et al (2011) source by PMEL in order to extend the source further to the north is provided by Eungard et al. (2018).

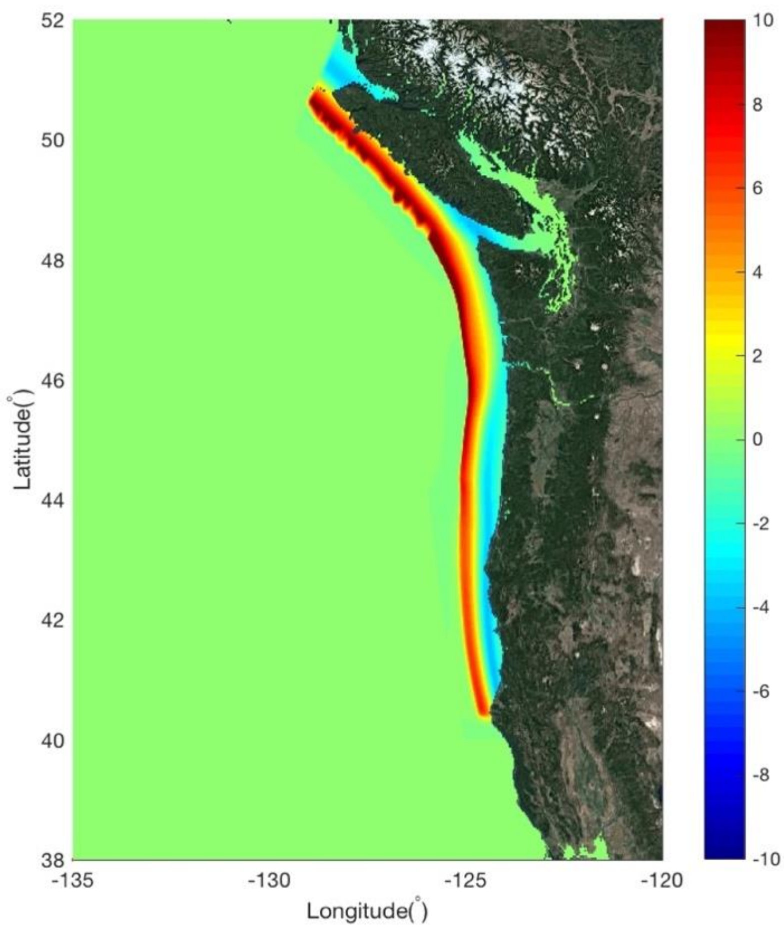

Figure 2-3
CSZ-L1 Source (Witter et al., 2011, with Washington State Modifications)

2.1.2 Cascadia Subduction Zone - Northern Segment (CSZ-NS)

The source considered here is taken from the Witter et al. (2011) L1 source (see also Witter et al., 2013). Wang et al. (2013) developed a multi-segment version of the Cascadia source. The source used here was constructed by using the L1 source provided by The State of Oregon, Department of Geology and Mineral Industries (DOGAMI), updated in 2019 (personal communication Jon Allen, DOGAMI).

Table 2-2 provides a list of general earthquake parameters for each of the scenarios used by the State of Oregon. The northern segment source used here corresponds to Segment A in **Table 2-2**, with a southern limit placed at 46.2° N. DOGAMI provided the ground displacement map for L1, which was used directly in constructing model input. This version of the L1 source is used by the State of Oregon in local inundation studies under NTHMP.

It is important at this juncture to appropriately explain the difference between this study's "CSZ-L1" source and the "CSZ-NS" source, as both use a form of the L1 source formally summarised in the DOGAMI scenarios shown in **Table 2-2**. The CSZ-NS is the L1 source described in the DOGAMI table (**Table 2-2**). It has a return period of 500 - 800 years, depending on the literature reviewed. For this study, a return period of 500 - 600 years has been assumed.

The "CSZ-L1" source (**Section 2.1.1**) used in this study is an extension of the DOGAMI (CSZ-NS) L1 source, that adds additional rupture length as far as the north of Vancouver Island, as described in the preceding section. This was done by Eungard et al. (2018) in support of the 2018 Washington State tsunami modelling work, to provide an even larger tsunami with a more remote return period. Hence, it has a return period of 2,500 years. As such, the 'L1' source given in **Table 2-2** is not the same event as this project's CSZ-L1 event. It is important to understand the distinction. This description also applies to this project's CSZ-CS source. It too is based on DOGAMI's **Table 2-2** L1 scenario; but occurring at a different rupture section (see **Section 2.1.3**).

Table 2-2
Cascadia Earthquake Scenarios Used by the State of Oregon (2019 Update)

Recurrence assigned to each segment according to rupture scenario:

Rupture Scenario	Segment A	Segment B	Segment C	Segment D
XL	1200	1150	1100	1050
L	800	750	700	650
M	525	525	450	450
S	300	300	300	300

Segment boundary regions defined by northern and southern latitudes and midpoint.

Segment Boundary	North Latitude	Midpoint	South Latitude
A-B	46.5 N	46.35 N	46.2 N
B-C	45.1 N	44.55 N	44.0 N
C-D	43.7 N	42.7 N	41.7 N

Cascadia earthquake source parameters used to define 16 rupture scenarios. Logic tree weighting factors for each parameter shown in parentheses.

Rupture Scenario	Recurrence Interval (yrs)	Slip Range (m)	M_w	Fault Model	Total Weight
XL 1 (0.05)	1050-1200	36-44	~9.3	Splay fault (0.8)	0.04
XL 2 (0.05)	1050-1200	36-44	~9.3	Shallow buried rupture (0.1)	0.01
XL 3 (0.05)	1050-1200	36-44	~9.3	Deep buried rupture (0.1)	0.01
L 1 (0.16)	650-800	22-30	~9.2	Splay fault (0.8)	0.13
L 2 (0.16)	650-800	22-30	~9.2	Shallow buried rupture (0.1)	0.02
L 3 (0.16)	650-800	22-30	~9.2	Deep buried rupture (0.1)	0.02
M 1 (0.53)	425-525	14-19	~9.1	Splay fault (0.6)	0.32
M 2 (0.53)	425-525	14-19	~9.1	Shallow buried rupture (0.2)	0.11
M 3 (0.53)	425-525	14-19	~9.1	Deep buried rupture (0.2)	0.11
S 1 (0.26)	275-300	9-11	~8.9	Splay fault (0.4)	0.10
S 2 (0.26)	275-300	9-11	~8.9	Shallow buried rupture (0.3)	0.08
S 3 (0.26)	275-300	9-11	~8.9	Deep buried rupture (0.3)	0.08
Southern Segment Ruptures					
SS 1	400	14	~8.7	Buried rupture, segments C-D	NA

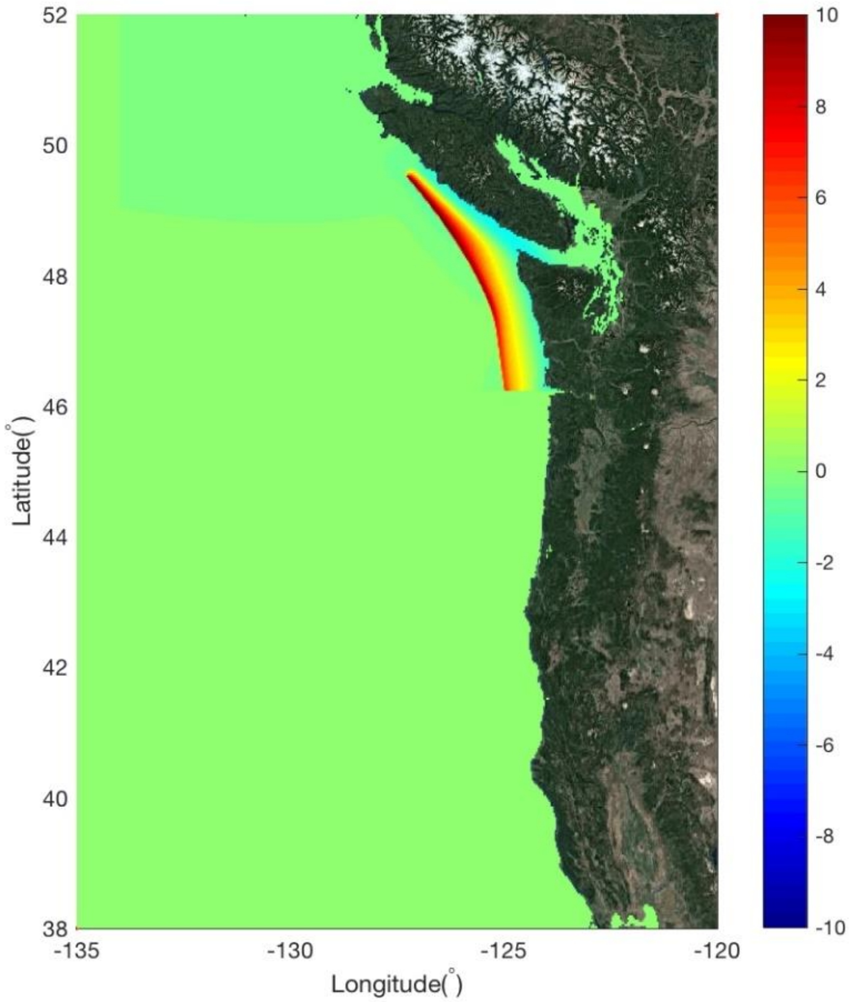

Figure 2-4
Tsunami Source (Surface Elevation in Metres, Above HHWMT): CSZ-NS

2.1.3 Cascadia Subduction Zone - Central Segment (CSZ-CS)

The central segment Cascadia source consists of the portion of the original L1 source (Witter et al., 2011) located south of latitude 46.2° N, labeled Segments B and C as indicated in **Table 2-2**. Again, the **Table 2-2** scenario is not to be confused with this study's CSZ-L1 event, which is an extension of the L1 scenario to the north of Vancouver Island, accompanied with a full rupture over all segments. The return period associated with the CSZ-CS event is estimated to be 500 - 600 years.

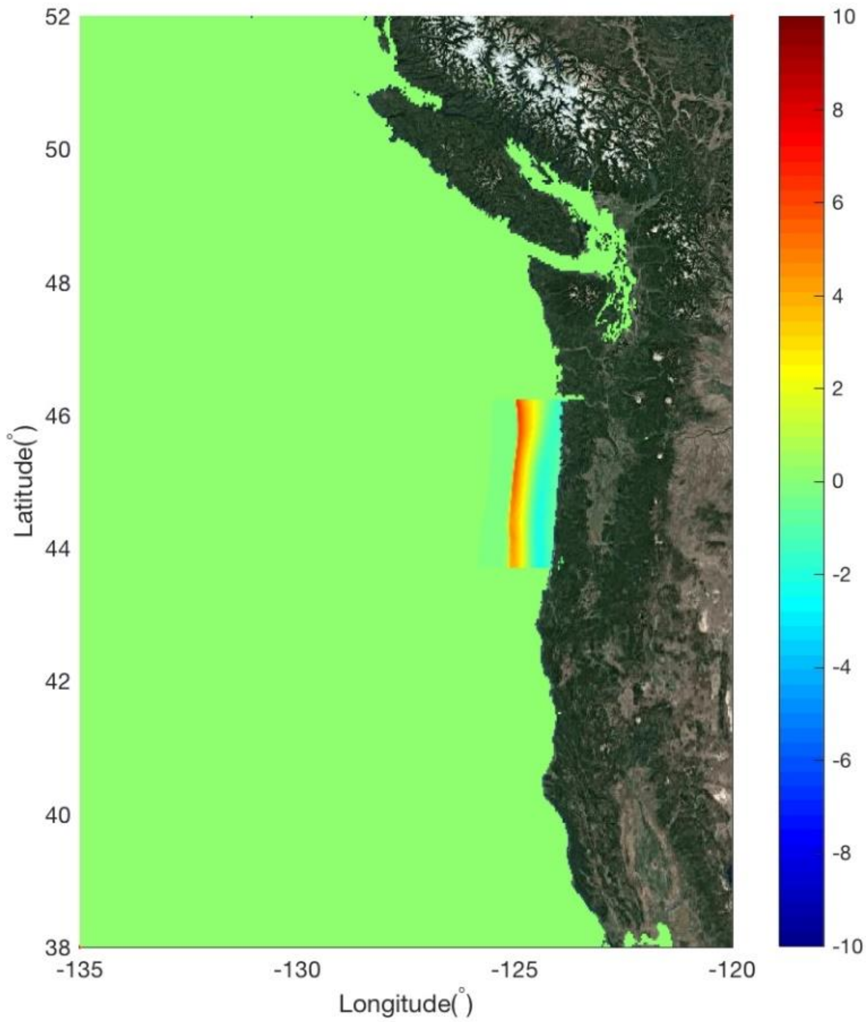

Figure 2-5
Tsunami Source (Surface Elevation in Metres): CSZ Central Segment, Segments B and C of the Oregon (DOGAMI) L1 Source. (Witter et al., 2011)

2.1.4 Alaska 1964 Earthquake (AL)

Nicolsky et al. (2017) have carried out an extensive study of tsunami inundation from the 1964 Alaska earthquake along the southern coast of Alaska, with a focus on Juneau. This study used four previously developed source scenarios to model the 1964 tsunami along the coast, down towards British Columbia. Based on these results, Nicolsky (private communication) expressed a preference for the source of Suito and Freymueller (2009), who applied a 3-D viscoelastic model to describe the post-seismic deformation of the 1964 Alaska earthquake. **Figure 2-6** shows the surface displacement for their result.

This source configuration was provided by the State of Alaska as a ground deformation map, eliminating the need to carry out calculations of ground displacements based on a given map of slip distributions. The ground displacement map is used directly as a static initial condition for surface displacement. The uplift and subsidence associated with the source is far removed from the area around Vancouver Island and the Strait of Juan de Fuca, and thus initial correction of the grid bathymetry to account for these effects is not required.

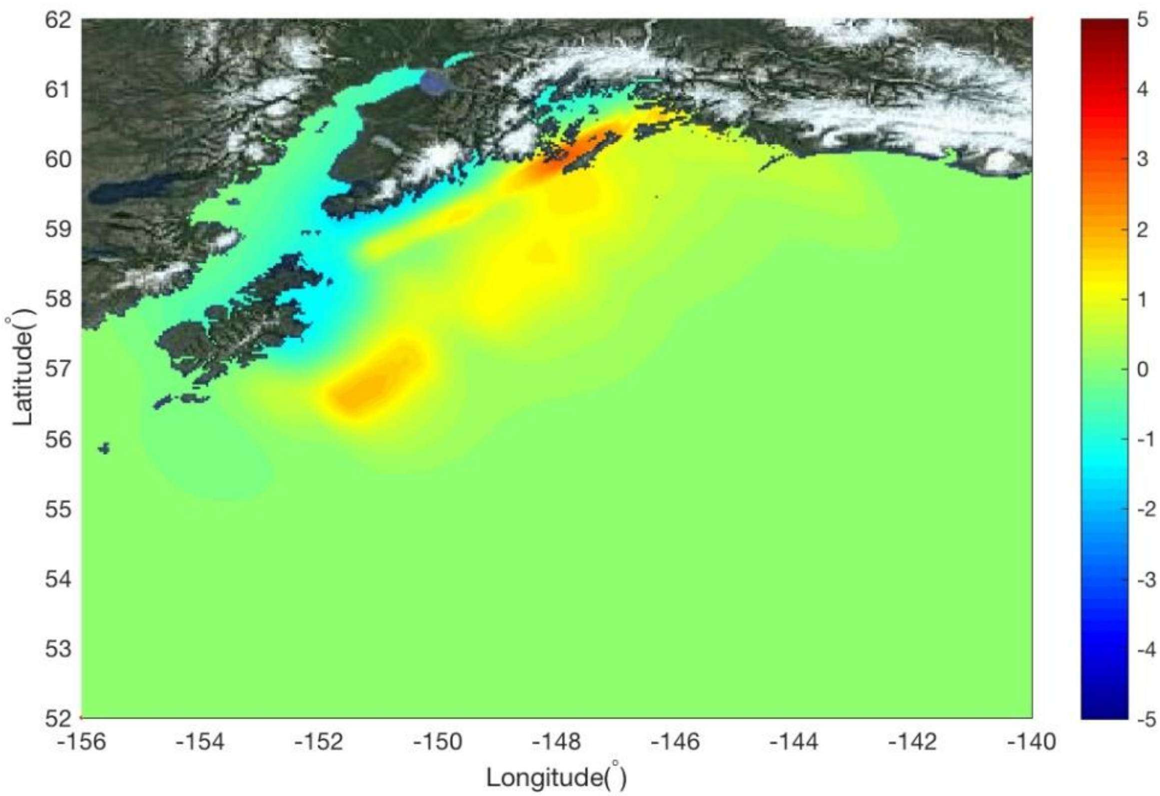

Figure 2-6
Ground Displacement Map for the 1964 Alaska Event Source of Suito and Freymueller (2009).

2.1.5 Alaska 1946 Unimak Island Event (UN)

This source is based on the 1946 Unimak Island event which created runups of up to 40+ m in local areas, famously destroying the Scotch Cap lighthouse, with significant effects felt at a number of distant Pacific sites including Hilo, Hawaii. The event has been modelled in the past as both a seismic event (Johnson and Satake, 1997; Tanioka and Seno, 2001) and as a seismically triggered landslide event (Fryer et al., 2004). **Figure 2-7** shows the proposed seismic source areas suggested by Johnson & Satake and Tanioka & Seno.

Here, we treat the event as a seismic source, using the published configuration from Tanioka and Seno (2001) to develop a source based on a single slip plane. The configuration is based on a length L = 160 km and width W=60 km, with a strike of 250°, rake of 90° and dip of 6°. The event magnitude is assumed to be Mw = 8.2, which leads to an estimated slip of 5.83 m. The plane is centered at longitude 163.5° W and latitude 53.75° N.

Based on this geometry, the half plane solution of Okada (1985) is used to compute ground displacement, which is saved and used as the initial condition for surface and ground displacement. The displacement field is shown in **Figure 2-8**.

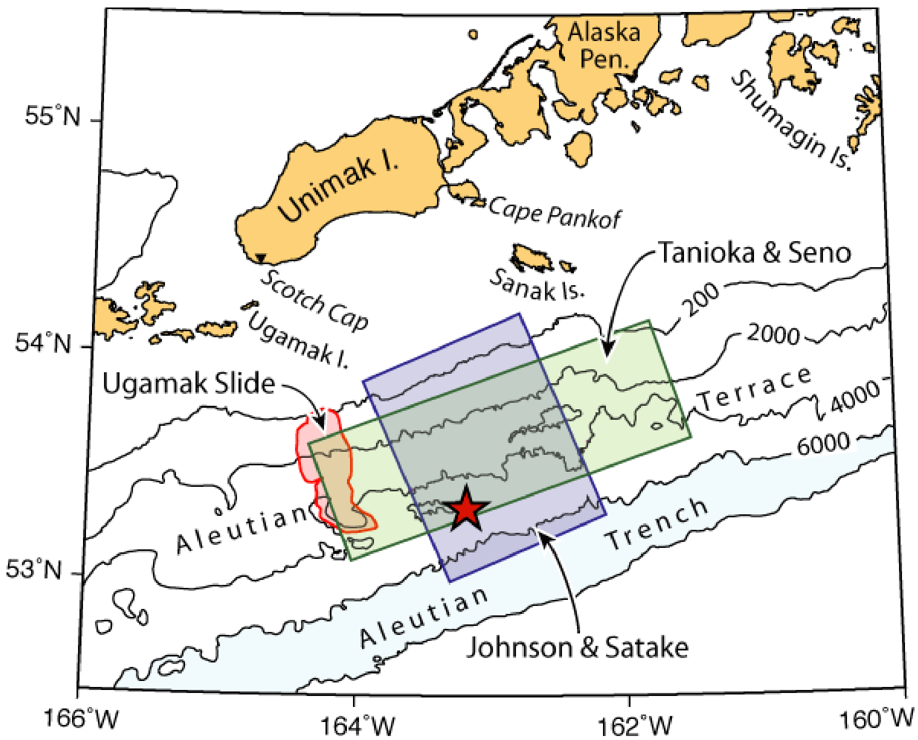

Figure 2-7
Estimated Geometry of Seismic Sources from the Studies of Johnson & Satake (1997) and Tanioka & Seno (2001).

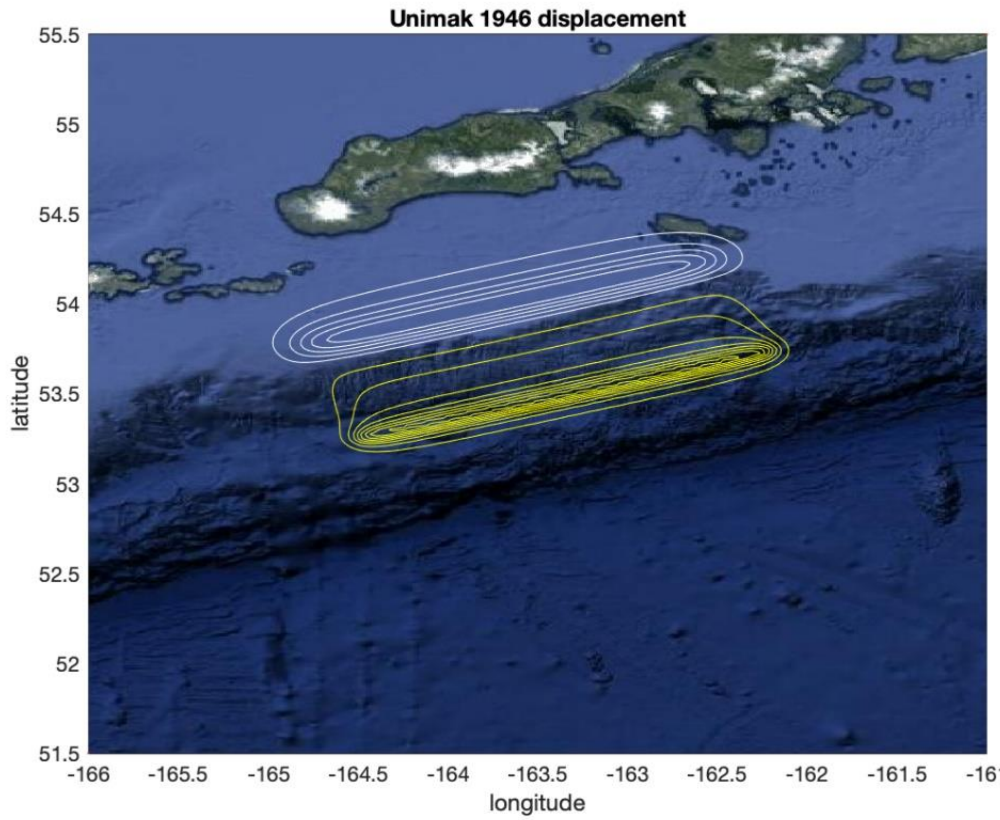

Figure 2-8
Computed Displacement Field for Unimak 1946 Seismic Event. Positive Displacements (Upthrust) Contoured in Yellow, Negative Displacements (Subsidence) Contoured in White, and Contour Intervals of 0.25 m.

2.1.6 Haida Gwaii 2012 Event (HG1)

The source for the historic 2012 Haida Gwaii earthquake and tsunami event is based on a map of ground deformation developed by the U. S. Geological Survey, with technical information available for download from the link provided below[6].

This version of the event has previously been used by one of the present authors in the study of Abdolali et al. (2015). Results using the ground displacement map for that study (obtained from Ali Abdolali, personal communication) and the FUNWAVE-TVD model are used as the principal model validation study, described in **Section 3**.

This event was the primary means by which the tsunami modelling was validated. Refer to **Section 3** for further details.

[6] https://earthquake.usgs.gov/earthquakes/eventpage/usp000juhz/finite-fault

2.1.7 Haida Gwaii: Southern Rupture (HG2)

A final remote source is based on a hypothetical rupture of the remaining segment of the Queen Charlotte Fault zone extending 100 km further south along the fault from the southern limit of the Haida Gwaii 2012 rupture. The failure plane has a width of 50 km and a slip of 1 m, leading to a Mw 7.5 event with a maximum vertical displacement of 0.37 m.

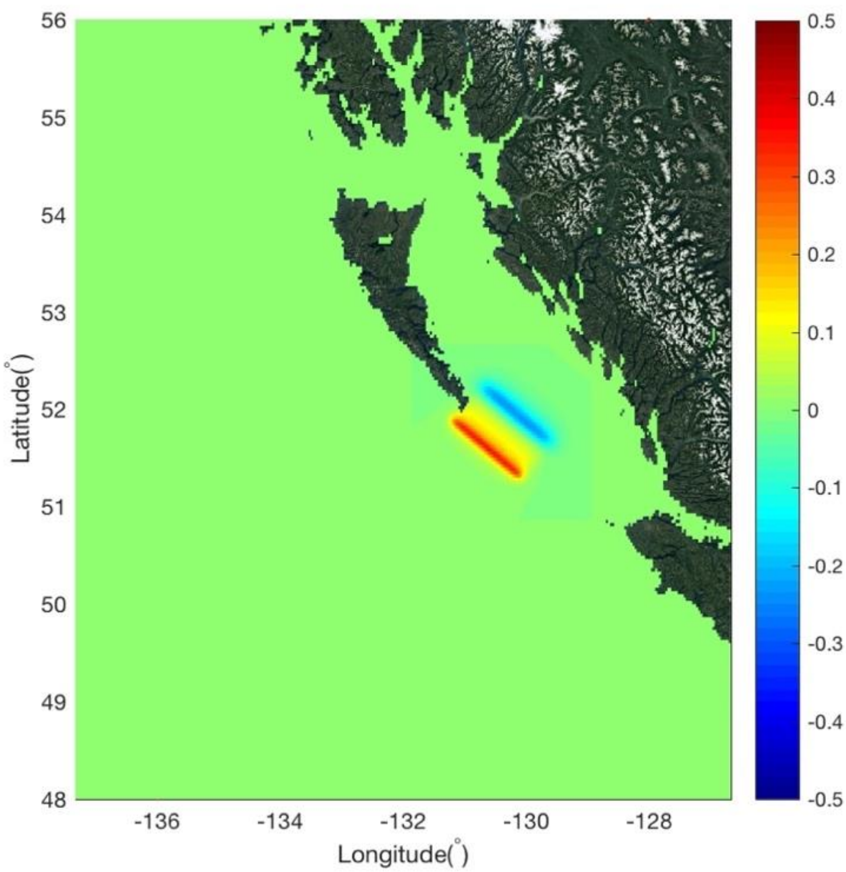

Figure 2-9
Configuration of the Southern Rupture Extension to the Haida Gwaii 2012 Rupture (Surface Elevation in Metres).

2.1.8 Devil's Mountain Fault (DM1 & DM2)

The east-west striking Devil's Mountain fault extends from the foothills of the Cascade Range, across northern Puget Sound and eastern Juan de Fuca Strait, to the southern tip of Vancouver Island where it meets the Leech River and San Juan faults (**Figure 2-10**). The fault zone has been active for at least 40 million years and has sustained both transtensional and transpressional movement (Dragovich and DeOme 2006). The fault remains active, as it offsets late Quaternary marine sediments on the Salish seafloor between Whidbey Island and Vancouver Island.

Offshore seismic reflection data suggest the Devil's Mountain fault has a moderate to steep (45 - 75°) north dip, becoming steeper eastward (Johnson et al. 2001a, 2001b). Johnson et al. (2001a, 2001b) infer that the Devil's Mountain fault is currently a left-lateral oblique transpressional structure with a dominant sinistral (left-lateral) strike-slip component. Dragovich and DeOme (2006) and Dragovich and Stanton (2007) argue that the Devil's Mountain fault flattens with depth into a décollement at about 16 km depth. The USGS Quaternary fault and fold database describes the fault as sinistral with a reverse component.

There is little information on the magnitudes or rates of displacement for the Devil's Mountain fault. Johnson et al. (2001a) inferred about 12 ± 8 m of vertical displacement on the ca. 125,000-year-old Whidbey Island Formation, consistent with Quaternary vertical displacement rates obtained from offshore data. Dragovich and DeOme (2006) and Dragovich and Stanton (2007) report evidence of Holocene displacement on the Devil's Mountain fault in Puget Lowland, including apparently uplifted Holocene terrace deposits, offset latest Pleistocene lake sediments in Lake Cavanaugh, and apparently faulted 15,000-year-old glacial deposits exposed in a trench.

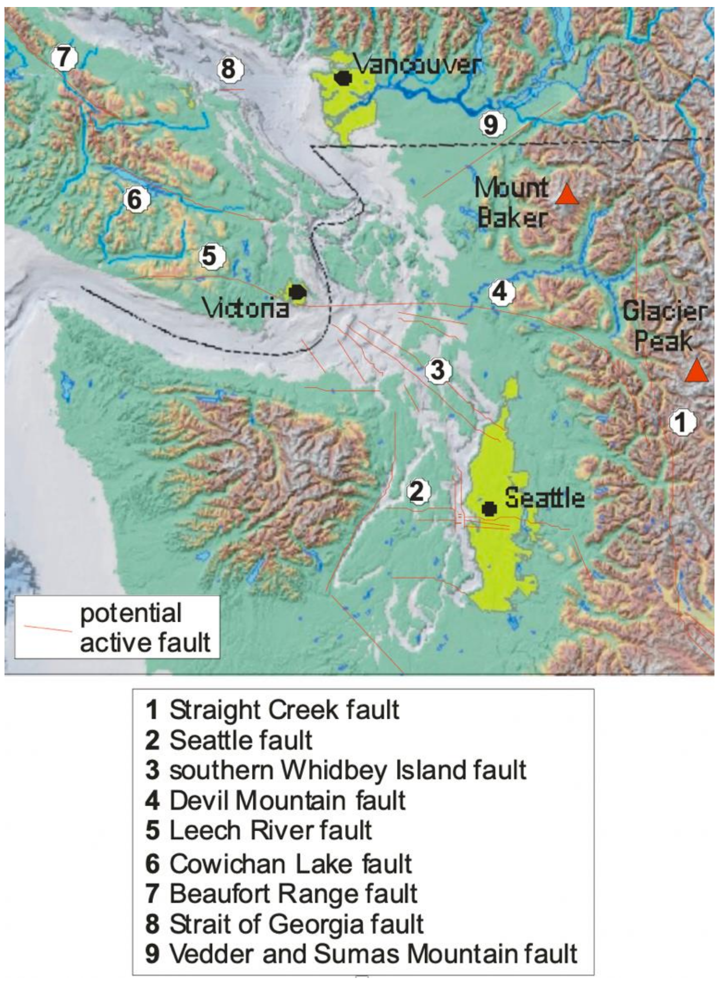

Figure 2-10
Active and Potentially Active Faults in Northwest Washington and Southwest British Columbia, Including the Devil's Mountain and Southern Whidbey Island Faults.

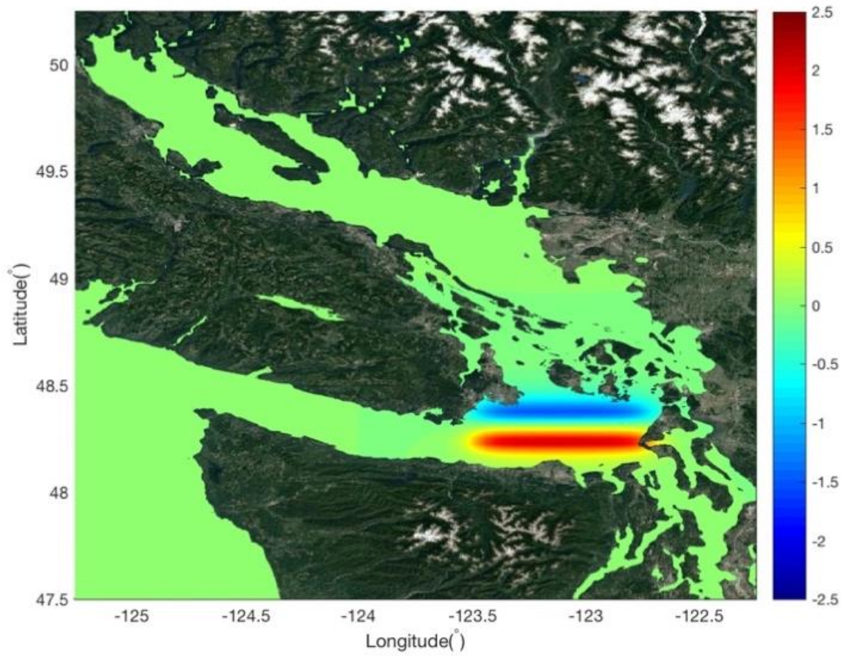

Figure 2-11
Devil's Mountain Fault. Hypothetical Long Transpressive Fault, Mw 7.5

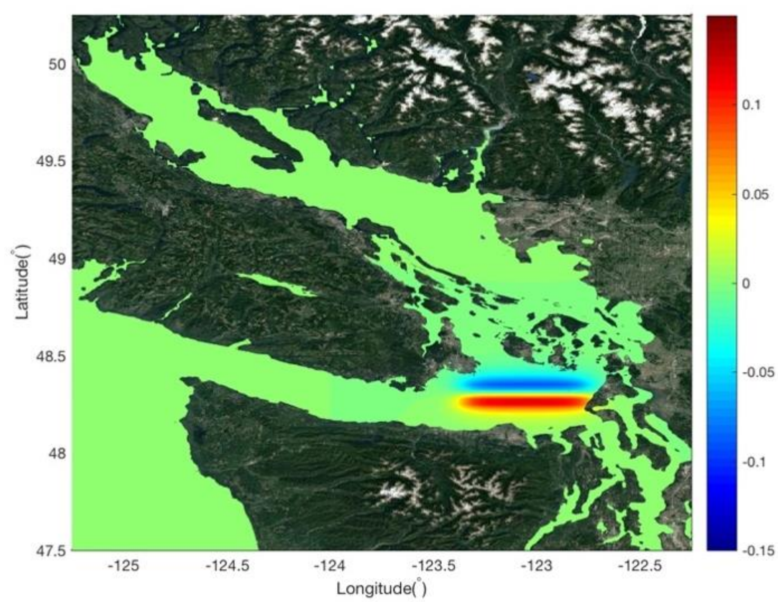

Figure 2-12
Devil's Mountain Fault. Hypothetical Mid-Length Transpressive Fault, Mw 6.5

2.1.9 Southern Whidbey Island Fault (SW1 & SW2)

The Southern Whidbey Island fault extends at least 90 km northwest from near the west edge of Puget Lowland between Seattle and Everett, across southern Whidbey Island, and across northern Puget Sound and eastern Juan de Fuca Strait (**Figure 2-10**). The western limit is uncertain, but Ramachandran et al. (2005) propose that the fault extends to just offshore of Victoria where it merges with the Devil's Mountain fault.

The Southern Whidbey Island fault is included in the USGS Quaternary fault database as three subparallel strands that converge to the northwest. The fault zone, which includes two main, north-side-up faults west of Whidbey Island, becomes progressively wider and more complex to the southeast (Johnson et al. 1996; Sherrod et al. 2008).

Johnson et al. (1996) analyzed seismic reflection, outcrop, and borehole data and propose that the fault is a steeply north-dipping transpressional fault with north-side-up reverse movement. Brocher et al. (2005) suggest that the fault formed in response to NE-SW compression in the forearc and that its major strands are northeast-dipping reverse faults that flattens into a SW-dipping blind master thrust fault at shallow depth. Sherrod et al. (2008) propose that the fault lies within a stress field in which north-south convergence in southern and central Puget Sound gives way to NE-SW-directed shortening in the north. In this model, the fault has predominantly north-side-up reverse motion to the northwest and becomes primarily dextral-oblique to the southeast where the stress and the fault are oriented differently.

The fault has clear evidence of recent activity. Johnson et al. (1996) show offshore seismic reflection profiles documenting folding and faulting of late Quaternary strata, and borehole data on Whidbey Island show abrupt thickness differences in Quaternary strata across the fault. Johnson et al. (1996) further document numerous Quaternary liquefaction features in the vicinity of the fault. Onshore coastal marshes on opposite sides of the fault record different late Holocene, relative sea-level histories, indicating that the north side of the fault has been uplifted 1 to 2 m relative to the south side.

Bourgeois and Johnson (2001) present evidence of abrupt subsidence, a tsunami, and at least three liquefaction episodes on the Snohomish delta near the Southern Whidbey Island fault since AD 800. Sherrod et al. (2008) trenched several scarps identified in LiDAR data that have north-side-up separation and are 1 to 5 m high.
The trenches reveal evidence of multiple seismogenic fault and fold events since deglaciation (ca. 16,000 years ago). Combining their observations with the paleoseismic data from Whidbey Island, Sherrod et al. (2008) argue for at least four large Southern Whidbey Island fault earthquakes over the postglacial period. They suggest there may have been as many as eight large Holocene earthquakes if deformation from Snohomish delta and a possible early Holocene event exposed in their trenches constitute independent events.

Johnson et al. (1996, 2004) report a minimum slip rate of 0.6 mm/yr. on the Southern flattens with depth into a décollement Whidbey Island fault based on observations of 150 m of structural relief on an onshore anticline overlying a positive flower structure identified in offshore reflection profiles; the material in the core of the anticline is 250,000-year-old Double Bluff drift.

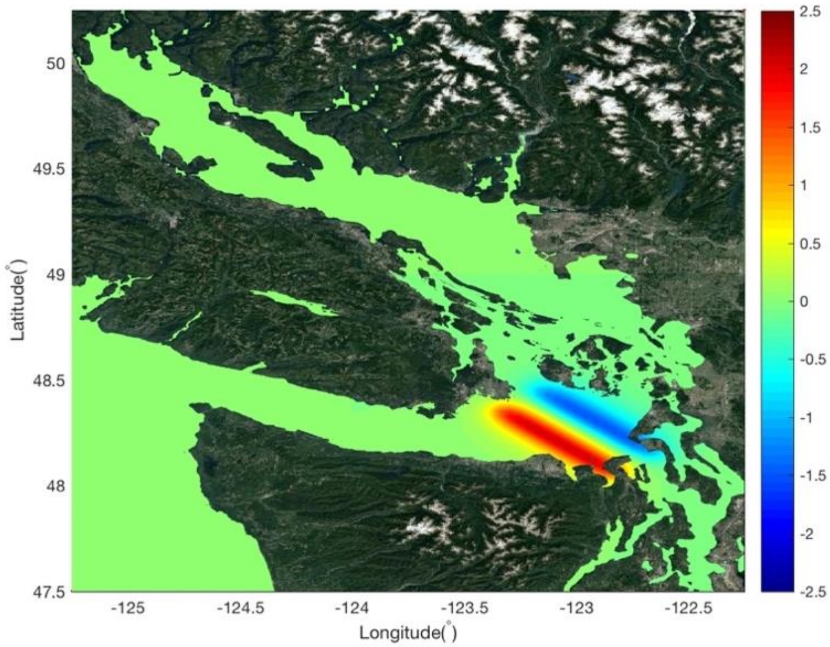

Figure 2-13
Southern Whidbey Island Fault: Hypothetical Long Transpressive Rupture, Mw 7.5

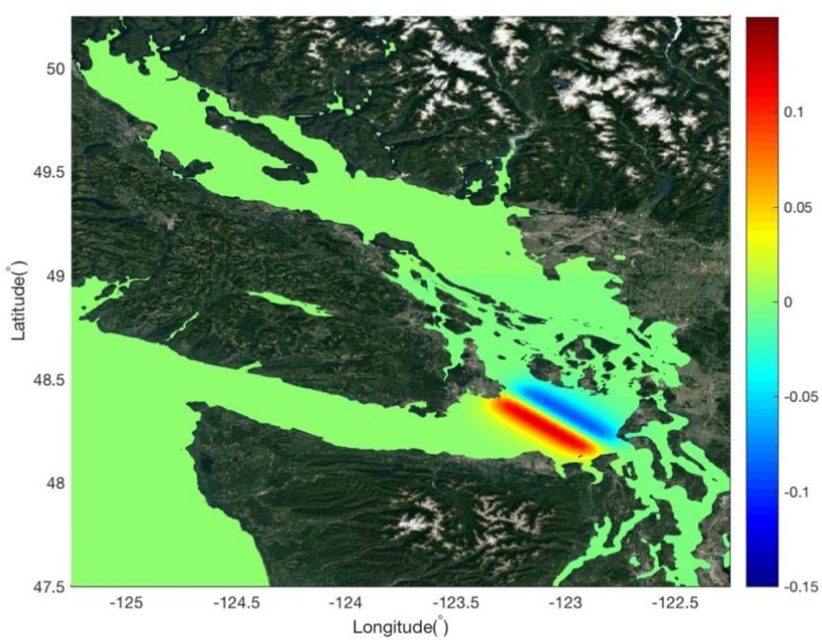

Figure 2-14
Southern Whidbey Island Fault: Hypothetical Medium-Length Transpressive Rupture, Mw 6.5

2.2 Bathymetric and Topographic Inputs

As will be described in the following section, FUNWAVE-TVD was the modelling package chosen to model tsunamis in this project. The FUNWAVE-TVD tsunami model was constructed using a multi-grid nesting technique. There are four levels of nested grids used in this project for modelling of remote tsunami sources:

- Grid A
- Grid B
- Grid C
- Grid D / Grid C' – Both grids were similar in resolution; but were used for different tsunami sources, covering different geographic expanses (See **Section 2.3.3**).

The modelled tsunami event travels from source to coastline. The level of accuracy / model resolution (or bathymetric / topographic fidelity) increased, as the grids progressed from Grid A to D / C'. Grids for high resolution studies of inundation, currents and vorticity were constructed for five areas lying within Grid D (i.e. detailed inundation modelling), see **Section 2.4** for details.

Inputs for the A, B and C grids described below were obtained from several online resources provided by NOAA, including:

- The ETOPO2 2 arc-minute global relief model (National Geophysical Data Center, 2006).
- The ETOPO1 1 arc-minute global relief model (Amante and Eakins, 2009).
- The Coastal Relief Model (CRM, vol. 8 – Pacific Northwest.

These data sets may be downloaded based on chosen latitude and longitude limits and provide digital elevation models (DEMs) for the low-resolution A, B and C grids without further modification.

Grids C', D and the 4 m-resolution detailed inundation grids were constructed based on the DEM developed in Task 1 (Task 1 – DEM Development Report) of this project and adjusted to HHWMT (Higher High-Water Mean Tide) (choice of HHWMT is explained further in **Section 2.3.2**). Refer to the Task 1 report for further information.

2.3 Modelling Procedure

2.3.1 Modelling Overview

Hydrodynamic modelling and mapping for each tsunami source was completed as per the US National Tsunami Hazard Mitigation Program (NTHMP) guidelines. The NTHMP program is a federal-state partnership, founded by the National Oceanic and Atmospheric Administration (NOAA), whose objective is to plan for and reduce tsunami risk to US coastal communities.

The propagation, shoreline runup and inundation and current patterns caused by the tsunami scenarios studied here were calculated using the Boussinesq wave model FUNWAVE-TVD, developed at the University of Delaware. In the present application, FUNWAVE-TVD solves the Cartesian or Spherical coordinate forms of the fully or weakly-nonlinear, weakly-dispersive Boussinesq equations, described respectively by Shi et al. (2012) or Kirby et al. (2013). Shi et al. (2011) describes the operation of both Cartesian and spherical-polar versions of the code.
The model incorporates bottom friction and turbulent mixing effects.

In addition to the primary FUNWAVE-TVD modelling package, DHI's MIKE 21 modelling software was used to cross-reference the performance of the FUNWAVE-TVD model as part of the validation / calibration element of this Task. Refer to **Section 3** for further details.

FUNWAVE-TVD has been benchmarked for tsunami application using the PMEL-135 benchmarks provided in Synolakis et al (2007), which are the presently accepted benchmarking standards adopted by the National Tsunami Hazard Mitigation Program (NTHMP) for judging model acceptance for use in development of coastal inundation maps and evacuation plans. Benchmark tests of the code are described in:

- Tehranirad et al. (2011)[7].
- Shi et al. (2012)[8] for the spherical version.
- The model has also been benchmarked for current simulations based on benchmarks developed for a second NTHMP exercise, described by Lynett et al. (2017).
- Model performance on the benchmarks developed for the current workshop is described in Kirby et al. (2016)[9]

A multi-grid nesting technique was used in the project. The grid-nesting scheme uses a one-way nesting method, which passes surface elevation and velocity components calculated from a larger, lower-resolution domain to a nested smaller, higher-resolution domain by interpolating the coarser grid results at virtual, or ghost, grid cells distributed around the boundary of the nested grid. A linear interpolation is performed between a large domain and small domain at nesting boundaries. A test of the nesting process is included in Shi et al. (2011).

The FORTRAN program, documentation, and descriptions and input files for carrying out benchmark tests and various example calculations are available through the FUNWAVE-TVD web portal[10].

It is important to note that in order to maximise the number of sources and magnitudes modelled, **no account for relative sea level rise was made in the tsunami modelling**. This could be the focus of future work and study.

2.3.2 Initial Water Level for Modelling

As per NTHMP modelling guidelines, the initial water level used for tsunami modelling was the Higher High-Water Mean Tide (HHWMT). HHWMT is defined as the average from all the higher high waters from an 18.6 year tide cycle. It is important to note there are higher tides possible at the project location like the Highest Astronomical Tide (HAT) or Higher High-Water Large Tide (HHWLT, defined as the average of the annual maximum series for an 18.6 year tide cycle). However, the statistical probability of these initial tide levels occurring at the same time as an extreme tsunami event results in a joint-probability far more remote that the actual return period of the tsunami event being modelled. Therefore, the choice of HHWMT is a technically robust selection, incorporating an acceptable level of conservatism. (Refer to **Appendix N** for further information on conversion between HHWMT and elevations reported to CGVD2013)

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[7] https://cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/0/7241/files/2018/03/CACR-11-02-Tehranirad-etal-rhswer.pdf) for Cartesian version
[8] https://cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/0/7241/files/2018/03/CACR-12-02-Version-2.0-115qpkg.pdf
[9] https://cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/0/7241/files/2018/03/CACR-16-01-kirby-etal-180vouu.pdf
[10] https://fengyanshi.github.io/build/html/index.html.

As described in **Section 2.2**, the Grids C', D and the 4 m detailed inundation modelling grid were adjusted to HHWMT (i.e. zero metre elevation = HHWMT).

2.3.3 Model Grids

There are four levels of nested grids used in this project for modelling of remote tsunami sources:

- Grid A
- Grid B
- Grid C
- Grid D / Grid C'

The ratios of grid resolutions, representing the reduction in grid spacing or increase in grid resolution for each level of nesting, are given by: GridA / GridB = 4, GridB / GridC = 5, and GridC / GridD = 6. For example, the ratio of 4 for GridA / GridB represents a shift from the 2 arc-minute resolution of the ocean basin-spanning Grid A to the 30-arc-second resolution of the more localized Grid B, a factor of 4 increase in resolution. For the local Devil's Mountain Fault and Southern Whidbey Island Fault sources, Grid C' was used as the initial grid without nesting within the larger Grid B. Grid C' was constructed for the same domain as Grid C but has a higher resolution (1.5 arc-second, or 31.3 m x 46.3 m) than Grid C (6 arc-second). Detailed information and figures of the grids are shown in the subsequent sub-section. **Everywhere in the capital region was modelled in Grid D / C', therefore, to a minimum of 30 m grid resolution.**

In addition to the four levels of nested grids, detailed inundation modelling was undertaken at a select number of locations in the capital region, with a modelling resolution of 4 m. Further details are provided in **Section 2.4**.

2.3.3.1 Grid A

Grid A is a far-field grid covering the area shown in **Figure 2-15**. It provides the basis for the initial level of computation for Cascadia, Alaska and Haida Gwaii sources. Bathymetry data is obtained from the ETOPO2 data set (National Geophysical Data Center, 2006). The grid covers the area bounded by longitudes -228° E and -95° E and latitudes from 0° to 65° N at a resolution of 2 arc-minute, or about 4000 m. The grid dimension is 3991 x 1951. Calculations from Grid A are used as boundary data for the inset Grid B shown in **Figure 2-16**.

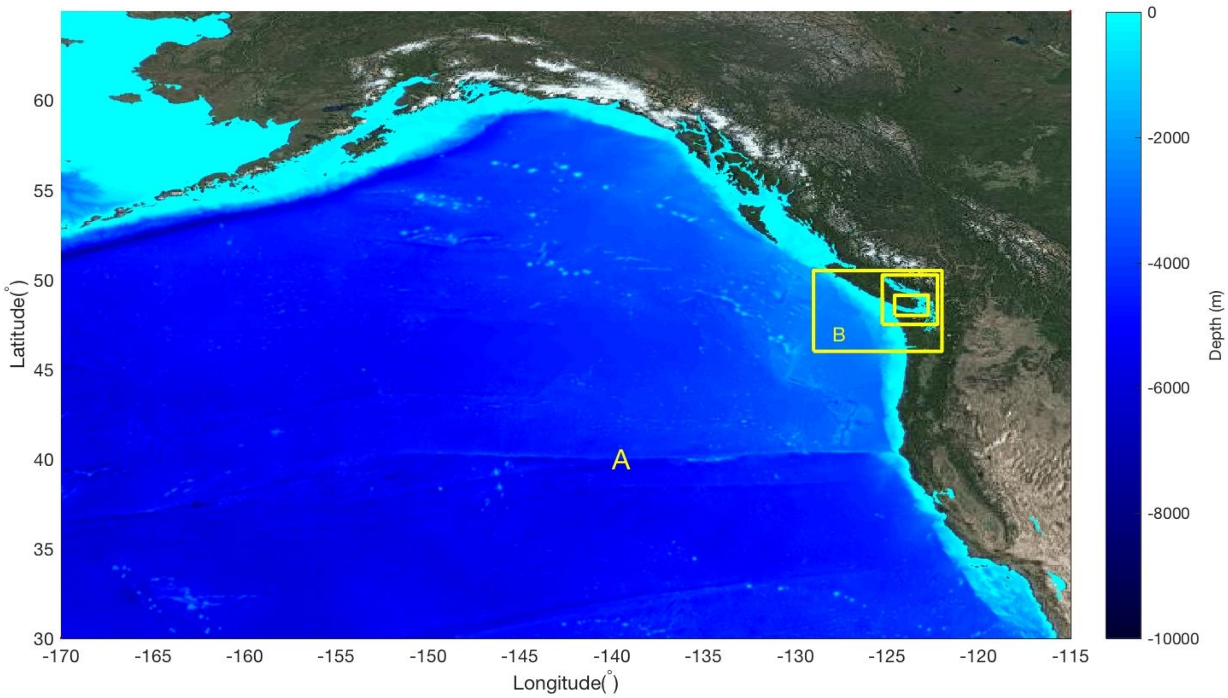

Figure 2-15
Model Grid A Covering the North Pacific, for use with the Alaska 1964, Unimak and Haida Gwaii Sources.

2.3.3.2 Grid B

Grid B (**Figure 2-16**) is nested within Grid A for Cascadia, Alaska and Haida Gwaii events. Bathymetry for the grid is taken from the ETOPO1 data set (Amante and Eakins, 2009). The grid covers the region (lon. lon. lat. lat.): [-129° - 122° W, 46° - 50.5° N] at a resolution of 30 arc-second, giving a spatial resolution of about 1000 m. Grid dimensions are 841 by 541. The results of computations on Grid B are used as boundary data to drive the nested Grid C, shown as the larger inset in **Figure 2-17**.

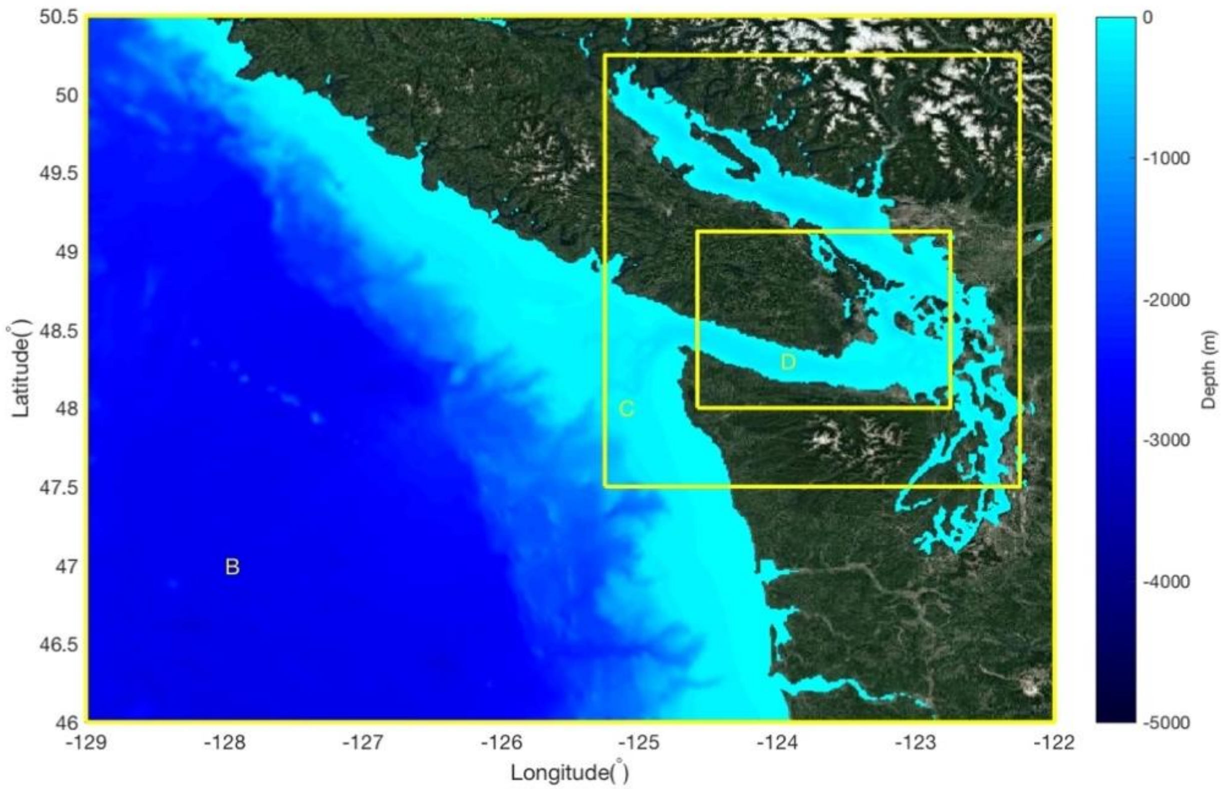

Figure 2-16
Area Covered by Grid B. Grids C and D Shown as Progressively Smaller Insets.

2.3.3.3 Grid C

Grid C (**Figure 2-17**) is nested within Grid B and is used to propagate the tsunamis from the CSZ and remote sources into the capital region. Sources for the bathymetry and topography data for this grid are taken from the NOAA Coastal Relief Model (CRM) and Canadian Hydrographic Survey (CHS) bathymetry data[11]. The grid covers the domain (lon. lon. lat. lat.): [-125.25° - 122.25° W, 47.5° - 50.25° N] and has a spatial resolution of 6 arc-seconds, or about 180 m, leading to a grid with dimensions 1801 by 1651. Results of Grid C calculations are used as boundary data to drive Grid D computations.

[11] Task 1 - DEM Development Report, Associated Engineering, 2020

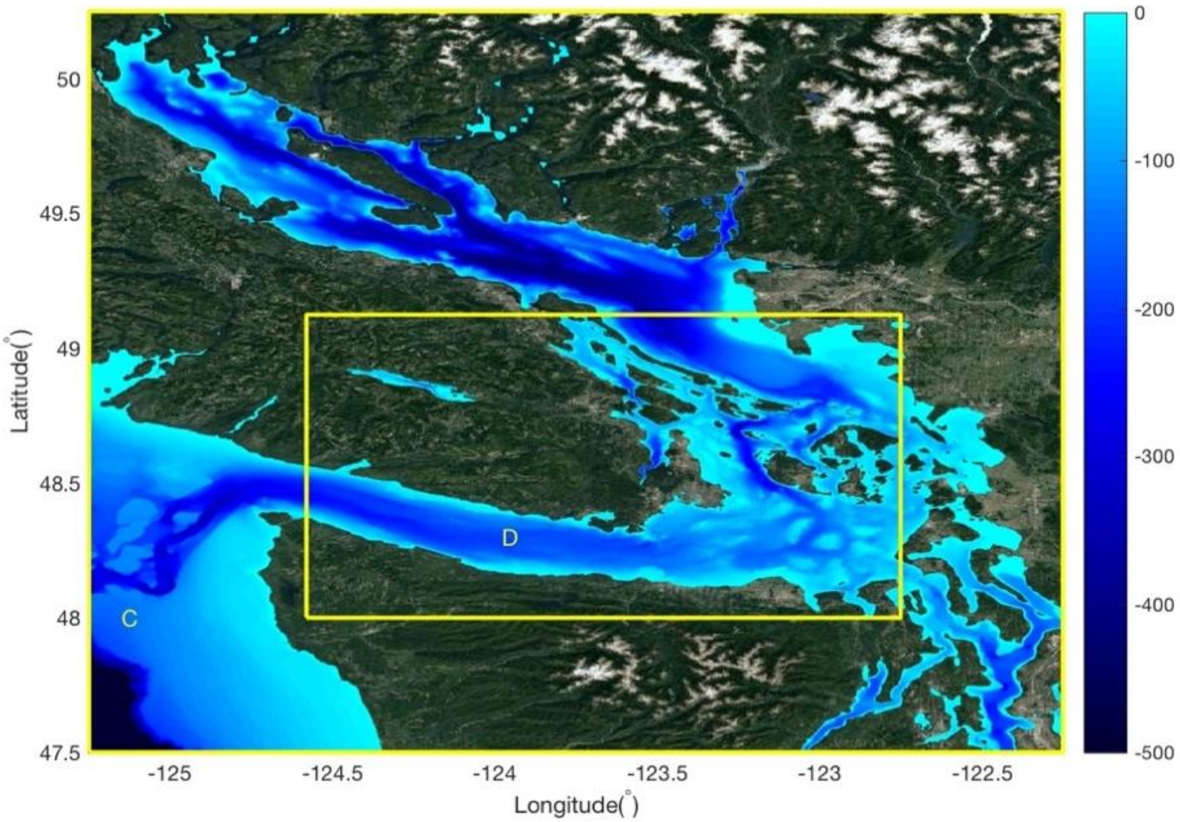

Figure 2-17
Grid C

2.3.3.4 Grid C’

Grid C’ covers the same physical area as Grid C but is constructed with a higher spatial resolution of 1.5 arc-seconds, or about 45 m. Grid C’ is used as the grid for the calculation of the local source events based on the Southern Whidbey Island and Devil’s Mountain faults. Data for constructing the grid comes from the NOAA Coastal Relief Model Vol. 8, CHS Bathymetry and the recently flown GeoBC LiDAR. Grid C’ is the only coarse-scale grid used to drive the high-resolution grid models.

2.3.3.5 Grid D

Grid D (**Figure 2-18**) is the final of the four coarse-scale grids. It covers the geographical area (lon. lon. lat. lat.): [-124.58° - 122.75° W, 48° - 49.125° N] with a resolution of 1 arc-second, or approximately 30 m, leading to a grid with dimensions 6589 x 4051. Data for constructing the grid comes from the NOAA Coastal Relief Model Vol. 8, CHS Bathymetry and the recently flown GeoBC LiDAR. Again, details on the various bathymetric and topographic datasets can be found in Task 1 – DEM Development Report.

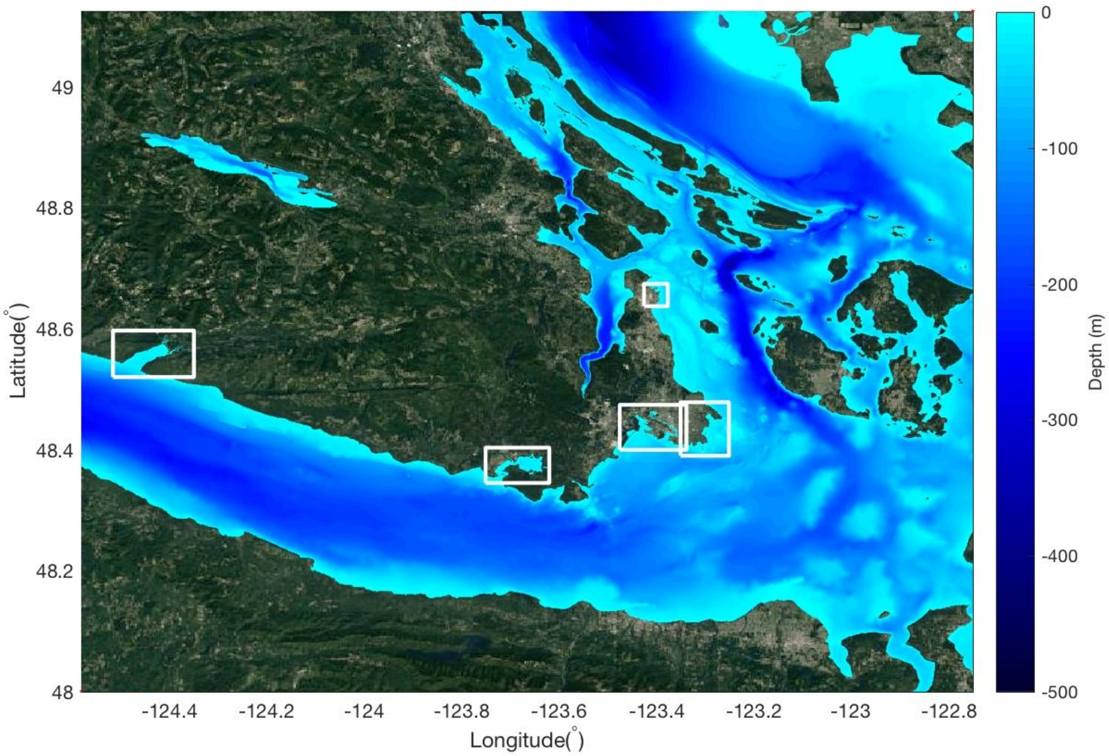

Figure 2-18
Grid D, with Insets Indicating Positions of Five Detailed Inundation Area Grids

2.4 Detailed Inundation Modelling

2.4.1 Detailed Inundation Domains

Accurate estimation of local tsunami inundation effects as well as current patterns in waterways and harbours requires a grid resolution fine enough to resolve distinctive coastal features such as shoreline irregularities.

Grids for high resolution studies of inundation (i.e. detailed inundation modelling), currents and vorticity were constructed for five areas lying within Grid D:

- Victoria / Esquimalt,
- Sidney,
- Saanich / Oak Bay,
- Sooke, and
- Port Renfrew.

These areas were chosen to complement the detailed sea level rise inundation areas (see Task 2 – Coastal Flooding Modelling and Mapping Report), as well as communities within Juan de Fuca Strait that have greater exposure to the

Cascadia Subduction Zone. These areas were selected due to their relatively low-lying nature, extensive potential floodplains and higher-density of vulnerable populations within those floodplains[12]. Many areas in the capital region are sited at higher elevations, fronted by steep coastline, thus making them less suitable for detailed inundation modelling.

The grid for the Victoria / Esquimalt detailed inundation area is shown in **Figure 2-19**. Elevation information for the grid is taken from the CHS bathymetry and the recently flown GeoBC LiDAR. The grid covers a domain (lon. lon. lat. lat.): [-123.4883° - 123.3502° W, 48.3995° - 48.4753° N], and has grid dimensions 2566 x 2094 and a horizontal resolution of 4 x 4 m.

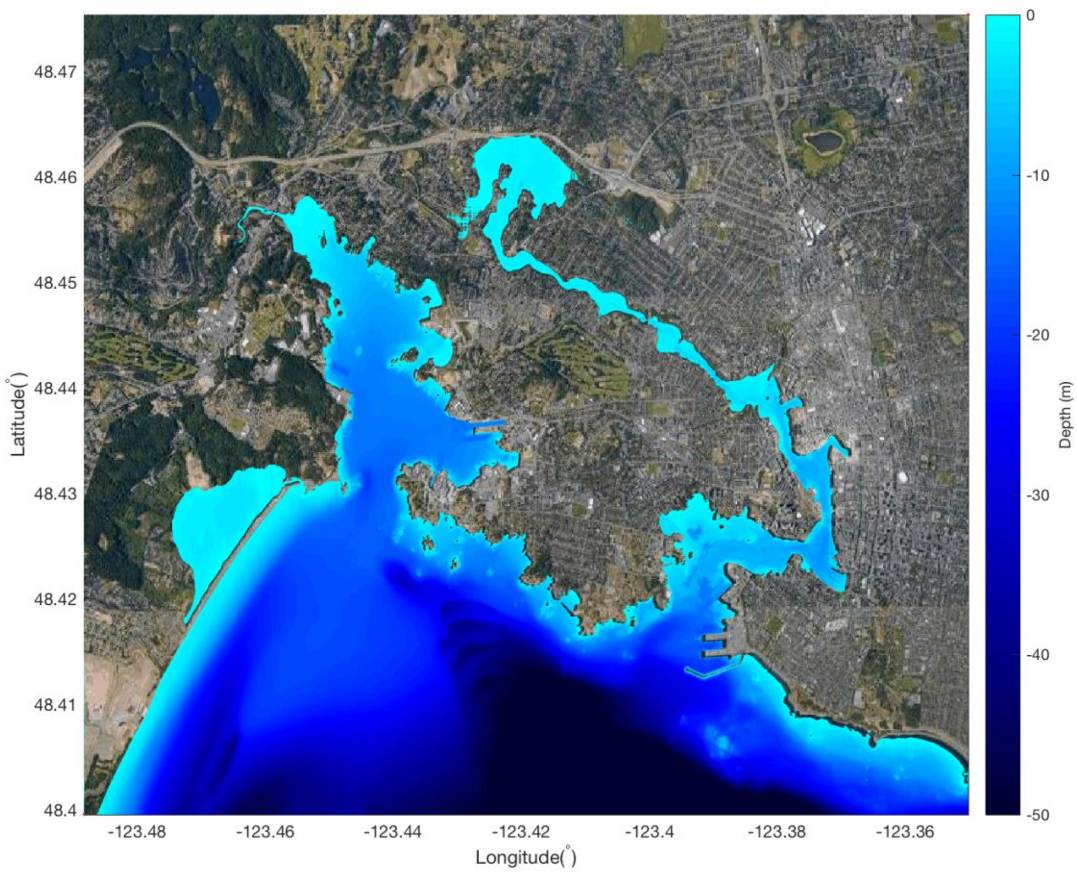

Figure 2-19
Grid for Victoria / Esquimalt Detailed Inundation Area

[12] The selection of these areas is summarised in greater detail in Finalized Project Methodology Technical Memo (December 2019)

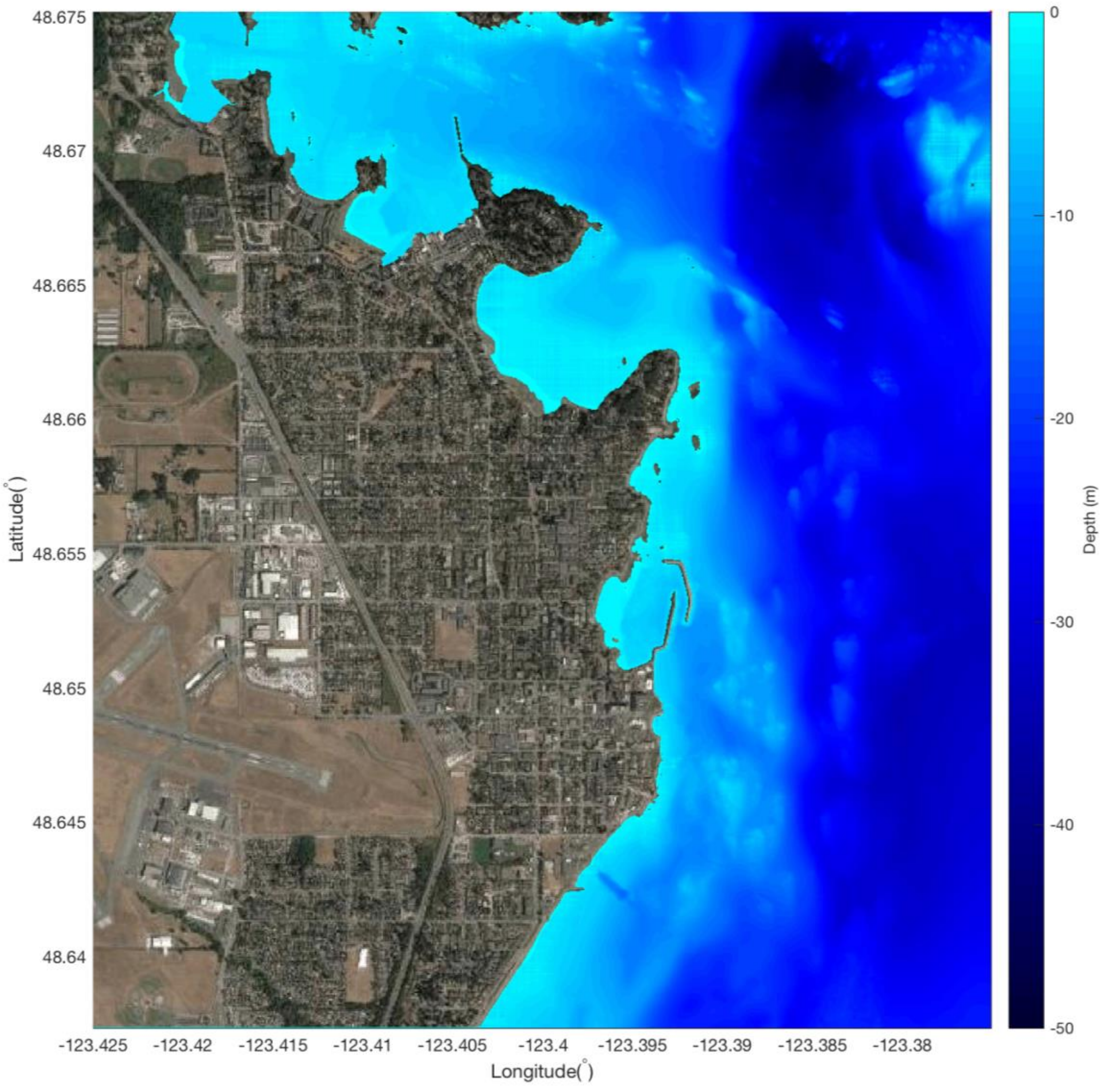

Figure 2-20
Grid for Sidney, BC Detailed Inundation Area

The grid for the Sidney detailed inundation area is shown in **Figure 2-20**. Elevation information for the grid is taken from the CHS bathymetry and the recently flown GeoBC LiDAR. The grid covers a domain (lon. lon. lat. lat.): [-123.4250° - 123.3751° W, 48.6373° - 48.6752° N], and has grid dimensions 926 x 1048 and a horizontal resolution of 4 x 4 m.

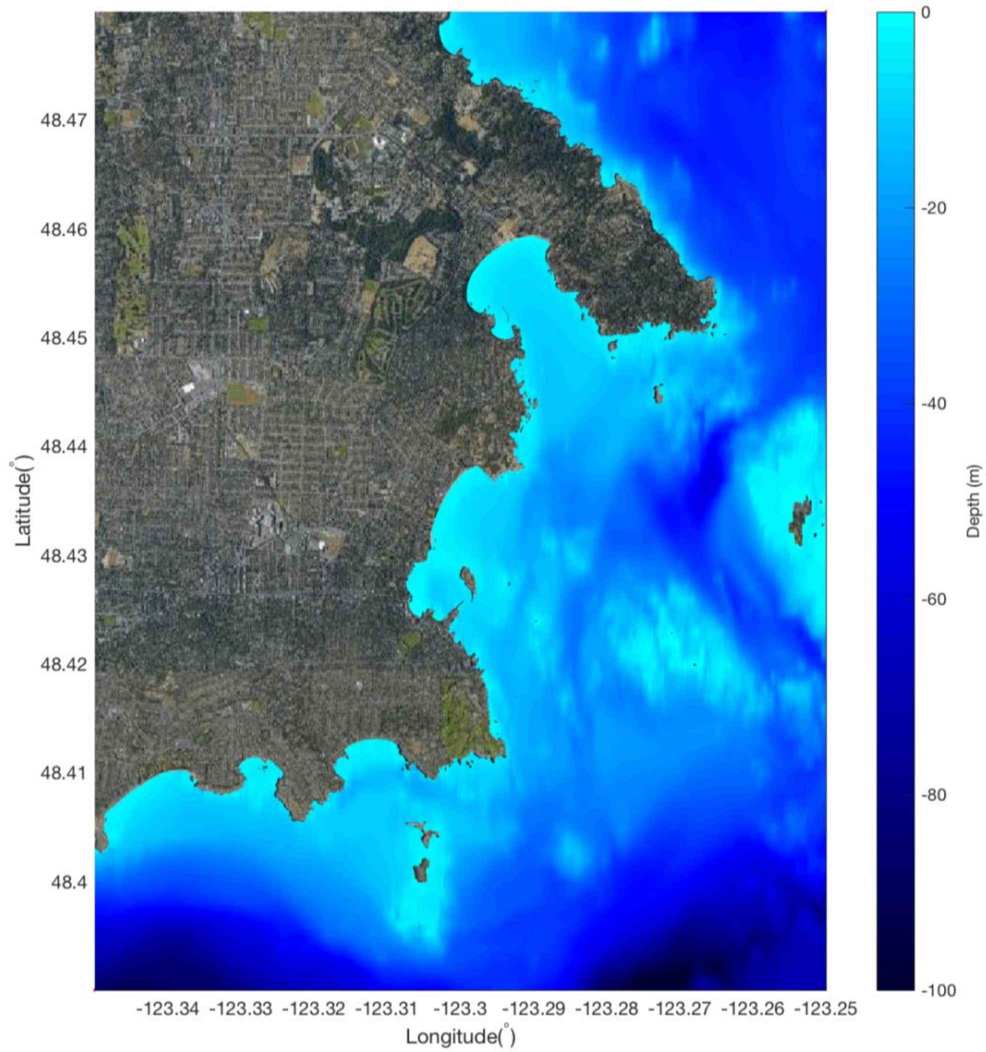

Figure 2-21
Grid for Saanich / Oak Bay, BC Detailed Inundation Area

The grid for the Saanich / Oak Bay detailed inundation area is shown in **Figure 2-21**. Elevation information for the grid is taken from the CHS bathymetry and the recently flown GeoBC LiDAR. The grid covers a domain (lon. lon. lat. lat.): [-123.3500° - 123.2500° W, 48.3900° - 48.4799°N], and has grid dimensions 1860 x 2492 and a horizontal resolution of 4 x 4 m.

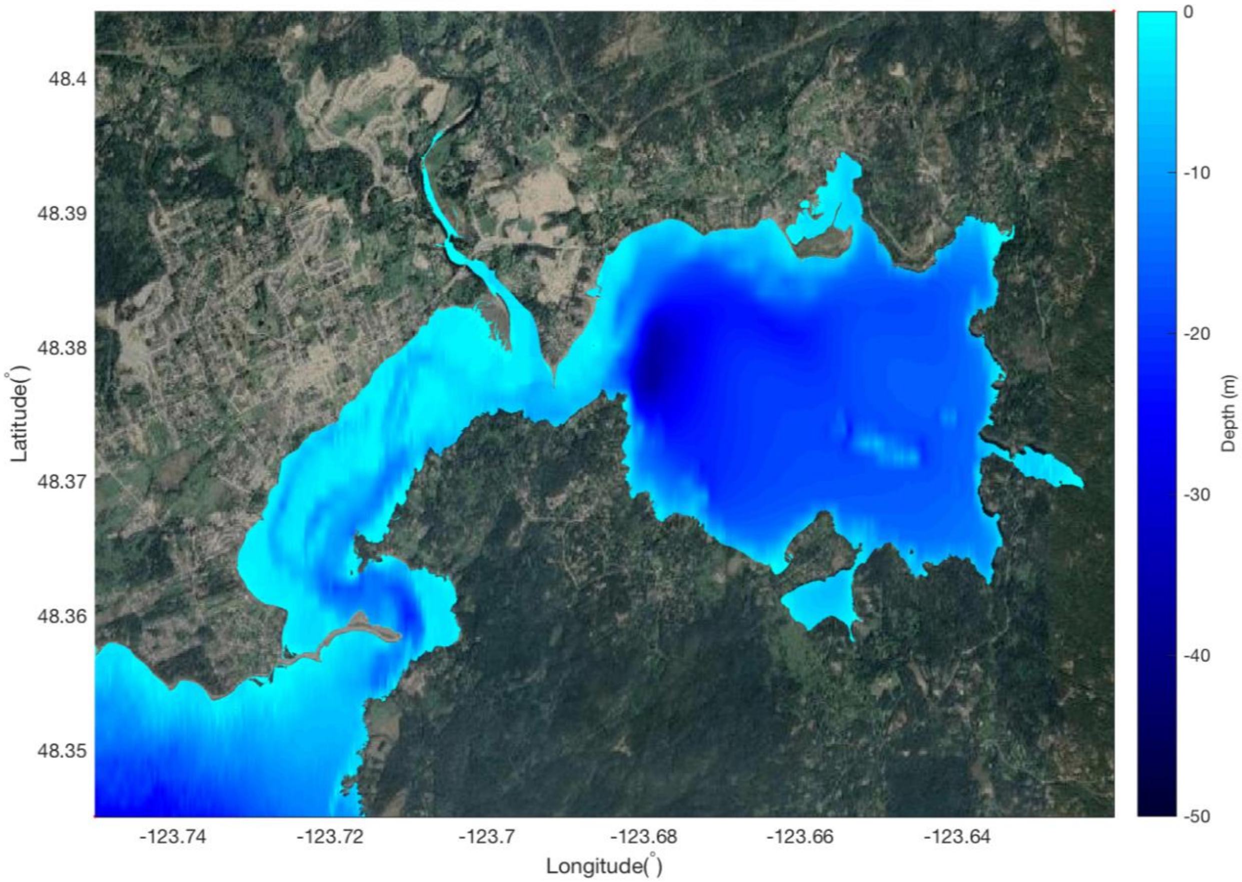

Figure 2-22
Grid for Sooke, BC Detailed Inundation Area

The grid for the Sooke detailed inundation area is shown in **Figure 2-22**. Elevation information for the grid is taken from the CHS bathymetry and the recently flown GeoBC LiDAR. The grid covers a domain (lon. lon. lat. lat.): [-123.75° - 123.62° W, 48.345° - 48.405° N], and has grid dimensions 2422 x 1647 and a horizontal resolution of 4 x 4 m.

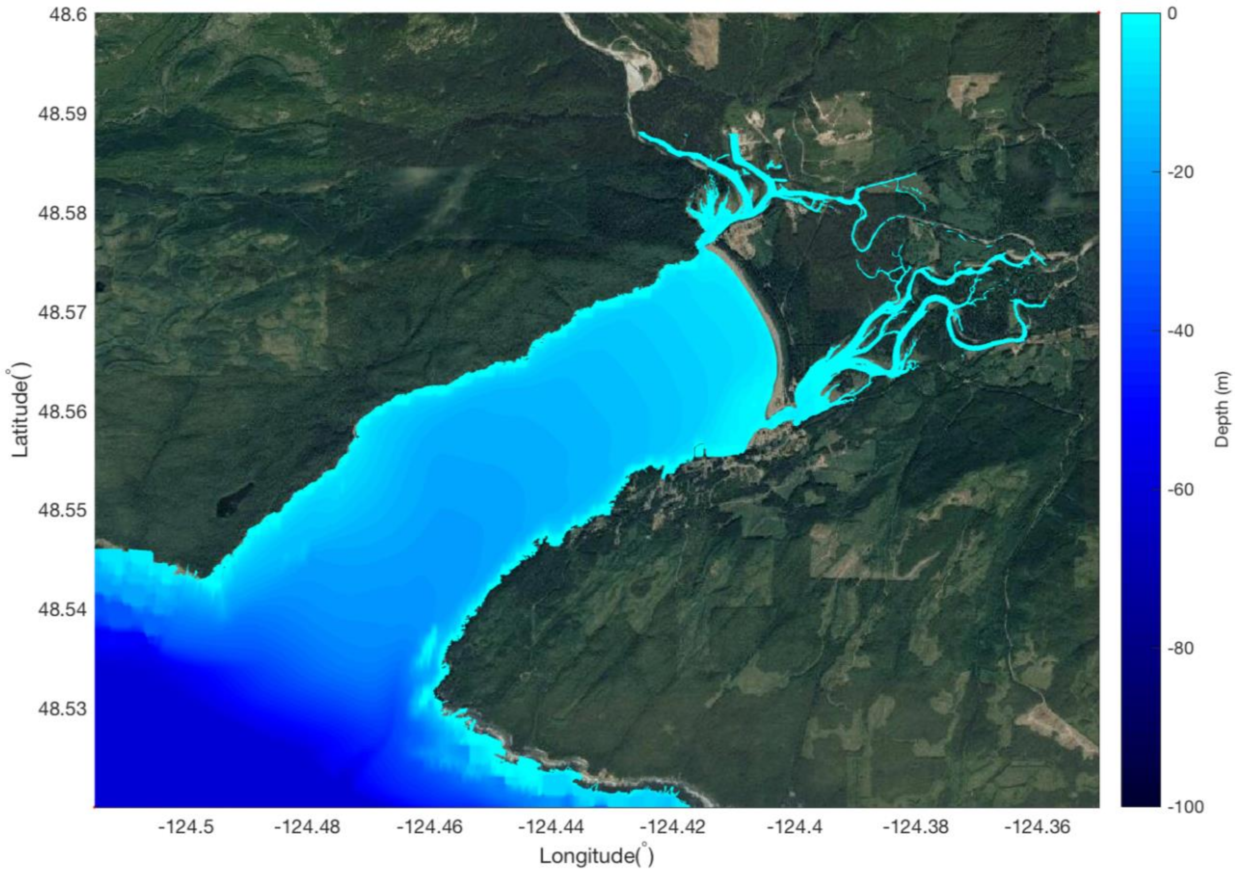

Figure 2-23
Grid for Port Renfrew, BC Detailed Inundation Area

The grid for the Port Renfrew detailed inundation area is shown in **Figure 2-23**. Elevation information for the grid is taken from the CHS bathymetry and the recently flown GeoBC LiDAR. The grid covers a domain (lon. lon. lat. lat.): [-123.75° - 123.61° W, 48.34° - 48.40° N], and has grid dimensions 3086 x 2170 and a horizontal resolution of 4 x 4 m. However, after an initial testing of the model domain, it was found that this grid needed to be extended slightly to the north and to the east to account for lower-lying areas beyond the bounds of the original domain. The detailed inundation plots in **Section 4.4** show the updated model extents for Port Renfrew.

2.4.2 Detailed Inundation Modelling Scenarios

In initial scenario testing, it was found that many of the modelling scenarios selected in **Table 2-1** did not significantly affect some parts or all of the capital region. Therefore, for detailed inundation modelling, some scenarios were omitted. The finalised list of scenarios modelled in the detailed inundation grids are shown in the table below.

Table 2-3
Matrix of Detailed Tsunami Inundation Scenarios Modelled at Each Domain

Detailed Modelling Scenarios	Abbrv.	Victoria / Esquimalt	Saanich / Oak Bay	Sidney	Sooke	Port Renfrew
Cascadia Subduction Zone - L1 Source	CSZ-L1	✓	✓	✓	✓	✓
Cascadia Subduction Zone - Northern Segment	CSZ-NS	✓	✓	✓	✓	✓
Cascadia Subduction Zone - Central Segment	CSZ-CS	✓	✓	✓	✓	✓
Alaskan 1964	AL	✗	✗	✗	✓	✓
Aleutian Trench	UN	✗	✗	✗	✓	✓
Haida Gwaii	HG1	✗	✗	✗	✗	✗
South of Haida Gwaii	HG2	✗	✗	✗	✗	✗
Devil's Mountain Fault Mw 7.5	DM1	✓	✓	✓	✗	✗
Devil's Mountain Fault Mw 6.5	DM2	✓	✓	✓	✗	✗
Southern Whidbey Island Fault Mw 7.5	SW1	✓	✓	✓	✗	✗
Southern Whidbey Island Fault Mw 6.5	SW2	✓	✓	✓	✗	✗

✓ - Source modelled for that detailed tsunami inundation domain
✗ - Source not modelled for that detailed tsunami inundation domain

2.5 Model Outputs

Model outputs for the present study consist of maximum water surface elevation above the initial still water datum (taken to be HHWMT) on the coarse Grids A, B, C, C' and D. For the detailed inundation grids, values of maximum water elevation and current velocity for the entire grid, maximum inundation depth and momentum flux for initially dry regions, and maximum vorticity for initially wet regions are recorded. In addition, time histories of water surface elevation are reported at a number of locations to provide estimates of arrival times after the start of the events. For further information, consult **Sections 3** and **4** for a discussion of the results, generated mapping and model validation.

3 TSUNAMI MODEL VALIDATION & SENSITIVITY ANALYSIS

To ensure that the modelled tsunami inundation and subsequent mapping were as accurate as possible, validation and sensitivity analysis was undertaken. The process consisted of five distinct work items:

- **Validation of the Model Code** – FUNWAVE-TVD code was re-tested to ensure that the modelling equations were solved correctly.
- **Comparison of Initial Conditions** – FUNWAVE-TVD's ability to appropriately represent the initial conditions of a number of event sources was cross-referenced against a specially-constructed MIKE 21 model. This enhanced the confidence in model performance at simulation start-up.
- **Haida Gwaii 2012 Event Validation Test** – The FUNWAVE-TVD model's performance was tested in its ability to replicate observed / measured data for the Haida Gwaii 2012 event. This included a second cross-reference against a MIKE 21 model performance for the same event, to better explain a slight underprediction in the observed vs. modelled wave heights. The purpose of this test was to assess the model's ability to properly propagate a tsunami event from source, through the different levels of grids.
- **Sensitivity Testing** - A sensitivity analysis was carried out to assess the impact of uncertainties in the source description on the water elevations in the project area, for the same Haida Gwaii 2012 event.
- **Comparison of Model Results Relative to Previous Tsunami Studies** – A brief comparison was undertaken between this project's results and the findings of some of the studies identified in **Section 1.4**, for a handful of events modelled as per **Table 2-1**.

All of these distinct work-items are explained in greater detail in the following sub-sections.

3.1 Validation of Model Code

The FUNWAVE-TVD code was re-tested on the University of Delaware community cluster, Farber. Farber consists of 100 compute nodes (2000 cores, 6.4 TB memory). Two nodes were used for the testing work. Benchmark test cases were conducted in accordance with instructions in Research Report Nos. CACR-11-02 (Tehranirad et al., 2011), CACR-12-02 (Shi et al., 2012b) and CACR-16-01 (Kirby et al., 2016) to demonstrate that the software accurately solves the equations used to model or represent the physical process. The results from tests of the present model configuration were found to be identical to those from Research Reports No. CACR-11-02, CACR-12-02 and CACR - 16-01.

3.2 Comparison of initial conditions

Among the tsunami sources considered in this study (see previous sections), many are derived using Okada's (1985) formula only (as per **Section 2.1**) and are thereby based on empirical methods rather than event-specific inverse modelling. In order to verify the interpretation of the tsunami source data used in FUNWAVE-TVD, sources were also created using DHI's MIKE 21 Toolbox. Both methods are based on Okada (1985), such that the verification is related to the interpretation of the raw source data. **Figure 3-1** compares the initial water surface elevations of Devil's Mountain Island Mw 7.5 (DM1); Devil's Mountain Mw 6.5 (DM2), Southern Whidbey Island Mw 6.5 (SW2) and Southern Whidbey Island Mw 7.5 (SW1).

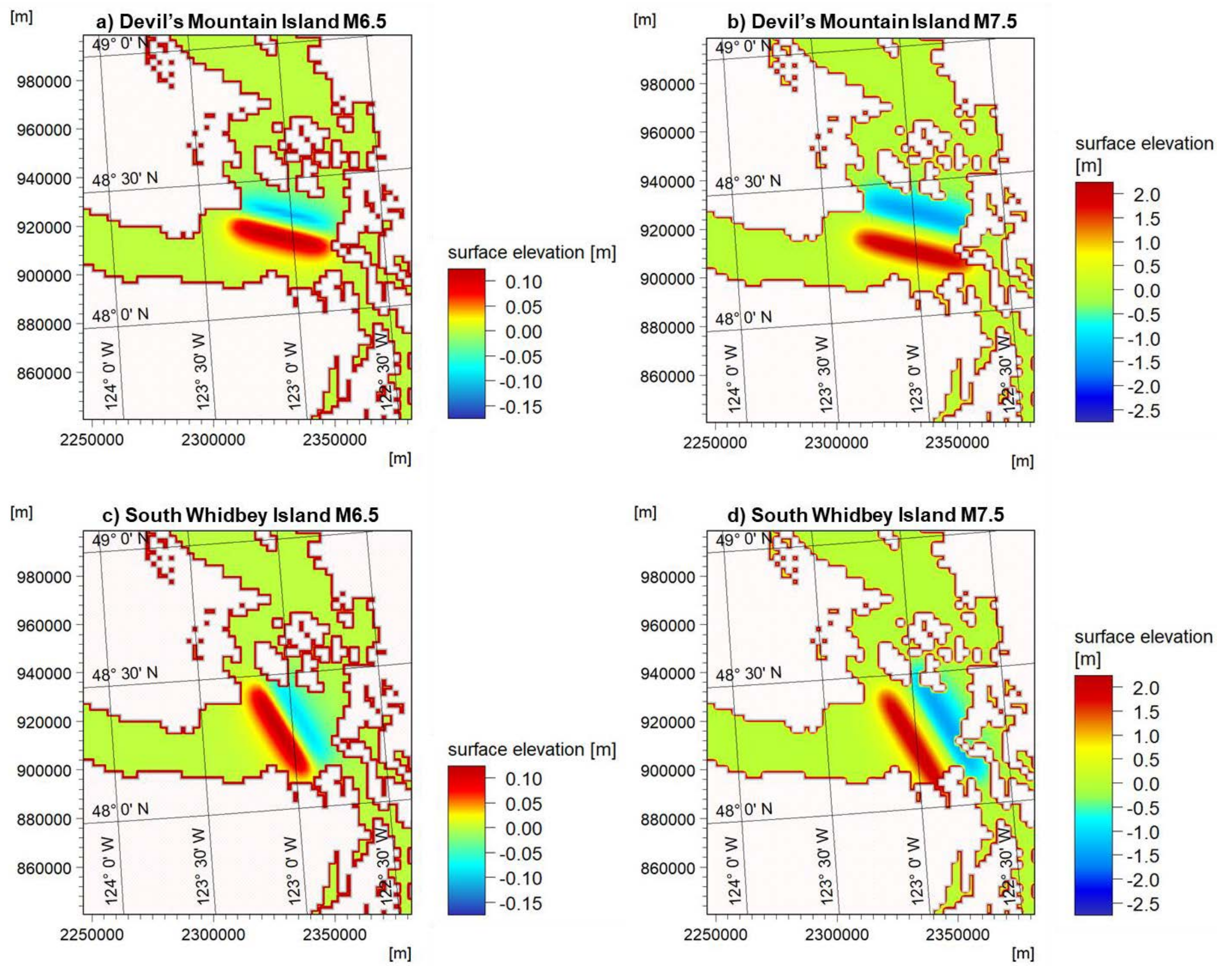

Figure 3-1
Tsunami Sources Generated by MIKE 21 Toolbox: a) Devil's Mountain Mw 6.5, b) Devil's Mountain Mw 7.5, c) Southern Whidbey Island Mw 6.5, d) Southern Whidbey Island Mw 7.5.

The initial tsunami waves shown in **Figure 3-1**, are based on the open ocean bathymetry of the MIKE 21 HD model, which is comparable to Grid A of the FUNWAVE-TVD model. Visual comparison of sources (**Figure 3-1** with **Figures 2-3** to **2-14**) shows good agreement between the two source generators. The observed deviations from the FUNWAVE-TVD sources being related to differences in model projection.

3.3 Haida Gwaii 2012 Event Validation Test

As previously outlined, FUNWAVE-TVD model's performance was tested in its ability to replicate observed / measured data for the Haida Gwaii 2012 event. This event was chosen for the availability of data, as well as it being quite recent. The objective of this test was to assess the model's ability to propagate a tsunami wave from source, through the model domain.

3.3.1 Validation Event Description

A Mw 7.8 earthquake struck central Moresby Island in the Haida Gwaii archipelago, Canada at October 28, 2012, 03:04 UTC. The earthquake hypocenter was located at (52.788° N, 132.101° W) at a depth of 14 km. The National Earthquake Information Center (NEIC) reports a strike of 323° and dip of 25° for this earthquake event.
The earthquake-induced residual seabed displacement was modelled starting from the USGS data and using the Okada (1985) formula. The rupture surface is approximately 130 km along the strike direction and 40 km along the dip.

A description of the event and the multi-segment source distribution was developed by Dr. Gavin Hayes, USGS and may be found at the link below[13]. The ground deformation used to initiate the tsunami was calculated using the Okada (1985) deformation formulae, based on the source description provided by USGS (see **Section 2.1.6**), and was obtained from Ali Abdolali, NOAA NCEP (see Abdolali et al., 2015). **Figure 3-2** shows the initial surface elevation calculated using Okada's (1985) formula.

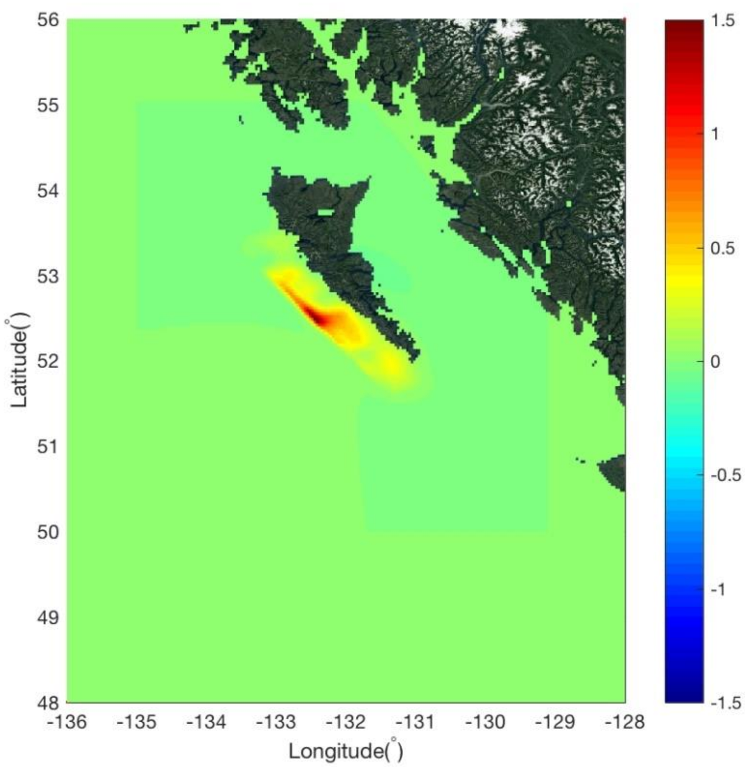

Figure 3-2
Haida Gwaii Tsunami Source (2002) Constructed Using Okada's Formula.

[13] https://earthquake.usgs.gov/earthquakes/eventpage/usp000juhz

3.3.2 Validation Model Results

The model was run in a computational grid ranging from 228° - 295° W and 0 - 65° N, referred to as Grid A in the previous sections. Data from four DART[14] buoys; 46419, 46404, 46409 and 46410, as shown in **Figure 3-3**, were used for model / data comparisons. DART buoys are an early detection and forecasting system implemented by NOAA, as part of their National Tsunami Hazard Mitigation Program (NTHMP). **Table 3-1** lists the locations of the DART buoys used in the model validation.

Table 3-1
List of DART Buoys Used in the Model Validation

Buoy #	Latitude (°N)	Longitude (°W)
46419	48.80660	-129.62219
46404	50.97833	-163.94833
46409	55.32333	-148.55167
46410	57.63233	-143.74966

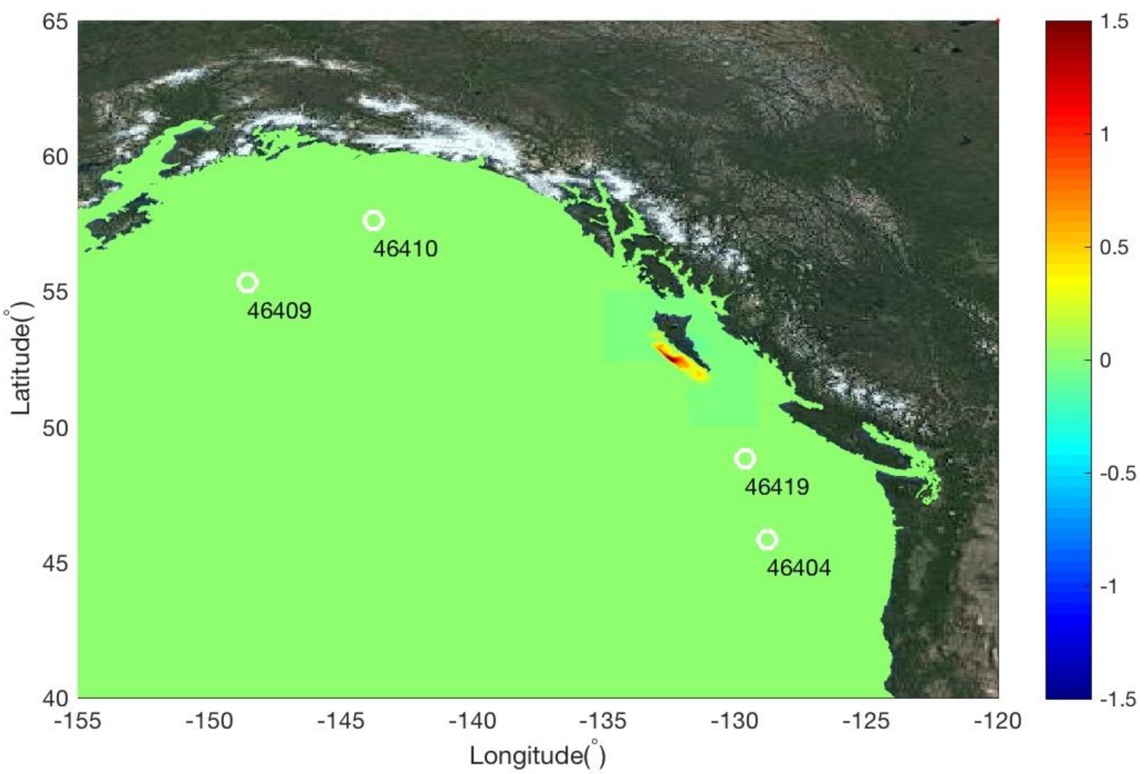

Figure 3-3
Locations of Four DART Buoys in the Model / Data Comparisons

[14] https://www.ndbc.noaa.gov/dart/dart.shtml

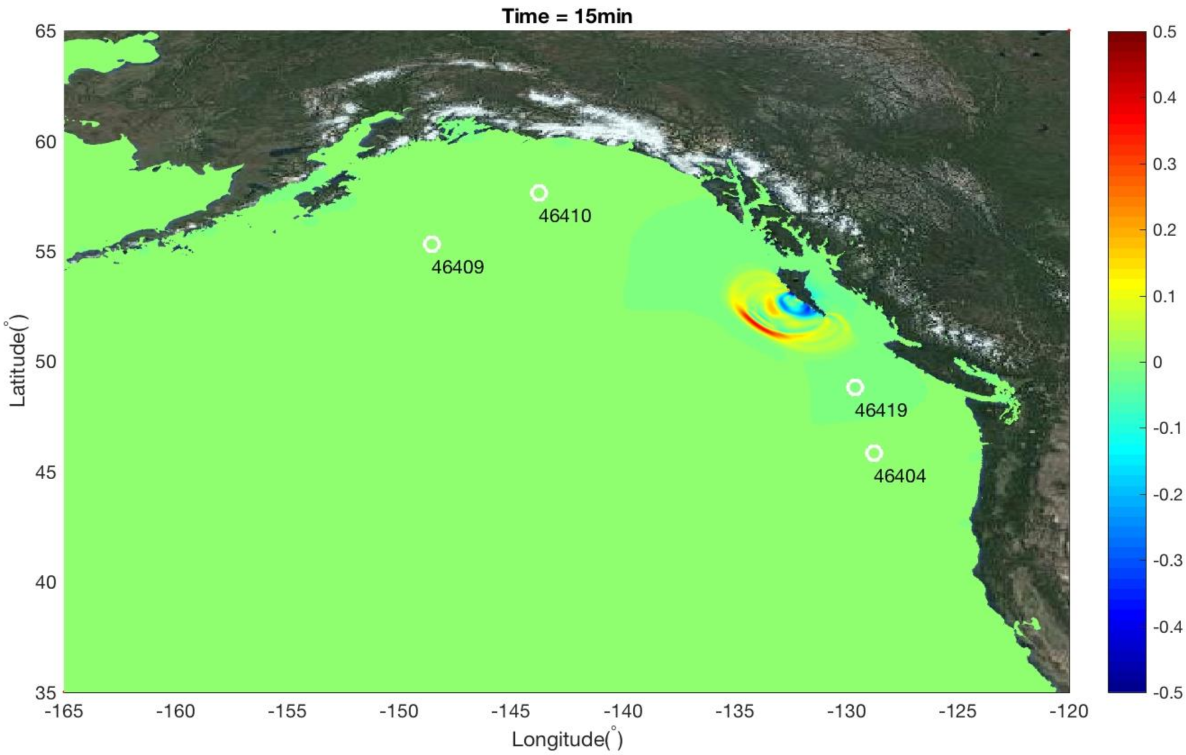

Figure 3-4
Snapshot of Modelled Surface Elevation (in Metres) 15 min. After Initial Fault Rupture.

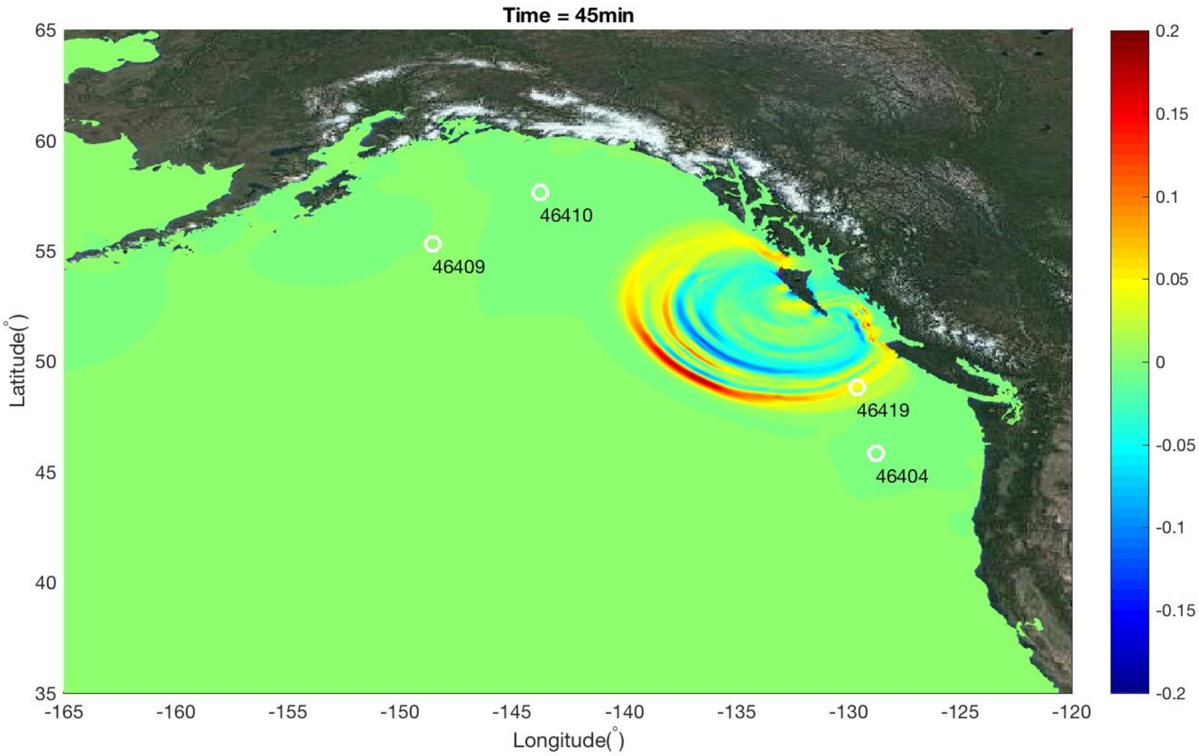

Figure 3-5
Snapshot of Modelled Surface Elevation (in Metres) 45 min. After Initial Fault Rupture.

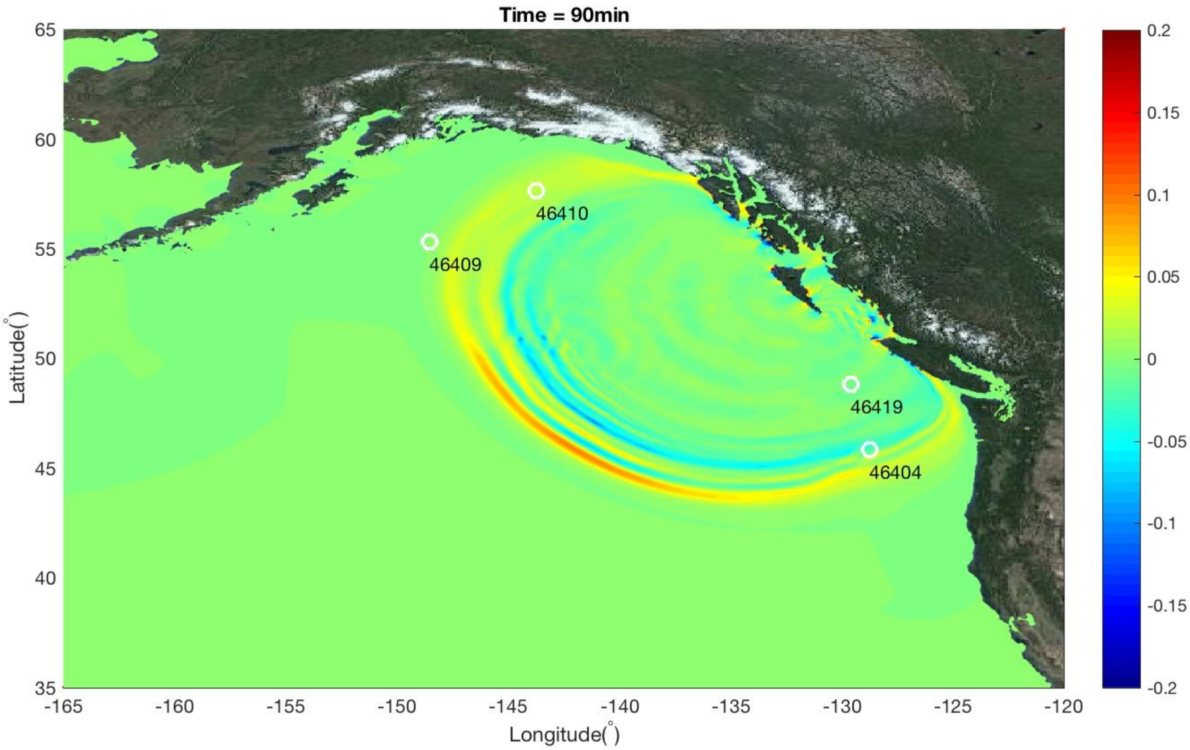

Figure 3-6
Snapshot of Modelled Surface Elevation (in Metres) 90 min. After Initial Fault Rupture

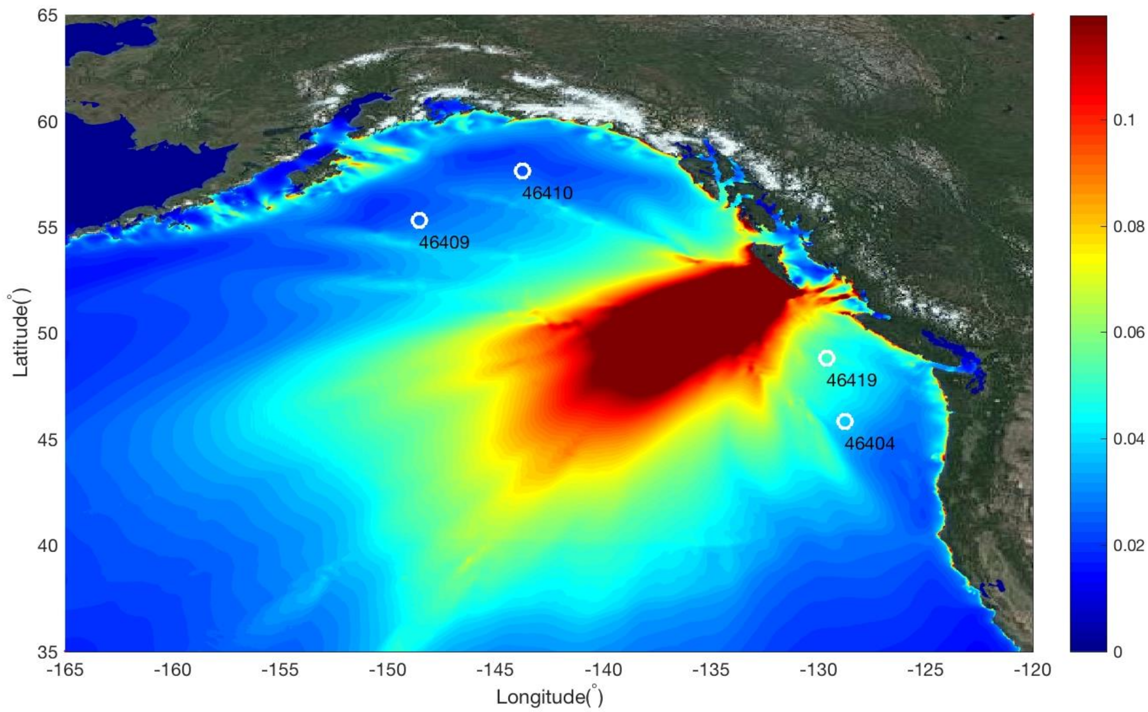

Figure 3-7
Modelled Maximum Surface Elevation (in Metres).

Figures 3-4 to **3-6** shows snapshots of surface elevation at time = 15, 45, and 90 minutes, respectively, after the fault rupture. The surface elevation decreases with time as the waves radiate outward in all directions away from the source. The front wave arrives at the Salish Sea around 90 minutes after the fault rupture. **Figure 3-7** shows the maximum surface elevation in the computational domain. It shows that the large waves are mainly directed towards the southwest. Wave focusing patterns can be found along the coast east of the Haida Gwaii Island.

Figure 3-8 compares the time series of surface elevation between the model results and the data at the four DART buoy locations. The modelled surface elevations are generally in good agreement with the data in terms of period and arrival time. The model predicted the wave height very well at all of the four DART buoy locations, but with a tendency for under prediction of the peak elevation by about 15-20% at DART 46419 and 46404. The results are consistent with the results reported in Abodolali et al. (2015) who used the same source configuration. It should be mentioned that the model / data comparison plot in Abodolali et al. (Figure 12) used a sparse time series of measured data which did not capture the peaks of 6.7 cm and 5.2 cm, respectively, for DART 46419 and 46404. The present model predicted the peaks of 5.18 cm and 4.22 cm, respectively at the two buoys, which are close to the prediction by Abodolali et al.

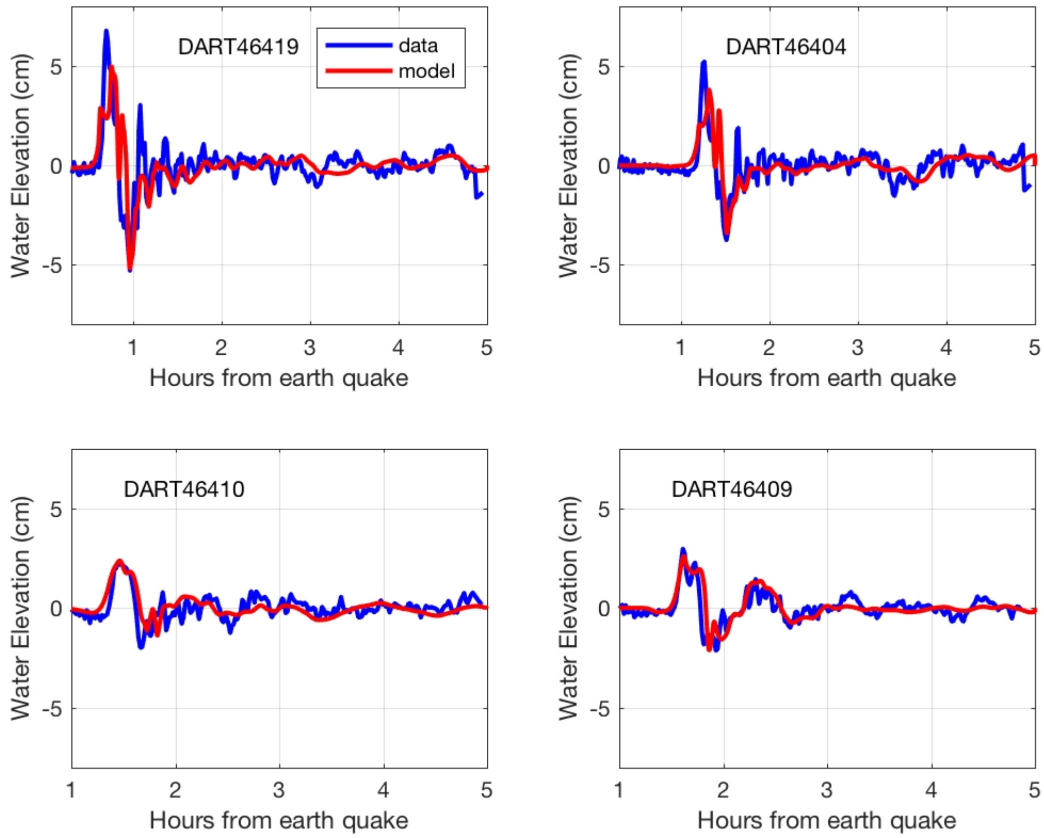

Figure 3-8
Model (red) and Data (blue) Comparisons of Surface Elevation at DART Buoys 46419, 46404, 46410, and 46409.

3.3.3 Validation Event Model Performance Comparison

It was decided to undertake a check of FUNWAVE-TVD model performance, against the ability of a separate model (i.e. MIKE 21 HD) to represent the same event. This was done for the following reasons:

- The second peaks in the water elevation of the buoys DART 46419 and DART 46404 are underpredicted.
- These two buoys are the ones located in the direction of propagation towards the project area.

The model extent is provided in **Figure 3-9(a)**. A grid resolution of 2430 m was selected and was based on ETOPO data, similar to the FUNWAVE-TVD model. The comparison of water elevations for buoys DART 46419, DART 46404 are provided in **Figure 3-9 (b)** and **(c)**, respectively.

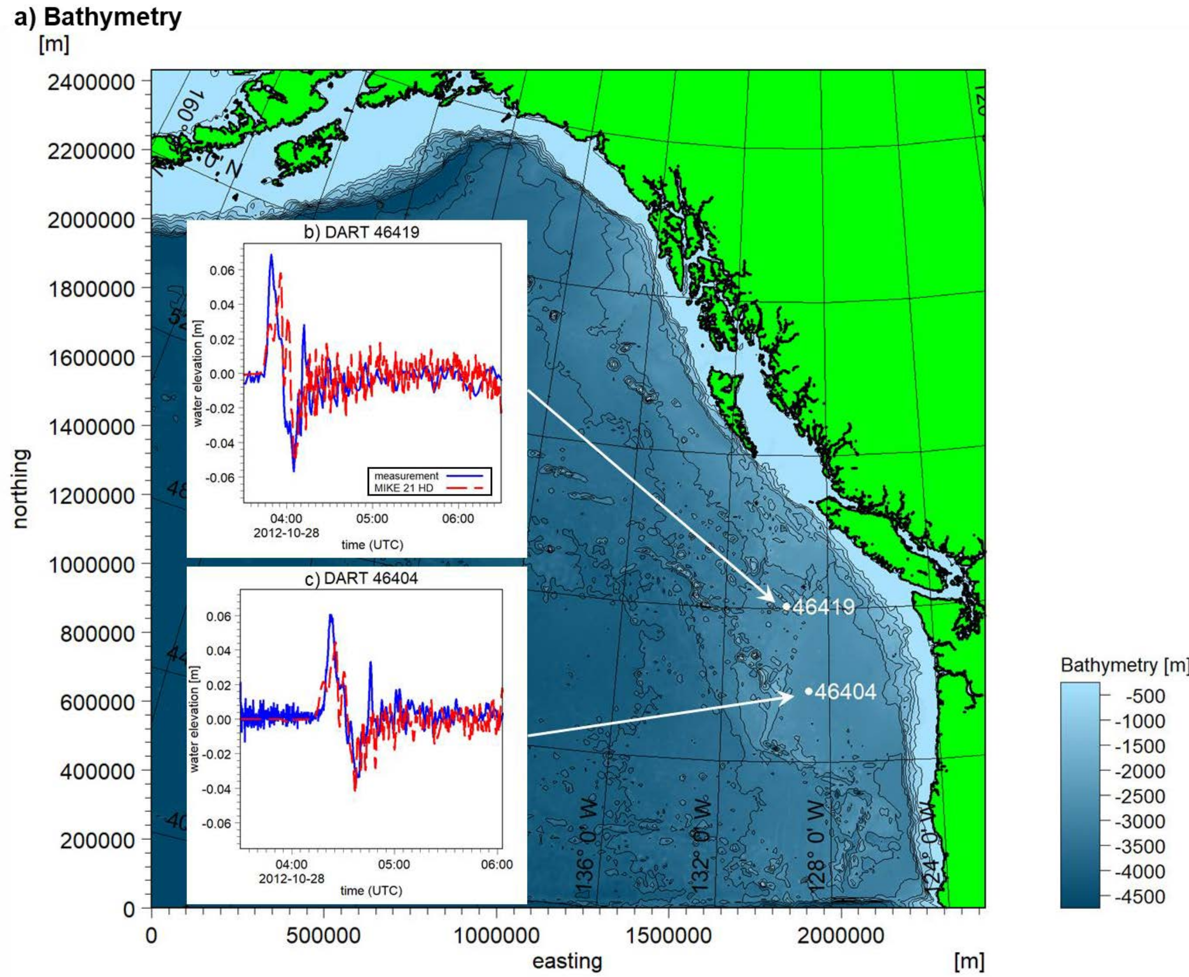

Figure 3-9
MIKE 21 HD Model and Simulated Surface Elevations: a) Bathymetry, b) Water Elevation at DART4649, c) Water Elevation at DART46404.

With the same source description, compared to the FUNWAVE-TVD model, the MIKE 21 HD model calculates similar primary and secondary peak water elevations. It can therefore be concluded that the deviations between models and the buoy data in **Figure 3-8** and **Figure 3-9**, respectively, are likely related to the source description and resulting initial water displacement rather than issues relating to wave propagation in the model.

3.4 Sensitivity Testing

In order to assess the impact of uncertainties in the source description on the water elevations in the project area, a sensitivity test was carried out on the Haida Gwaii event using a source, the initial displacement of which was 25 % larger than the original source. Seven (7) additional stations were specified in the Salish Sea and nearshore regions as shown in **Figure 3-10,** in order to examine the effects of the source uncertainty within the area of interest.

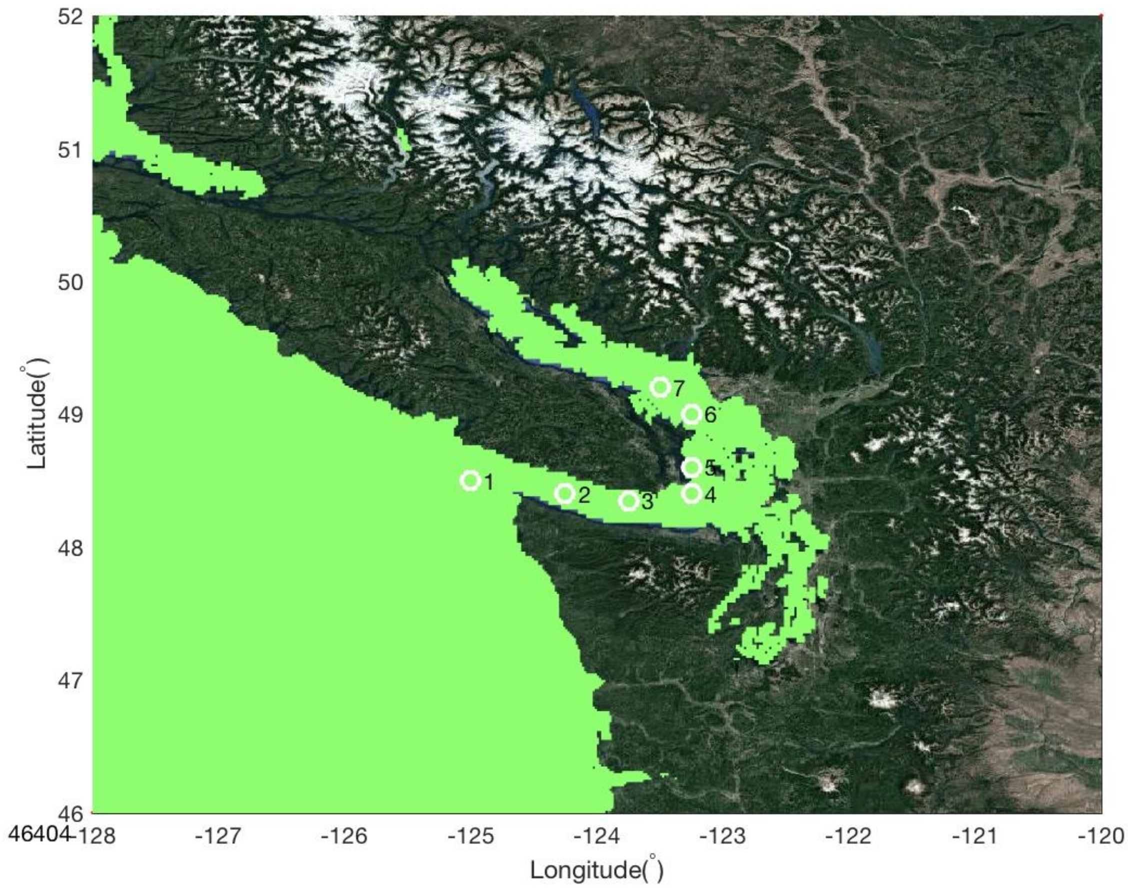

Figure 3-10
Extra Stations, 1-7, for the Sensitivity Test

Figure 3-11 shows the comparisons of time series of surface elevation between the original source, the source with the initial displacement 25% larger than the original source, and data at four DART buoys. The increase of the initial displacement does not change the wave evolution pattern but does change the maximum and minimum surface elevations. The larger source better-predicted the peaks at DART 46419 and 46404 and slightly over-predicts wave peaks at DART 46410 and 46409.

The model differences at the seven comparison stations are illustrated in **Figure 3-12**. Generally, an increase of 15% - 18% can be observed in peak elevation between the models with the original source and the source 25% larger than the original source. Whilst each source will have a different sensitivity to source strength and resulting tsunami wave height in the project area, this sensitivity test indicates, that for the remote event the sensitivity appears to be less than a ratio of 1:1, which is important in terms of the level of reliability in the overall tsunami inundation mapping.

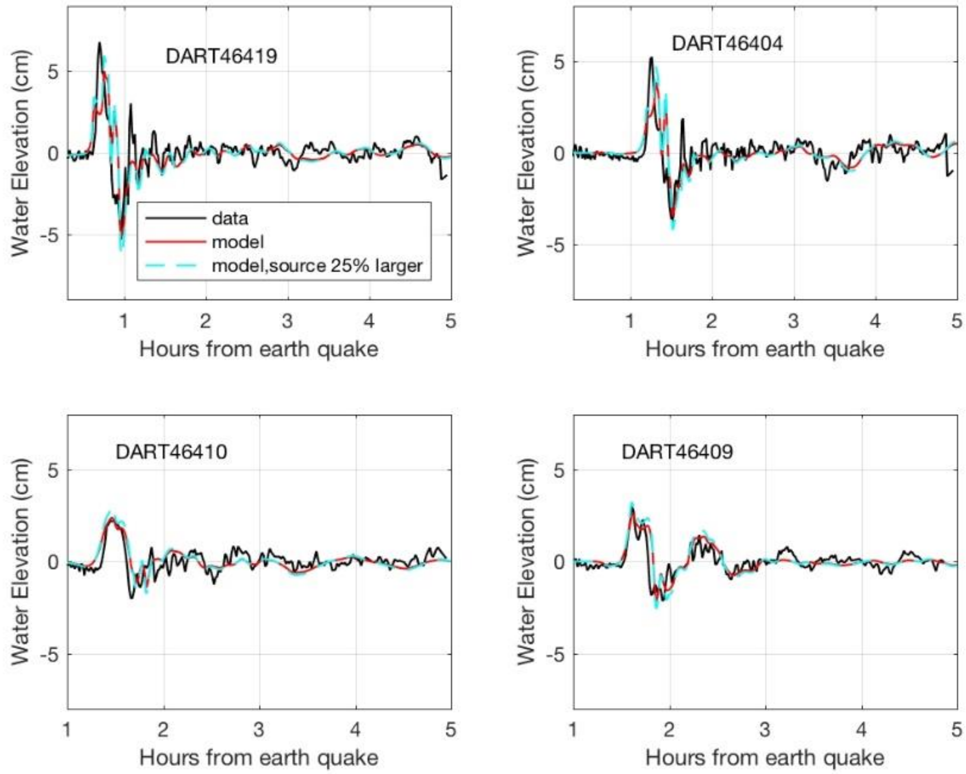

Figure 3-11
Comparisons of Time Series of Surface Elevation Between the Original Source, a Source with the Initial Displacement 25% Larger Than the Original Source, and Data at Four DART Buoys

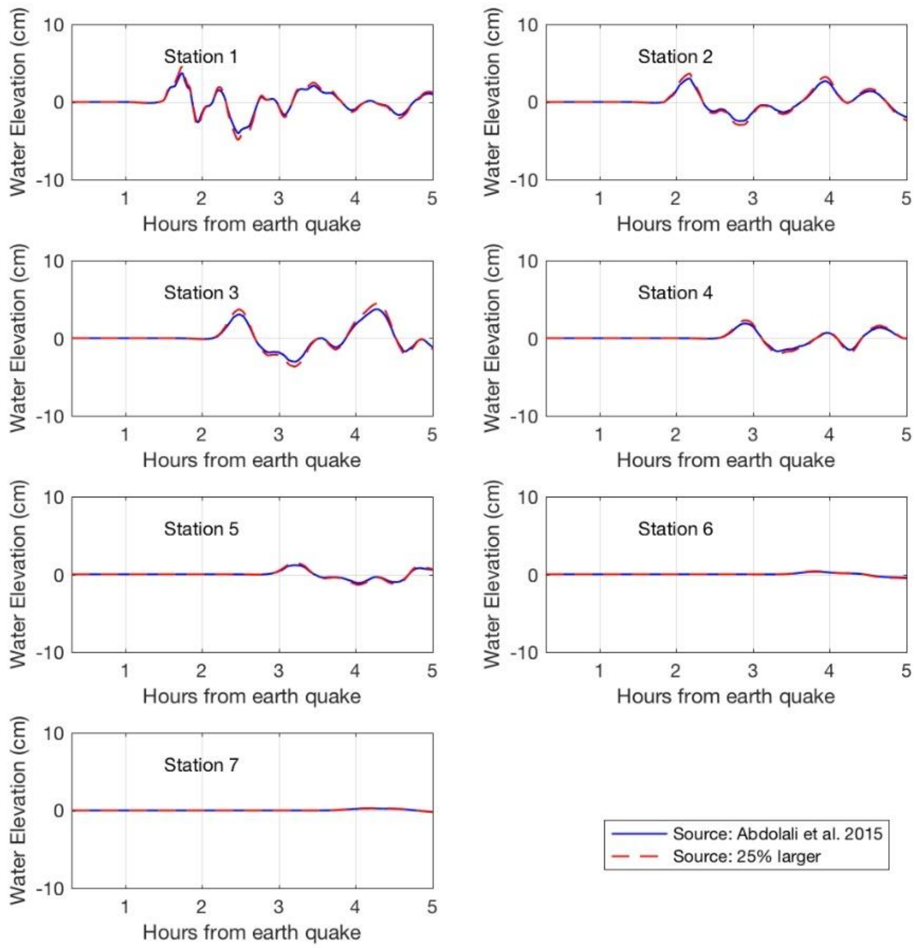

Figure 3-12
Comparison of Modelled Surface Elevation Between the Original Source, a Source with the Initial Displacement 25% larger than the Original Source at the Stations Denoted in Figure 4-3

3.5 Comparison of Model Results Relative to Previous Tsunami Studies

In addition to the comprehensive validation testing outlined in the preceding sub-sections, a brief comparison was undertaken between this project's results and the findings of previous tsunami modelling studies in the local environs. A summary of findings is presented in the following sub-sections.

3.5.1 2013 AECOM Report

The 2013 AECOM study (AECOM, 2013) utilized a Cascadia Subduction Zone event based on an estimated 500-year return period, giving an event that would be comparable in magnitude to the 1700 AD historic event (as per **Section 1.4.2**). In contrast, the largest CSZ source used in the present study is considerably stronger, representing a source with a return period on the order of 2,500 years.

It is thus not appropriate to make a direct comparison between results of the two studies for the largest event considered. A more appropriate comparison is the CSZ Northern Segment (CSZ-NS) event, which has an estimated return period of 500 - 600 years in the present study; a similar return period to the single event considered in the AECOM study. The AECOM study provides detailed results only for the Victoria / Esquimalt harbor area, with results for maximum surface elevation reported in AECOM (2013) (their Figure 5.1 and maximum flow speed in their Figure 5.3). Results for the present study for the same regions are shown in **Figures F-1** and **F-3**.

Overall, qualitative features of the tsunami response in the two studies are similar, with the occurrence of a strong resonance in Esquimalt harbor reproduced in each event as well as a gradual increase in maximum water elevation with distance inland in Victoria harbor, which is also due to a weaker resonance in this body created by reflection of the tsunami wave at the inland boundary. The resulting wave heights in the present study are comparable to AECOM predictions in Victoria harbor, but are significantly larger in Esquimalt Harbor with the present study predicting maximum run-ups on the order of 7 m at the head of the harbor, as compared to 4.3 m in the AECOM study. These differences could be due partially to differences in source geometry and resulting incident wave characteristics between the studies. It is also noted that the simulation of Esquimalt Harbor in the AECOM study was carried out at a grid resolution of 18 m as compared to the 4 m resolution in the present study, which could also lead to differences between the two simulations. In contrast, the AECOM simulation of Victoria Harbor was carried out at a resolution of 9 m, closer to the 4 m used here, with a significant reduction in differences between the studies.

Maximum flow speeds are systematically higher in the present study than in the AECOM study. This would be expected for the Esquimalt Harbor, where the higher water levels at head of harbor require a large flux of water into and out of the harbor during the event. The reported speeds are also higher in Victoria Harbor as well, despite the comparable maximum water levels. The higher current speeds in the present study are likely due to the finer grid resolution and better representation of the spatial variability of currents, which is accentuated in the present study since no spatial smoothing of results is carried out.

3.5.2 2018 Washington State Tsunami Hazard Mapping

The report of Eugard et al (2018) provides tsunami inundation maps (refer to **Section 1.4.3**) for the Washington State communities of Port Angeles and Port Townsend[15], using the same CSZ-L1 source (as extended by the State of Washington), used here as the most severe tsunami condition considered.

The primary differences in model setups for both studies are as follows:

- Modelling Software: The Washington study used 'Geoclaw' to model inundation, in comparison to this study's use of FUNWAVE-TVD.
- Nesting of grids: It is unlikely that the locations of grids used in both studies directly coincide.
- Model resolution: The Washington study aimed to provide detailed inundation modelling resolution at Port Angeles and Port Townsend, with cell sizes of 1 m – 16 m; whereas the corresponding resolution for those locations in this study is 30 m (i.e. Grid D).

To provide a test of the FUNWAVE-TVD model predictions, maximum water level elevations were extracted from the present Grid D results at grid points which were closest to the Port Angeles Paper Mill and the Port Townsend Yacht

[15] https://washingtonstategeology.wordpress.com/2018/08/17/newly-published-port-angeles-and-port-townsend-tsunami-inundation-hazard-maps/

Club sites listed in the results for the Washington State study. The present study predicts a 10.5 m runup close to the Port Angeles Paper Mill based on the Grid D simulation, as compared to a runup of 30 ft (or 9.2 m) estimated from Figure 7 in the 2018 Washington State study. The present model prediction for maximum surface elevation at the Port Townsend Yacht Club for the L1 source is 6.5 m, compared to 16 ft or 4.9 m estimated from Figure 7 in Eungard et al (2018). The discrepancies here are at least partially due to differences in model resolution between the two simulations at the two sites considered, with the sites not being treated with the level of resolution used for local inundation calculations in the present capital region study. The comparison of present results and those of Eugard et al. (2018) is thus only qualitative.

4 TASK RESULTS & MAPPING

The purpose of this section is to present and summarise the findings of the tsunami inundation modelling, as well as to refer to the produced project deliverables. The results have been divided into those contained within the report and those that form the GIS deliverable of this project.

4.1 Results Directory

4.1.1 Reported Results

The following summarises the produced results and the location of each in this report. More detailed commentary on the results is provided in **Sections 4.2**, **4.3** and **4.5** (as well as the preceding model validation and sensitivity analysis section).

Coarse Grid Maximum Water Surface Elevations

Maximum water surface elevations occurring within the coarse grids are presented as plots in **Appendix A**. The results are provided for Grids A -D (CSZ-L1, CSZ-NS, AL, UN, HG1 and HG2) and Grid C' (DM1, DM2, SW1, SW2). These results show maximum water surface elevation for tsunami events as it moves from offshore to onshore.

Modelled Time History Plots

Time history plots that document the progression of a tsunami as it propagates through the study area are presented in **Appendix B**.

Tsunami Inundation Maps

PDF maps are included in **Appendix C**. These are a set of four (4) maps (41 sheets each) on scale 1:25,000 sheets, showing maximum inundation depths resulting from a tsunami generated by the CSZ-L1, CSZ-NS, SW1 and DM1 events. These maps show maximum tsunami inundation for those particular events, with results clipped to the coastline.

As described in **Section 2.3.3**, the coarse Grid D results cover the entire capital region coastline. These results are shown on the Tsunami Inundation Maps for all areas.

The Detailed Inundation Model results (**Section 2.4**) replace the coarse model results in these maps, in the areas where the domains overlap.

Tsunami Model Results at Project Transects

Using the coastal transects established in the Task 2[16] reporting, tsunami results were extracted at those locations to give a comprehensive snapshot of tsunami risk in the capital region for each local government and electoral area in the capital region. These results are included in this report as **Appendix D**; but a simplified version is presented in **Section 4.2**.

Detailed Inundation Grid Results

Detailed inundation grid results, for the scenarios outlined in **Section 2.4** are presented in **Appendices E - M**.

[16] Task 2 – Sea Level Rise Modelling and Mapping Report, Associated Engineering, Version 2.0, 2021

4.1.2 GIS Deliverables

The GIS results have been delivered via an external hard drive. There are three sets of tsunami inundation modelling results that have been provided corresponding to:

- Results for Grid D,
- Results for Grid C', and
- Results for the Detailed Inundation Areas.

For all three cases, the results are provided in an ESRI File Geodatabase raster file format, and the results include the following parameters (file name prefix as shown):

- Maximum Water Surface Elevation (hmax)
- Maximum Velocity (umax)
- Maximum Inundation Depth (InunD)
- Maximum Vorticity (VORmax)
- Maximum Momentum Flux on Land (MFmax)

A summary of the three sets of results follow:

Results for Grid D

These results cover the entire capital region including the Gulf Islands. The results are provided for two Cascadia Subduction Zone events, CSZ-L1 and CSZ-NS.

Results for Grid C'

Again, these results cover the entire capital region including the Gulf Islands. The results are provided for two local source events: the Devil's Mountain Fault Mw 7.5 (DM1) source and the Southern Whidbey Island Fault Mw 7.5 (SW1) source.

Results for the Detailed Inundation Areas

Again, these results have been provided in an ESRI File Geodatabase raster file format. These results now cover the five detailed inundation areas (refer to **Section 2.4**):

- Victoria / Esquimalt,
- Sidney,
- Saanich / Oak Bay,
- Sooke, and
- Port Renfrew.

Some insignificant results have been omitted – for example, results of Momentum Flux on Land with no inundation. Some combinations of sources and areas did not result in a significant impact (i.e. water surface level increase in the order of 100 mm or less) and have been omitted. The matrix in **Table 4-1** indicates the detailed inundation area results that have been included.

Table 4-1
Tsunami Inundation Model GIS Results – Detailed Areas

Victoria / Esquimalt	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓
	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓
Saanich / Oak Bay	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓
	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗
Port Renfrew	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗

✓ - Results provided
✗ - Results insignificant and not provided

4.2 Results Summary

Prior to describing the modelled results in any great detail, or showing the large number of plots generated, summaries of modelled results for each local government and electoral area are provided in this sub section. Extracted tsunami water surface elevations and wave height information have been generated at the coastal transects used in Task 2. These transects have been used to yield the results representative of each local government and electoral area shown in the following tables.

Table 4-2
Summary of Modelled Average Tsunami Water Surface Elevations (m CGVD2013)

Tsunami Source / Local Government or Electoral Area	(L rce)	(rt er e e t)	(e tral e e t)	(lask)	(le ti re c)	(ai ii)	(t f ai ii)	(Devil' s tai .5)	(Devil' s tai .5)	(t er i ey .5)	(t er i ey .5)
Central Saanich	4.21	3.26	1.42	1.37	1.23	nt s d f r calibration p r s s nl . ff cts in capital r gion minimal.	ff cts in capital r gion minimal.	3.30	1.30	2.36	1.27
Colwood	6.93	4.64	1.09	1.03	0.84			3.53	0.88	2.39	0.88
Esquimalt	6.82	4.48	1.08	1.04	0.84			3.57	0.87	2.38	0.88
Highlands	3.54	2.94	1.41	1.37	1.28			1.97	1.25	1.72	1.24
Juan de Fuca Electoral Area	7.68	5.09	1.49	1.37	1.14			1.78	1.16	1.94	1.16
Langford	3.60	3.06	1.42	1.39	1.25			2.58	1.31	2.05	1.28
Metchosin	5.25	3.51	1.04	0.95	0.80			2.10	0.85	1.75	0.85
North Saanich	3.92	2.77	1.40	1.34	1.23			2.51	1.29	1.98	1.26
Oak Bay	3.84	2.67	0.94	0.92	0.78			3.50	0.90	2.02	0.90
Saanich	3.53	2.55	0.96	0.90	0.78			3.32	0.91	1.84	0.84
Salt Spring Electoral Area	3.32	2.60	1.36	1.31	1.23			2.15	1.27	1.84	1.25
Sidney	4.78	3.01	1.42	1.38	1.24			3.42	1.31	2.26	1.27
Sooke	6.42	4.05	1.29	1.23	1.06			1.46	1.06	1.43	1.07
Southern Gulf Islands Electoral Area	3.11	2.37	1.35	1.32	1.23			2.03	1.26	1.75	1.25
Victoria	5.62	3.99	1.03	0.98	0.80			3.09	0.86	2.26	0.88
View Royal	8.46	6.27	1.18	1.14	0.90			4.54	0.96	3.65	0.97

Note that any gaps in the above table denote that the event in question has minimal effect on the location in question and results have accordingly not been provided.

In addition, the approximate travel times for each tsunami scenario, for each local government / electoral area are given in the table below. Travel times denote the amount of time required for the first tsunami wave to travel to a particular location, after generation at the source. These numbers will give decision-makers a sense of how much time is available to emergency services and the greater community to facilitate evacuation (if required) etc.

Table 4-3
Summary of Approximate Arrival Time for Each Modelled Tsunami Event (min.)

Tsunami Source Municipality											
Colwood	75	75	100	255	300	145	145	5	5	5	5
Esquimalt	75	75	100	255	300	145	145	5	5	5	5
Highlands	120	120	145	300	345	190	190	30	30	30	30
Juan de Fuca Electoral Area	40	40	65	220	265	110	110	15	15	15	15
Langford	75	75	100	255	300	145	145	5	5	5	5
Metchosin	70	70	95	250	295	140	140	5	5	5	5
North Saanich	105	105	130	285	330	175	175	10	10	10	10
Oak Bay	85	85	105	265	310	155	155	5	5	5	5
Saanich	90	90	115	270	315	160	160	5	5	5	5
Salt Spring Electoral Area	115	115	135	290	340	180	180	15	15	15	15
Sidney	110	110	135	290	335	180	180	15	15	15	15
Sooke	60	60	85	240	285	130	130	15	15	15	15
Southern Gulf Islands Electoral Area	100	100	125	280	325	170	170	5	5	5	5
Victoria	80	80	105	260	305	150	150	5	5	5	5
View Royal	80	80	105	260	305	150	150	5	5	5	5

4.3 Coarse Grid Results Overview

4.3.1 CSZ-L1 Source

As expected, the CSZ-L1 source as used by the State of Washington is the most extreme event modelled here, and results are given for the maximum occurring water level on the nest of Grids A, B, C and D in order to show the gradual reduction of wave height during passage through Juan de Fuca Strait as well as locations of greater wave height due to resonance effects or other bathymetric controls. The results for the four grids are shown in **Figures 4-1 – 4-4**. Grid A results in **Figure 4-1** basically show the projection of the resulting tsunami wave towards the Pacific basin and indicate potentially strong impact in Hawaii and other Pacific islands. Grid B results in **Figure 4-2** provide a better view of the landward propagation of the tsunami. Large surface elevations of over 10 m occur at the shelf break and are the result of significant initial ground displacement as well as shoaling effects as the resulting waves propagate onto the shallower shelf region. Subsequently there is some reduction of wave height due to bottom friction effects, before the wave undergoes final shoaling and interaction with the coastline.

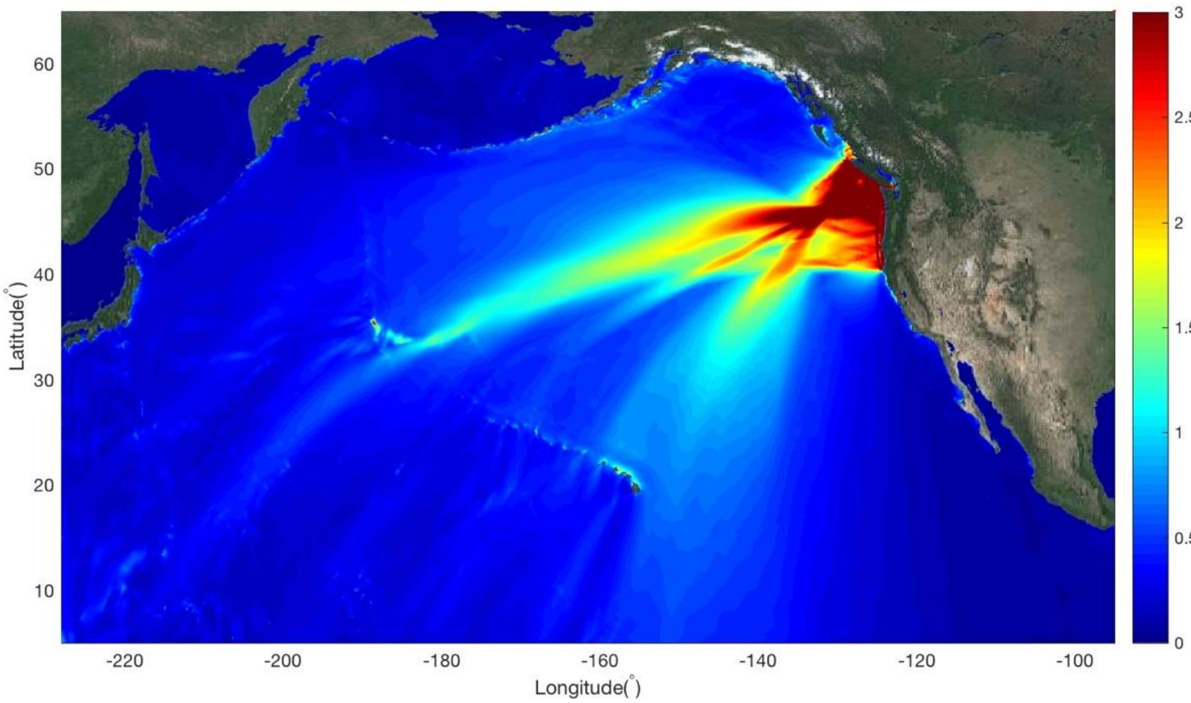

Figure 4-1
CSZ-L1 source. Maximum Water Surface Elevation (m) for Grid A Simulation. Horizontal Resolution is 2 arc-min., or about 4000 m.

Results for Grid C provide a better view of the propagation of the tsunami event through Juan de Fuca Strait. The results indicate that there is only minor attenuation of the tsunami passing through the strait. This result are in agreement with similar patterns seen in AECOM (2013).

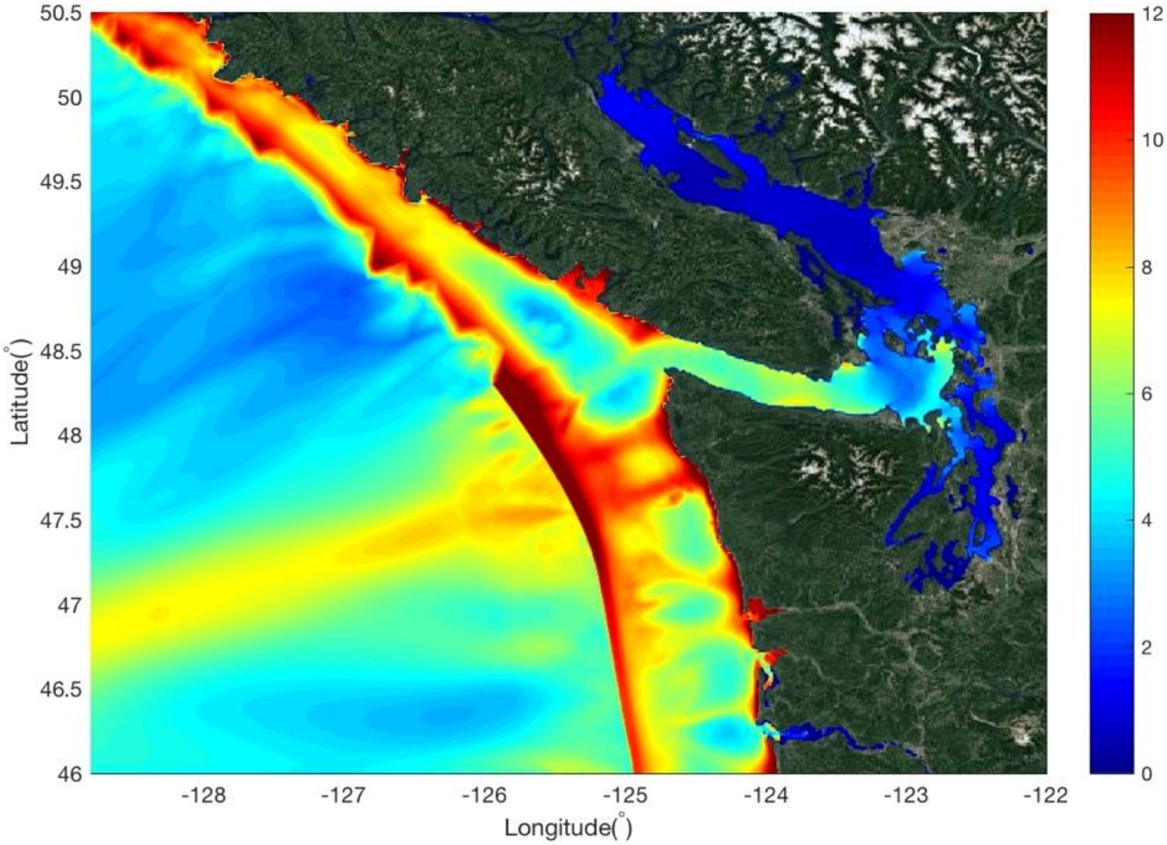

Figure 4-2
CSZ-L1 Source. Maximum Water Surface Elevation (m) for Grid B Simulation. Horizontal Resolution is 30 arc-sec., or about 1000 m.

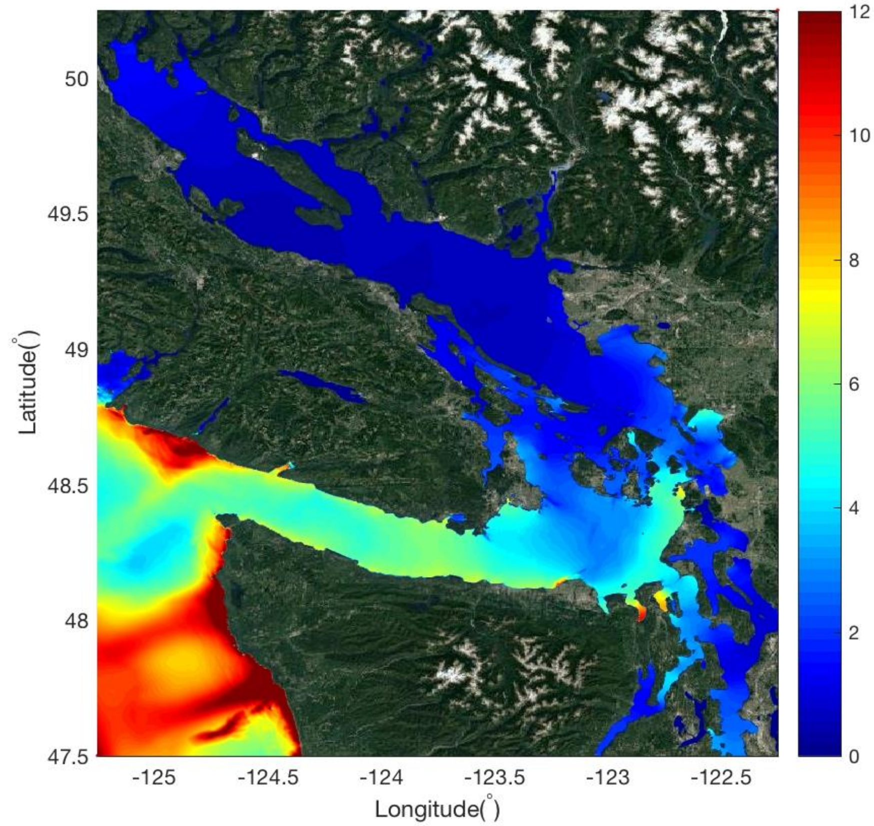

Figure 4-3
CSZ-L1 source. Maximum Water Surface Elevation (m) for Grid C Simulation. Horizontal Resolution is 6 arc-sec., or about 180 m. (Elevations Reported to HHWMT)

Figure 4-4 shows results for Grid D, which show more detail about the spatial variability of the water level response in the capital region. The grid resolution of approximately 30 m on this grid is comparable to the resolution often used to simulate tsunami effects on more gradually varying coastlines such as sand spits and barrier islands. However, the complex coastline geometry and the need to provide detailed estimates of currents and other maritime hazards in harbours leads to the need for much more detailed inundation studies on high resolution grids, as described below in **Section 4.4**.

Figure 4-4 shows a number of distinct features. In particular, there is an apparent strong resonant response of Port Renfrew to the tsunami excitation, leading to its choice as one of the high-resolution simulation sites. The water surface elevation is also significantly amplified at Sooke and in front of Victoria / Esquimalt. Sites along the southern boundary of the strait, in Washington State, also show the effect of amplifications due to interaction with complex coastal features. The communities of Port Angeles and Port Townsend, WA lie along this southern boundary and provide an indicative test of the present model in comparison to the study done by Eungard et al. (2018), discussed in **Section 3.5**.

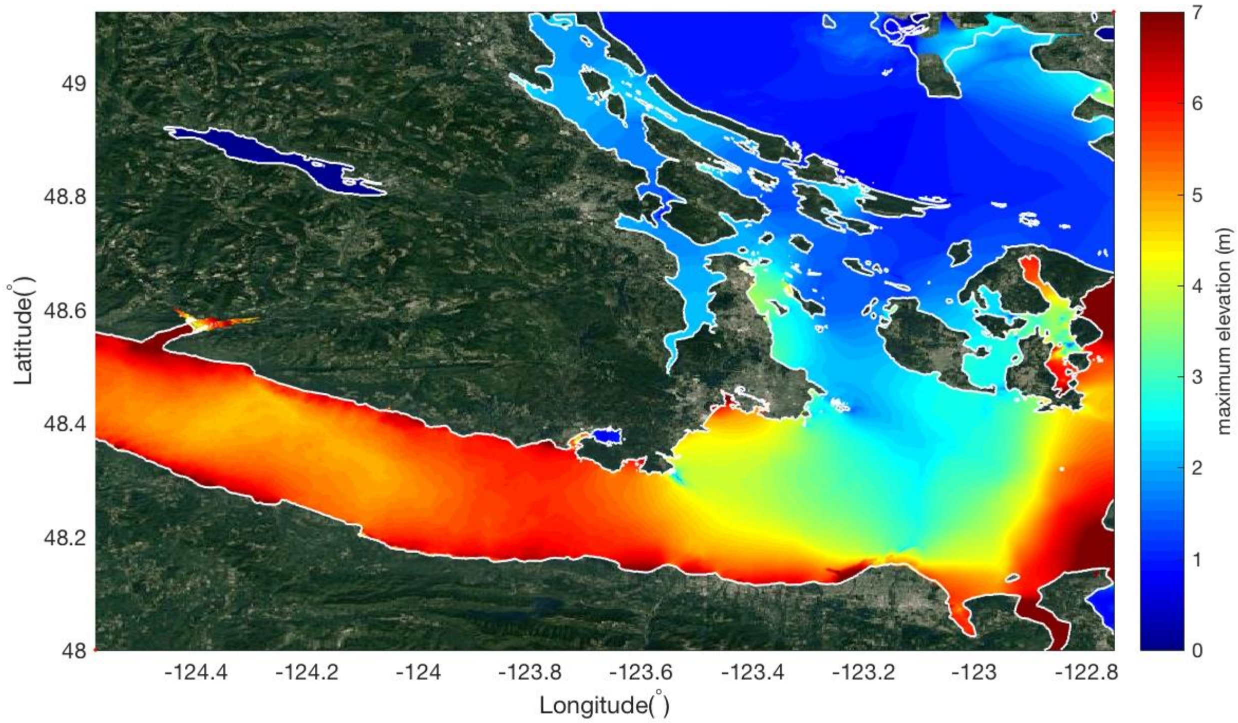

Figure 4-4
CSZ-L1 Source. Maximum Water Surface Elevation (m) for Grid D Simulation. Horizontal Resolution is 1 arc-sec., or about 30 m. (Elevations Reported to HHWMT)

4.3.2 Other Sources

Each of the other remote seismic sources considered have lower impacts on the capital region, with the impacts from Alaska or Haida Gwaii sources being relatively minor. **Figures 4-5** and **4-6** show selected results for Grid D water elevations for the Cascadia Northern Segment (CSZ-NS) source, which are still impactful, and the 1964 Alaska (AL) earthquake, where water surface elevations are generally on the order of 20 cm. A complete set of outputted plots are presented in **Appendix A**.

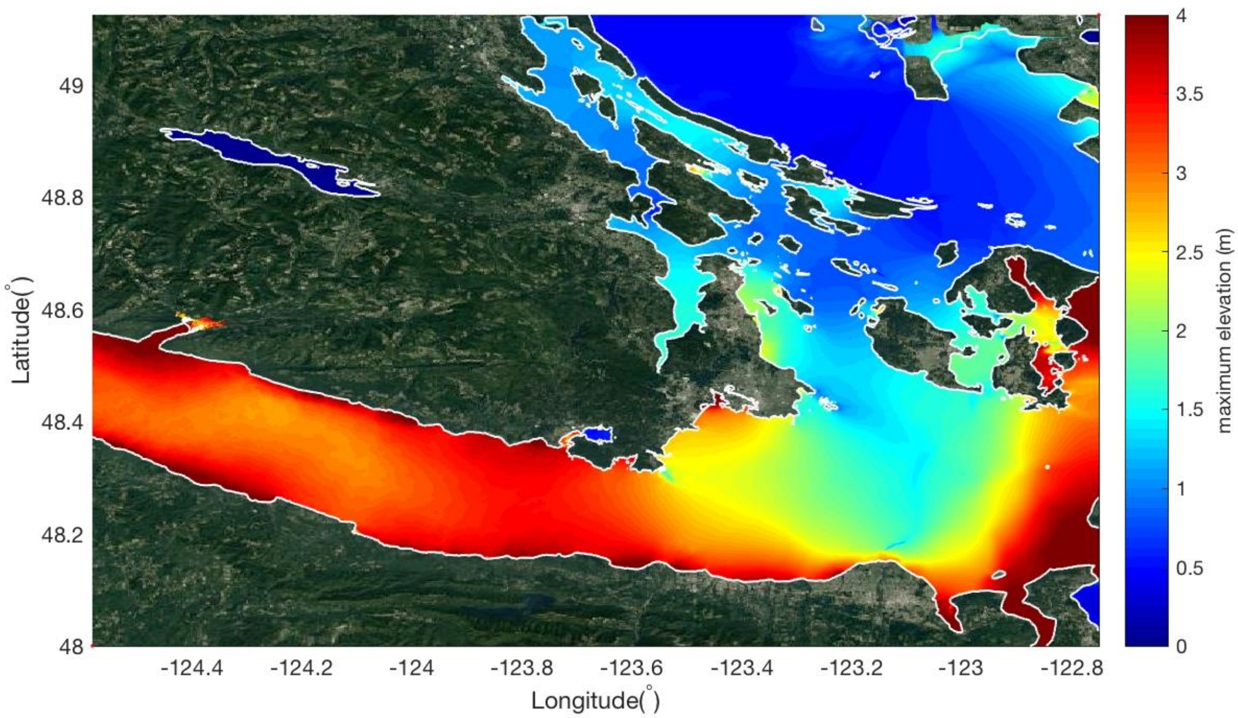

Figure 4-5
CSZ-NS: Maximum Water Surface Elevation on Grid D. (Elevations Reported to HHWMT)

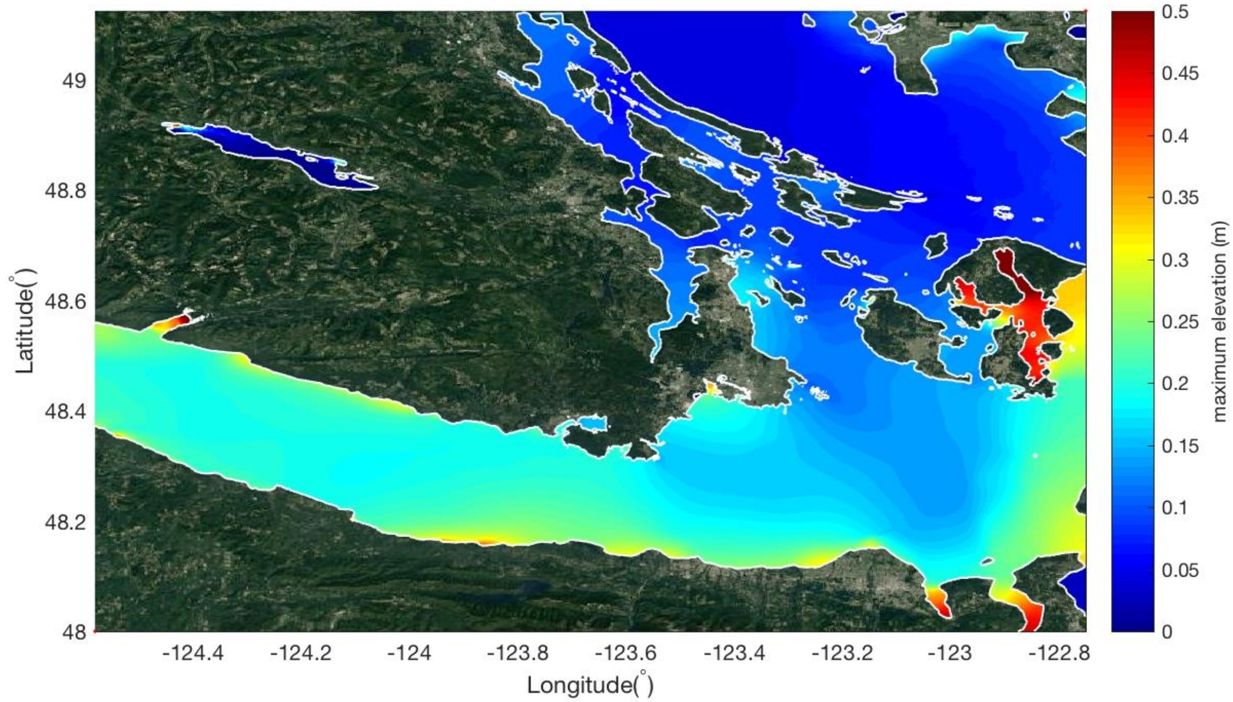

Figure 4-6
Alaska 1964 (AL) Event: Maximum Water Surface Elevation, Grid D. (Elevations Reported to HHWMT)

Local sources (DM1, DM2, SW1 and SW2) are computed initially on a special Grid C', which covers the area of Grid C but with the spatial resolution of Grid D. Results are shown here for the Mw 7.5 Devil's Mountain fault event. These local source events have minimal impact on the study sites of Sooke or Port Renfrew but can have impacts on the capital region, east of Sooke, that are comparable to the CSZ scenarios, particularly in Sidney. The full set of coarse grid results for Grids A, B, C, C' and D may be found in **Appendix A**.

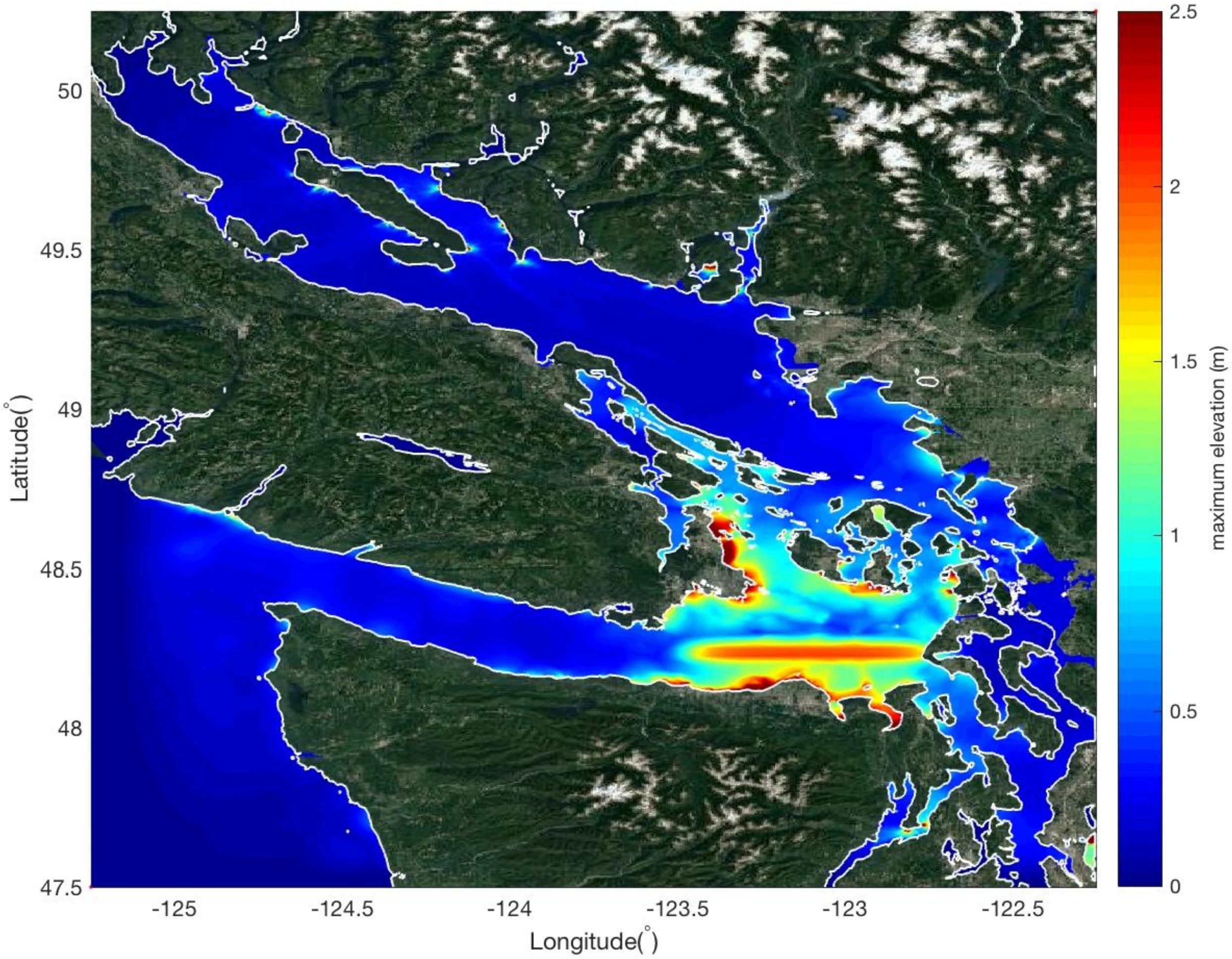

Figure 4-7
Devil's Mountain Fault, Mw 7.5 Event (DM1). Maximum Water Surface Elevations, Grid C'. (Elevations Reported to HHWMT)

4.3.3 Time histories

An important aspect of tsunami hazard analysis is the estimation of arrival time for waves generated by a seismic event with a readily apparent initial time. Results for the Grid D simulation are shown at the five measurement locations indicated in **Figure 4-8**, which are representative of the offshore location of the detailed inundation grids for each of the five sites.

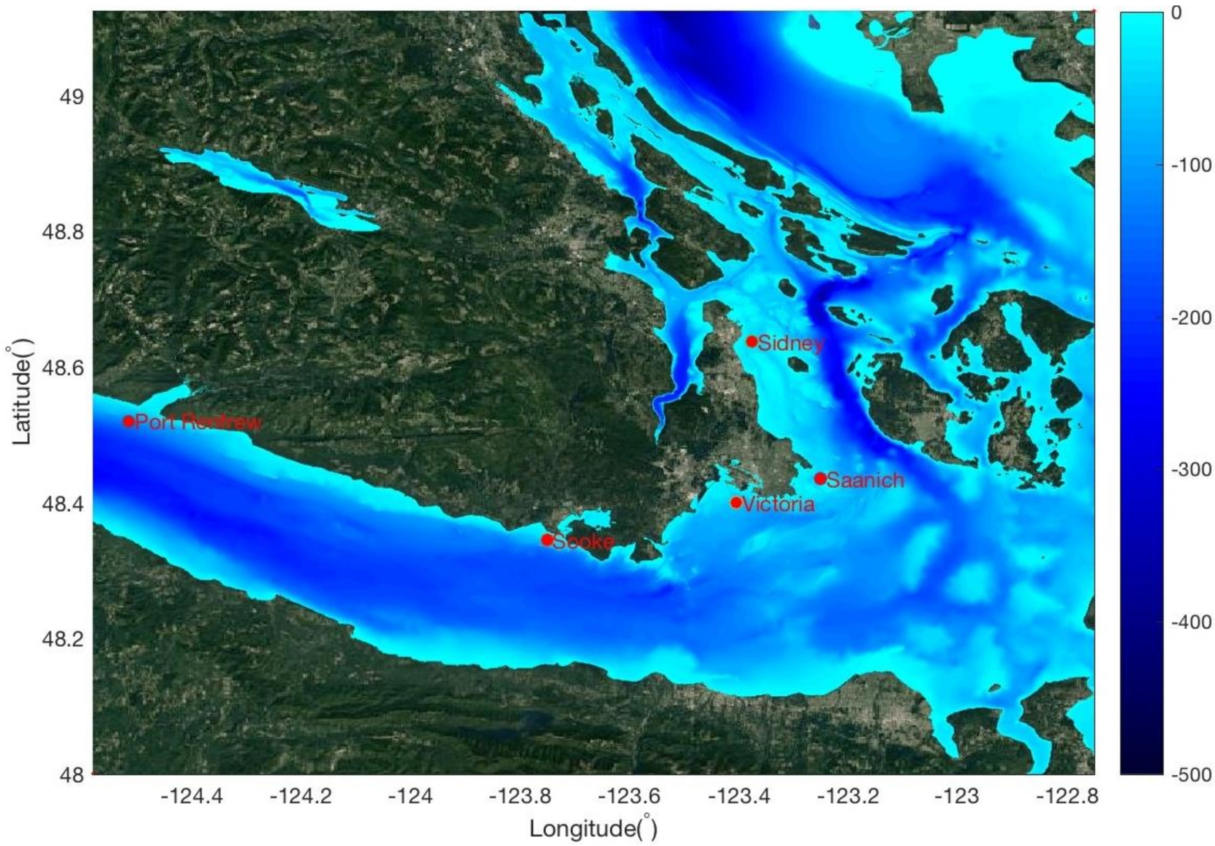

Figure 4-8
Locations in Grid D for Reported Histories of Water Surface Displacements

A full suite of time histories is presented in **Appendix B**. An example plot is given in **Figure 4-9** for the CSZ-NS event. A complete summary of tsunami travel times was also given in **Table 4-3**.

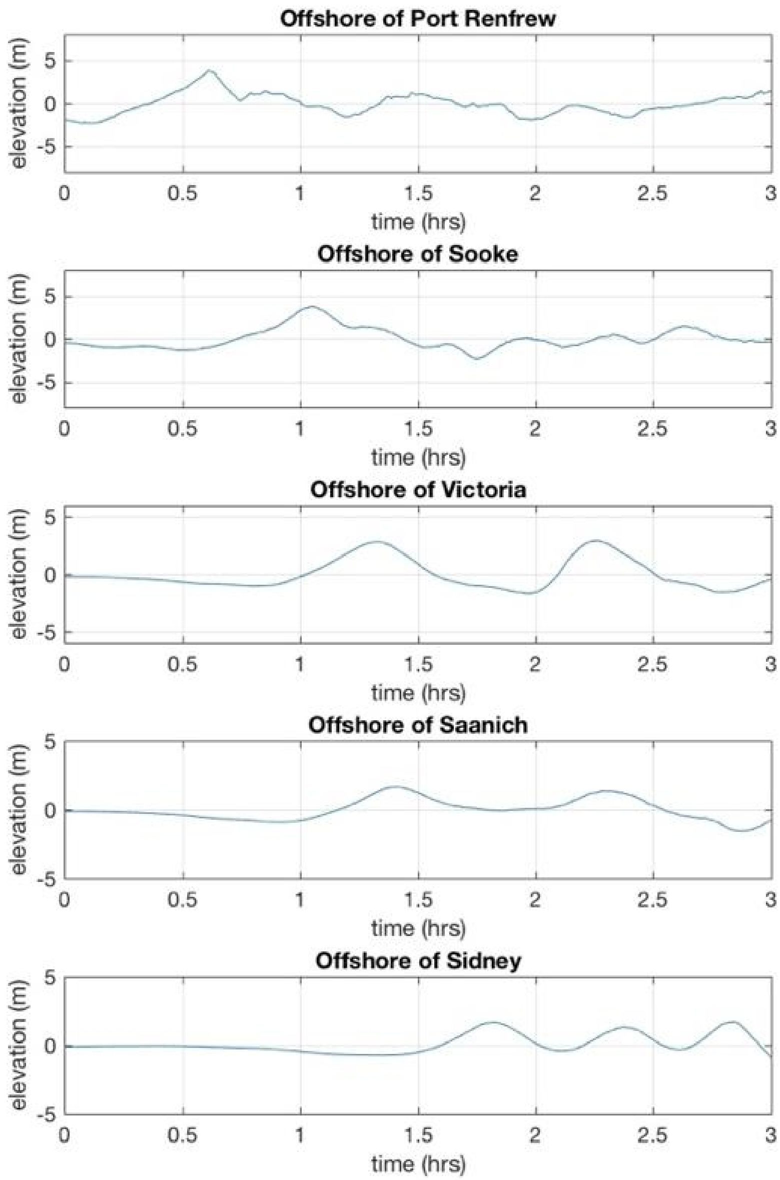

Figure 4-9
CSZ-NS: Water Surface Time Histories at Five Locations Near the Detailed Inundation Studies, Grid D.

4.4 Detailed Inundation Modelling Results Overview

Detailed inundation modeling was carried out at a grid resolution of 4 m for areas including Victoria / Esquimalt, Sidney, Saanich / Oak Bay, Sooke, and Port Renfrew. **Table 2-3** refers to the modelled scenarios at each domain location.

The grids / domains for each region are described in **Section 2.4**. Results are shown in the following sub-sections which illustrate the range of conditions resulting from the various source scenarios for each of the high-resolution model areas. Output data processed for these plots included maximum occurring water level (in metres, relative to the initial still water level), maximum inundation depth in initially dry areas (or maximum water level above local topography), maximum momentum flux (also in initially dry areas), maximum flow speed (entire wet and inundated area), and maximum vorticity (entire wet and inundated area). Map products are available for each variable having a value differing significantly from zero. Inundation depth and momentum flux plots are omitted for cases where there was no significant inundation. High resolution modelling was not conducted for the local sources for Port Renfrew or Sooke, which were not significantly impacted by these events.

Refer to **Table 4-2** for a summary of results at each detailed inundation model area.

4.4.1 Victoria / Esquimalt

Results for the CSZ-L1 source significantly impacted all of the inundation sites studied and provided the largest water level values in Victoria / Esquimalt, Sooke and Port Renfrew. Results for maximum water level and inundation depth for Victoria / Esquimalt are shown in **Figures 4-10** and **4-11**. The spatial pattern of water surface elevation is similar to that seen in earlier studies of Cherniawsky et al (2007) and AECOM (2013), with a strong resonant response in Esquimalt Harbour. For the CSZ-L1 source, there is significant overtopping of areas in Victoria and Esquimalt harbours. Most of the harbour waterfront area in Victoria is affected.

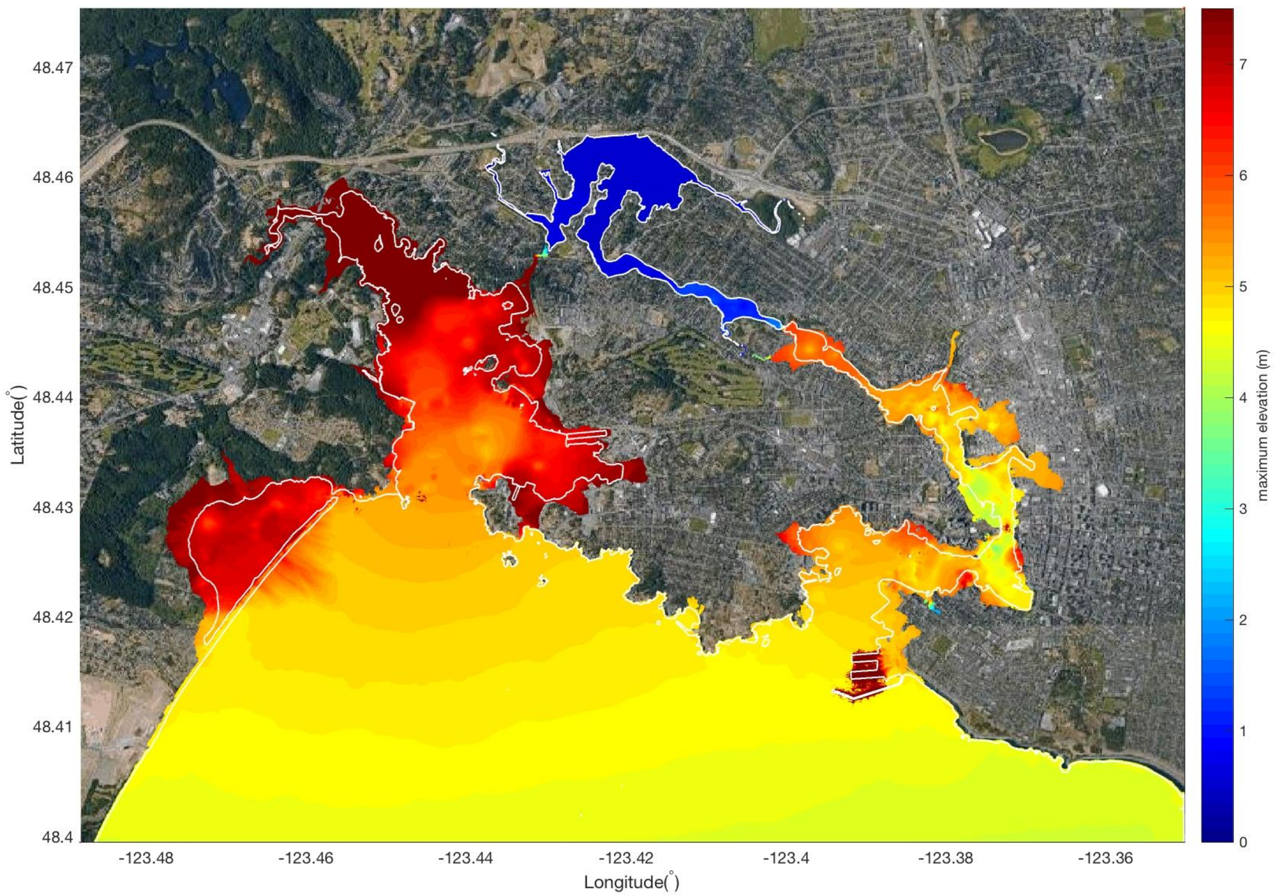

Figure 4-10
Maximum Occurring Water Surface Elevation in Victoria / Esquimalt: CSZ-L1 Event. (Elevations Reported to HHWMT)

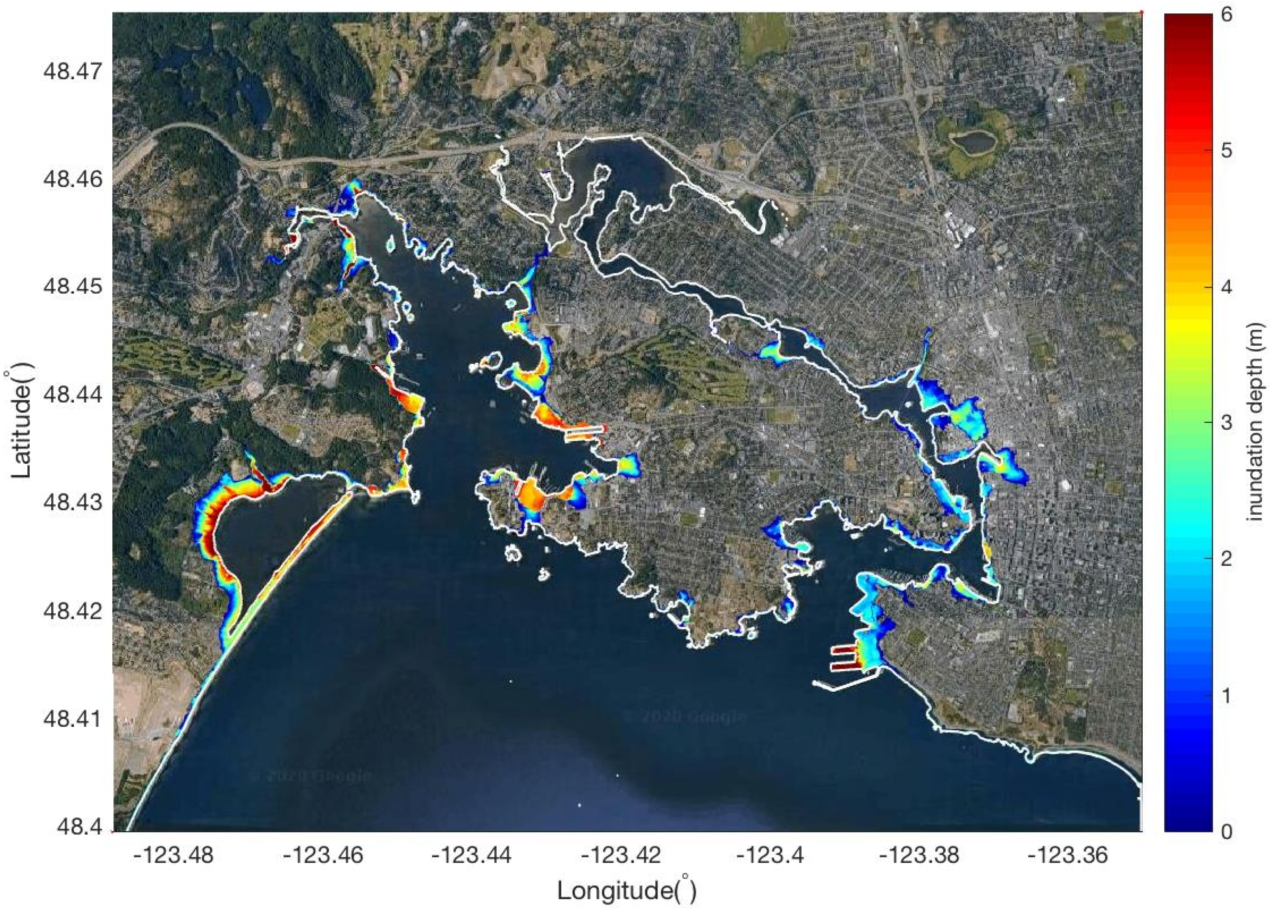

Figure 4-11
Maximum Inundation Depth in Victoria / Esquimalt: CSZ-L1 Source

Current speeds for the CSZ-L1 event are shown in **Figure 4-12**. Current speeds are also significantly higher than in the AECOM (2013) study but are similar to the results shown in Cherniawsky et al. (2007), for most of the area. The overall pattern of a near doubling of effects between the present study and AECOM (2013) is consistent with the increased magnitude of runup between the two studies. The high values of maximum current speeds reported in Esquimalt harbor by Cherniawsky et al. (2007) are unexplained by the analysis carried out here.

The response of the Victoria / Esquimalt harbours is proportionally lower for all other events studied. The tendency for a strong resonance to occur at the northern part of Esquimalt Harbour in all cases is illustrated for the Southern Whidbey Island Mw 7.5 local source (SW1), which has only moderate impacts on the rest of the region (**Figure 4-13**).

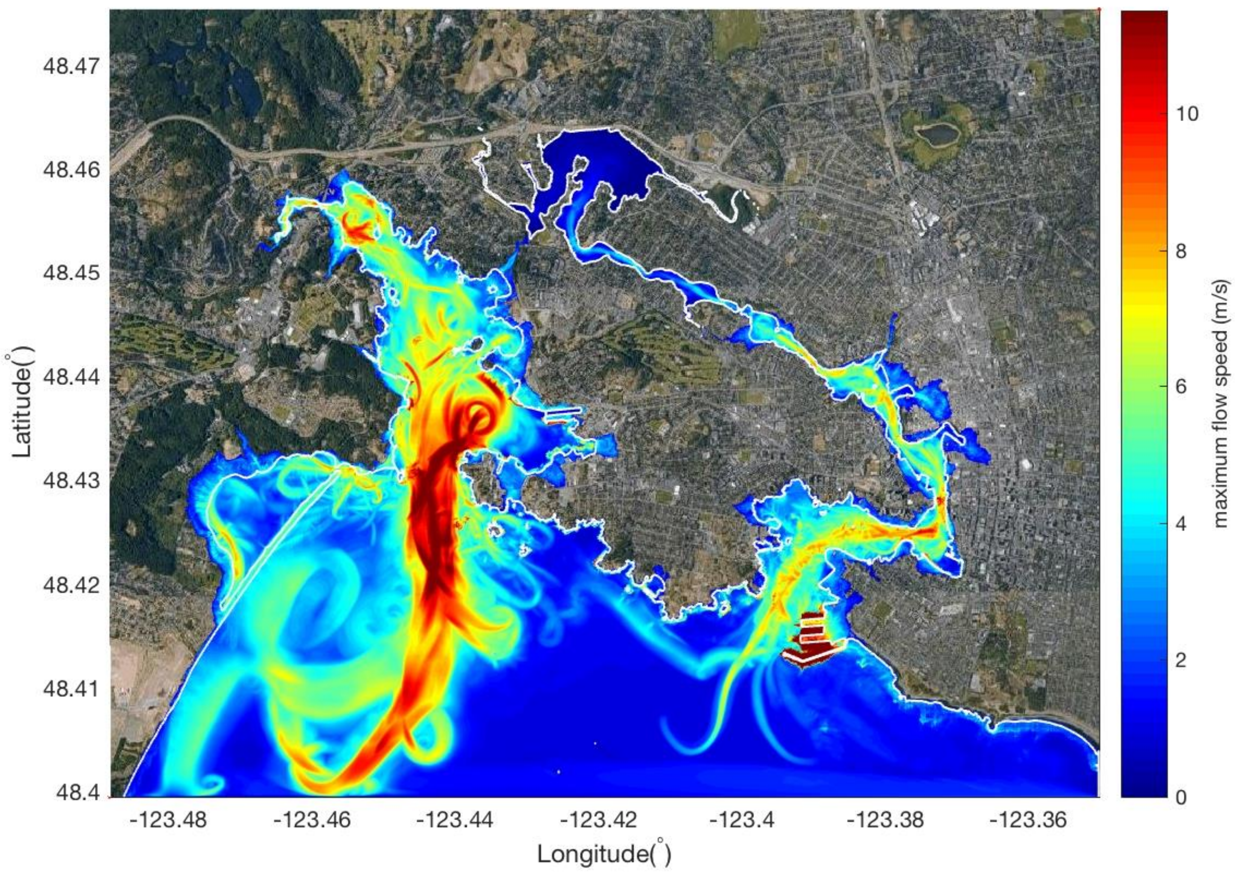

Figure 4-12
Maximum Occurring Current Speed in Victoria / Esquimalt: CSZ-L1 Event

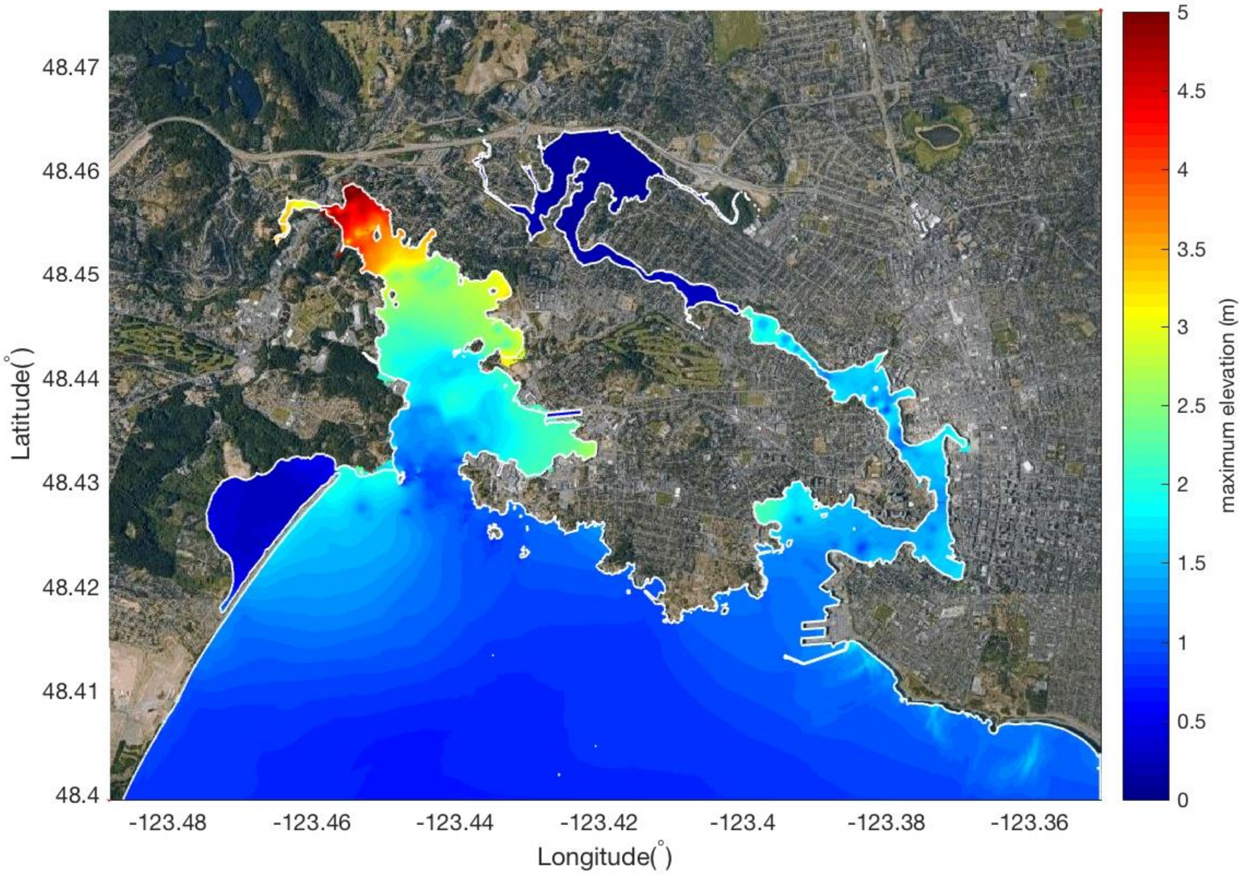

Figure 4-13
Maximum Water Level in Victoria / Esquimalt: Southern Whidbey Island Fault, Mw 7.5 Event (SW1). (Elevations Reported to HHWMT)

4.4.2 Sidney

The Sidney and Saanich local inundation regions present a more complex picture than the other detailed inundation grids, as they are impacted by the local sources to a considerable degree. **Figures 4-14** and **4-15** show maximum water elevation for the CSZ-L1 source and the Devil's Mountain Fault Mw 7.5 source (DM1). These events represent potentially the worst-case events that can occur from the CSZ and local sources. Water levels from the local event (DM1) are up to 60% as large as from the CSZ-L1 event and represent a significant potential hazard for the area. Corresponding inundation depths are illustrated in **Figures 4-16** and **4-17**.

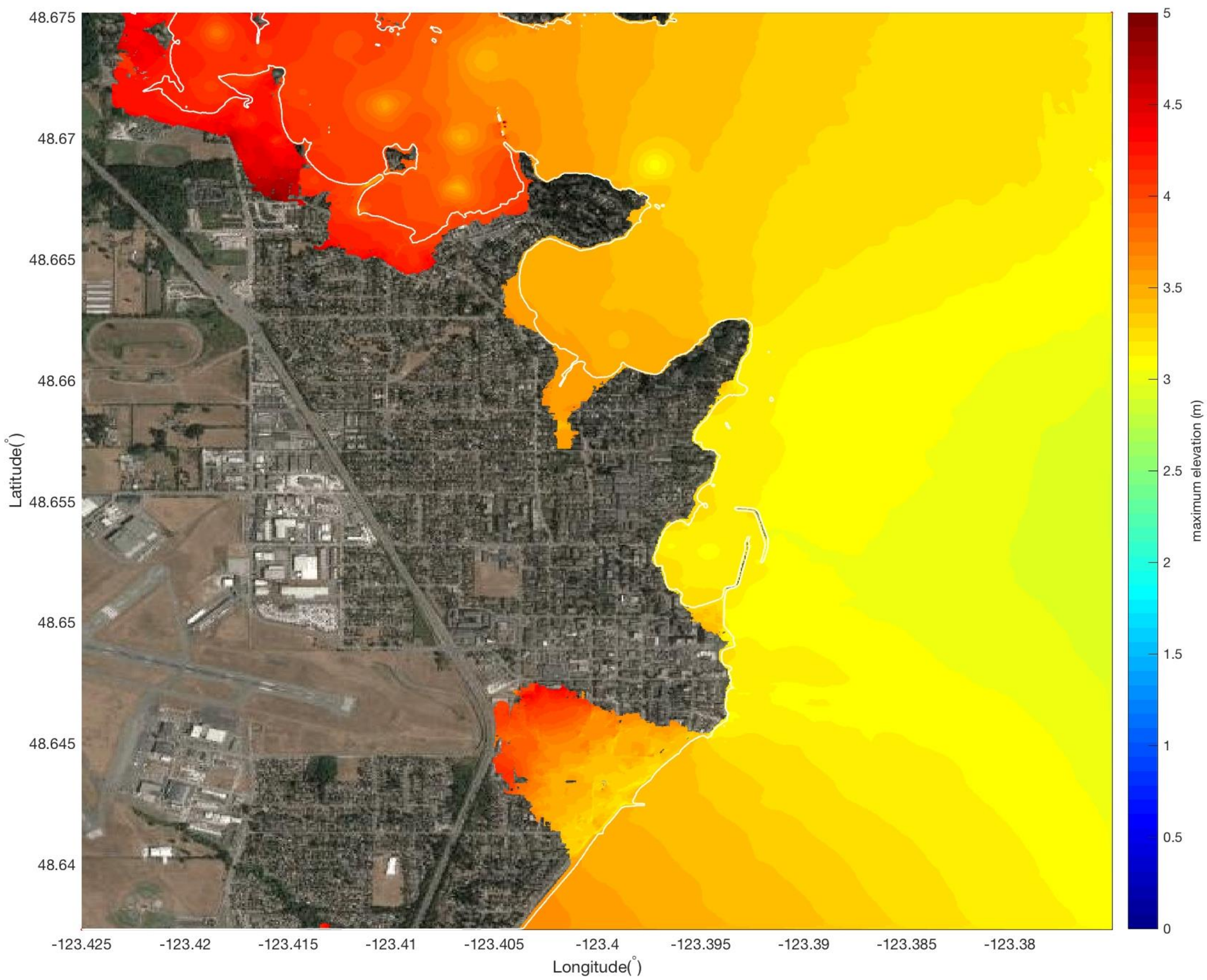

Figure 4-14
Maximum Occurring Water Surface Elevation at Sidney from the CSZ-L1 Event. (Elevations Reported to HHWMT)

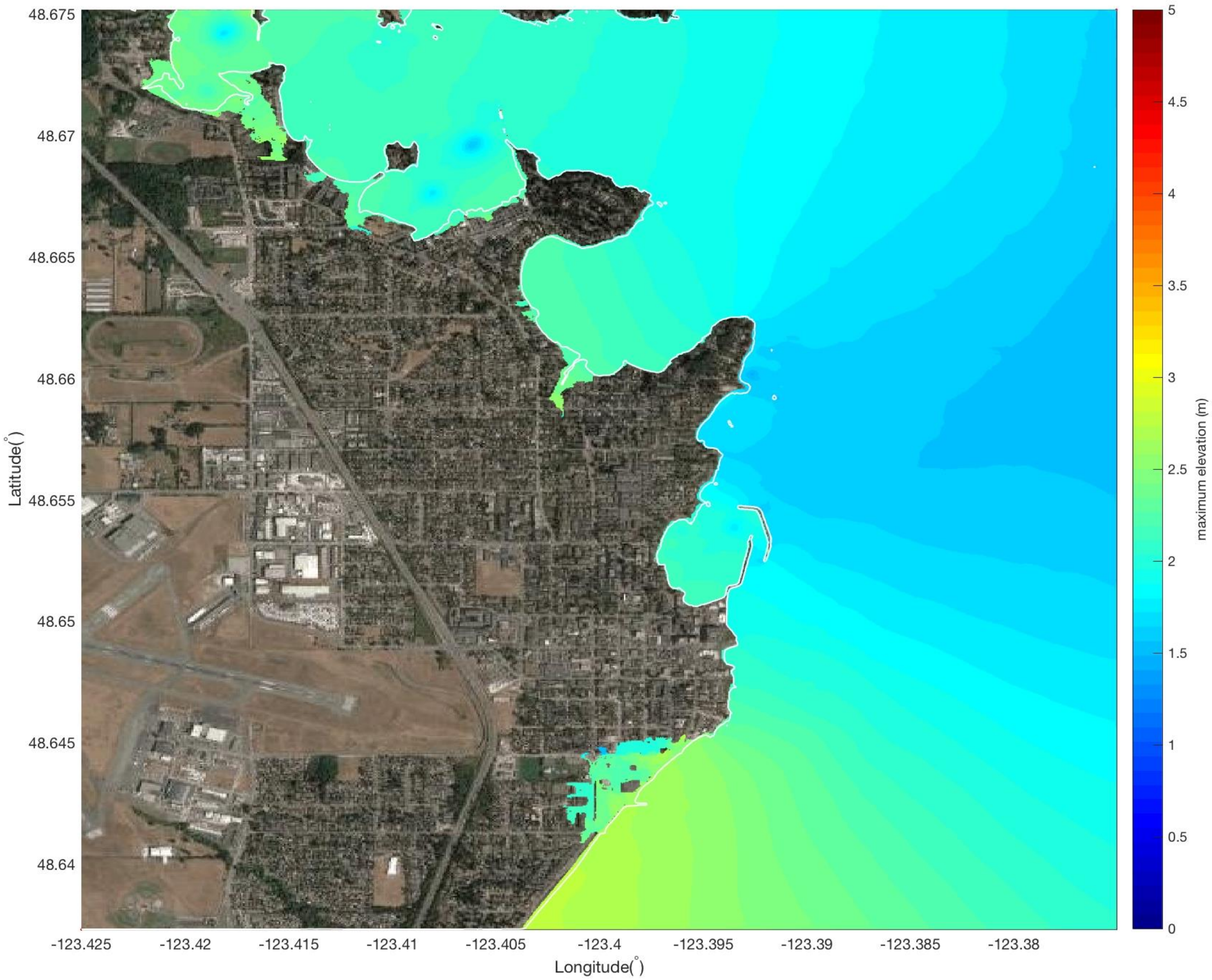

Figure 4-15
Maximum Occurring Water Surface Elevation at Sidney from the Devil's Mountain Fault Mw 7.5 Event (DM1).
(Elevations Reported to HHWMT)

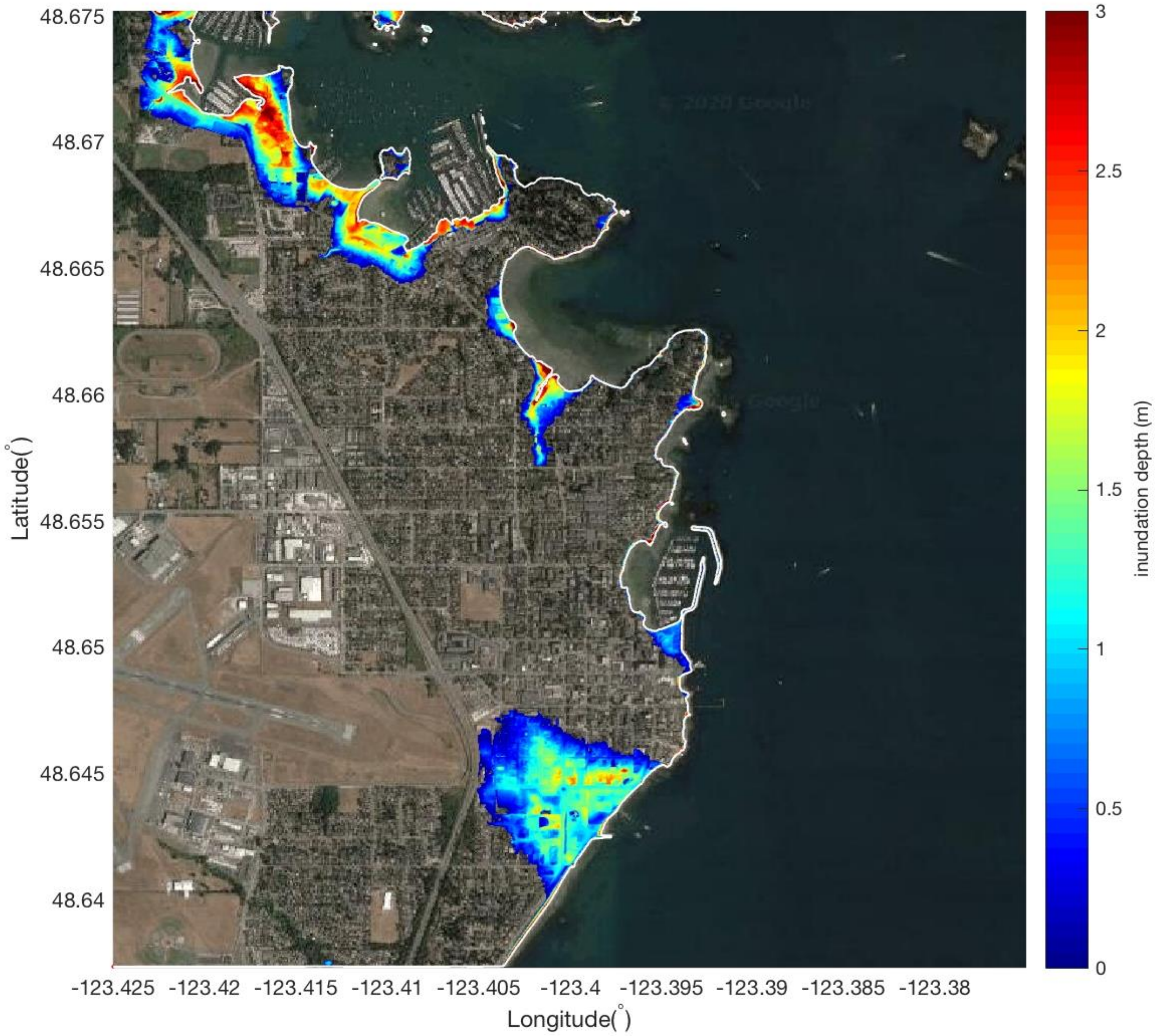

Figure 4-16
Maximum Inundation Depths at Sidney from the CSZ-L1 Event

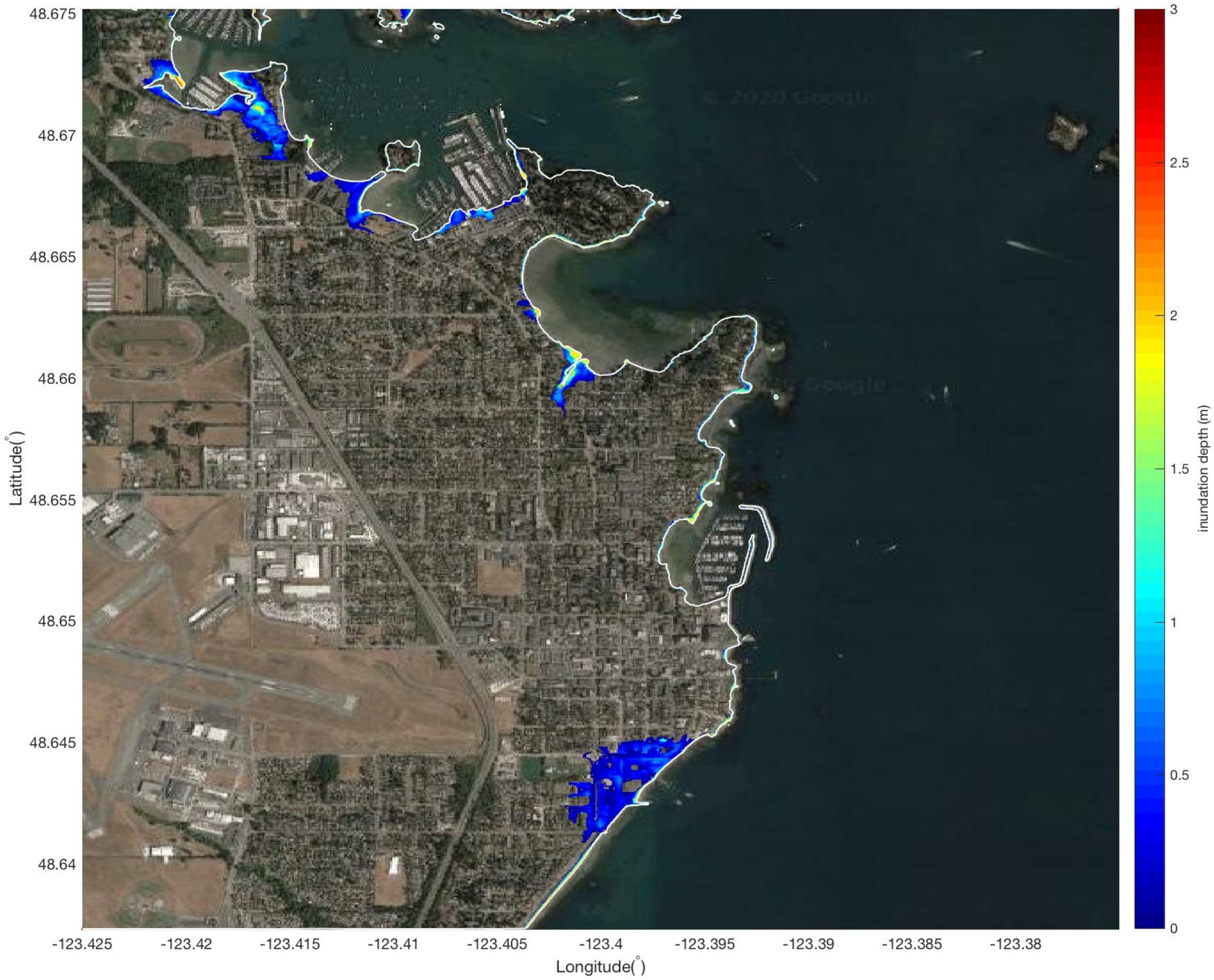

Figure 4-17
Maximum Inundation Depths at Sidney from Devil's Mountain Fault Mw 7.5 Event (DM1)

4.4.3 Saanich / Oak Bay

The response in the Saanich / Oak Bay local inundation grid also presents a mixed picture in which the Devil's Mountain fault becomes the dominant event for the northern portion of the region's shoreline. Overall, inundation effects are relatively minor except in Gyro Park in the north, where the Devil's Mountain Fault event is dominant, and along the area around St. Patrick Street in the south, where the CSZ-L1 event is dominant.

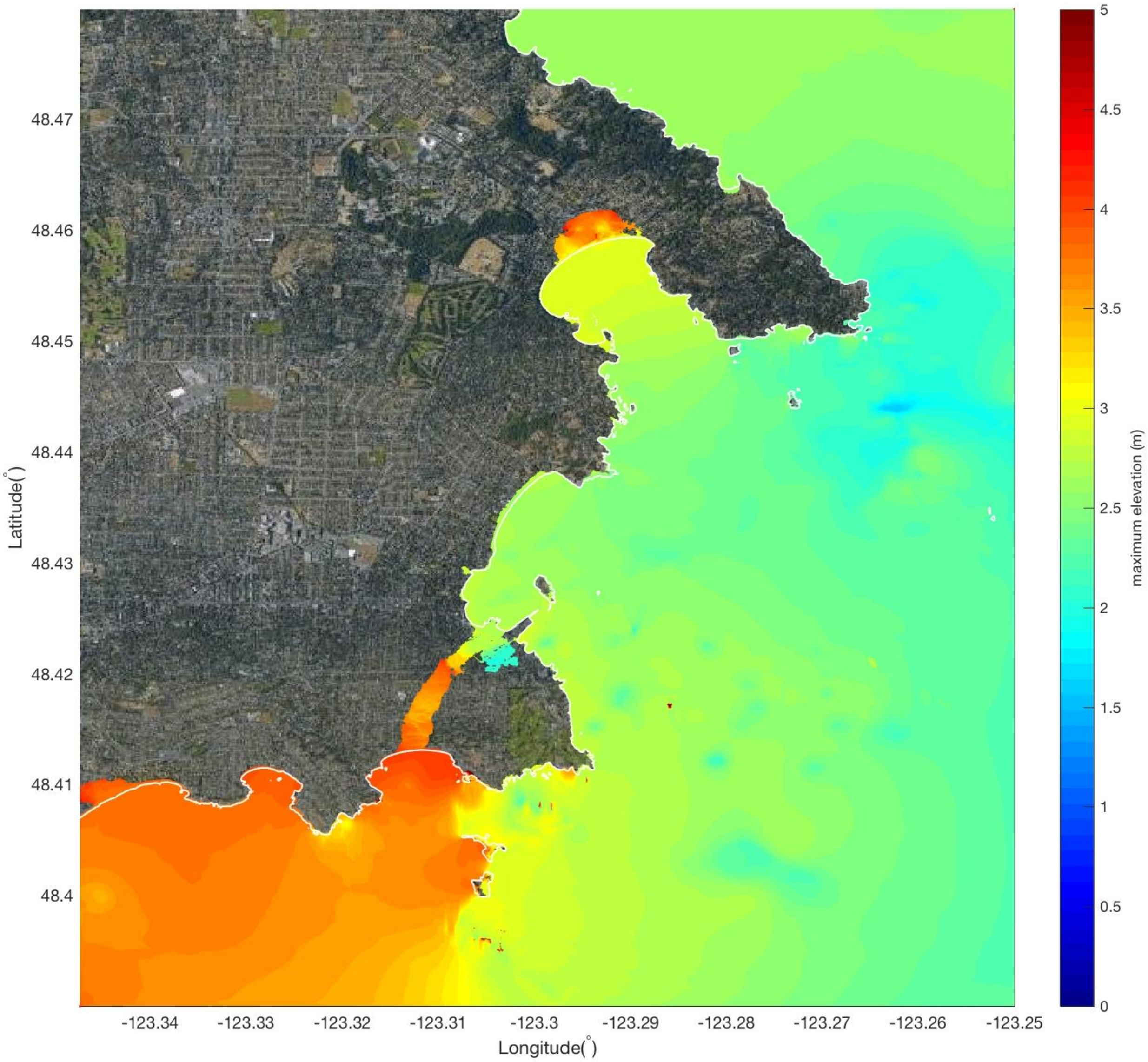

Figure 4-18
Maximum Water Levels in the Saanich / Oak Bay Inundation Grid for the CSZ-L1 Event. (Elevations Reported to HHWMT)

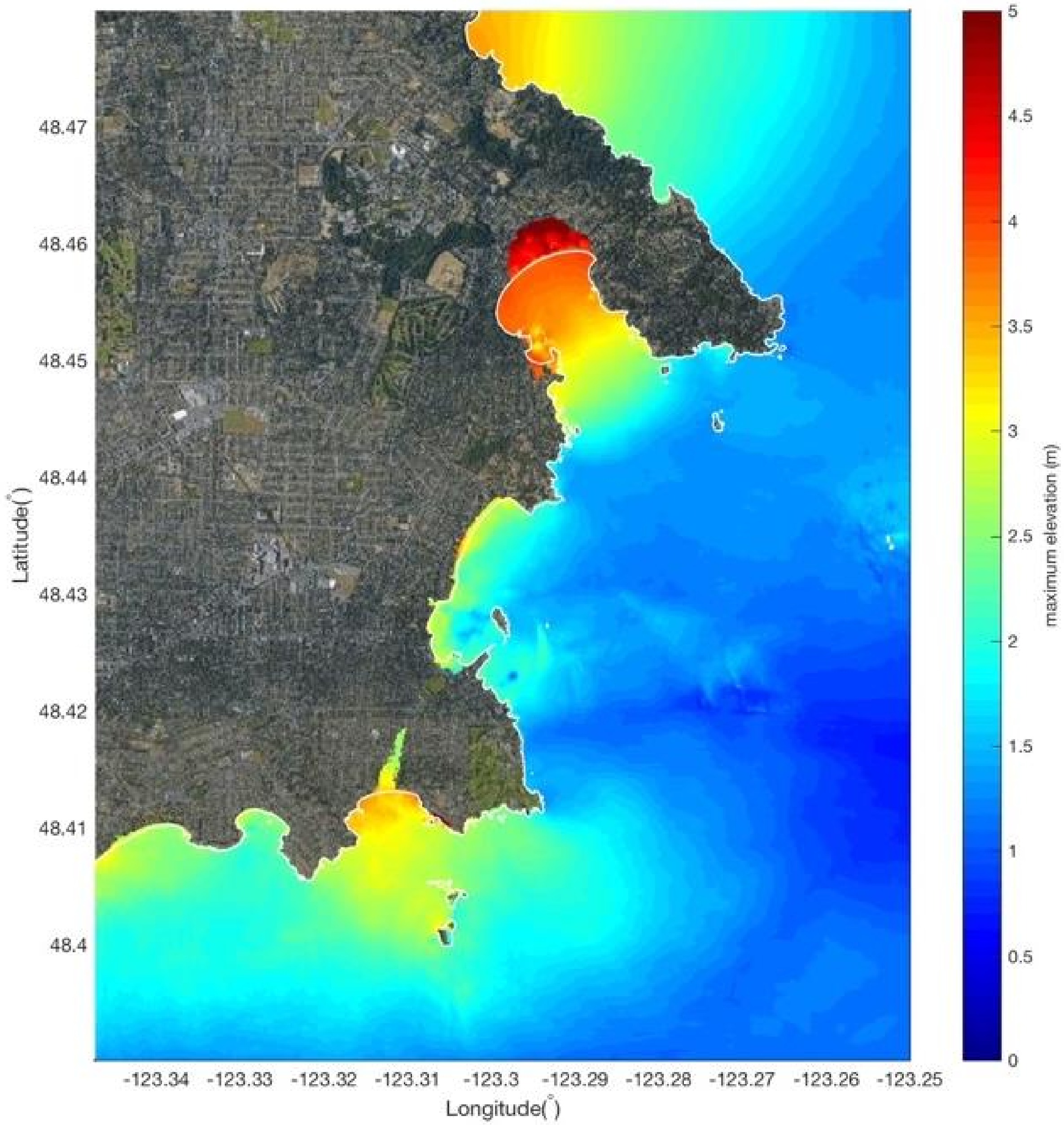

Figure 4-19
Maximum Water Levels in the Saanich / Oak Bay Inundation Grid for the Devil's Mountain Mw 7.5 Event (DM1). (Elevations Reported to HHWMT)

4.4.4 Sooke

The water body studied in the Sooke high resolution inundation grid consists of two regions which are progressively sheltered from tsunami wave attack by spits or submerged sills. As with most of the sites studied, the greatest impact is from the CSZ-L1 source. **Figure 4-20** shows the maximum occurring water level for this event and shows the effectiveness of the various bathymetric barriers to reduce the impact of the event inside the harbour. As a result, the predicted inundated area is fairly limited (**Figure 4-21**). Current speeds over the sills and the inundated barrier spit (i.e. Whiffin Spit) can be quite strong, however (**Figure 4-22**), and it is not unlikely that the barrier spit could be breached or largely eroded by the strong overtopping currents.

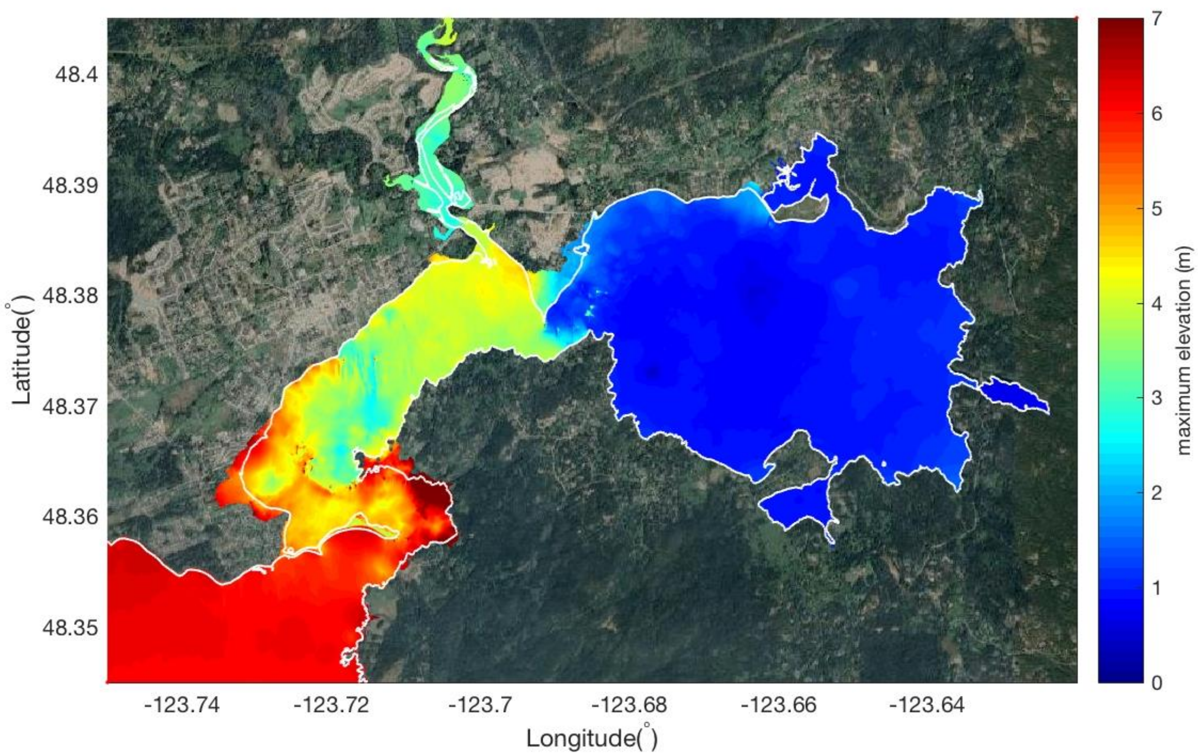

Figure 4-20
Maximum Occurring Water Elevation in Sooke: CSZ-L1 Source. (Elevations Reported to HHWMT)

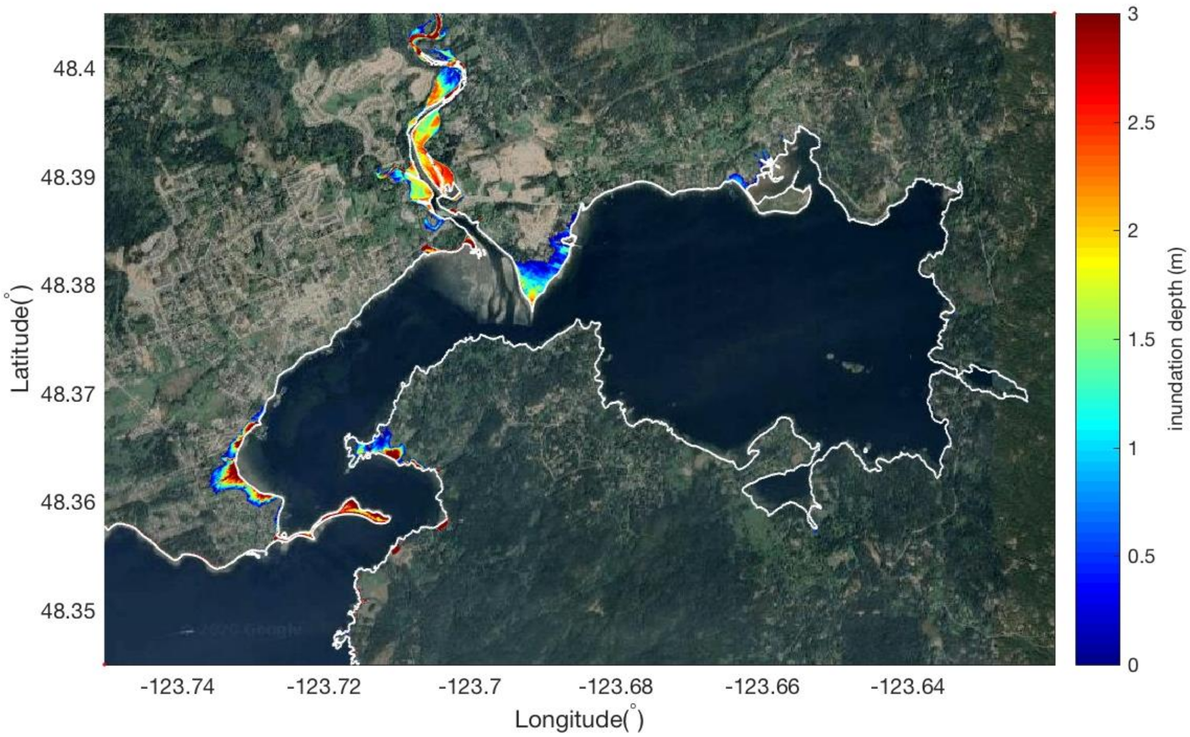

Figure 4-21
Maximum Inundation Depth in Sooke: CSZ-L1 Source

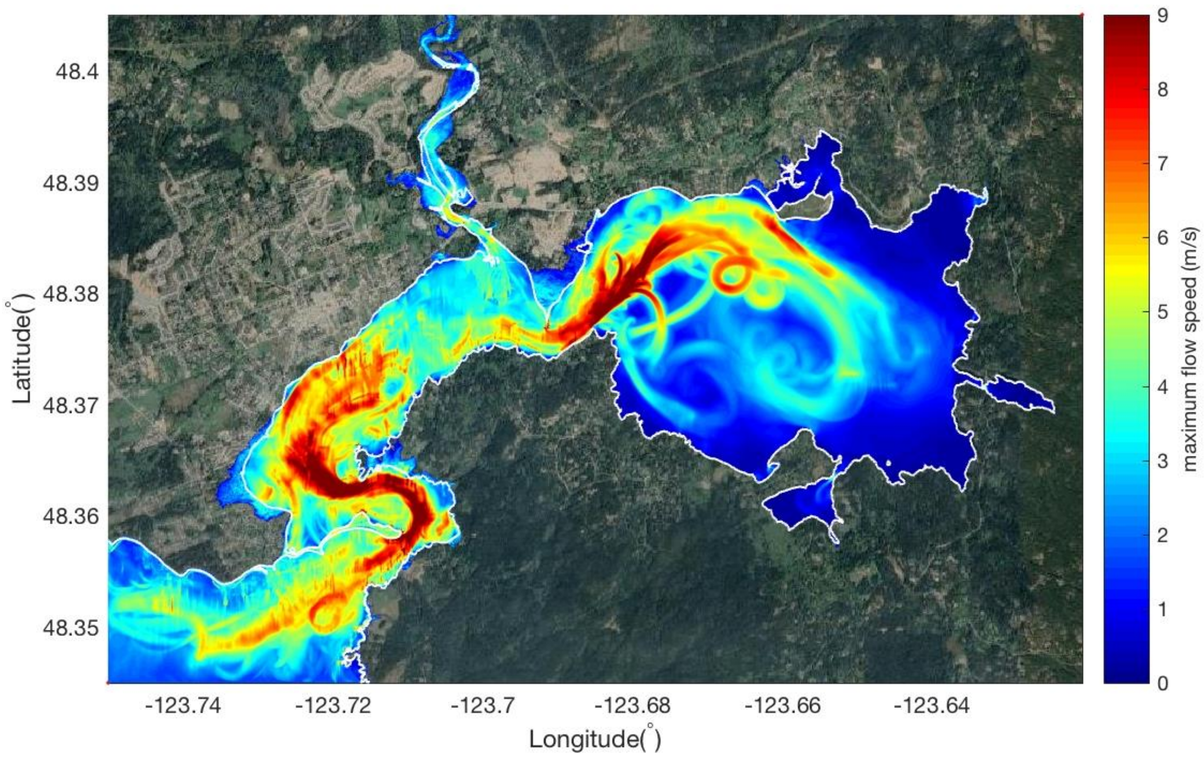

Figure 4-22
Maximum Current Speed in Sooke: CSZ-L1 Source

4.4.5 Port Renfrew

Port Renfrew is the local inundation site, which is most exposed to CSZ and remote events and conversely, has no significant impact from the local sources considered. Maximum water levels and inundation depths for the CSZ-L1 event are shown in **Figures 4-23** and **4-24**, which indicate that a great deal of flooding of the low areas at the landward end of the inlet would be expected for this large event. The event creates strong currents along the lateral boundaries of the main water body and at the shore of the river delta formation at the head of the inlet, illustrated in **Figure 4-25**. This pattern of response is also repeated for the CSZ-NS event, with proportionally lower water levels and current speeds. The CSZ-CS event and the Haida Gwaii and Alaska events do not cause any significant inundation in the region, and currents generated by the CSZ-CS event are not larger than 1.5 m/s and are localized at stream mouths and around irregular coastal features.

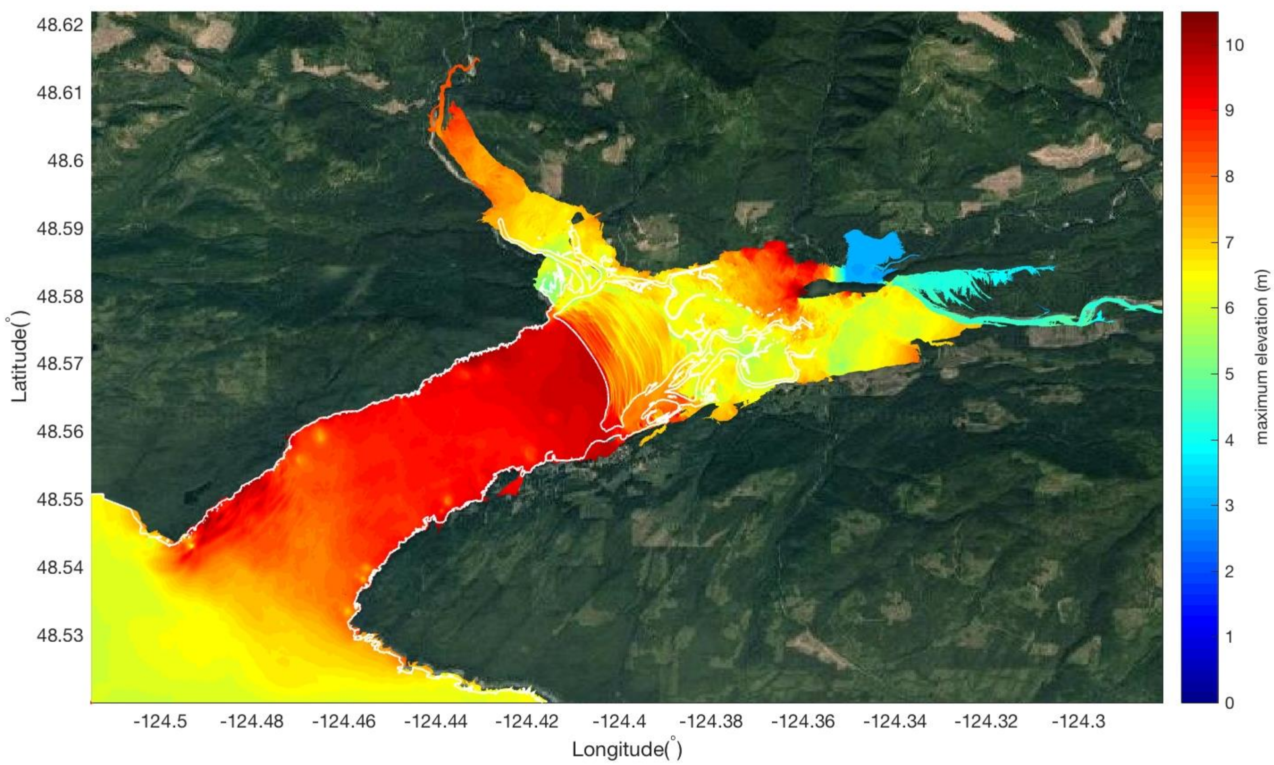

Figure 4-23
Maximum Occurring Water Surface Elevation in Port Renfrew: CSZ-L1 Event. (Elevations Reported to HHWMT)

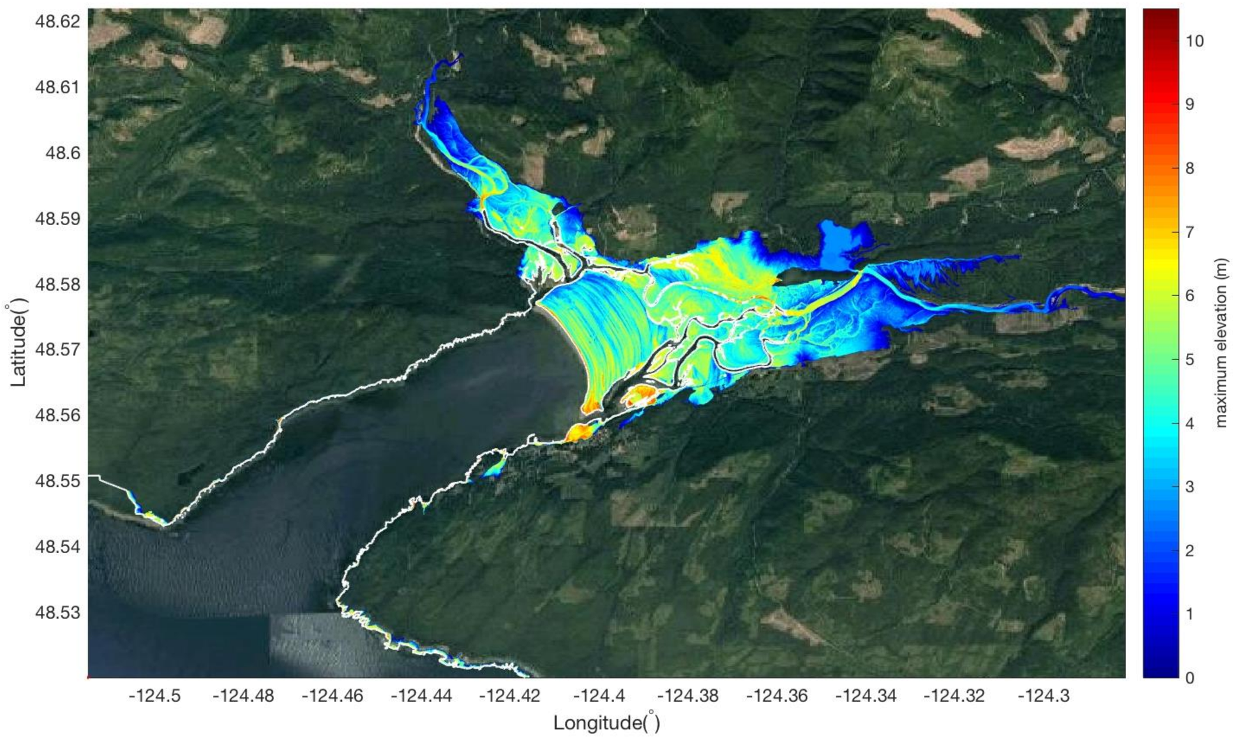

Figure 4-24
Maximum Occurring Inundation Depth in Port Renfrew: CSZ-L1 Event

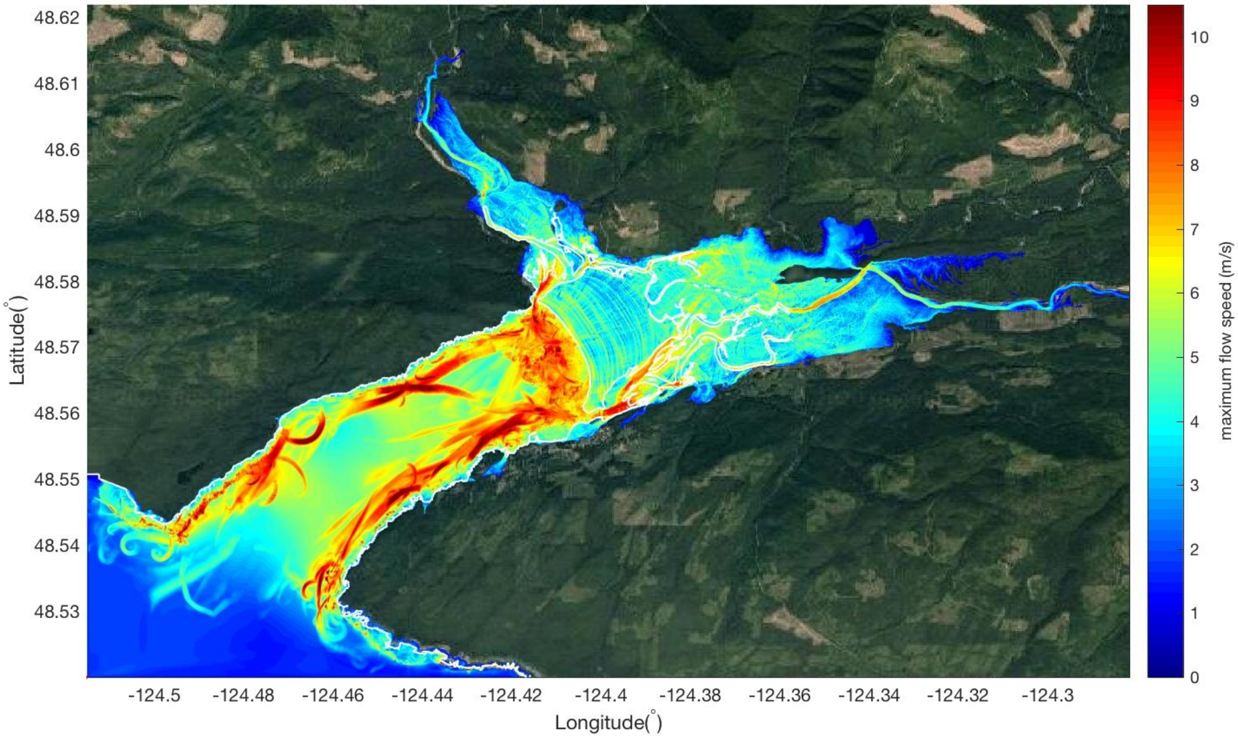

Figure 4-25
Maximum Occurring Current Speed in Port Renfrew: CSZ-L1 Event

4.5 Limitations in the Tsunami Modelling

As with all forms of hydrodynamic modelling, there are limitations on the ability of the software to replicate some types of hydraulic phenomena which can give rise to instabilities or oddities in the model results. These limitations arise from the numerical solution scheme for the underlying hydraulic equations coupled with choices related to resolution and other model parameters made to achieve the best results on average over the bulk of the model domain. The following sub-sections attempt to provide commentary on common oddities observed in the modelling results and guide the interpretation of the results.

4.5.1 Coarse Grids Failing to Make Landfall

In some localised instances in the coarse grid model results (i.e. Grid D / C'; approximately 30 m cell resolution), the inundation extents look like they haven't made landfall (see the figures below). This is because there is an elevation value assigned to the 'dry cell' that is higher than the Hmax of the adjacent tsunami wave, thereby always being dry. This can happen for all types of modelling when you have (a) steep coastline / abrupt changes in coastline profile and (b) a cell resolution which is not capable of replicating / capturing these detailed topographical changes; resulting in 'steps' or 'stairs' in the underlying model mesh. Users can compare the modelled Hmax values close to the interface with elevations on dry land to get a more accurate inundation extent if they desire. The primary means by which this type of oddity would be rectified would be through adopting a finer model grid / mesh. However, in large geographic areas such as the capital region, this becomes unrealistic due to the computational demands such a change would be generated.

Figure 4-26
Examples of Coarse Grid Results Not Inundating the Coastline Boundary Due to Model Resolution

4.5.2 Model Instabilities

Upon examination of the modelling results, it is evident that in some very localised instances, there are significant elevation spikes in the outputted data. The spikes are usually caused by sharp changes in bathymetry / topography. A Boussinesq model performs best at slopes less than 1:1. If a slope is too large (e.g. >1:1), the model accuracy would reduce, which would affect some localised cells around where that sharp change in topography is occurring.

This becomes more noticeable in resolutions of finer and finer scale as models become able to replicate docks, quay walls, berms etc. in greater detail (see the red shading at Ogden Point, on the right, below as an example).

It also becomes a problem in the coarser grid mesh, as subtle changes in slope are simplified, leading to 'steps' or 'stairs' in the model DEM. Unfortunately, these 'noises' or 'instabilities' are a by-product of the theoretical limitation of the Boussinesq-model. When project stakeholders and users are examining the model deliverables, it is recommended that one would ignore any obvious spikes like this in the results and use values from nearby, more stable cells.

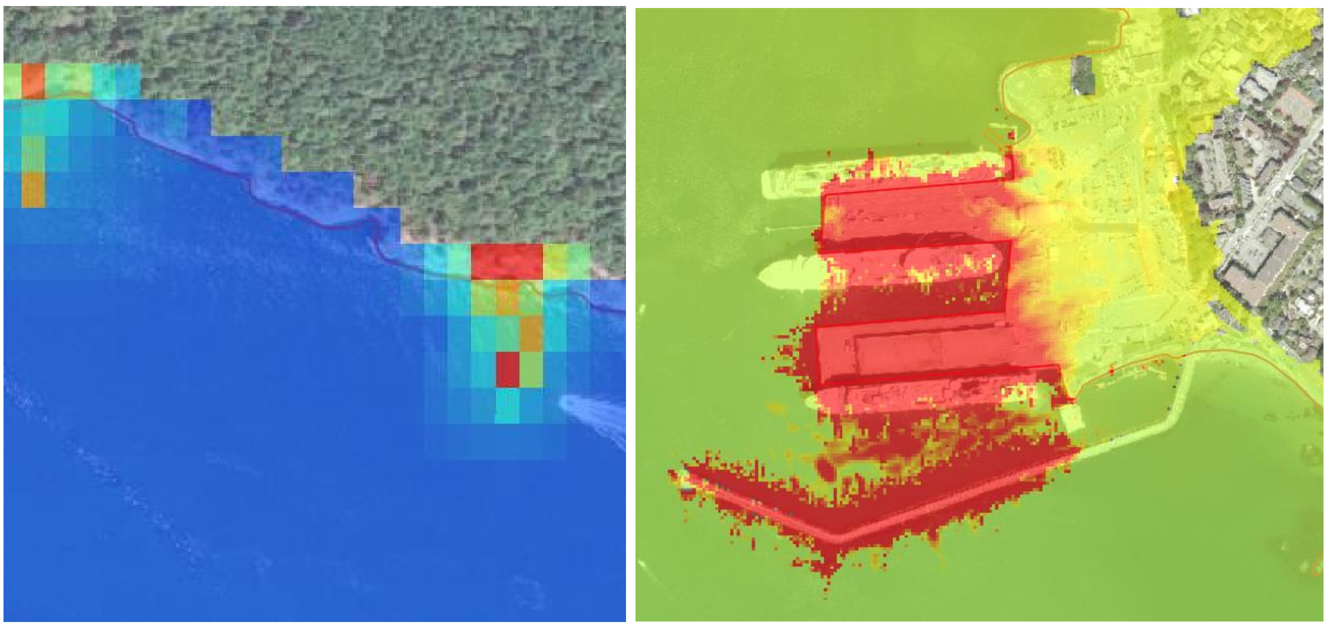

Figure 4-27
Example of Model Instabilities at Sharp Elevation Changes in the Tsunami Modelling

4.5.3 Differences in Tsunami Modelling Results at the Ocean Boundary Between Detailed and Coarse Modelling Domains

In some instances, adjacent to the ocean boundary between detailed and coarse tsunami model domains, there are differences in modelled tsunami wave heights; some as large as 1 m. These differences between Grid D / C' and detailed inundation grid results were caused by so-called 'one-way nesting'. In the nested grid, one usually observes a wave height slightly higher than that in the coarser grid because of wave reflection from the nesting boundary. This is an issue inherent to nested grid modelling and would not be something to alter the outcome of the project.

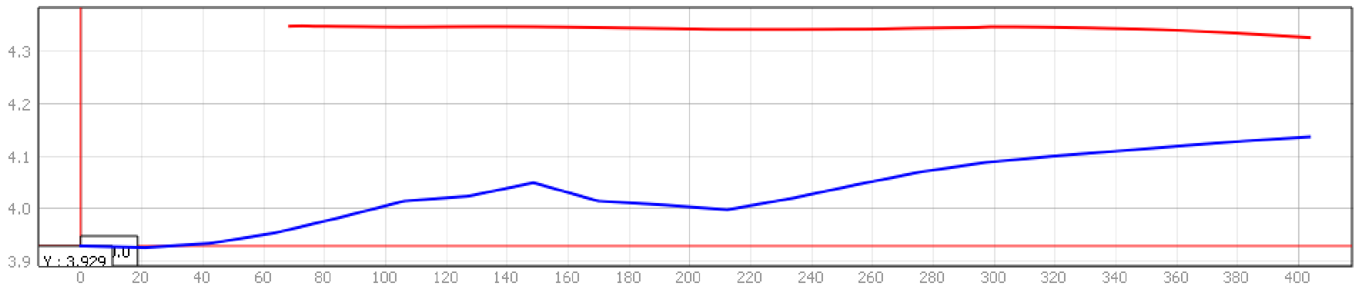

Figure 4-28
Example of Difference Between Coarse Grid Hmax (Blue Line) and Detailed Victoria Grid Hmax (Red Line) at Detailed Grid Boundary

5 TSUNAMI RISK ASSESSMENT

The purpose of this assessment is to identify the potential risk of damage to ports and harbours as a result of flooding and strong currents generated by tsunami waves.

5.1 Risk Assessment Methodology

There are two general types of risk analysis – quantitative and qualitative. The quantitative approach requires large amounts of incident data across different sites and requires significant resources to establish a numerical evaluation of the level of risk. Techniques such as fault and event trees are used for quantification. It is used in cases to demonstrate compliance with a prescribed safety margin or level of safety. The quantitative type of analysis is outside the scope of work for this study.

The qualitative approach uses a risk event in a comparative way to identify if one incident or event is of higher risk than another. This comparative assessment allows for the identification of activities which result in higher levels of risk, without the need to determine the absolute value of the risk. This reduces the time and effort required for the assessment yet still provides the information required to determine risk and allow commentary on mitigation options. This assessment is based on a qualitative approach to provide an overview of the risk associated with the effect of tsunami waves impacting selected harbour sites within the CRD region.

The risk assessment begins with the identification of hazards. A hazard is defined as an incident or event with the potential to cause harm to:

- People,
- Environment, and
- Property.

The hazards are taken here to refer to the high-water levels and current velocities associated with specific tsunami sources and their effect on relevant ports and harbours. Once a hazard is identified, the frequency of an event is assessed which is then combined with the potential consequence, giving an assessment of risk. For this study, the frequency of events is defined as the return period of the tsunami event. Therefore, this assessment is confined to a discussion of the consequences or impacts. In this context, the risk assessment is undertaken through the following steps:

- Identification of hazards
  - Identification of harbours and facilities,
  - Identification of tsunami sources, and
  - Estimation of resulting water levels and currents.
- Consequences or impacts
  - Summary of typical potential impacts, and
  - Potential impacts at the selected harbours.

The following assessment summarizes the above components through successive sub-sections.

Subsequently, statements are provided on risk mitigation approaches; and as well as the implications on related risk policies and management approaches (the latter being considered more generally, beyond the application to ports and harbours).

5.2 Identification of Harbours and Facilities

The ports and harbours that have been identified as being of primary concern in the event of a tsunami are shown in **Figure 5-1** and described in the following sections. Descriptions of marine infrastructure at each location have been extracted from "Fisheries and Oceans Canada, Sailing Directions, PAC 201, First Edition, corrected to 03/2020", and supplemented by local knowledge.

5.2.1 Port Renfrew

Port Renfrew is located at the head of Port San Juan, which is entered from the Juan de Fuca Strait between Owen Point and San Juan Point. Primary marine infrastructure includes:

- Community Wharf – a 160 m long approach structure leading to a 33 m x 15 m wharf head. There are a number of small craft floats attached to the facility, with access provided from the approach structure.
- Pacific Gateway Marina – located to the northeast of the Community Wharf, the marina provides moorage for vessels of up to 24.4 m in length. The marina is protected from the southwest by a breakwater.

5.2.2 Sooke Harbour

Sooke Harbour is used mainly by commercial and sports fishing vessels. The harbour is entered between the east end of Whiffen Spit and Grant Rocks. The primary marine facility is the public wharf that is operated by the Sooke Harbour Authority. It comprises a 74 m approach structure leading to a 15 m x 18 m wharf head. A number of, approximately, 90 m long floats are attached to the northeast side of the wharf head.

Within the harbour, there are several small marinas and private float facilities. These generally consist of an approach structure, hinged access ramp and small craft moorage floats. At the north end of the harbour, a channel runs north of Trollope Point and Hill Head, into the Sooke Basin. As with the harbour, there are small marinas and numerous private float facilities.

5.2.3 Esquimalt Harbour

Esquimalt Harbour is administered by the Department of National Defence and is the Canadian Forces, Maritime Forces Pacific (MARPAC) headquarters. It is also a public port that provides repair and refit facilities for large commercial deep-sea vessels.

There are two dry docks and a marine railway in the harbour. The largest of these is the Esquimalt Graving Dock which can handle vessels of up to 100,000 DWT. The other major port facilities are summarized in **Table 5-1**.


350000E
400000E
450000E
500000E
5400000N
5350000N
N
Upper Harbour
Fuelling Dock (East)
Small Craft Facility
Gorge Waterway
Harbour Entrance
Entrance to Rock Bay
Westbay
Canadian Coast Guard
Harbour Entrance
Black Ball Ferry Terminal
Sooke Lagoon
Rotary Pier
Inside Whiffen Spit
Upper Harbour
Upper Harbour
North Saanich Marina
Sidney WSDOT Ferry Terminal
North Saanich Marina
VanIsle Marina
Sidney WSDOT Ferry Terminal
Upper Harbour
Cordova Bay
Gorge Waterway
McNeill Bay
Sooke Lagoon
Inside Whiffen Spit
Cordova Bay
Oak Bay
McNeill Bay
0 10 20 30 40 50 km
Coastal Flood Inundation Mapping Project
Figure 5-1
Tsunami Risk Assessment Locations
Location
Legend
Coastline
Risk Analysis Locations
DHI
CRD
Making a difference...together
Project No. 20192676
© OpenStreetMap contributors. Icon made by Freepik & PixelPerfect from www.flaticon.com Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
plot date: 2020.05.01
file: P:\20192676\00_CoastFloodTsunami\Working_Dwgs\010_GIS

Table 5-1
Esquimalt Harbour Major Marine Facilities

Berth	Wharf Length (m)	Wharf Elevation (m) above Chart Datum)
Jetty A – North Face	230	4.8
Jetty A – East Face	60	4.8
Jetty B – East Face	183	4.5
Jetty B – West Face	90	4.5
Jetty C – Inside Piers	139	5.3
Jetty C – West Face	200	5.3
Jetty C – East Face	200	5.3
Jetty Y	57	-
Jetty E	290	5.1
Jetty D – North Face	137	4.4
Jetty D – East Face	137	4.4
Jetty F – North Side	230	4.7
Jetty F – South Side	198	4.7
Jetty G	60	-

Being the home base of the Royal Canadian Navy's Pacific Fleet, there will be a number of naval vessels moored alongside the jetties.

5.2.4 Victoria Harbour

Victoria Harbour is entered between Macaulay Point and Ogden Point Breakwater. The harbour is administered by the Greater Victoria Harbour Authority with Transport Canada being responsible for the harbour regulations. The harbour provides facilities for cruise ships, ferry services, tug and barge operations, seaplanes, water taxis and numerous pleasure craft. For the purpose of traffic control the harbour is divided into four parts, containing the following primary marine infrastructure:

- Outer Harbour – Ogden Point to Shoal Point
    - Ogden Point, Piers A and B cruise ship terminal and Pacific Pilotage Authority floats. It is protected by a breakwater.
    - Canadian Coast Guard base includes a wharf, heliport and hovercraft ramp.
- Middle Harbour – Shoal Point to Laurel Point
    - West Bay Marina, including float homes and small craft moorage.
    - Victoria International Marina, a relatively new facility designed primarily to accommodate large visiting recreational vessels.
    - Fisherman's Wharf, including float homes and recreational small craft.

- Inner Harbour – Laurel Point to the Johnson Street Bridge
  - Clipper Ferry and Black Ball Ferry Terminals.
  - Causeway Floats (Empress Hotel) primarily for transient moorage.
  - Wharf Street Marina provides permanent and transient moorage for small craft.
- Upper Harbour – North of the Johnson Street Bridge.
  - Johnson Street Bridge is a newly constructed bascule bridge.
  - Point Hope Shipyard.

5.2.5 Oak Bay

Oak Bay is located to the east of Victoria at the south end of the Saanich Peninsula. Primary marine facilities include:

- Oak Bay Marina – a full-service marina entered between the Turkey Head breakwater and Mary Tod Island.
- Royal Victoria Yacht Club – located in Cadboro Bay that provides a large private marina, protected by a breakwater.

5.2.6 Saanich

Between Oak Bay and Sidney, there are no significant commercial or private marine facilities.

5.2.7 Sidney

The town of Sidney and the Municipality of North Saanich are located at the north end of the Saanich Peninsula. Primary marine infrastructure includes:

- Sidney Ferry Terminal. Washington State Ferries' only terminal on Vancouver Island. The terminal comprises floating dolphins and wing walls for securing the ferry during vehicle and passenger transfer.
- Sidney Fishing Pier.
- Beacon Avenue Public Pier.
- Port Sidney Marina – a large full-service marina and customs clearing point, with 320 slips accommodating vessels of up to 42 m. The marina is protected from the south and east by rubble mound breakwaters.
- Tsehum Harbour is operated by the Tsehum Harbour Authority and is also known as Shoal Harbour. The harbour is entered between Armstrong Point and Curteis Point and is used extensively by pleasure craft. The harbour contains several major marina facilities and is frequented by permanent and transient anchored small craft.
- Canoe Cove Marina is a full-service marina in Canoe Bay, providing extensive berthing facilities for small craft.
- Swartz Bay Public Wharf. Approximately 40 m of floats, primarily used by daily commuters from the nearby islands.
- Swartz Bay Ferry Terminal. The terminal is BC Ferries' primary terminal for the south of Vancouver Island, providing service to the mainland and the southern Gulf Islands.
- Seaspan Ferry Terminal. Located adjacent to the BC Ferries' terminal it provides transport for truck and trailer traffic carrying general freight and regulated commodities.

5.3 Identification of Tsunami Sources

Table 5-2 lists the three tsunami sources that have been identified as being relevant for this risk assessment. The first of these, CSZ-L1, represents the most severe event. The second DM1, represents the most severe event at the Sidney and Saanich / Oak Bay locations. And the AL source represents a severe far-field event that may generate emergency response measures within the capital region.

Table 5-2
Selected Tsunami Events for the Risk Assessment

Source	Magnitude	Probability	Comment
Cascadia Subduction Zone – CSZ-L1	9.1 – 9.2	2,500-year return period	Worst-case earthquake scenario
Devil's Mountain Fault Mw 7.5 – DM1	7.5	2,000-year return period	Worst-case earthquake – Long transgressive rupture
Alaskan 1964 - AL	9.2	500 – 1,000-year return period	Same as 1964 earthquake

5.4 Water Levels and Currents

Table 5-3 provides the tide data that has been used for the assessment. The data was extracted from Fisheries and Oceans Canada, Canadian Tide and Current Tables, 2020, Volume 5 – Juan de Fuca Strait. Except for Esquimalt Harbour, the deck elevations (top of structure) are unknown. For the purposes of the assessment, it is assumed that deck elevations will be 2.0 m above HHWLT. These elevations have been included in the table for reference. It is noted that this may be an over-estimate for the older timber structures.

Table 5-3
Tide Data and Estimated Maximum Deck Elevations

TIDE DATA - Relative to Chart Datum

	HHWLT	HHWMT	MWL	Deck Elev.
	metres	metres	metres	metres
Port Renfrew	3.7	3.0	1.9	5.7
Sooke	3.4	2.8	1.9	5.4
Esquimalt	3.0	2.4	1.9	5.0
Victoria	3.1	2.5	1.9	5.1
Oak Bay	3.2	2.7	2.0	5.2
Sidney	3.5	3.1	2.1	5.5
Swartz Bay	3.7	3.3	2.3	5.7

In the above table, the following notation is used:

HHWLT: Higher High-Water Large Tide
HHWMT: Higher High-Water Mean Tide
Deck Elev.: Estimated Deck Elevation (assumed 2 m above HHWLT)

At this conceptual level of assessment, the primary criteria for assessing consequences are defined as the maximum water elevation and current velocity. **Table 4-2** summarizes key results for the maximum water elevations for the capital region, obtained by extracting results at the coastal transects generated as part of Task 2[17]. In a similar fashion, using the modelled water surface elevation and current velocity results, values coincident to the locations of the harbours identified in the attached **Figure 5-1** have been extracted, as per **Table 5-4**.

[17] Task 2 – Sea Level Rise Modelling and Mapping Report, Associated Engineering, 2020

Table 5-4
Summary of Tsunami Maximum Surface Elevations and Current Velocities

		Hmax metres, above Chart Datum			Umax metres / second		
LOCATION REFERENCES		**AL**	**CSZ-L1**	**DM1**	**AL**	**CSZ-L1**	**DM1**
Sooke	Inside Whiffen Spit	3.00	7.46		0.10	4.90	
	Sooke Basin	2.94	3.84		2.44	8.96	
	Harbour Entrance		7.83	4.16		12.37	
	Fuelling Dock (East)		8.40	5.06		8.34	5.04
	Upper Harbour		11.02	7.05		9.40	6.58
Victoria	Harbour Entrance		7.30	4.17		7.79	
	Canadian Coast Guard		7.54	4.42		7.61	5.17
	Black Ball Ferry Terminal		7.24	5.16		8.87	1.07
	Gorge Waterway		7.42	4.42		6.44	
	Entrance to Rock Bay		7.07	4.85		6.92	3.93
	McNeill Bay		6.32	5.99		0.67	
	Oak Bay		5.05	4.54		1.38	6.74
	Cordova Bay		5.69	6.58		1.96	
Sidney	WSDOT Ferry Terminal		6.23	4.95		1.82	1.66
	VanIsle Marina		6.77	5.14		3.59	4.49
	North Saanich Marina		7.11	5.36		3.65	3.77

Where:

Hmax: Tsunami wave crest elevation above Chart Datum

Umax: Maximum current velocity

5.5 Typical Tsunami Impacts on Harbour Infrastructure and Vessels

Prior to considering potential tsunami impacts on the selected locations and facilities, the following section an outline of typical tsunami impacts that may occur in harbours. Canada does not have an overall code for the design of marine structures. Engineers usually seek guidance from internationally recognized standards and guidelines.
Examples include the following:

- British Standard BS 6349 – Code of Practice for Maritime Structures.
- PIANC – Several design guidelines for approach channels and marine structural design.
- ASCE 61-14 – Seismic Design of Piers and Wharves.

However, the structural design of individual components is subject to Canadian codes, such as those for timber, steel and concrete. Apart from the Johnson Street Bridge, Victoria International Marina and some components of the BC Ferries' Terminal, the majority of the structures within the area of consideration pre-date current design codes by several years. Given that tsunami events are rare and potentially result in widespread catastrophic structural damage, sustainable design has generally been seen to be unrealistic.

A tsunami results in a rapid rise in water elevation and a significant increase in current velocity. The potential effects on various types of marine infrastructure, within the area of consideration, is described here and summarized in **Table 5-5**.

- Gravity Structures – Ogden Point and some of the structures within Esquimalt Harbour are caisson type structures, that are supported directly on the seabed and rely on their mass for stability. Under a tsunami event they could sustain horizontal displacement due to unbalanced hydrostatic forces and undermining due to scour of the foundation material. The result would be horizontal misalignment and vertical rotation of the structures.
- Pile Supported Structures – most of the facilities include some form of pile-supported structure.
  - Timber – in general, timber structures will have minimal resistance to the wave and current loads that would be experienced during a tsunami event. This will probably result in significant damage or failure.
  - Steel / concrete – these types of structure were designed and constructed more recently, but still have limited resistance to elevated water levels and high current loads. Significant damage should be anticipated.
- Floating Structures (Marinas) – by definition, these types of structure can accommodate changes in water elevation. However, their security is reliant on either piled dolphins or anchors. In general, the dominant loads for marina design result from a combination of wind and current forces applied to the structures and the vessels alongside. Although it would probably be unreasonable to anticipate full wind load in combination with a tsunami event, once the water level rises and current velocities increase, the dolphins will probably fail in bending and anchors would break out and drag.
- Breakwaters – these structures are designed to resist wave forces generated by local storm events. A tsunami event will overtop the breakwater and increase current velocities that will dislodge the main armour rock. As the wave recedes, the current velocities will probably compromise the unprotected side of the breakwater.

- Vessels – any vessel moored alongside or at anchor will experience a significant increase in water elevation and current velocity, resulting in the failure of mooring lines or the breakout and dragging of anchors. Unattended vessels could probably drift ashore. Larger vessels take time to restart their engines and in confined areas, may not be able to maneuver without tug assistance.

This information is tabulated for ease of reference below.

Table 5-5
Summary of Tsunami Maximum Surface Elevations and Current Velocities

Structure Type	Form of Construction	Effect of a Tsunami Event
Gravity Structures		
Concrete Caissons	Large concrete box shaped structures partially filled with sand and gravel ballast and founded directly on the seabed.	Potential for horizontal displacement and undermining of the foundation, resulting in misalignment and vertical rotation.
Pile-Supported Structures		
Timber	Timber piles driven into the seabed and supporting a timber deck structure.	Under full inundation and subject to high current velocities these structures will be subject to severe damage and probably collapse.
Steel or Concrete	Steel or concrete piles driven into the seabed and supporting a concrete deck structure	Depending on the level of inundation, these structures may survive, but with potentially significant damage.
Floating Structures		
Marinas	Various forms of construction, usually timber or a combination of timber and concrete. Buoyancy is provided by Polystyrene billets.	With increases in water level and current velocities, piled dolphin supports will fail and anchored supports will break out and drag. This will result in the floats being adrift complete with any moored vessels.
Fuelling Facilities	Similar construction to marina floats but of larger size to support fuel pumps and operations facility.	As with the marina floats, the fuel float will break adrift. In general fuel tanks are on shore. However, all fuel in the pipelines between the tanks and the pumps will drain into the sea
Breakwaters		
Rubble Mound	Rock construction consisting of a core material a filter layer and heavy rock armour on the seaward side.	The breakwater will be overtopped, and the increased current velocity will dislodge the main rock armour. As the wave recedes further damage will occur to the unprotected side of the breakwater. Either complete failure will occur or as a minimum, local breaching.
Vessels		

Structure Type	Form of Construction	Effect of a Tsunami Event
Commercial	Barges, coastal vessels and deep-sea vessels.	Larger vessels either moored alongside or at anchor will either break mooring lines or drag their anchors.
Recreational	Privately owned small craft	Small craft at a marina will come adrift with the marina floats. Small craft at anchor, will drag and probably drift ashore.

5.6 Potential Tsunami Impacts at Selected Locations

Using the data contained in **Table 5-4**, the following sections outline the potential consequences for each of the selected locations.

5.6.1 Port Renfrew

The location of the results shown in **Table 5-4** is shown on **Figure 5-1**.

Alaska

Community Wharf and Pacific Gateway Marina: The wave height and current velocity are less that presently experienced, resulting in no foreseen damage.

CSZ L1

Community Wharf and Pacific Gateway Marina: The wave height and current velocity far exceed any probable physical resistance offered by the marine facilities. It should be assumed that all structures will require reconstruction.

5.6.2 Sooke Harbour

The location of the results shown in **Table 5-4** is shown on **Figure 5-1**.

Alaska

The wave height and current velocity are generally less than presently experienced, resulting in no foreseen damage to the primary facilities. However, there are a number of private facilities where the design may not be adequate and could be subject to damage. This is particularly the case in the Sooke Basin where current velocities approach 2.5 m/s (5 knots).

CSZ L1

The wave height and current velocity far exceed any probable physical resistance offered by the marine facilities. It should be assumed that all structures will require reconstruction.

5.6.3 Esquimalt Harbour

The location of the results shown in **Table 5-4** is shown on **Figure 5-1**. The Esquimalt marine facilities are generally of a substantial nature, consisting of caissons and steel / concrete pile and deck structures. These structures would have been designed for a HHWLT condition and a current velocity probably in the order of 1.0 m/s (2 knots). However, the current loads would only have been applied to the lateral caisson / pile area between the seabed and HHWLT.

It is important to note that current loads are directly proportionate to the square of the velocity. Therefore, increasing the current velocity by a factor of two increases the imposed load by a factor of four.

The naval vessels moored alongside the jetties will add load to the structures as a result of the increased water elevation and current velocities.

CSZ L1

This tsunami event will overtop the structures by 3 m to 6 m depending on location and will subject the full lateral area of the structures to current velocities ranging from 7 to 12 m/s (14 to 24 knots). It is unlikely that the facilities will survive without significant damage and that the damage may not be repairable.

DM1

In general, the structures may not be overtopped, but will be subject to near full submergence. The current velocities will range from 3.5 to 6.5 m/s (7 to 13 knots), resulting in significant lateral loads. As with the CSZ-L1 event, significant damage should be anticipated.

5.6.4 Victoria Harbour

The location of the results shown in **Table 5-4** is shown on **Figure 5-1**.

The marine infrastructure comprises a number of fixed structures and several floating structures (marinas).

Marinas are the most susceptible to damage when it comes to an increase in water level and current velocity.

CSZ L1

This tsunami event will overtop most fixed structures by approximately 2.5 metres and subject them to current velocities ranging from 3.5 to 9 m/s (7 to 18 knots). Floating structures will experience water elevations in excess of 4.0 above HHWLT. The potential effects on each facility is summarized as follows:

- Outer Harbour – Harbour Entrance to Shoal Point
    - Ogden Point Cruise ship terminal, Pacific Pilotage Authority floats and Breakwater. The cruise ship terminal and breakwater are both gravity structures that can accommodate relatively large lateral loads from wave attack. 2.5 metres of overtopping will certainly result in significant damage to the buildings located on the terminal. The predicted current velocities may result in scouring of the caisson foundations and settlement and / or rotation. The Pilot floats will probably break free.
    - Canadian Coast Guard. The form of construction of the facility is unknown at this time. However, it is probable that damage will occur.
- Middle Harbour – Shoal Point to Laurel Point
    - West Bay Marina. The facility comprises both small craft moorage and float homes. The design for the supporting piled dolphins will rely on the significant wind load from the float homes. Although the modelling results show current velocities in the order of 3.5 m/s (7 knots) at the entrance to the bay, it is unlikely that this sustained velocity will be experienced at the marina. In which case damage may be limited to being repairable.

  - Victoria International Marina. The marina is of relatively new construction with large diameter steel pipe pile dolphins and concrete floats. Depending on the number of vessels berthed, it is possible that the facility could survive with limited damage.
  - Fisherman's Wharf. This marina probably predates any recent design standards for float homes and small craft vessels. The increase in water level and current velocity will probably result in floats breaking free.
- Inner Harbour – Laurel Point to the Johnson Street Bridge
  - Clipper Ferry and Black Ball Ferry Terminals. The form of construction of these facilities is unknown at this time. However, it is probable that that some level of damage will occur.
  - Causeway Floats (Empress Hotel). This marina probably predates any recent design standards. The increase in water level and current velocity will probably result in the floats breaking free.
  - Wharf Street Marina. This marina probably predates any recent design standards. The increase in water level and current velocity will probably result in the floats breaking free.
- Upper Harbour – North of the Johnson Street Bridge.
  - Johnson Street Bridge. The design meets all current design requirements and the increase in water level may have no effect structurally. However, the potential for flooding of the mechanical rooms in the bascule pier may be an issue.
  - Point Hope Shipyard. The shipyard facilities are not well defined at this time; however, some level of damage should be anticipated.

DM1

This tsunami event will probably not overtop most fixed structures and will subject them to current velocities ranging from 2.5 to 5.0 m/s (5 - 10 knots).

- Outer Harbour – Harbour Entrance to Shoal Point
  - Ogden Point Cruise ship terminal, Pacific Pilotage Authority floats and Breakwater. The predicted current velocities may result in some scouring of the caisson foundations and result in settlement and / or rotation. The Pilot floats will probably stay in place.
  - Canadian Coast Guard. The form of construction of the facility is unknown at this time. However, it is probable that minor damage will occur.
- Middle Harbour – Shoal Point to Laurel Point
  - West Bay Marina. It is probable that damage will be limited and repairable.
  - Victoria International Marina. It is probable that the facility could survive with limited repairable damage.
  - Fisherman's Wharf. Given the age of this facility the increase in water level and current velocity may result in floats breaking free.
- Inner Harbour – Laurel Point to the Johnson Street Bridge
  - Clipper Ferry and Black Ball Ferry Terminals. It is probable that minor damage will occur.
  - Causeway Floats (Empress Hotel). It is probable that damage will be limited and repairable.
  - Wharf Street Marina. It is probable that damage will be limited and repairable.
- Upper Harbour – North of the Johnson Street Bridge.

- Johnson Street Bridge. The design meets all current design requirements and increase in water level may have no effect structurally.
- Point Hope Shipyard. The shipyard facilities are not well defined at this time; however, some level of damage should be anticipated.

5.6.5 Oak Bay

The location of the results shown in **Table 5-4** is shown on **Figure 5-1**.

The primary marine infrastructure comprises floating structures (marinas). Marinas are the most susceptible to damage when it comes to an increase in water level and current velocity.

CSZ L1

The modelling provides results for Oak Bay, which are assumed to represent similar results for Cadboro Bay.

- Oak Bay Marina and the Royal Victoria Yacht Club. The tsunami event will result in water elevations exceeding HHWLT by between 1.8 m and 2.5 m. Current velocities will reach 2.0 m/s (4 knots). It is probable that both marinas will survive with some level of damage.

DM1

- Oak Bay Marina and the Royal Victoria Yacht Club. The tsunami event will result in water elevations of up to 3.5 m above HHWLT and current velocities reaching 6.7 m/s (13 knots). Under these conditions, it is probable that both marinas will suffer significant damage.

5.6.6 Sidney

The location of the results shown in **Table 5-4** is shown on **Figure 5-1**.

The marine infrastructure comprises two major ferry terminals and several floating structures (marinas). Marinas are the most susceptible to damage when it comes to an increase in water level and current velocity.

CSZ L1

Water elevations will exceed designed deck elevations by a range of 0.5 m to 1.3 m and current velocities will range from 1.8 to 3.6 m/s (3.6 to 7.2 knots).

- Sidney Ferry Terminal. The terminal provides intermittent service to Washington State and it is probable that damage to the floating dolphin anchoring system would be repairable.
- Sidney Fishing Pier and Beacon Avenue Public Pier. Design criteria for these structures is unknown and so some level of significant damage can be expected.
- Port Sidney Marina. The marina is protected by heavily armoured breakwaters that will be overtopped. Some level of damage to the breakwaters and the marina floats should be anticipated.
- Tsehum Harbour. The marinas within the harbour may not have been designed to meet current design codes or guidelines. They tend to be contained within embayments and as such may be protected to some extent from the current loads. However, damage should be anticipated.

- Swartz Bay Public Wharf. A floating facility secured by anchors that will possibly break out and drag, resulting in displacement of the floats.

Swartz Bay and Seaspan Ferry Terminals. These terminals were designed to relatively recent codes and are maintained in good condition. They are designed to withstand berthing, wind, wave and current loads for the fleet's largest vessels. Depending on berth occupancy, some damage will probably occur.

DM1

Water elevations will not exceed estimated design deck elevations. Current velocities will range from 1.7 to 4.5 m/s (3.4 to 9.0 knots).

- Sidney Ferry Terminal. The floating dolphin anchoring system can probably withstand the increased water elevation current velocity. However, it will be dependent on whether a ferry is at the berth and is unable to leave.
- Sidney Fishing Pier and Beacon Avenue Public Pier. Although it is unlikely that the deck elevations will be overtopped, damage can be anticipated due to the partial submergence of the structures and the increased current velocity.
- Port Sidney Marina. Under fair weather conditions, it is probable that the marina would survive without significant damage.
- Tsehum Harbour. The results indicate a current increase to 4.5 m/s (9.0 knots). This combined with the water elevation increase will probably fail some of the timber piles that retain the marina floats.
- Swartz Bay Public Wharf. A floating facility secured by anchors that will possibly break out and drag, resulting in displacement of the floats.
- Swartz Bay and Seaspan Ferry Terminals. As with the CSZ-L1 event, some damage should be anticipated.

5.7 Mitigation of Risk

Tsunami risk mitigation should have the primary objective of human life safety, with an objective of "zero" casualties. For a tsunami event this generally means safe evacuation, requiring adequate education regarding the effects and consequences of a local event. Safe evacuation routes and emergency areas need to be identified and broadcast to the affected population. An example of evacuation planning is the District of Tofino, where in addition to education, tsunami sirens are in place.

A secondary objective would be the reduction in economic loss due to the physical damage that would occur to harbour facilities and business continuity following the event. Any structural counter measures, under the scenarios being considered, cannot be defined without further site-specific study and concept development. It is probable that any feasible options would incur significant capital investment.

This leaves the evacuation of vessels that are moored or anchored within the harbours under consideration.
In general, vessels are safer at sea than in a harbour. However, the warning period may not be adequate to mobilize crews and put to sea. This is particularly the case at Esquimalt where a large number of naval vessels are moored. Mustering sufficient crew and providing tugs to assist in un-berthing and manoeuvring would require more time than that available during the warning period.

An example of an action plan for vessels, produced by the Japan Association of Marine Safety 2004, is shown in **Table 5-6**.

Table 5-6
Tsunami Action Plan from Japan Association of Marine Safety 2004.

Tsunami forecast		Time until tsunami arrival	Ship Action – Moored ship in port – Large ship, medium ship (incl. fishing boat) – Hazardous materials carrier	Ship Action – Moored ship in port – Large ship, medium ship (incl. fishing boat) – Ordinary ship (incl. cargo handling / working ship)	Ship Action – Moored ship in port – Small ship (Pleasure boat, small fishing boat, etc.)	Ship Action – Anchored ship, buoy-moored Ship	Ship Action – Navigating ship – Large ship, medium ship (incl. fishing boats)	Ship Action – Navigating ship – Small ship (Pleasure boat, Small Fishing Boat, etc.)
Tsunami Warning	Major Tsunami (3 m, 4 m, 6 m, 8 m, over 10 m)	Short	Halt (un-)loading activity In principle: Offshore evacuation	Halt cargo handling Land evacuation	Land evacuation	Use engine		Offshore evacuation / Land evacuation after berthing
		Medium	Halt (un-)loading activity In principle: Offshore evacuation	Halt cargo handling Offshore evacuation / Land evacuation	Landing and lashing / Land evacuation (in some cases, offshore evacuation)	Use engine / Offshore Evacuation	Offshore evacuation	Offshore evacuation / Landing and lashing after berthing (in some cases, land evacuation)
		Long	Halt (un-)loading activity Offshore evacuation	Halt cargo handling Offshore evacuation	Landing and lashing (in some cases, offshore evacuation)	Offshore evacuation		Offshore evacuation / Landing and lashing after berthing
	Tsunami (1 m, 2 m)	Short	Halt (un-)loading activity In Principle: Offshore evacuation	Halt cargo handling Land Evacuation / Strengthen mooring	Land evacuation	Use engine		Offshore evacuation / Land evacuation after nerthing
		Middle	Halt (un-)loading activity In principle: Offshore evacuation	Halt cargo handling Offshore evacuation / Land evacuation / Strengthen mooring	Landing and lashing / Land evacuation (in some cases, offshore evacuation)	Use engine / Offshore evacuation	Offshore evacuation	Offshore evacuation / Landing and lashing after nerthing (in some cases, land evacuation
		Long	Halt (un-)loading activity Offshore Evacuation	Halt cargo handling Offshore Evacuation / Strengthening mooring	Landing and lashing (in some cases, offshore evacuation)	Offshore evacuation		Offshore evacuation / Landing and lashing after berthing
Tsunami Advisory	Tsunami warning (0.5 m)		Halt (un-)loading activity Strengthen Mooring / Offshore Evacuation	Halt cargo handling Strengthen mooring / Offshore evacuation	Landing and lashing / Offshore evacuation	Attention to conditions (in some cases, offshore evacuation / use of engine)	Offshore evacuation	Landing and lashing / Offshore evacuation / Strengthen mooring
Notes			Action manuals should be prepared beforehand by businesses.		Offshore evacuation is suggested if there is a sea area where even small ships are safe against a tsunami outside the port and if there is adequate time for evacuation.	Sea areas where rapid tsunami currents are anticipated should be investigated beforehand.		

Commentary to Table 5-6

Time until tsunami arrival:

- Long: Adequate time is available for evacuation after a tsunami warning (until a ship is under safe conditions such as offshore evacuation, landing and lashing, etc.).
- Short: Little time is available for evacuation after a tsunami warning (until a ship is under safe conditions such as offshore evacuation, landing and lashing, etc.).
- Medium: Between 'Long' and 'Short'

- Small ship: The ships, which can be landed in a port, such as pleasure boats and fishing boats (excluding landing in a shipbuilding yard).
- Land evacuation: Crew members take refuge in a high land area because evacuation by ship is anticipated to involve a high degree of risk. They also prevent the outflow of ships and exercise safety precautions regarding dangerous goods.
- Offshore evacuation: Ships evacuate to deep and wide offshore area outside a port (if there is no time for offshore evacuation, ships should wait in an emergency evacuation area inside the port).
- Attention to conditions: Although crew members do not take evacuation measures, they pay attention to changing conditions and take measures for ship safety until the cancellation of tsunami advisory.
- Landing and lashing: Crew members land small ships, such as pleasure boats and fishing boats, and lash them to prevent them from being washed away by a tsunami.
- Use of engine: Crew members start the engine of an anchored ship to drive it against the tsunami if necessary.

Note: The above table shows the standard ship actions. Countermeasures should be examined on the basis of the features of each port area.

It is important to note that this risk assessment is based on publicly available information on the harbour infrastructure under consideration. No level of engineering design has been completed to determine the ability of structures to resist loads generated by the selected tsunami events. The description of possible consequences is based on professional engineering judgement. In that regard, mitigative measures should currently be limited to developing measures for human life safety. Engineering solutions to protect harbour facilities will require a more detailed analysis.

6 CONCLUSIONS

6.1 Summary of the FUNWAVE-TVD Model Performance

The validation of the FUNWAVE-TVD model described in **Section 3** points to uncertainties in model application which are inherent to the study of tsunamis. The geometry, time history and sequence of local fault rupture during a typical seismic event are poorly constrained by observed seismic data and are thus fundamentally unknown. The accuracy of an initial estimate of a source configuration can be limited by a number of factors, including the poor resolution of the actual fault configuration due to the windowing effect of the available seismic network, poor understanding of geometry and material properties of the region around the fault and its effect on seismic wave propagation, and the errors implicit in the use of the Okada half-plane solution to construct ground displacements over a 3D trench and shelf geometry. The Okada solution assumes a planar failure surface embedded in an elastic half-space with a flat upper surface. The simplification of geometry and treatment of material properties leads to uncertainties which overshadow the expected level of hydrodynamic model uncertainty seen in present-day models.

Fundamentally, an initial source, constructed using available data and present standard techniques for estimating ground displacement, is probably wrong to an extent that limits model accuracy, even if it is fully consistent with the available seismic information. The work considered here and the previous effort by Abdolali et al. (2015) do not consider further corrections to the original USGS source described by Hayes (2013). Another study by Fine et al (2015) gets better results but uses an inversion of the DART buoy data to adjust the source (as is done by NOAA / PMEL), giving a source which is shifted south relative to the original seismic estimate almost by an amount equal to the length of the original source (**Figure 6-1**). All of these factors, as well as compensating for the effect of water compressibility (which slows the wave) can factor into getting a model result which agrees best with data. Often these approaches lead to final source estimates which are not in particularly good agreement with the original seismic source estimate. More advanced approaches using complex 3D modeling of geometry and geological properties are rapidly being developed (e.g., Grilli et al., 2012) but are not yet in routine use.

Given the possibility of a competition between inaccuracy in source descriptions or model errors, it is worth emphasizing that hydrodynamic models in present use for calculating propagation and inundation by tsunamis are generally consistent with each other and capable of reproducing the early, energetic stages of a tsunami event even at great distances from the source region. **Figure 6-2** shows a comparison of FUNWAVE-TVD results and DART buoy measurements at four locations for the 2011 Tohoku-oki event, computed using the dynamic 3D ground motion model described in Grilli et al. (2012). In particular, buoy 46404 was used in the model validation in **Section 3** and was one of the two buoys for which the model underpredicted wave height. The results here indicate that there is no systematic model bias tending to lead to underpredictions at this buoy, thus lending support to the notion that model errors are typically going to be due to an incomplete understanding of the details of the source mechanism.

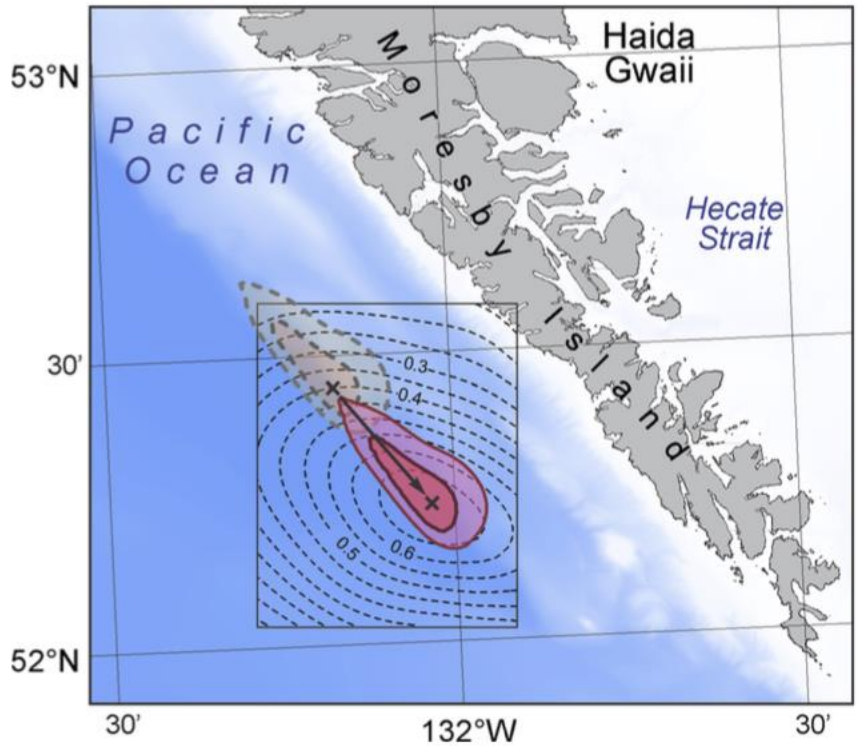

Figure 6-1
The Shift in Position of the Hayes (2013) Haida Gwaii Source (Dashed Contours) Carried Out by Fine et al (2015) (Solid Contours) in Order to Maximize Predictive Model Skill. (from Fine et al. (2015), Figure 10)

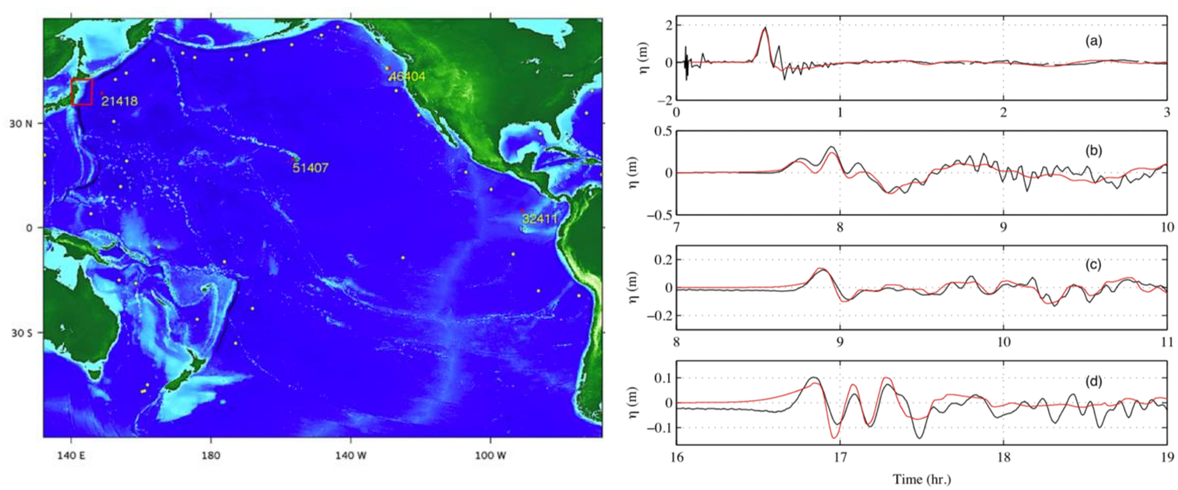

Figure 6-2
(left) Computational Domain for Far-Field Simulations with FUNWAVE-TVD, with the Marked Location of all DART Buoys in the Region (Labeled Red Dots Used in Comparisons). (right) Measured Surface Elevation at DART Buoys (Black) and Model Simulations (Red). Buoy Numbers and are (a) 21418, (b) 51407, (c) 46404, and (d) 32411. (from Kirby et al., 2013).

6.2 Tsunami Risk in the Capital Region

It is clear from the analysis in Section 5 that the CSZ-L1 source, with its return period estimated at 2,500 years, represents an unprecedented and, to this point, un-investigated level of hazard to marine infrastructure and vessels that is out of scale with the levels employed during the original design and construction in the impacted harbours.

Of the areas modelled, Port Renfrew is arguably the most vulnerable, due to its low-lying urban core, coastline geometry and its position relative to the entrance to Juan de Fuca Strait. More than most locations in the capital region, it will be extremely important for local residents and tourists in Port Renfrew to be aware of the risk of tsunami inundation, as Cascadia Subduction Zone-driven events will arrive here before anywhere else in the study area.

A natural successor to this work, which would be informed by this study's modelling results, would be a detailed risk analysis. This risk analysis could supplement the information contained within **Section 5** and focus on risk receptors such as environmentally-sensitive areas, municipal infrastructure, risk to life, economic risk etc. Further details on these types of analyses are given in the ensuing section.

6.3 Recommendations for Further Analysis

Further Detailed Inundation Modelling

This study has modelled the capital region in unprecedented detail, relative to previous studies. The resolutions adopted were selected to maximise the detail represented in this study, whilst balancing computational demands and an aggressive, compressed schedule.

Whilst the 30 m resolution offered everywhere within the study area greatly improves upon the minimum 90 m standard recommended by NTHMP guidelines; with all modelling studies, outputs can always be enhanced with further analysis and computational input. It is recommended that as computational power continues to become more affordable and improves in speed, that more areas of the capital region could be modelled to a level of detail like the five detailed model domains examined in this project (i.e. 4 m or less). This would improve the representation of many geographic features in the model and remove much of the instabilities observed in **Section 3.5**.

It is also recommended to revisit these modelling efforts in the short-medium term (5 - 10 years), as understanding of tsunami generation sources and mechanisms continue to deepen in academia; as well as the ability for modelling software to represent the complicated hydraulics that describe a tsunami wave. See the reference to 3D modelling in **Section 6.1**.

Detailed Comparison with 2018 Washington Modelling Results

As was presented in **Section 4.5**, a very high-level comparison of this study's results was carried out against the recently completed 2018 Washington Tsunami Hazard Mapping project. If the CRD or project stakeholders were granted access to the 2018 Washington model, then a more direct comparison could be made between the projects.

It is most likely that model grids between the two studies do not overlap, nor do the choice of grid resolutions. The 2018 Washington study used a grid resolution of between 1 m and 16 m for inundation modelling of Port Townsend and Port Angeles. However, this project's resolution was 30 m for the same locations, thereby not allowing a direct comparison between the findings. Securing the Washington State model would allow further investigation of model performance.

'Depth-Damage' Analysis

Similar to what was recommended in the Task 2 – Sea Level Rise Modelling and Mapping Report, a form of economic assessment could be carried out to infer damage ($) as a result of a tsunami event. However, deriving direct property damages as a result of an incredibly powerful tsunami wave would be considerably trickier than a 'traditional' coastal flooding event. The dynamic power of a tsunami wave (as a result of its momentum) is orders of magnitude larger than that of a conventional wind-driven wave or sea level rise. It is quite likely that many structures in a large tsunamis path would be destroyed as a result of the event. Therefore, the depth-damage relationship that we tend to use for conventional flooding is functionally redundant for a tsunami application. In this instance, the use of HAZUS building-stock would be a preferred option. HAZUS is a US specific (but can be applied to Canada) standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes. HAZUS uses Geographic Information Systems (GIS) technology to estimate physical, economic, and social impacts of disasters. Again, this information would be extremely important for mitigation planning and emergency fund budgeting.

Population and Infrastructure Risk Analysis

In a similar vein to the Task 2 recommendation, a population at risk (PAR) and / or infrastructure at risk analysis would be an extremely beneficial undertaking. The PAR analysis would integrate property and population statistics, as well as the study's tsunami modelling results, to estimate the number of people within the inundation zone. This would be the 'backbone' of any potential evacuation plan and emergency management procedure.

To supplement the findings of **Section 5**, the impact on municipal infrastructure as a result of tsunami inundation could also be estimated. This could be supported by a Class C / D cost estimation exercise, approximating the cost of repair / replacement works. This would feed directly into cost-benefit assessments for mitigation planning.

Evacuation Planning & Emergency Planning

A critical follow-on exercise would be the update to the capital region's evacuation and emergency management plans. This study's modelled results provide a myriad of information for emergency management staff, with regard to different tsunami probabilities, anticipated travel times, wave heights, current velocity etc. A natural consequence of this work will be further mapping; delineating tsunami hazard zones and evacuation routes. The detailed inundation models have been developed to such a scale, such that the 4 m cell-resolution allows for very targeted analysis. For example, as the 4 m cell size is generally fine enough to capture road widths, it is possible to infer flow depths and velocities on highways / local roads. This is important in determining if, for example, an emergency vehicle can travel this route during a tsunami event or if first responders can operate on foot in certain areas.

6.4 Impact on Flood Development Policy

This section should be read in conjunction with Section 6.5 in the Version 2.0 Task 2 – Sea Level Rise Modelling and Mapping Report. As per Provincial Flood Construction Level Guidelines[18], the capital region should allow its FCL policies (for each local government / electoral area) to be informed by tsunami risk. The guidelines go on to state that, in areas where tsunami risk governs, "at a minimum, building conditions should protect improvements from damage from a tsunami of equal magnitude to the March 28, 1964 tsunami that resulted from the Prince William Sound, Alaska earthquake and a possible Cascadia Subduction Zone earthquake".

[18] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/integrated-flood-hazard-mgmt/final_amendment_to_s_35_and_36_fhalumg_17-10-01.pdf

However, as has been presented in **Table 3-2** and throughout this report, the results for various tsunami sources at various project locations vary considerably. Therefore, the challenge becomes "what event is most appropriate for consideration as a planning standard?"

The Alaska 1964 event, as has been shown throughout the results, whilst having a large magnitude, does not yield the type of wave heights anywhere in the capital region, as was witnessed at Port Alberni for the same event. Conversely, the local sources (DM1 & SW1) yield significant wave heights, particularly on the eastern side of the Saanich Peninsula, however, their associated return period (approximately 2,000-year) is potentially far too remote for application as planning standard. The same could be said for the CSZ-L1 scenario, with a return period of 2,500-years.

As such, the project team would recommend the adoption of the CSZ-NS as the planning standard, where tsunami risk exceeds the corresponding 1 m Relative Sea Level Rise (RSLR) FCL at the location under scrutiny. With a probability of 0.2% AEP (approximately 500-year return period), it would be an appropriate standard to apply to development.

However, it is important to note, the setting of FCLs is solely the prerogative of each local government / electoral area and the recommendations given herein are not binding. Again, refer to Section 6.5 in the Version 2.0 Task 2 – Sea Level Rise Modelling and Mapping Report for a more detailed discussion on this topic.

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CERTIFICATION PAGE

This report presents our work for (Version 2.0) Task 3 – Tsunami Inundation Modelling & Mapping regarding the Capital Region Coastal Flood Inundation Mapping Project. The services provided by Associated Engineering (B.C.) Ltd., and its sub-consultants, in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.
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APPENDIX A - PLOTS OF MAXIMUM OCCURRING WATER ELEVATIONS ON COARSE GRIDS A-D FOR ALL SOURCES

Please note that all elevation results presented in all appendices are relative to HHWMT unless otherwise stated. Refer to **Appendix N** for a conversion to CGVD2013.

CSZ-L1 event

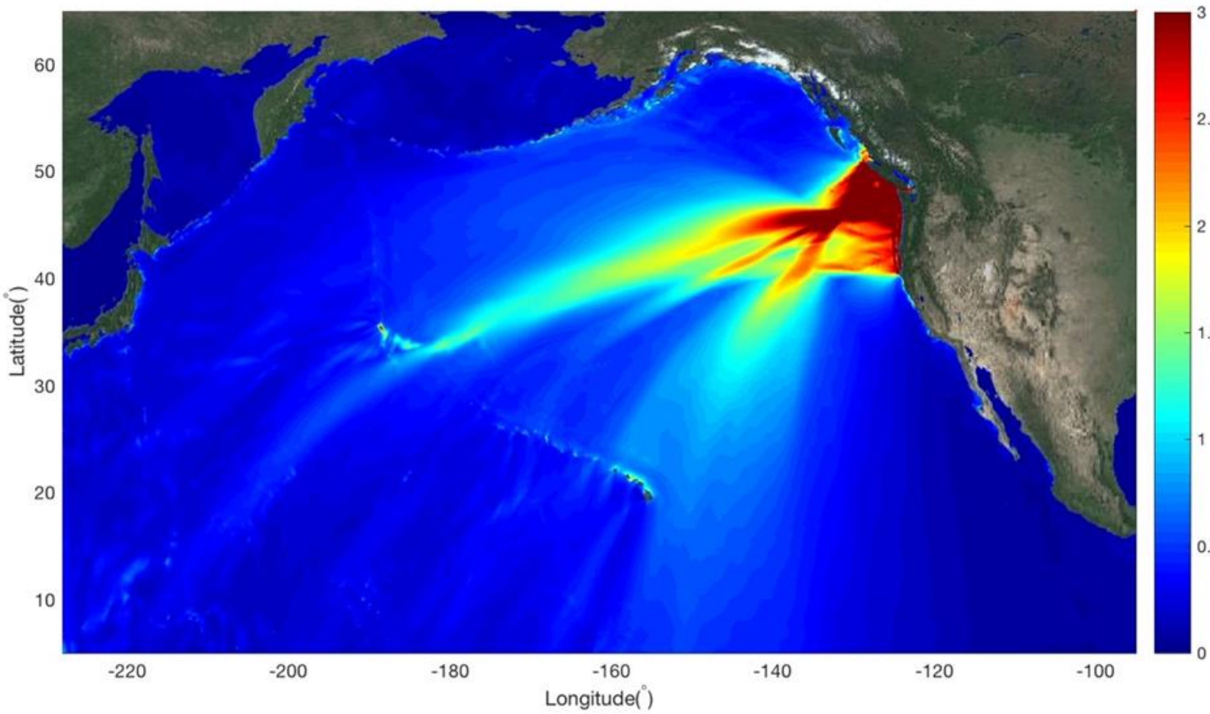


Figure A-1
Maximum sea surface elevation, Grid A, CSZ-L1

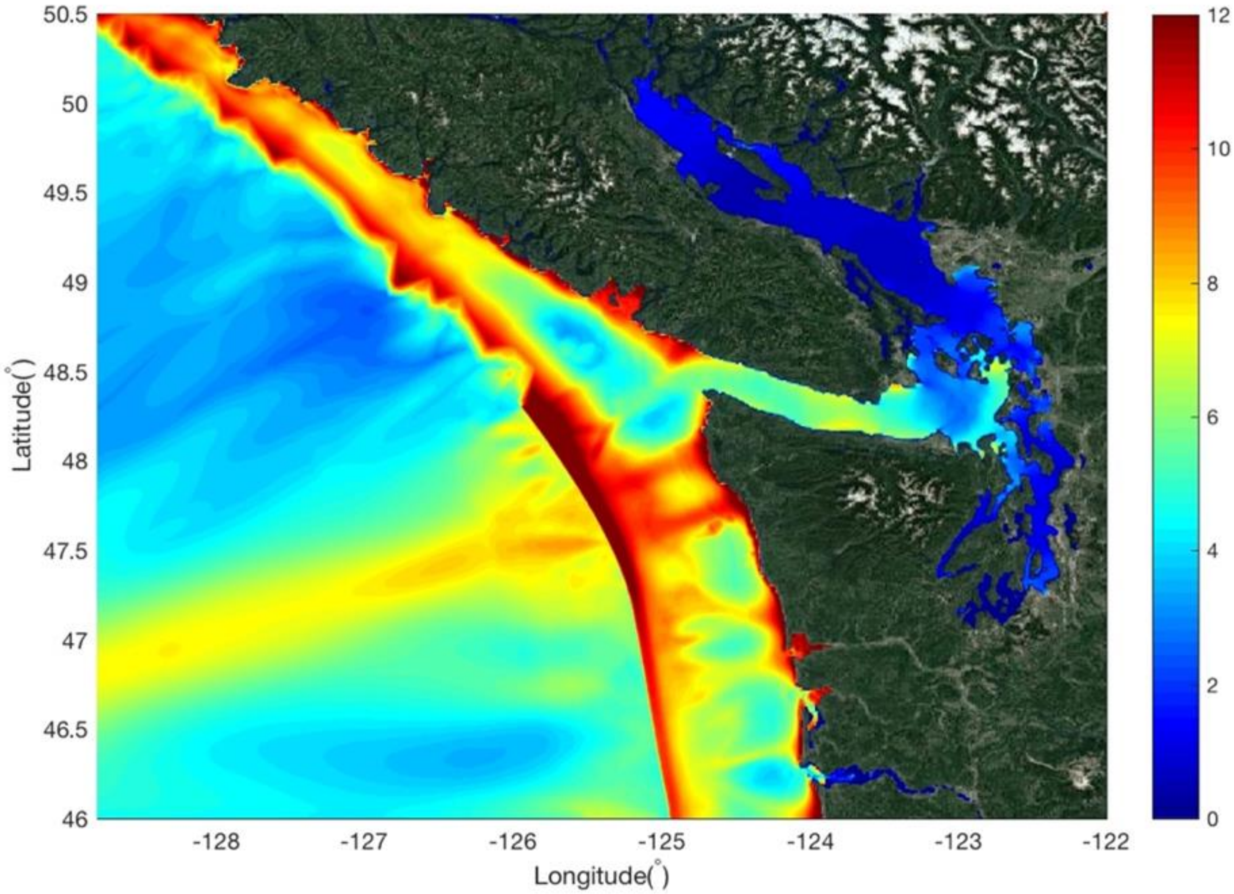


Figure A-2
Maximum sea surface elevation, Grid B, CSZ-L1

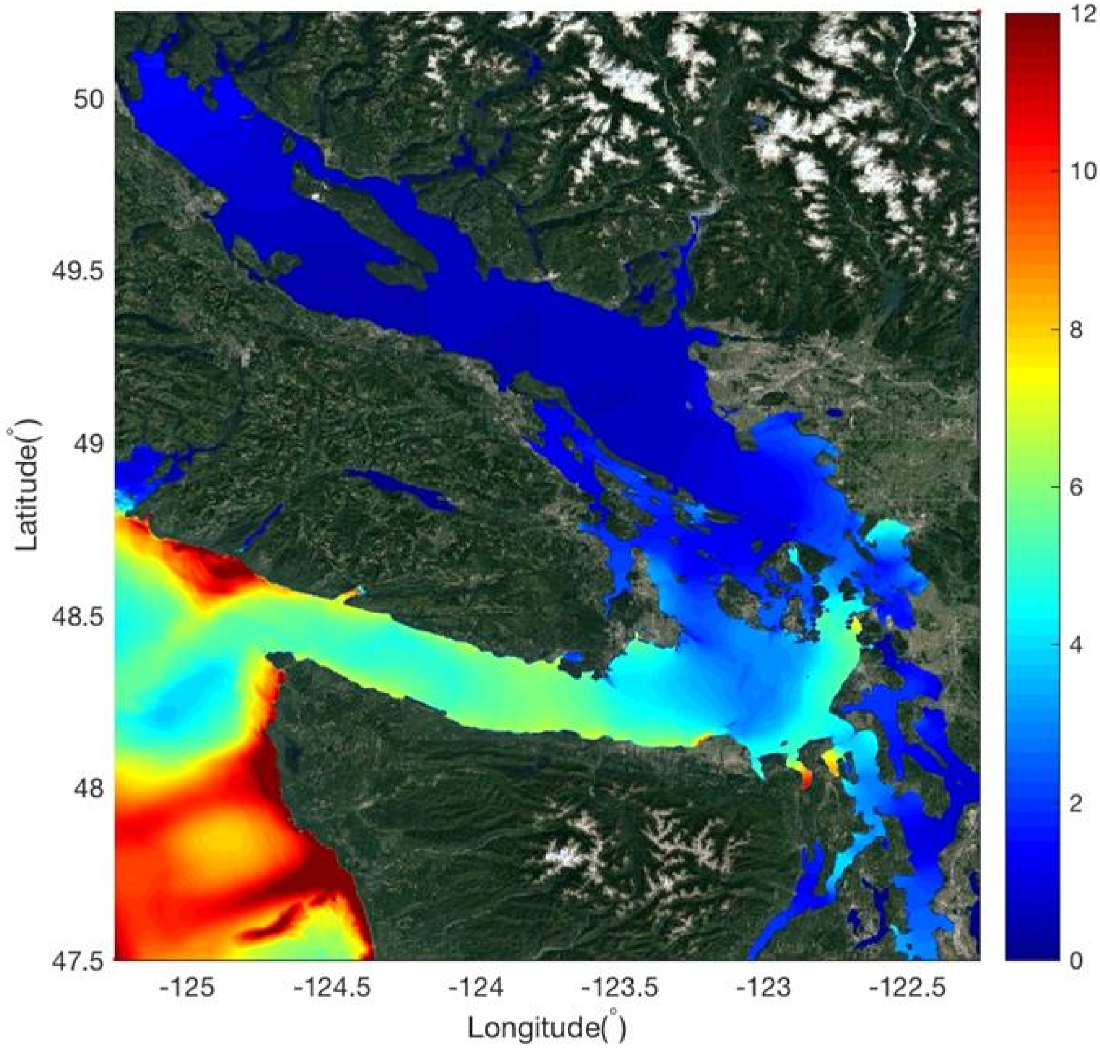


Figure A-3
Maximum sea surface elevation, Grid C, CSZ-L1

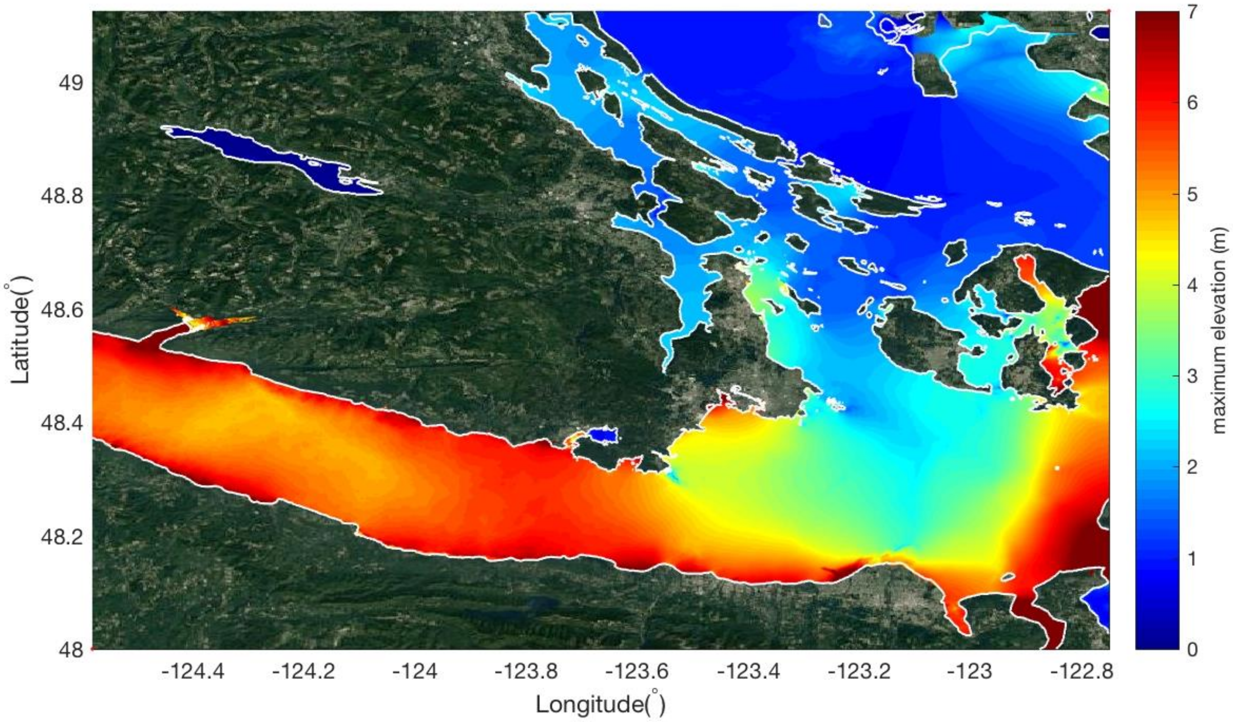


Figure A-4
Maximum sea surface elevation, Grid D, CSZ-L1

CSZ-NS event

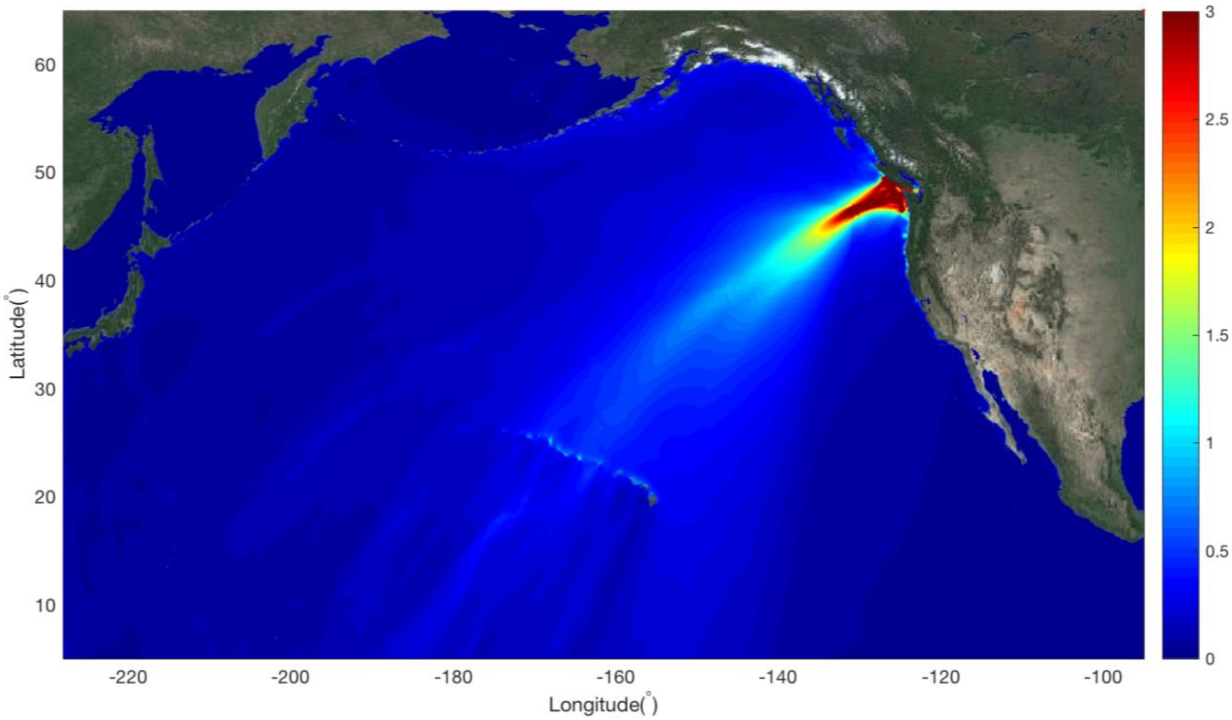


Figure A-5
Maximum sea surface elevation, Grid A, CSZ-NS

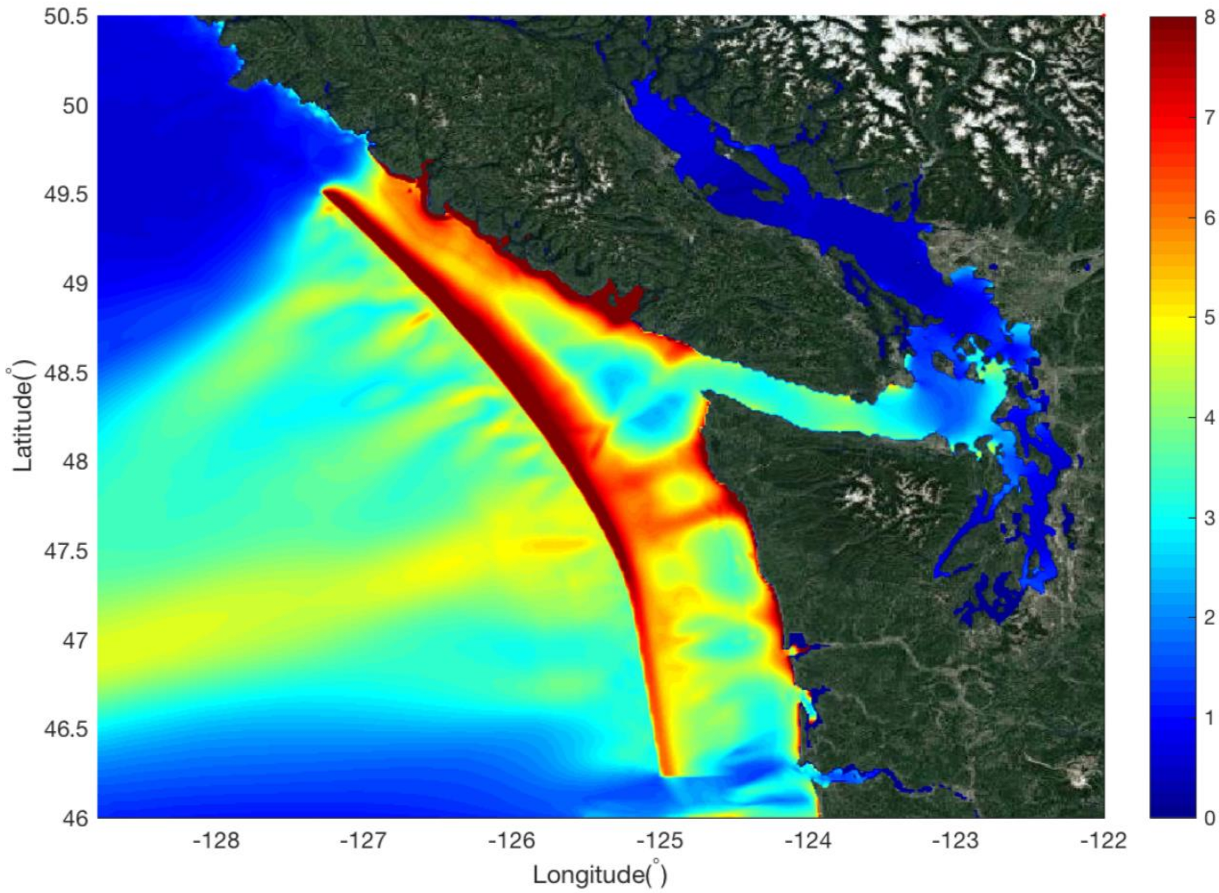


Figure A-6
Maximum sea surface elevation, Grid B, CSZ-NS

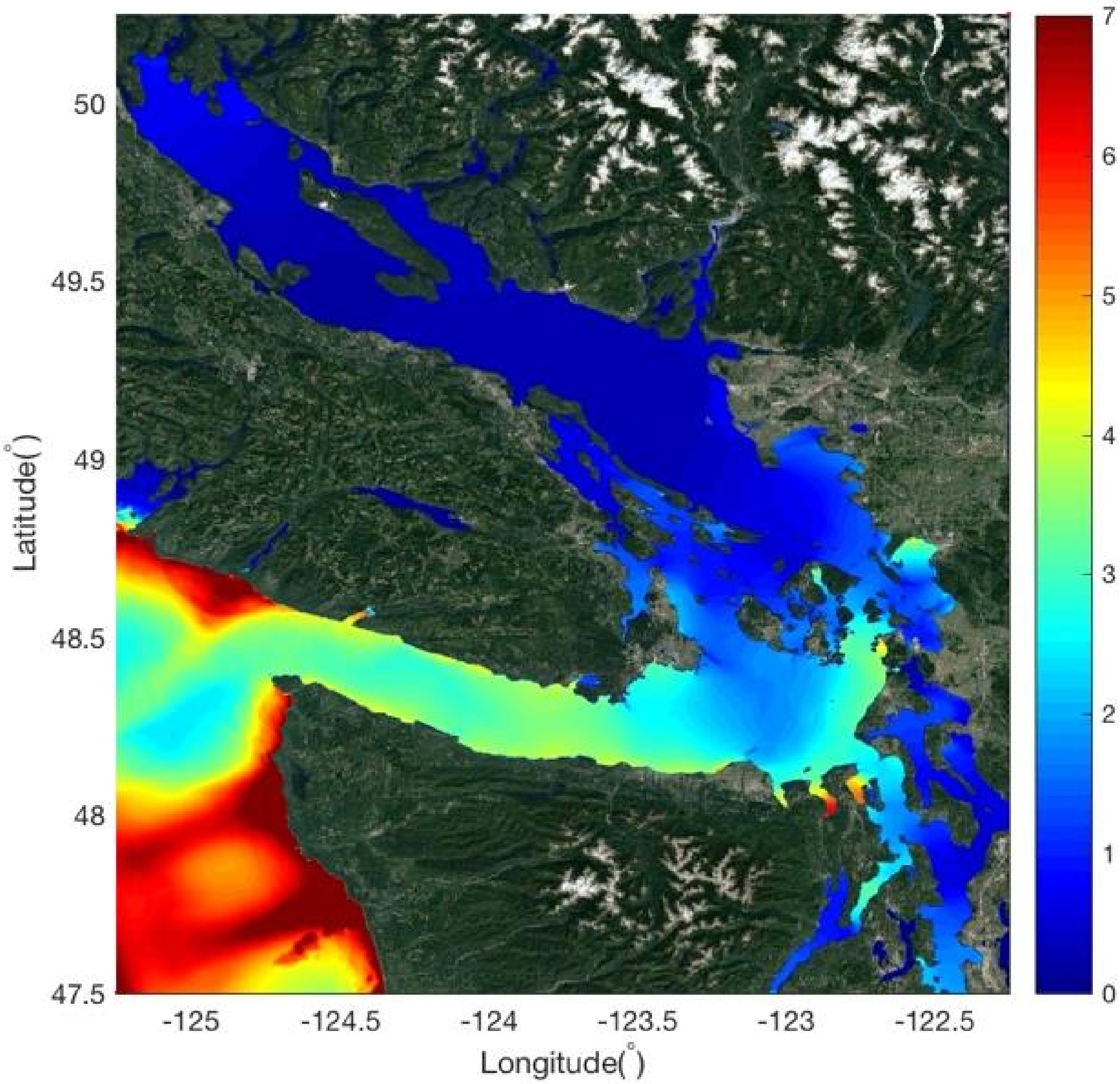


Figure A-7
Maximum sea surface elevation, Grid C, CSZ-NS

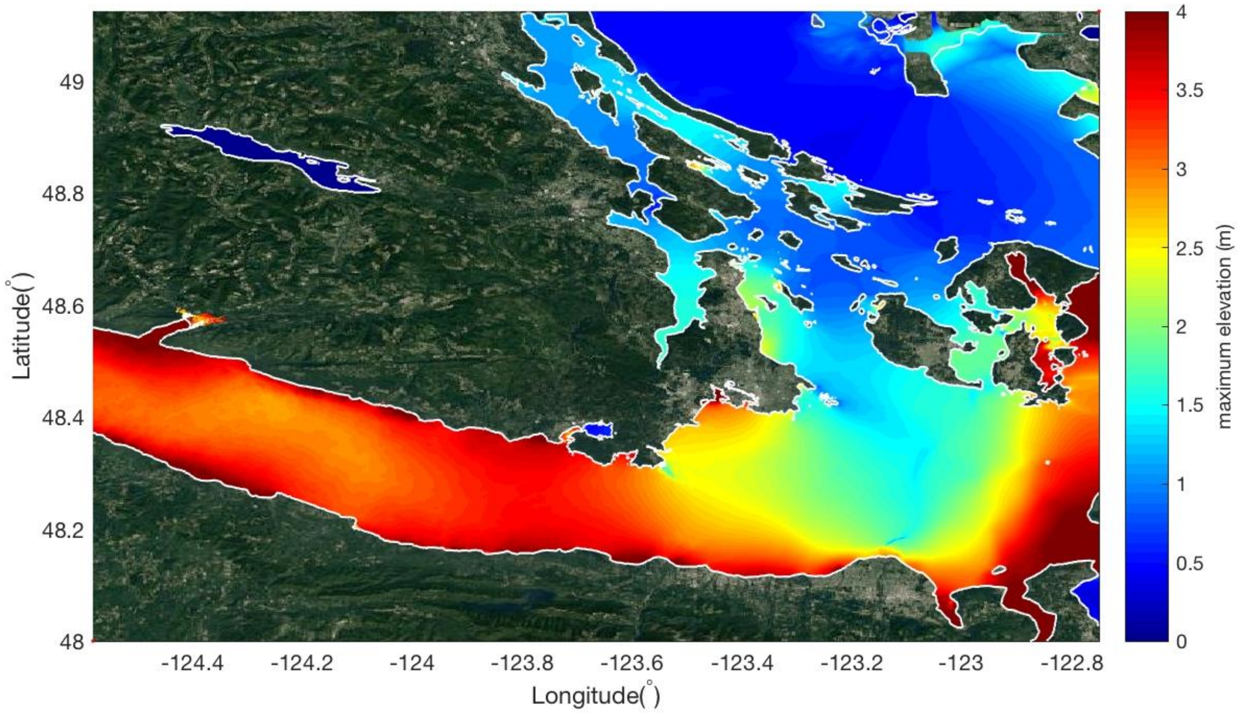


Figure A-8
Maximum sea surface elevation, Grid D, CSZ-NS

CSZ-CS event

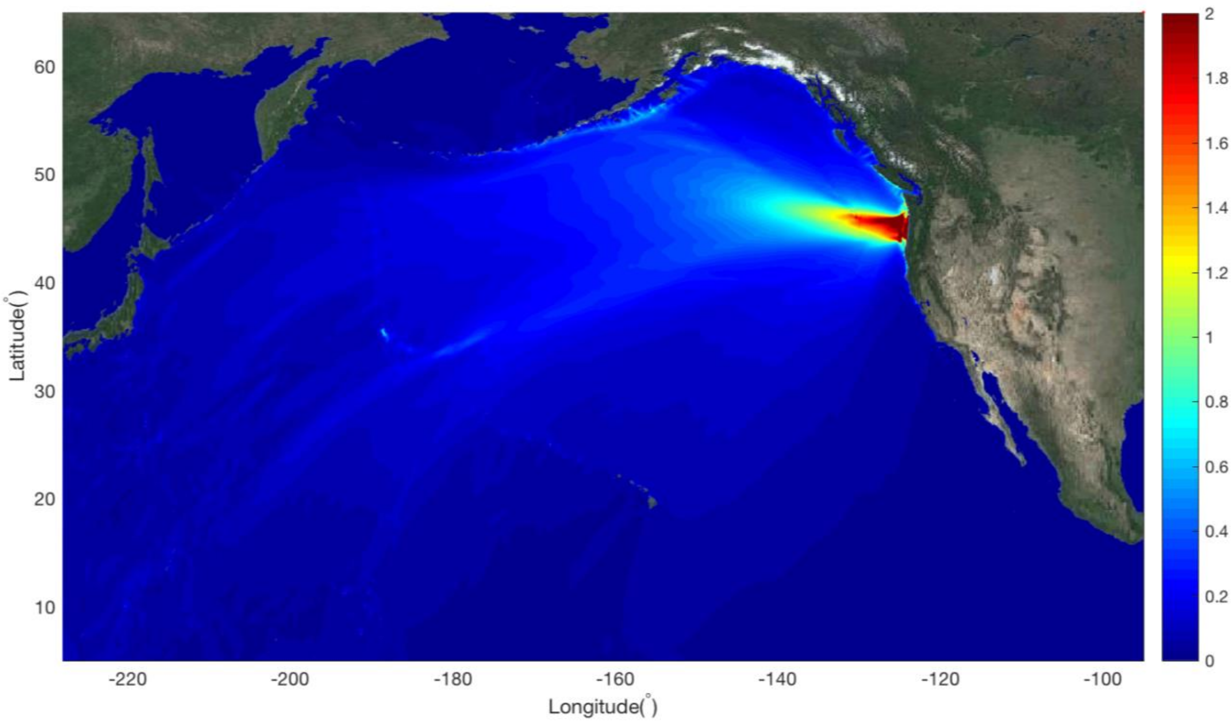


Figure A-9
Maximum sea surface elevation, Grid A, CSZ-CS

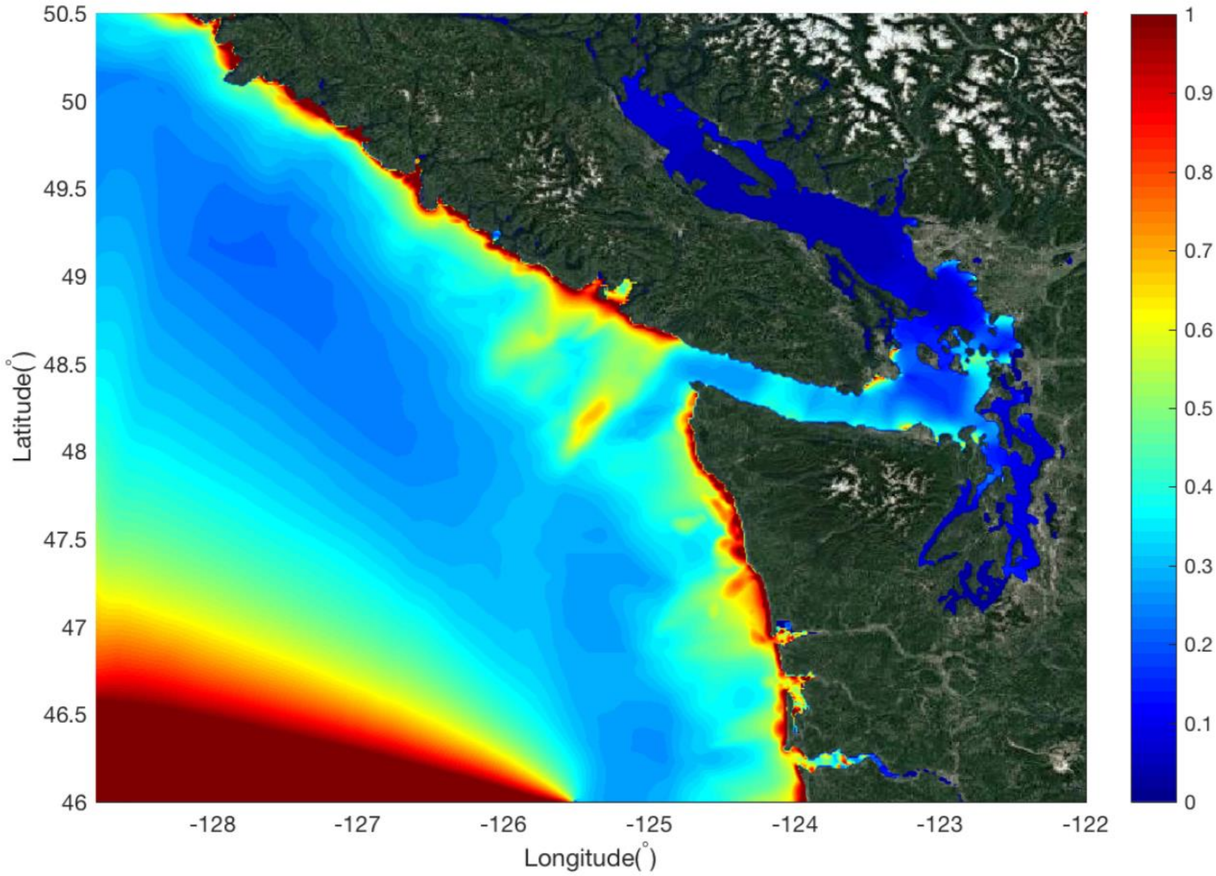


Figure A-10
Maximum sea surface elevation, Grid B, CSZ-CS

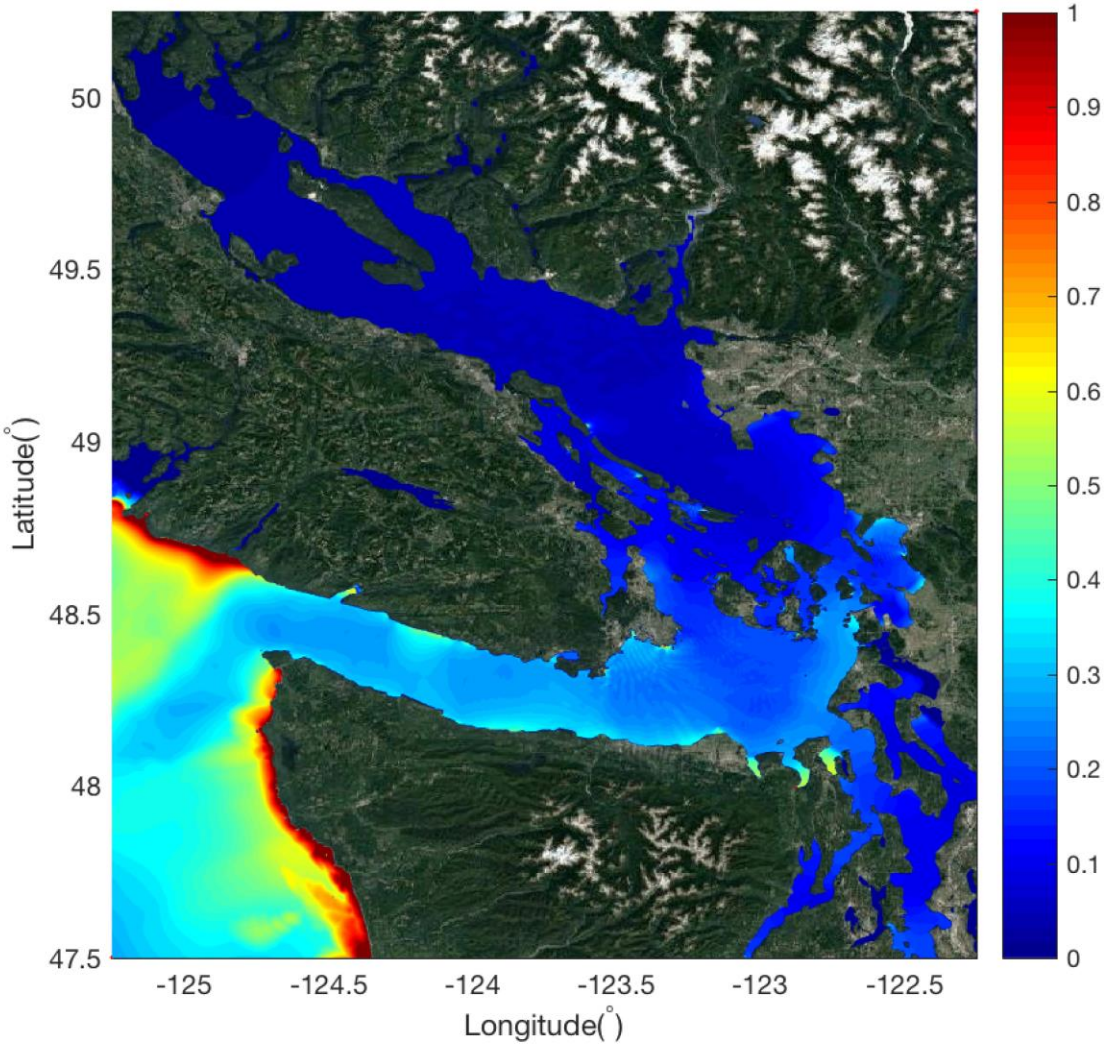


Figure A-11
Maximum sea surface elevation, Grid C, CSZ-CS

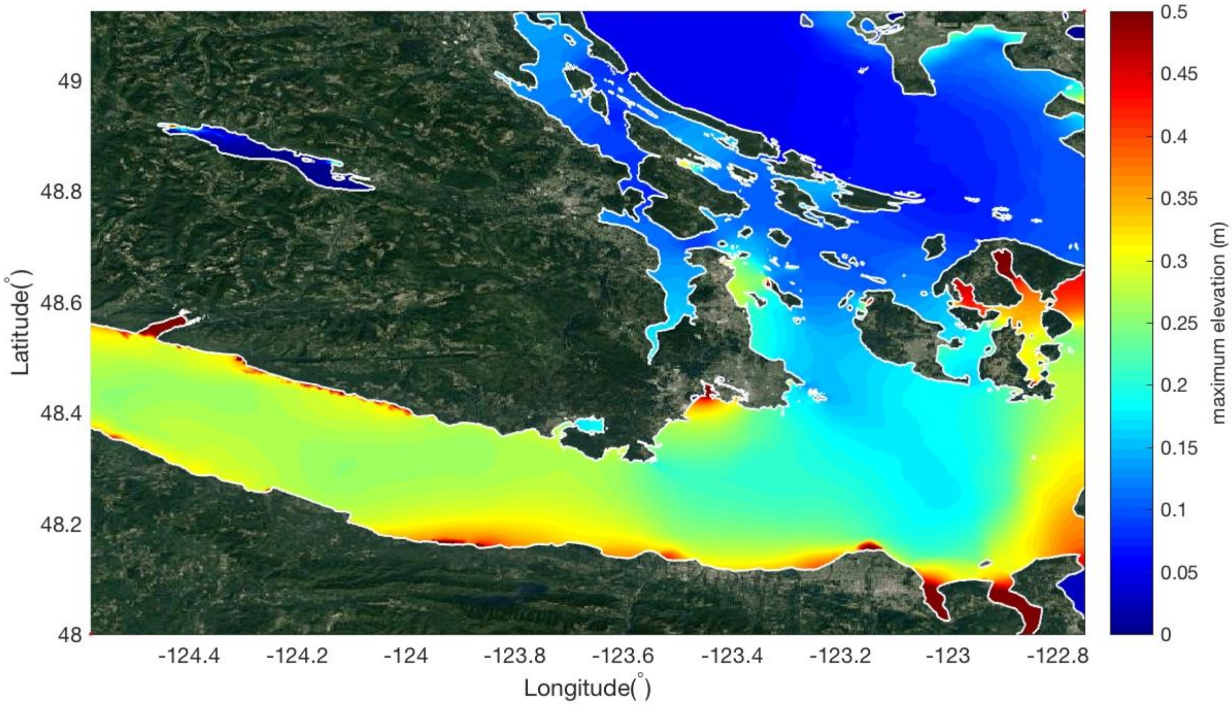


Figure A-12
Maximum sea surface elevation, Grid D, CSZ-CS

Alaska 1964 (AL) event

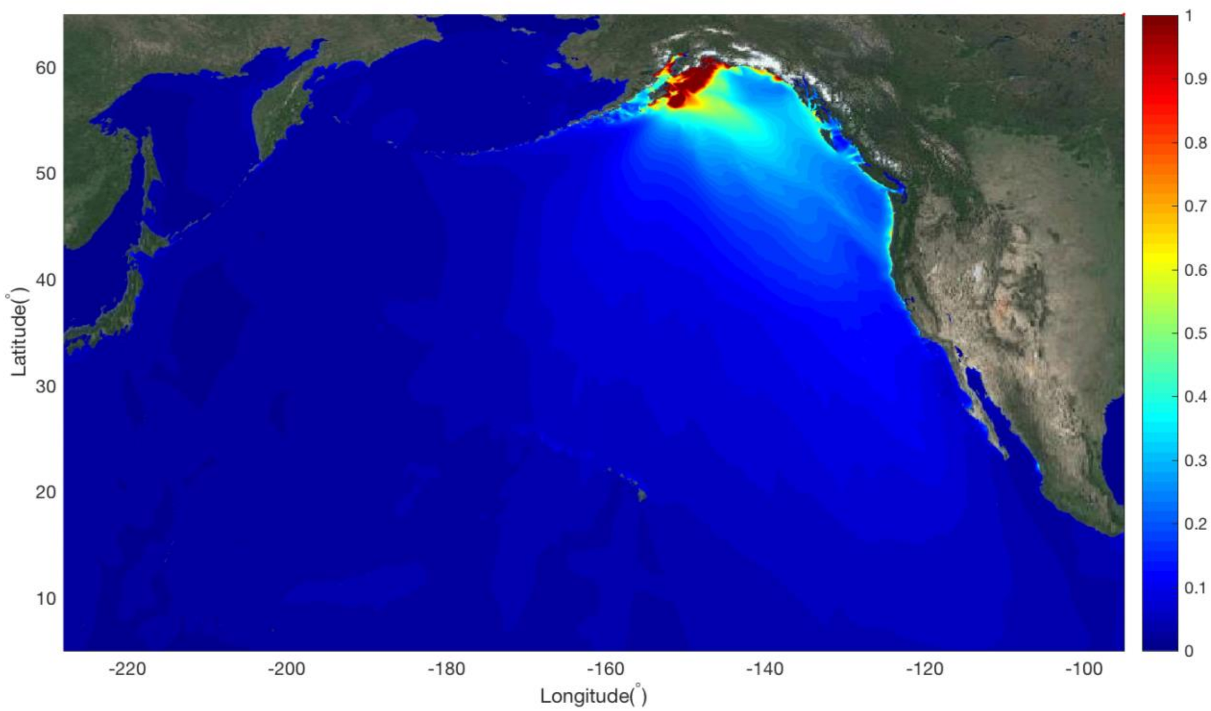


Figure A-13
Maximum sea surface elevation, Grid A, AL

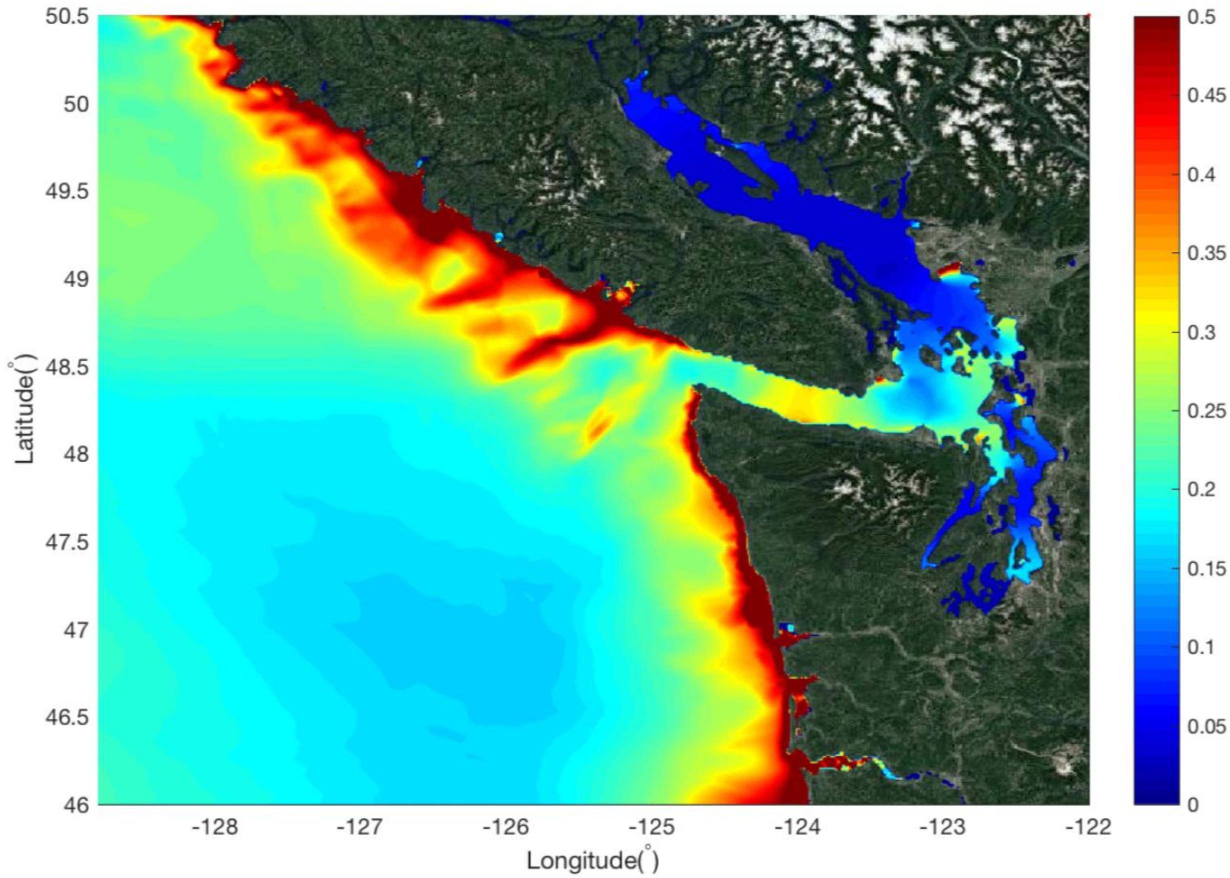


Figure A-14
Maximum sea surface elevation, Grid B, AL

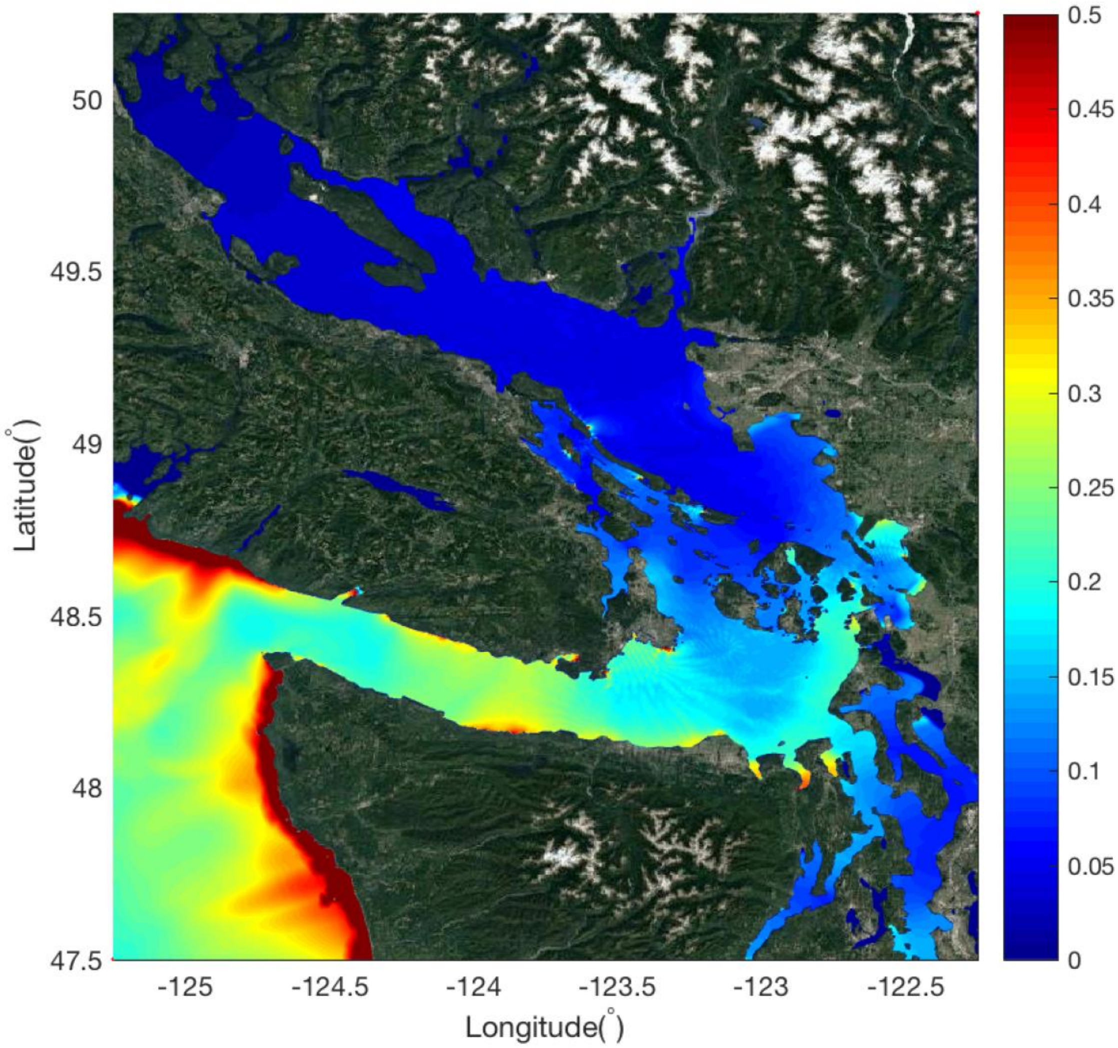


Figure A-15
Maximum sea surface elevation, Grid C, AL

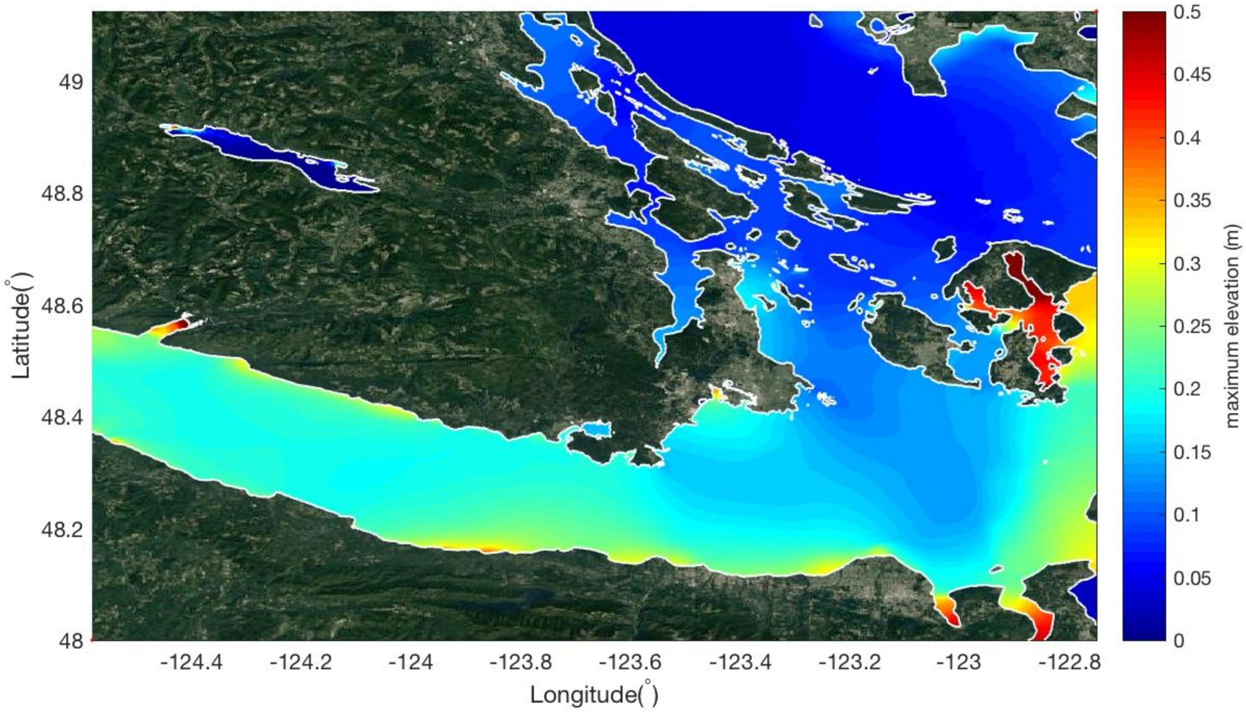


Figure A-16
Maximum sea surface elevation, Grid D, AL

Alaska – Unimak 1946 (UN) event

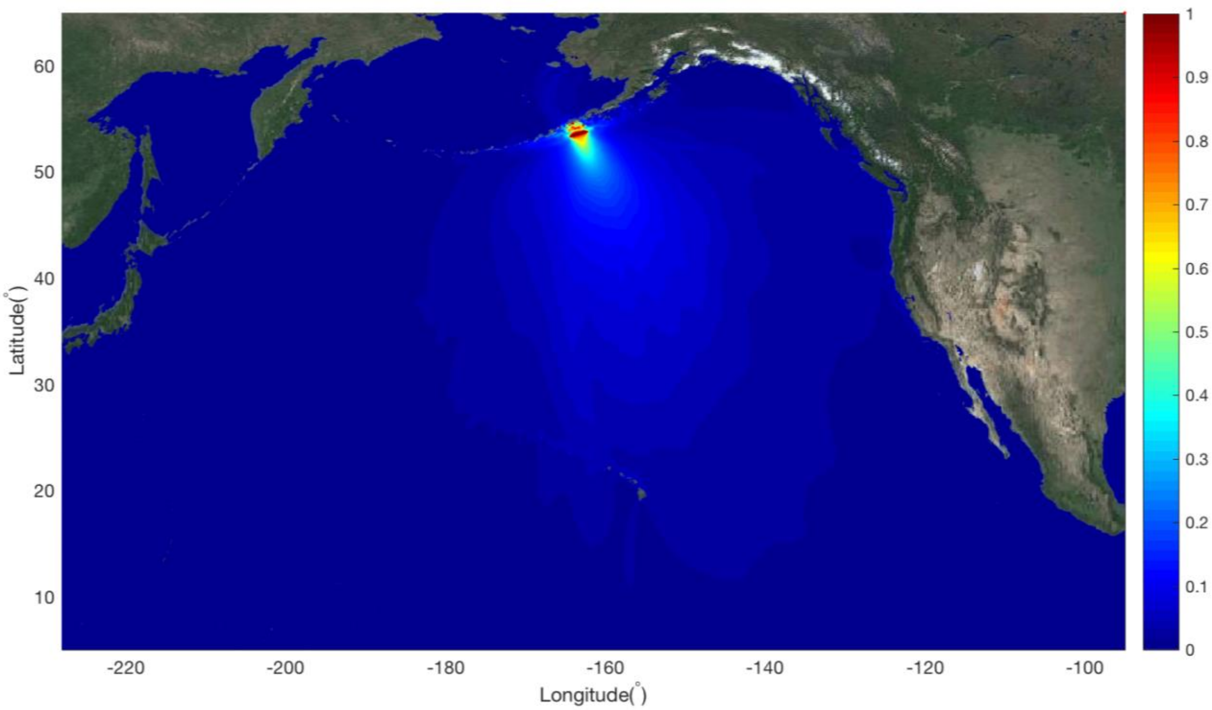


Figure A-17
Maximum sea surface elevation, Grid A, UN

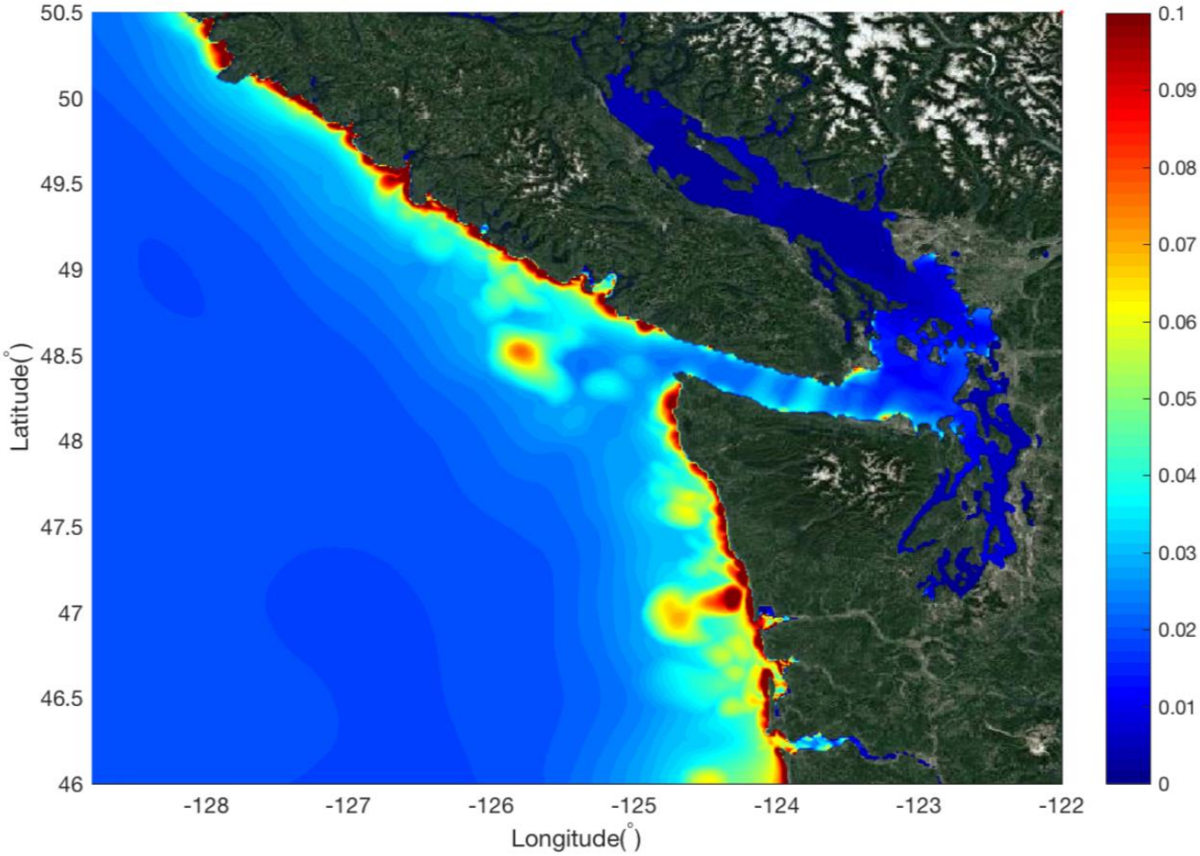


Figure A-18
Maximum sea surface elevation, Grid B, UN

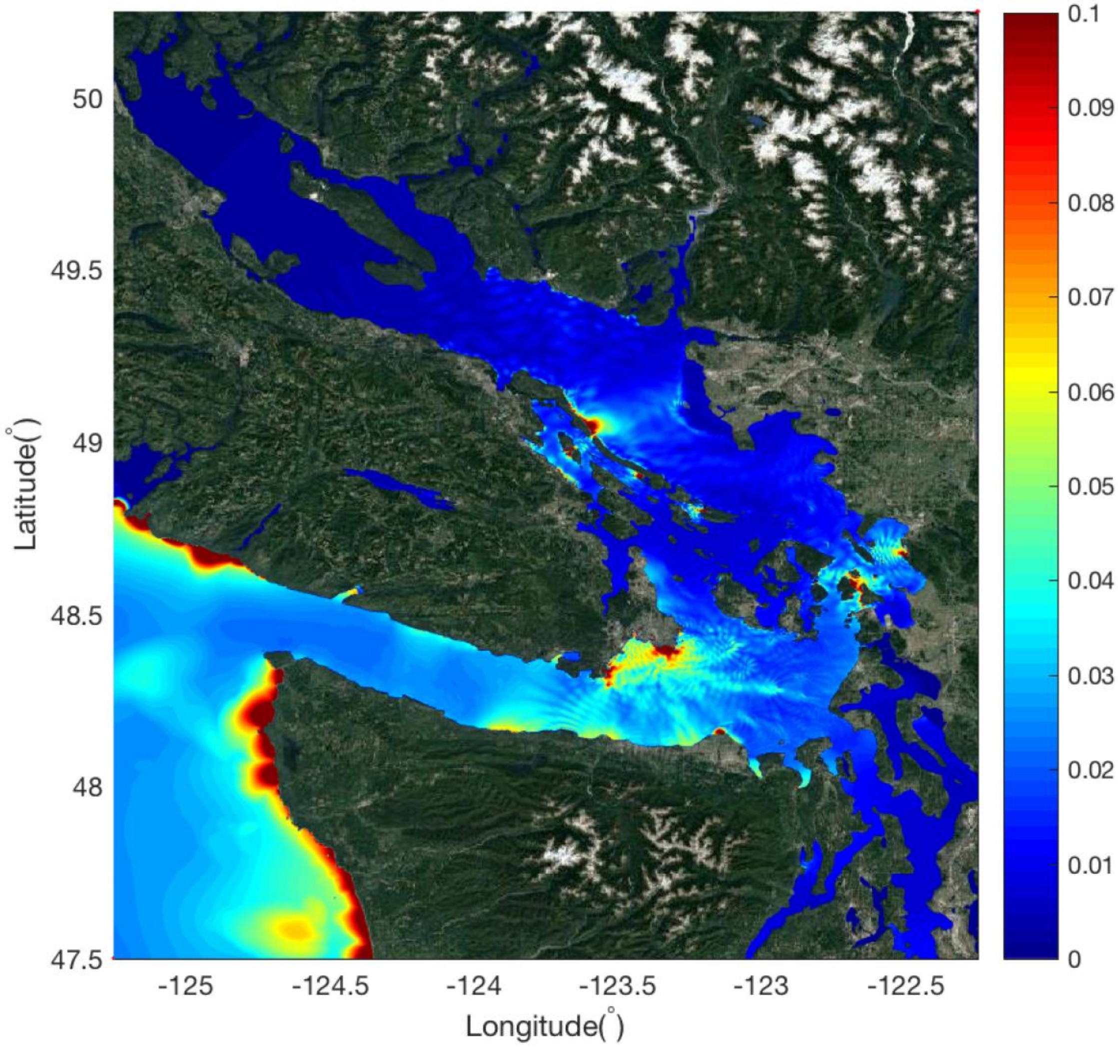


Figure A-19
Maximum sea surface elevation, Grid C, UN

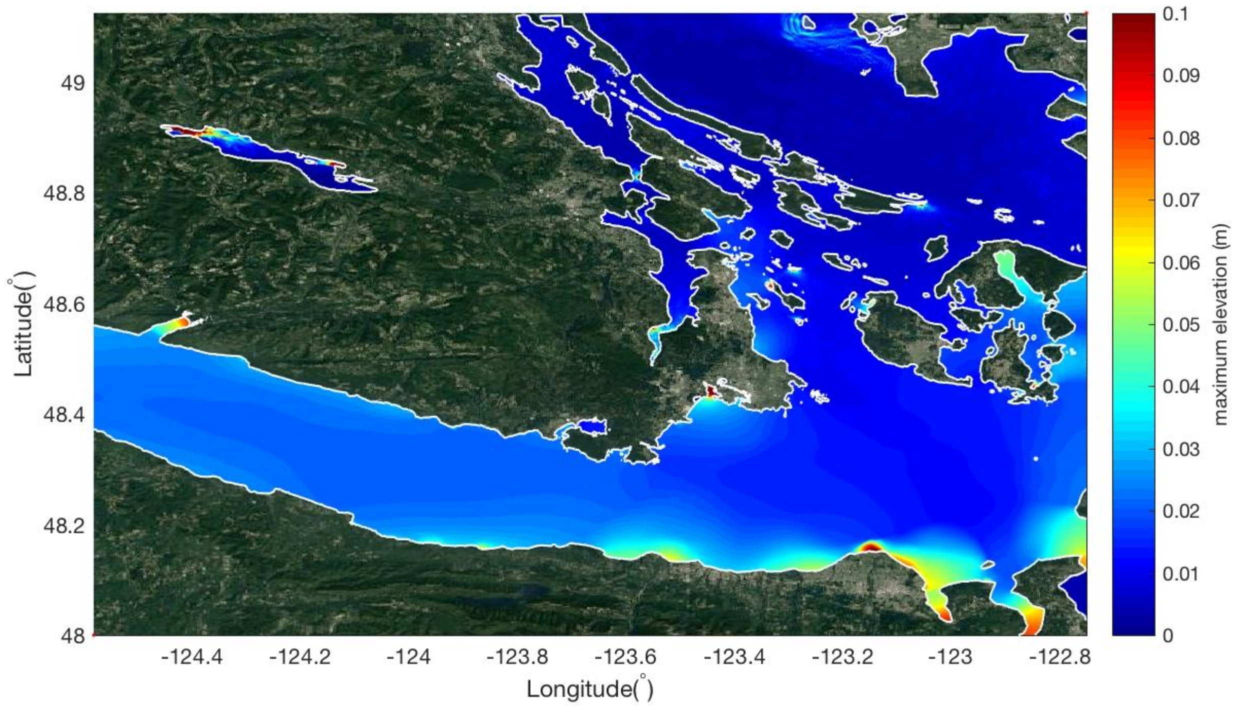


Figure A-20
Maximum sea surface elevation, Grid D, UN

Haida Gwaii, 2012 (HG1) event

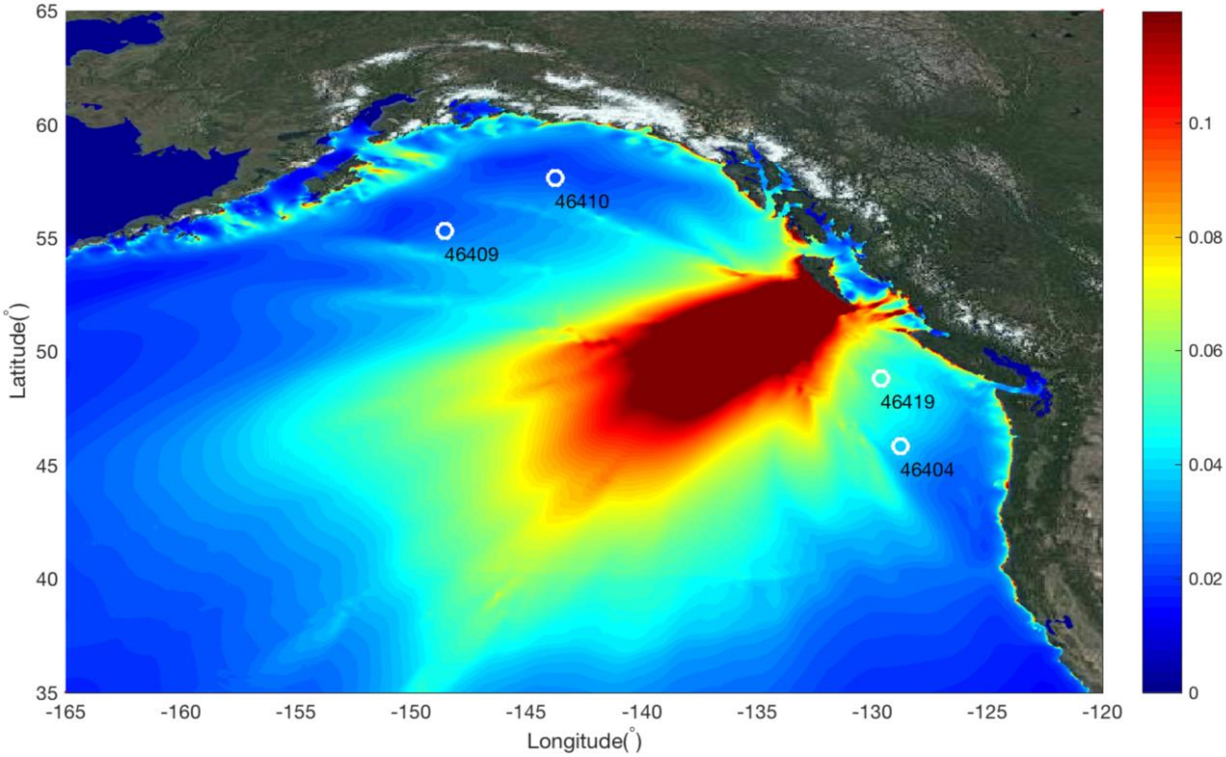


Figure A-21
Maximum sea surface elevation, Grid A, HG1

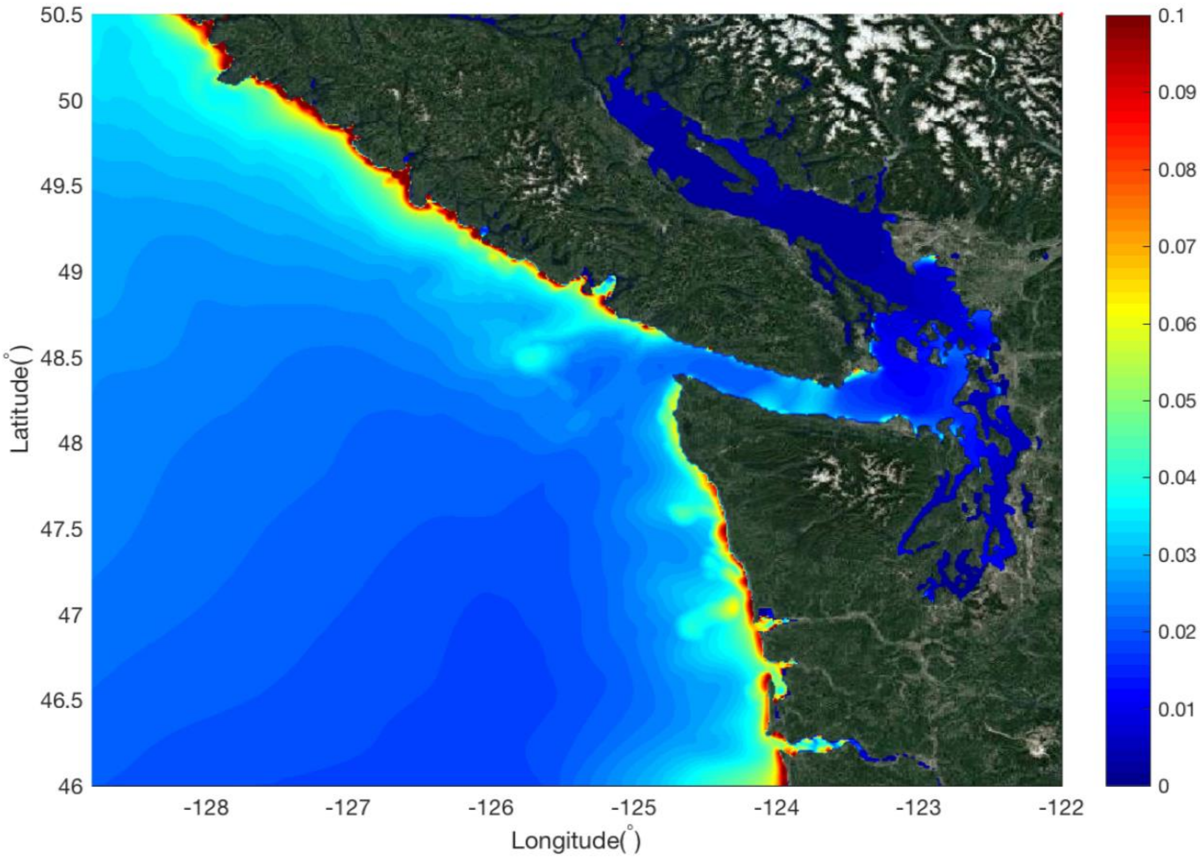


Figure A-22
Maximum sea surface elevation, Grid B, HG1

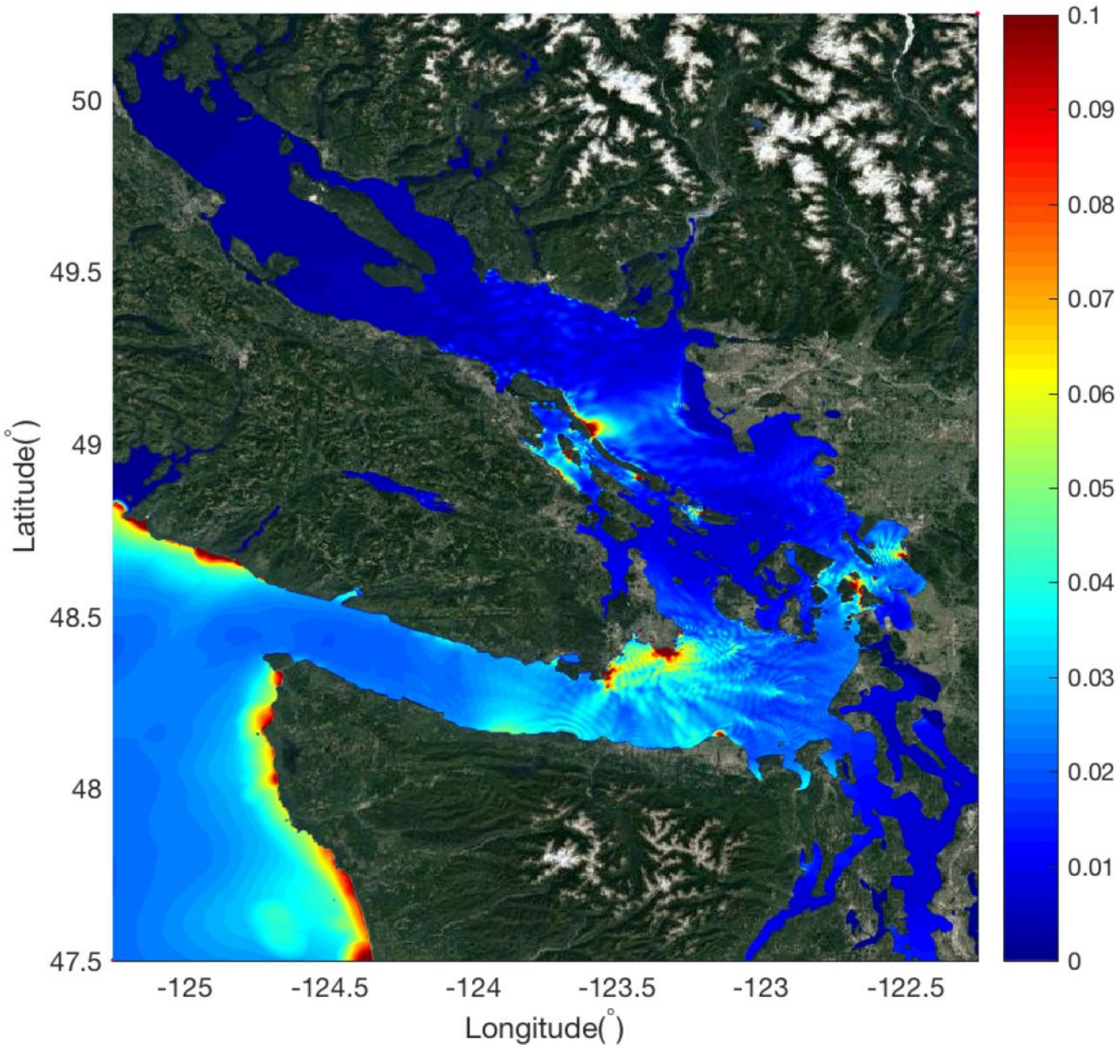


Figure A-23
Maximum sea surface elevation, Grid C, HG1

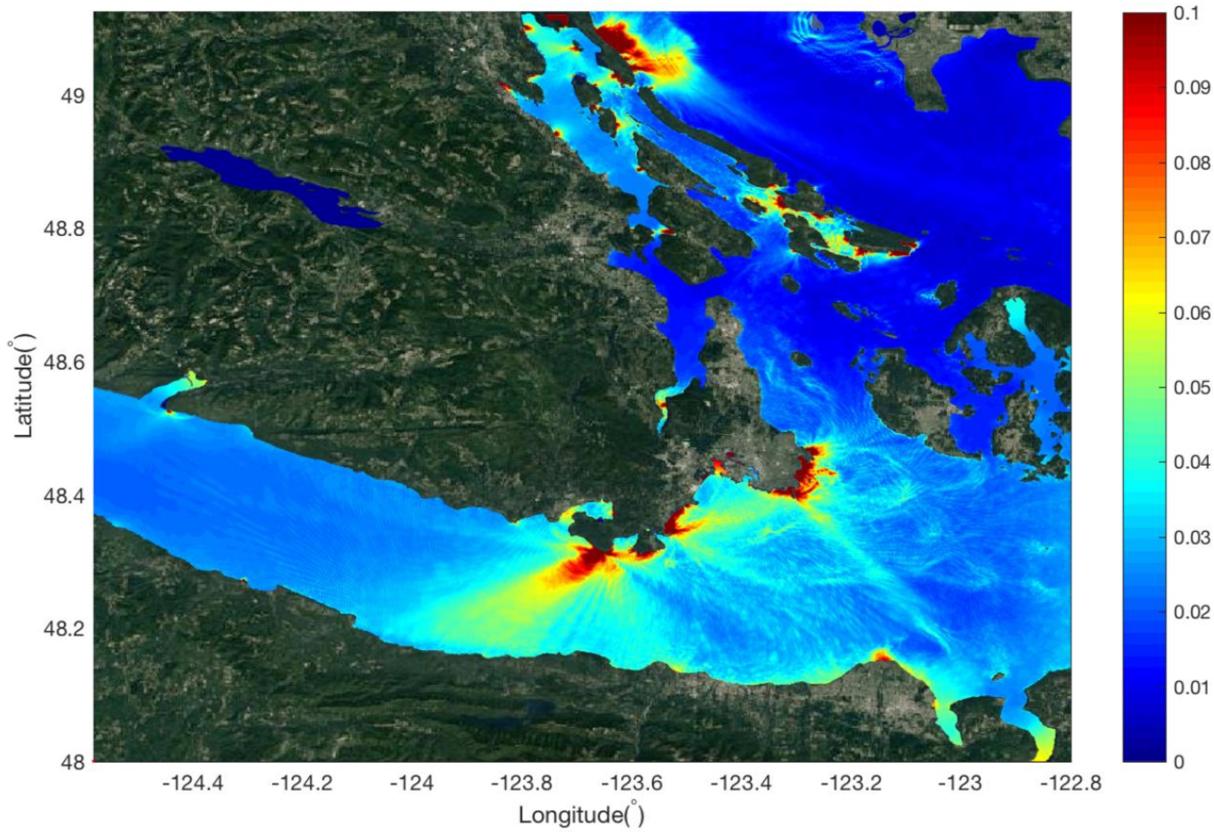


Figure A-24
Maximum sea surface elevation, Grid D, HG1

Haida Gwaii – southern extension (HG2) event

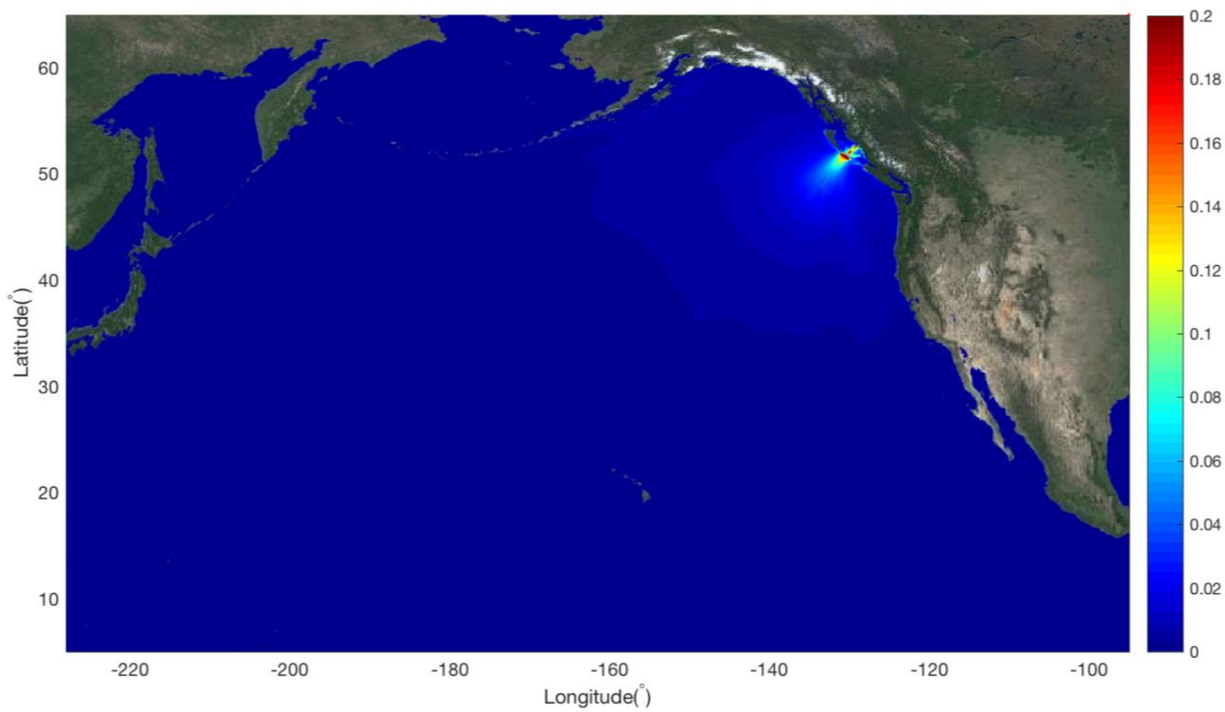


Figure A-25
Maximum sea surface elevation, Grid A, HG2

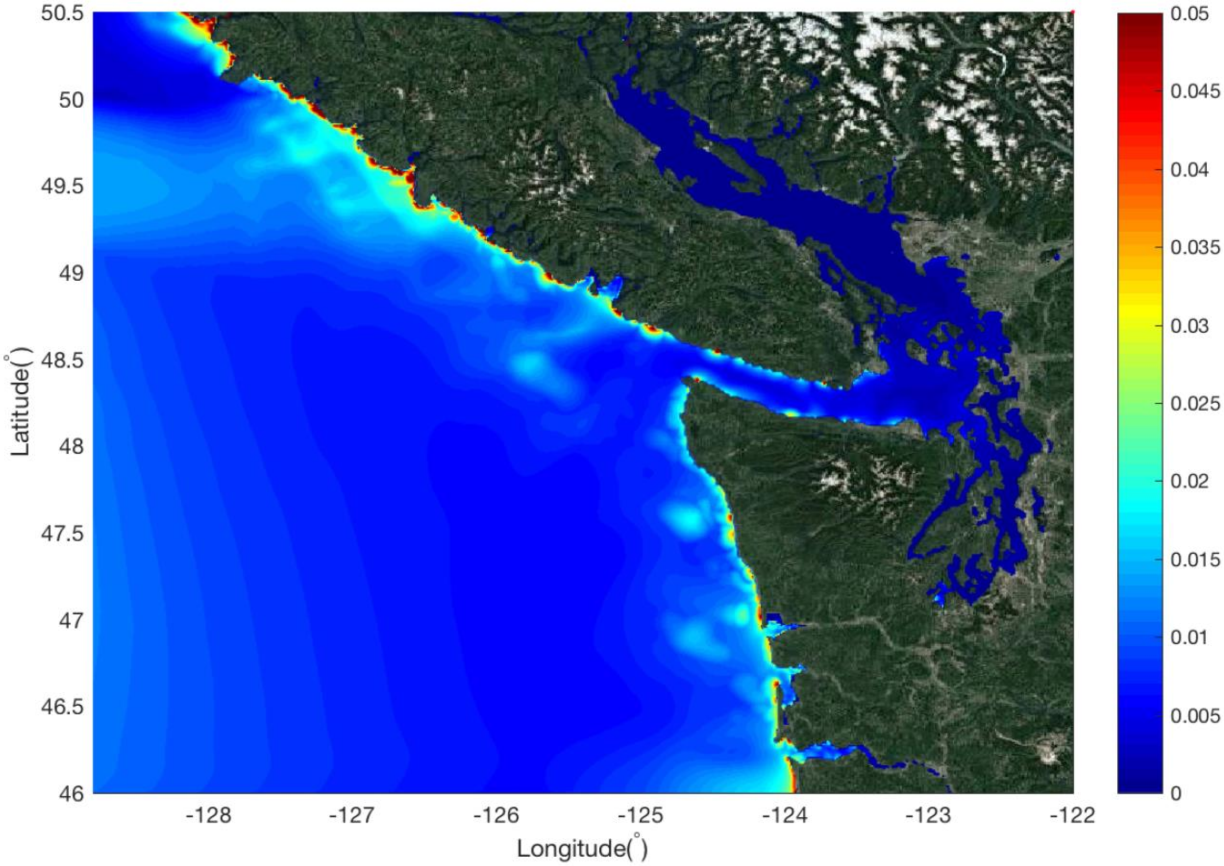


Figure A – 26
Maximum sea surface elevation, Grid B, HG2

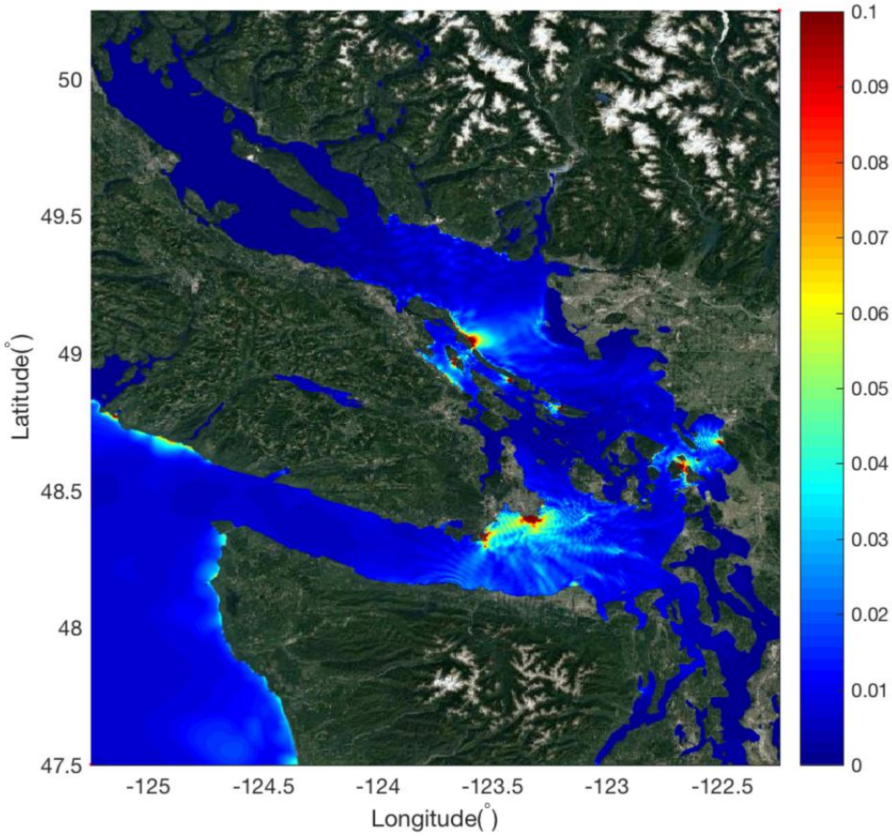


Figure A-27
Maximum sea surface elevation, Grid C, HG2

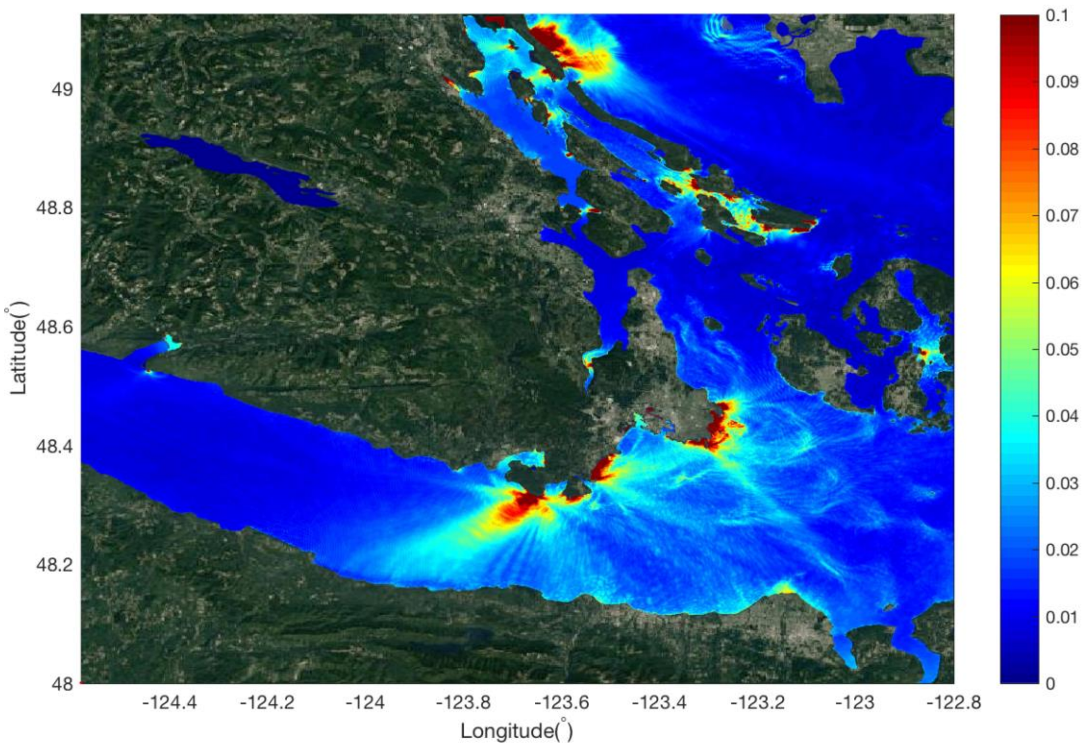


Figure A-28
Maximum sea surface elevation, Grid D, HG2

Southern Whidbey Island, Mw 7.5 (SW1) event

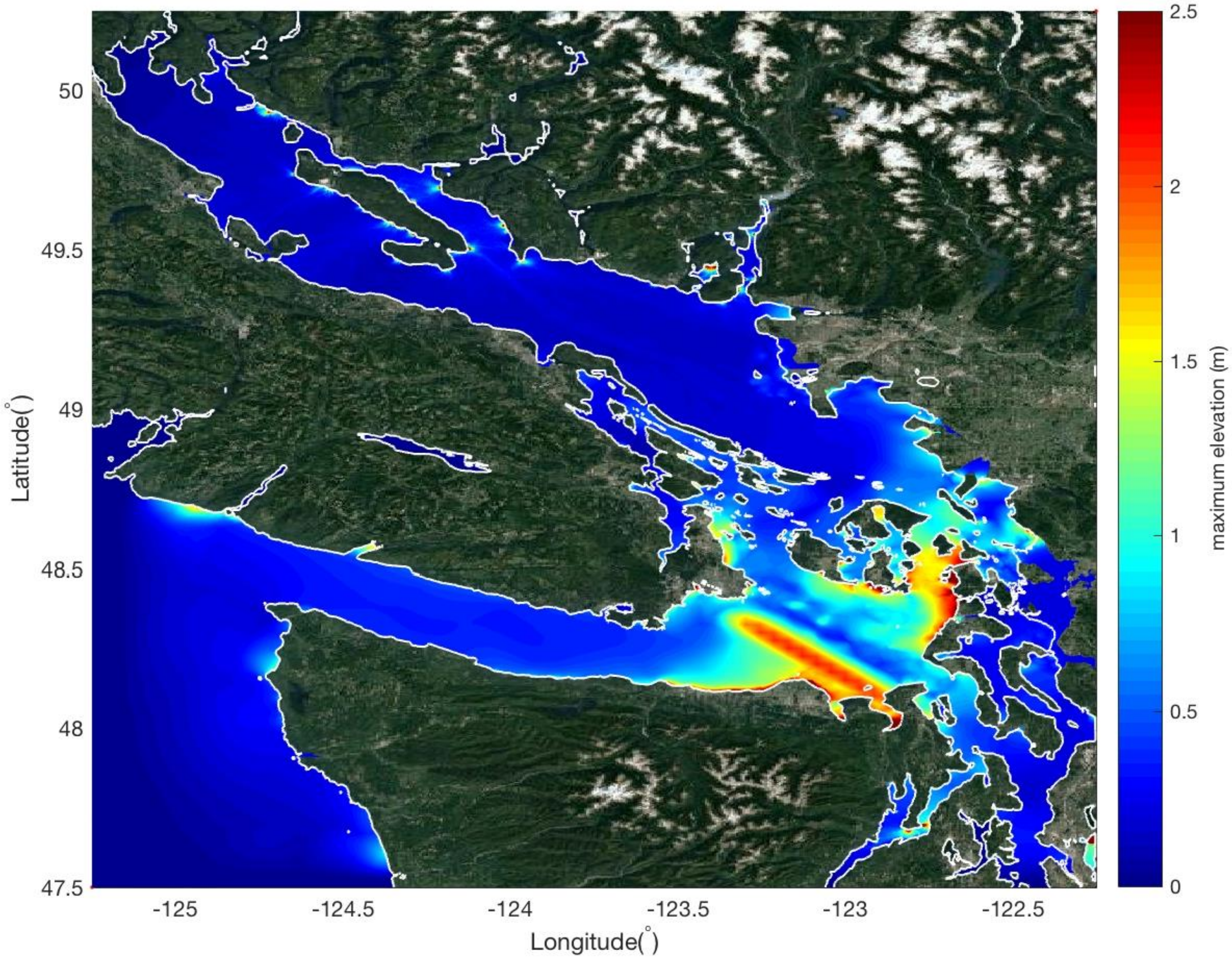


Figure A-29
Maximum sea surface elevation, Grid C', SW1

Southern Whidbey Island, Mw 6.5 event

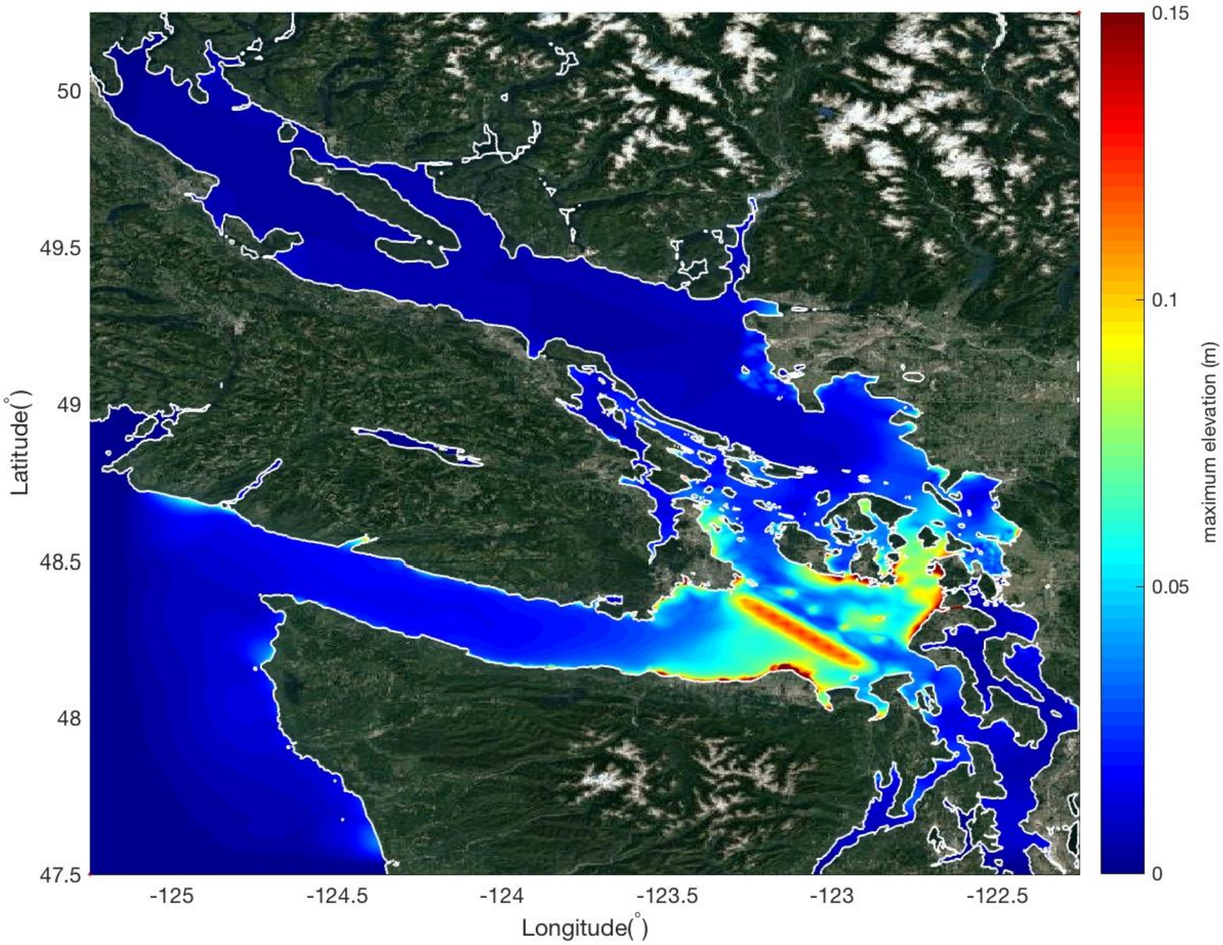


Figure A-30
Maximum sea surface elevation, Grid C', SW2

Devil's Mountain Fault, Mw 7.5 (DM1) event

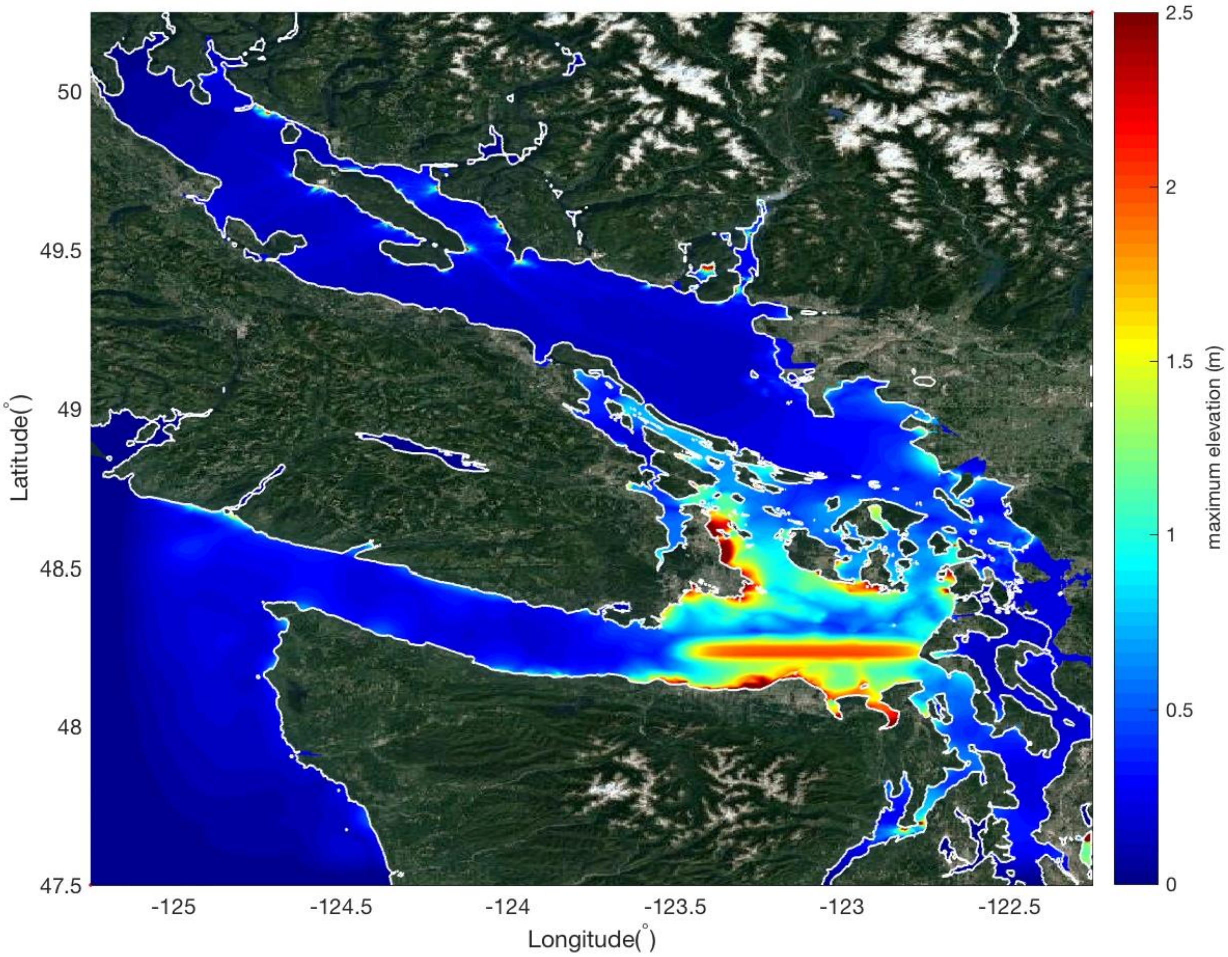


Figure A-31
Maximum sea surface elevation, Grid C', DM1

Devil's Mountain Fault, Mw 6.5 (DM2) event

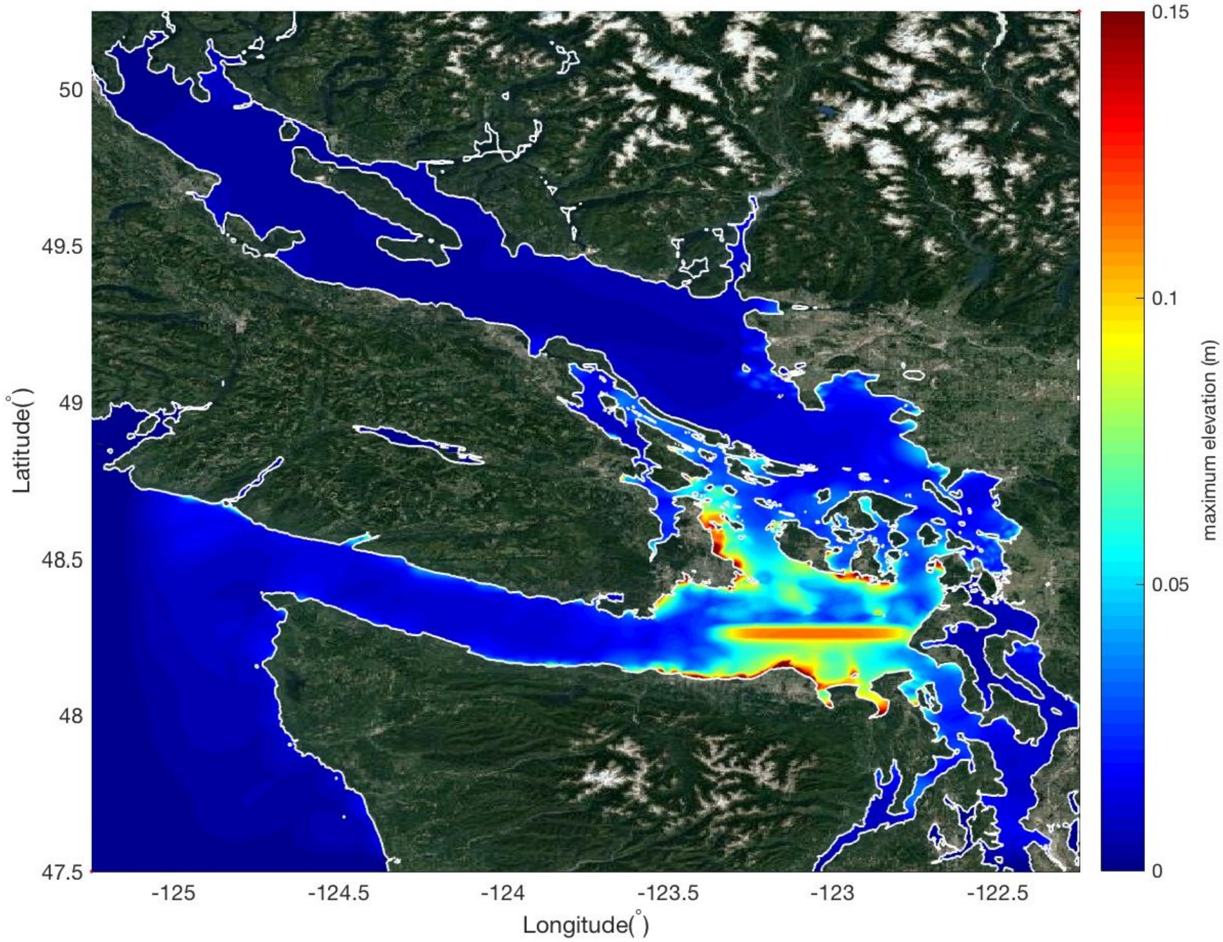


Figure A-32
Maximum sea surface elevation, Grid C', DM2

APPENDIX B - TSUNAMI TIME HISTORIES

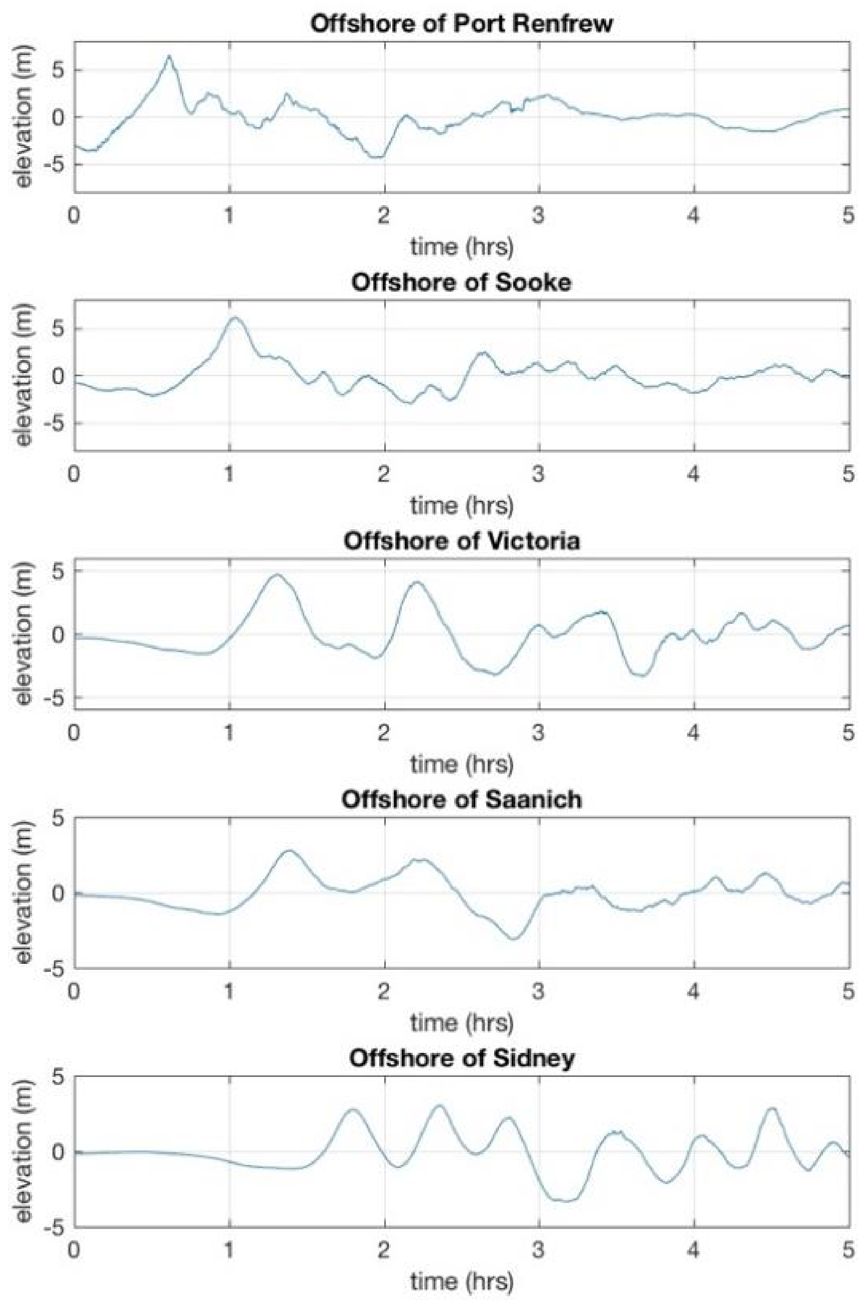


Figure B-1
CSZ-L1 Time histories of surface elevation near inundation study sites.

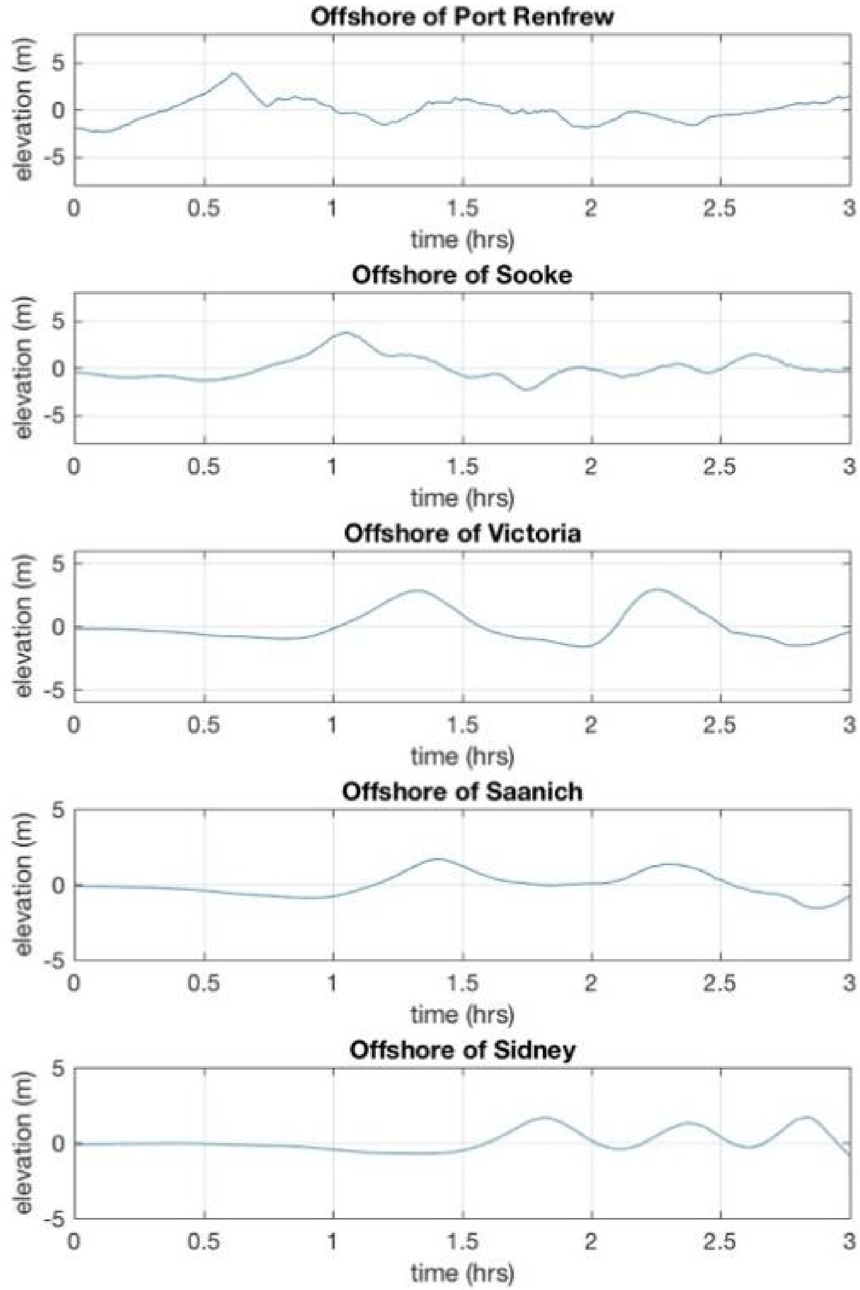


Figure B-2
CSZ-NS Time histories of surface elevation near inundation study sites.

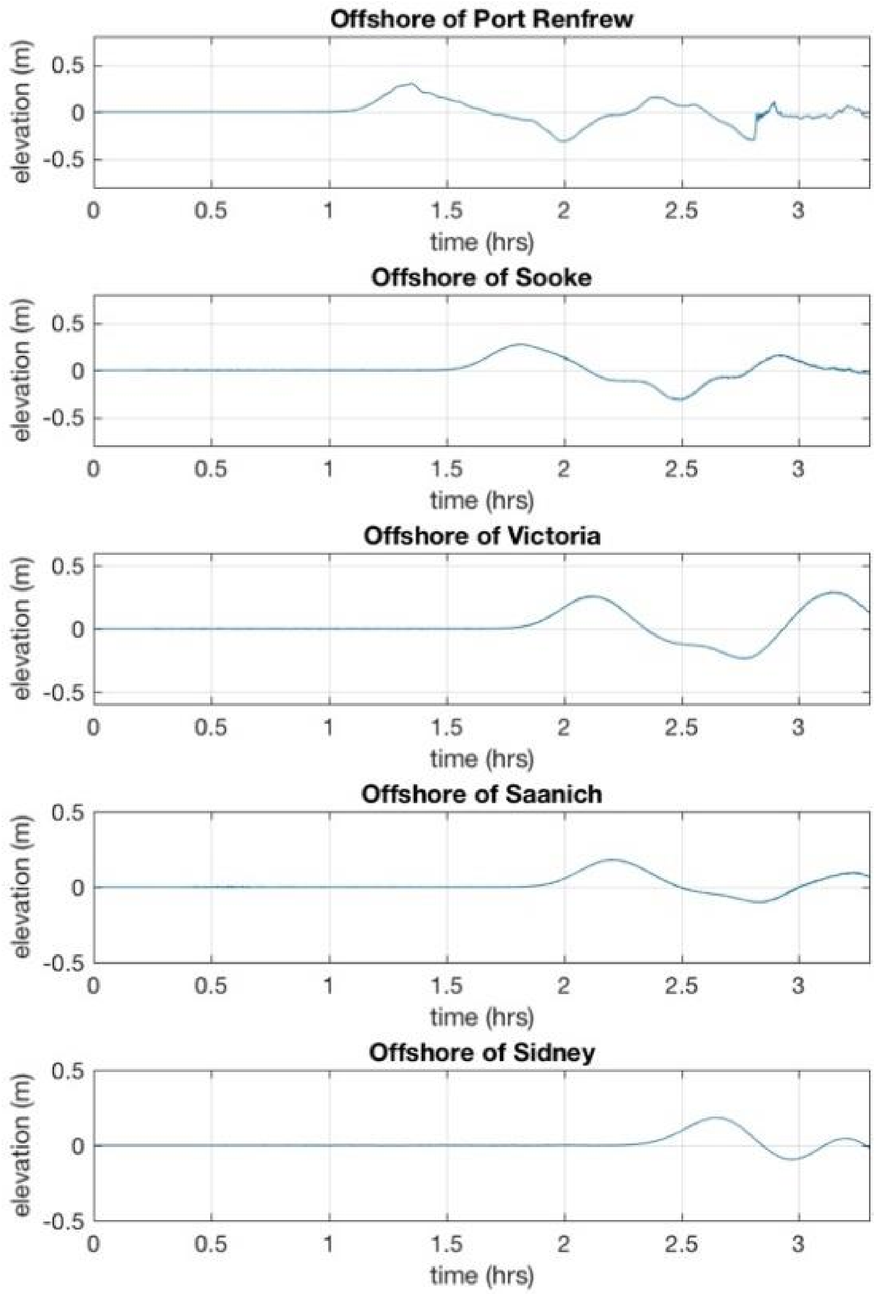


Figure B-3
CSZ-CS Time histories of surface elevation near inundation study sites.

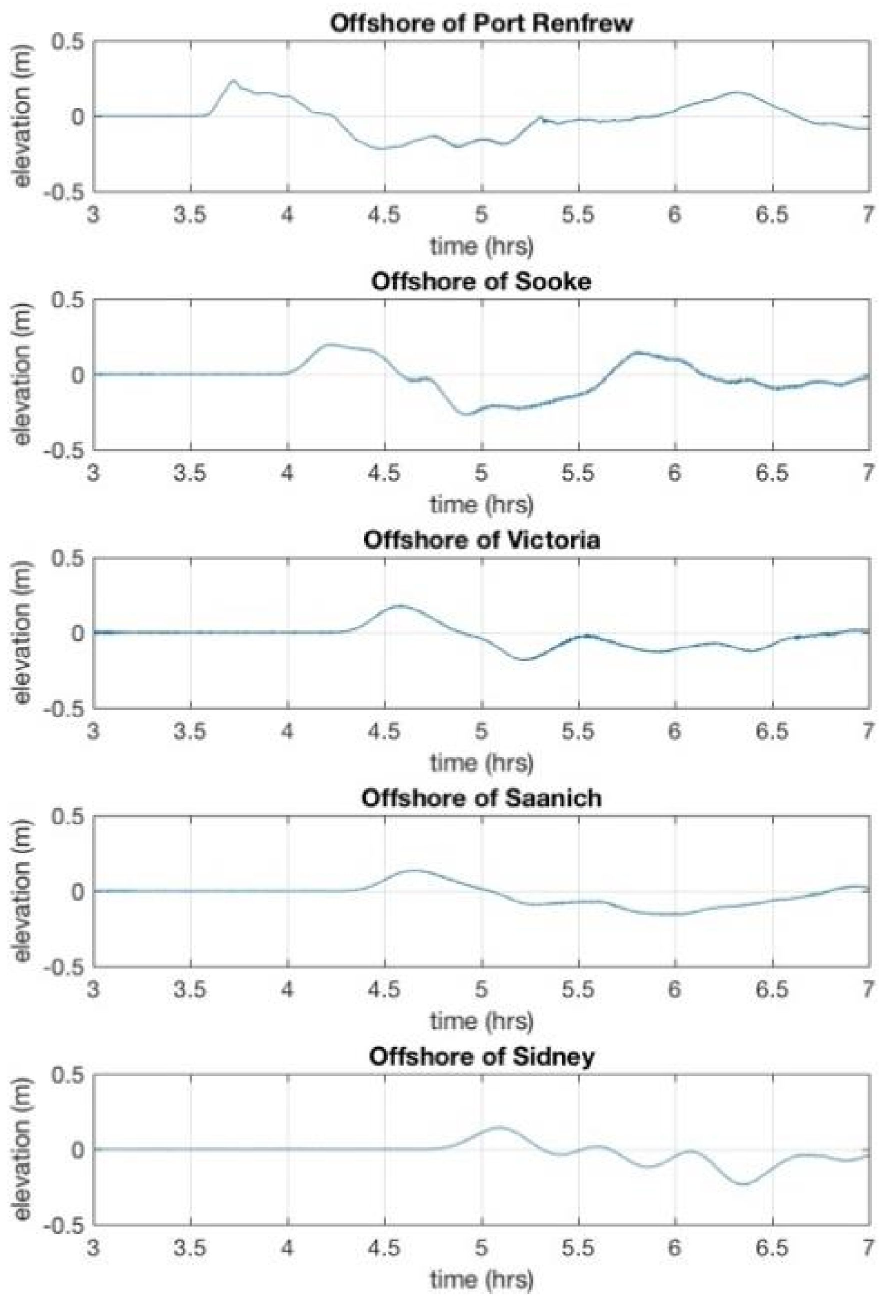


Figure B-4
Alaska 1964 (AL): Time histories of surface elevation near inundation study sites.

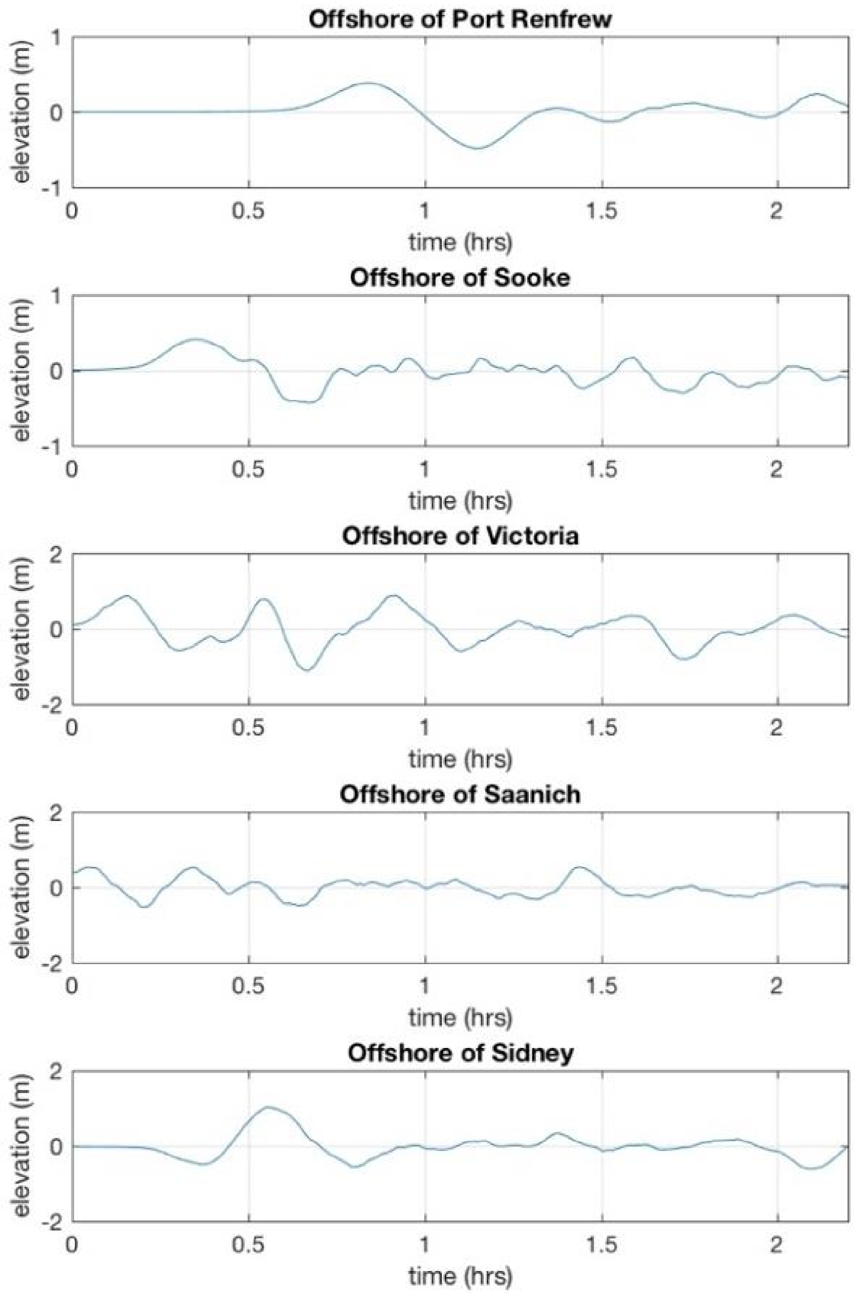


Figure B-5
Southern Whidbey Island Mw 7.5 (SW1). Time histories of surface elevation near inundation study sites.

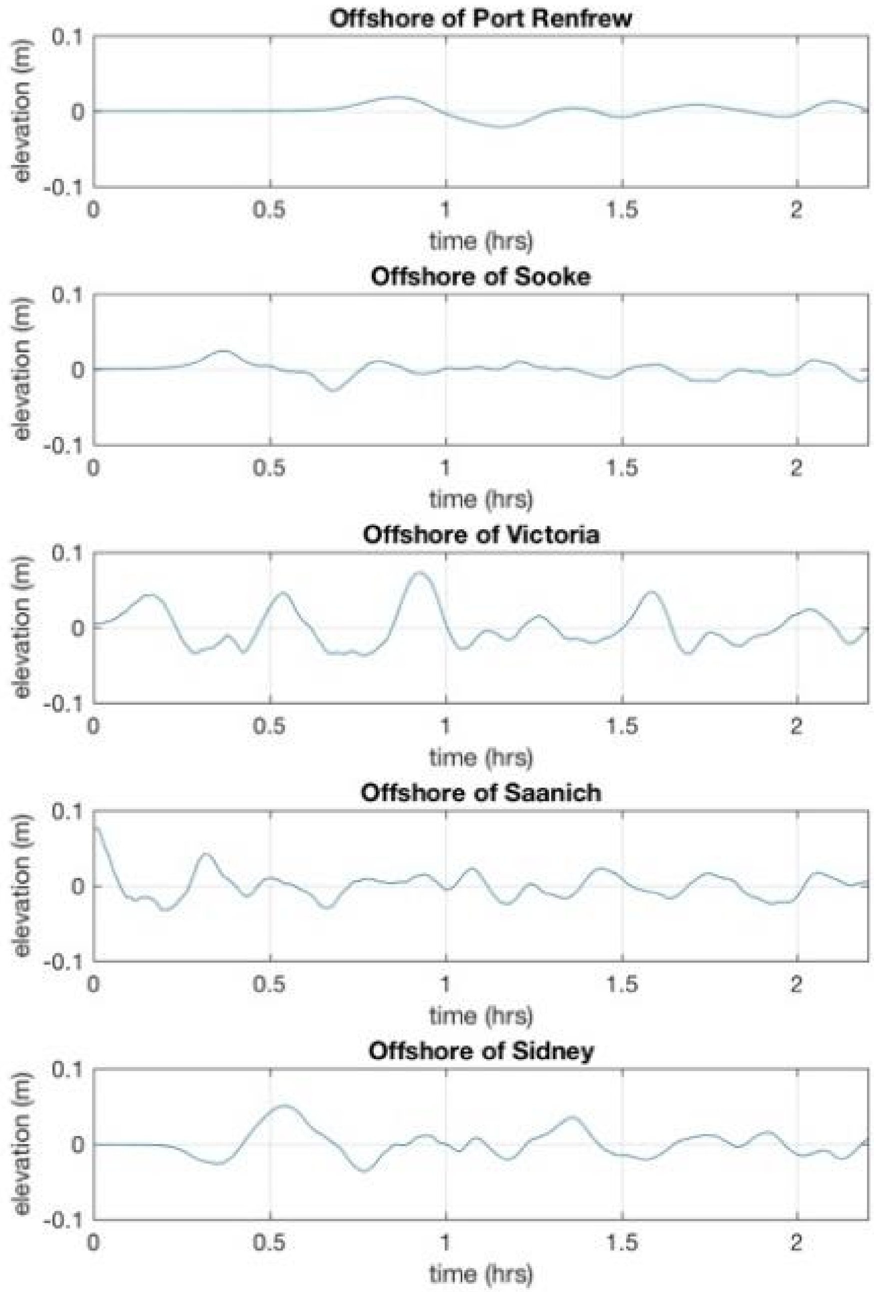


Figure B-6
Southern Whidbey Island Mw 6.5 (SW2). Time histories of surface elevation near inundation study sites.

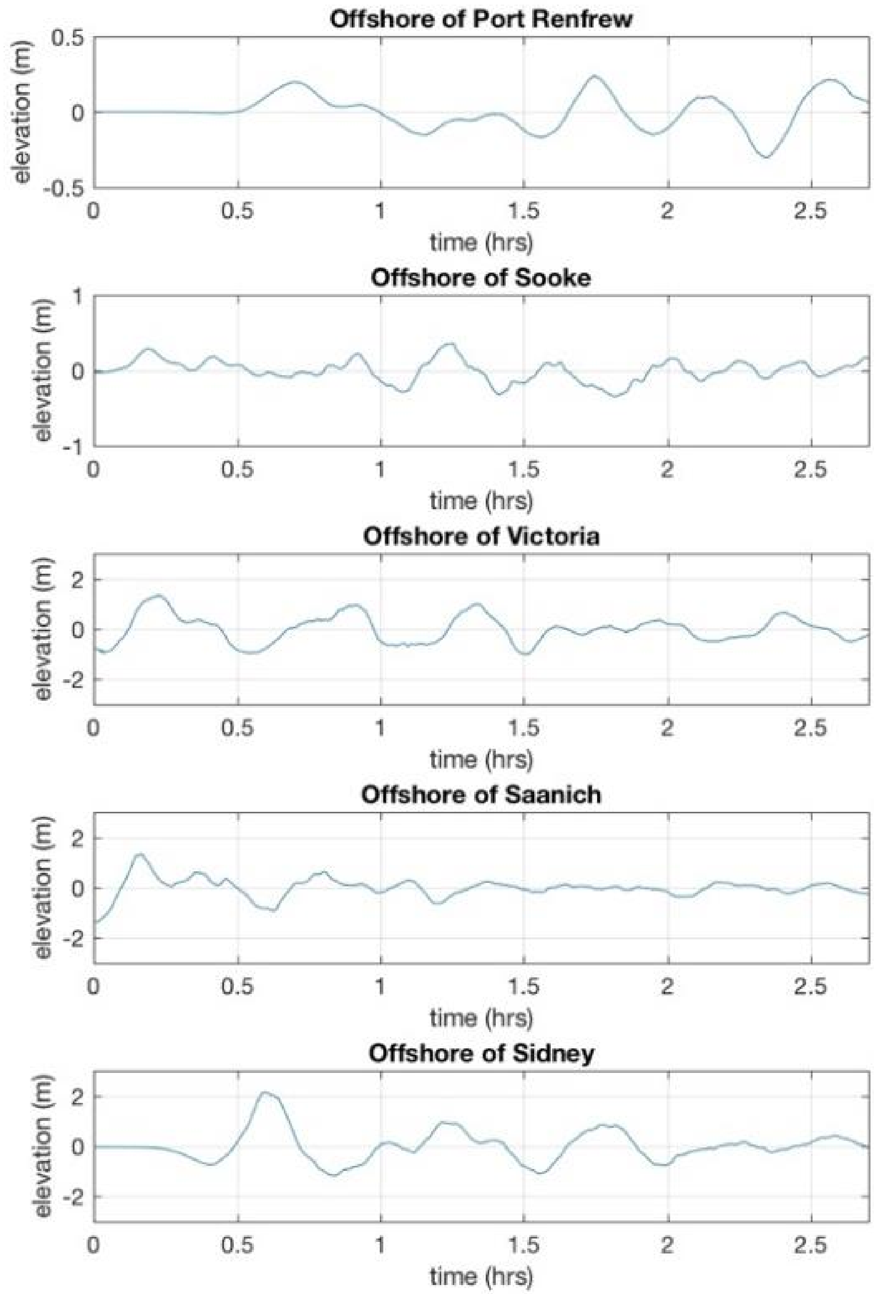


Figure B-7
Devil's Mountain Fault Mw 7.5 event (DM1). Time histories of surface elevation near inundation sites.

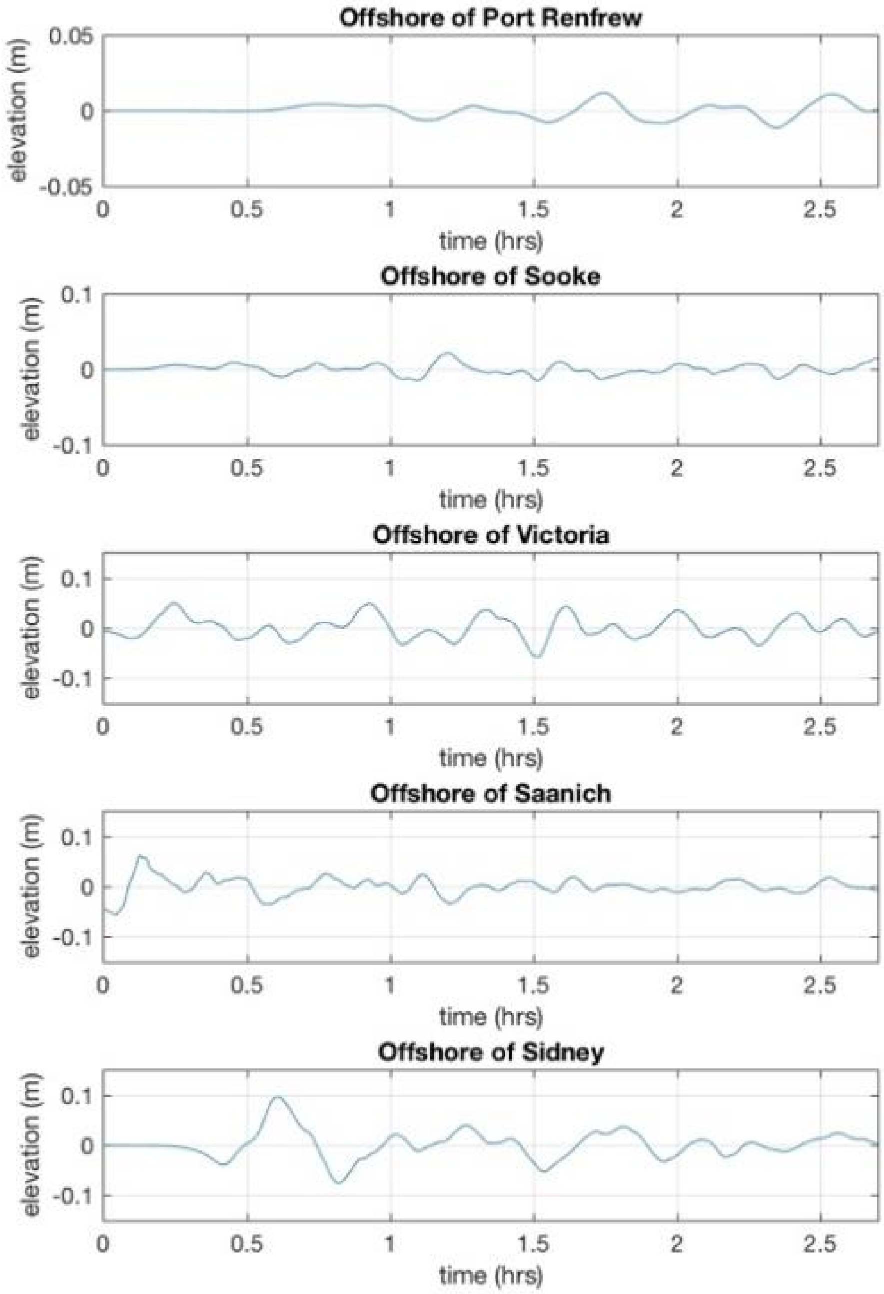
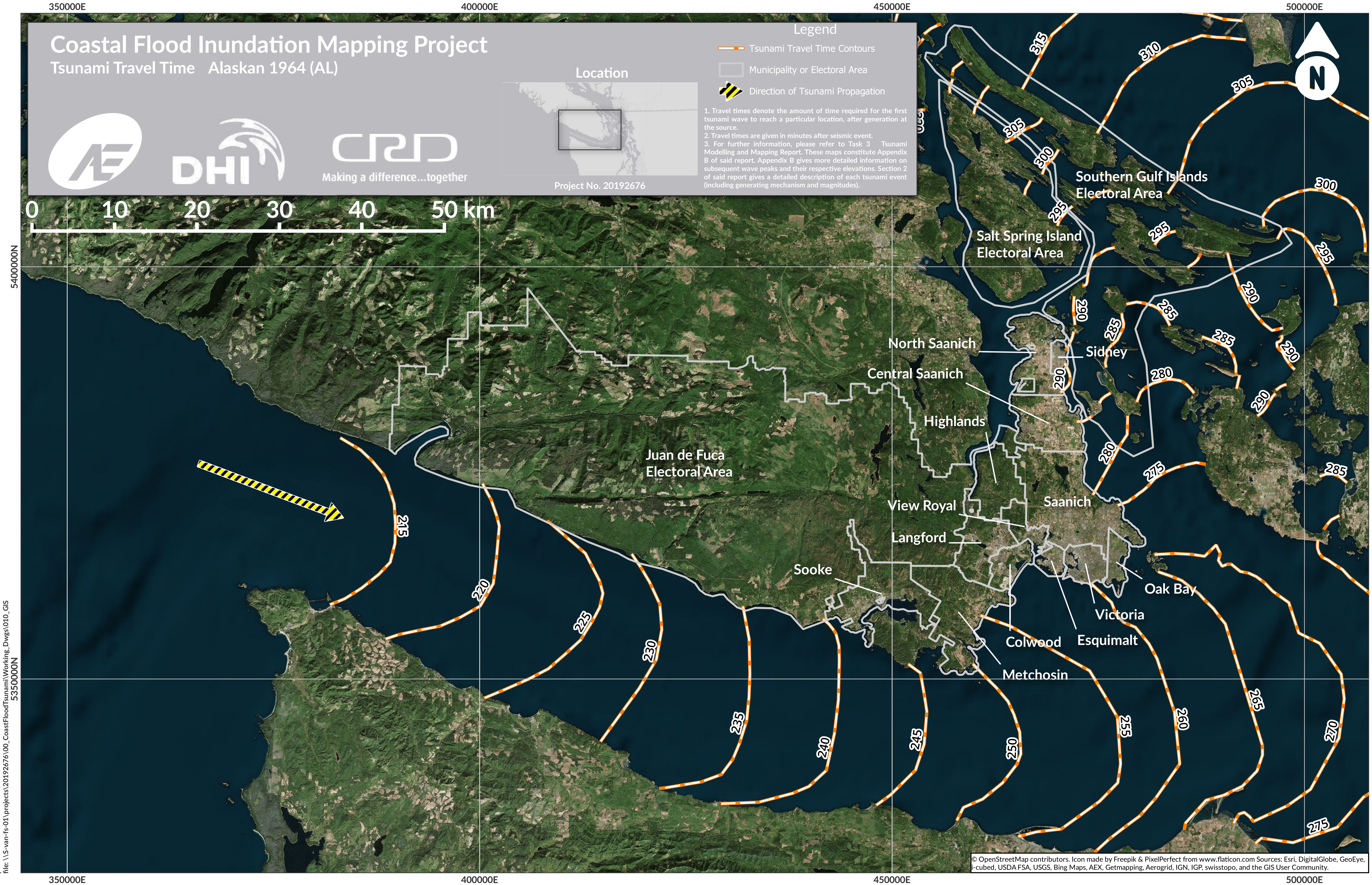


Figure B-8
Devil's Mountain Fault Mw 6.5 event (DM2). Time histories of surface elevation near inundation sites.



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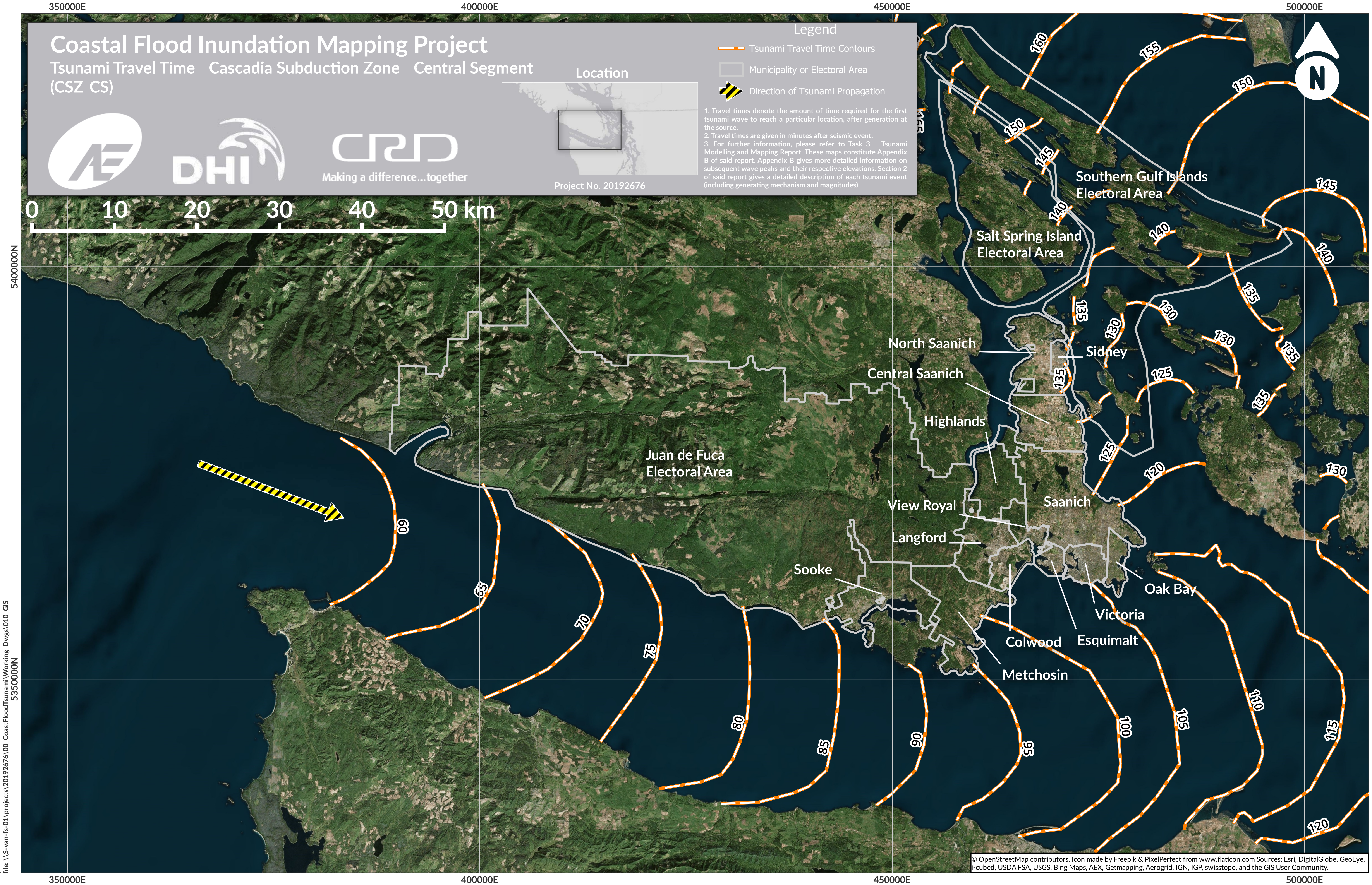

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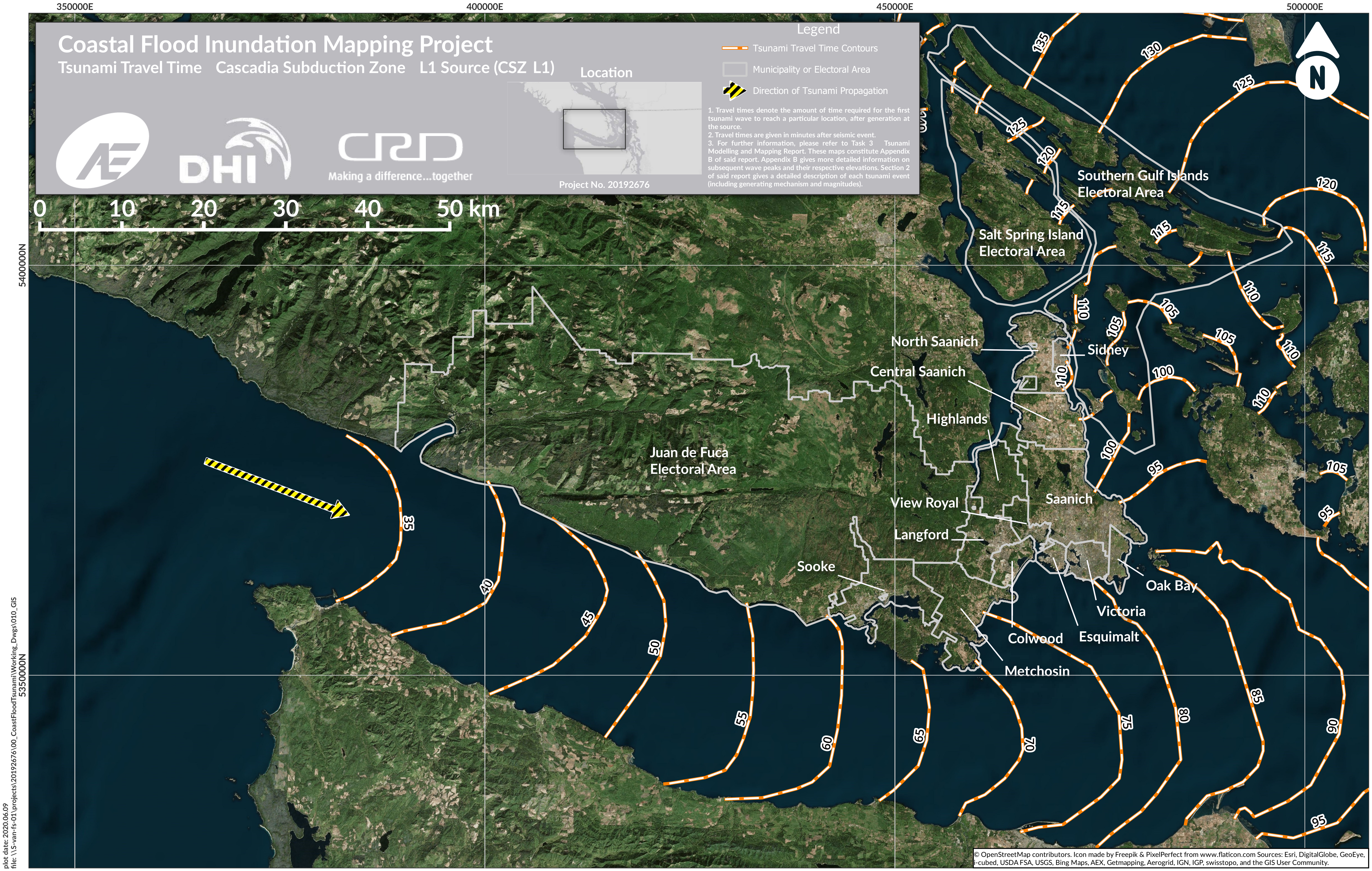

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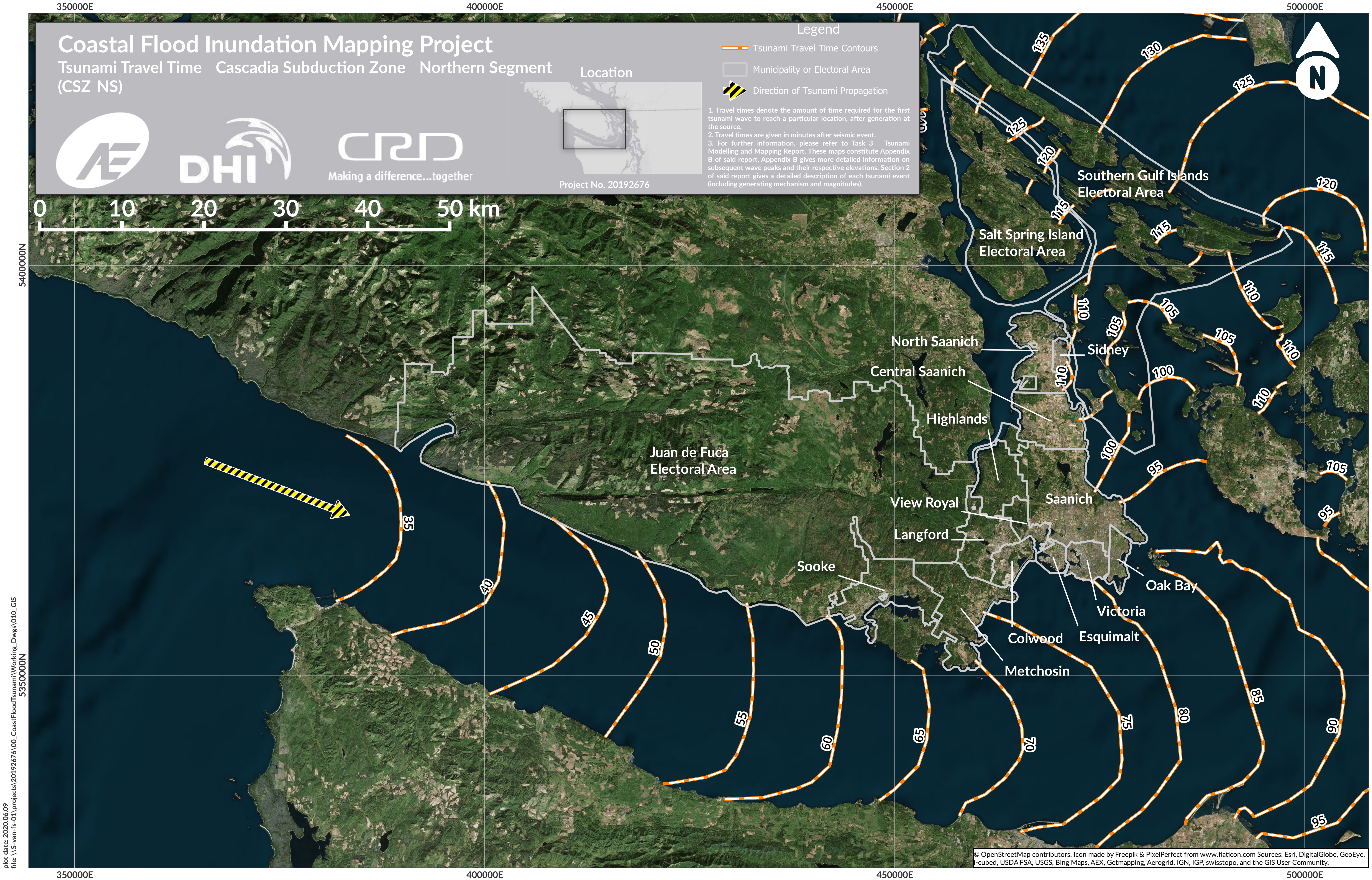

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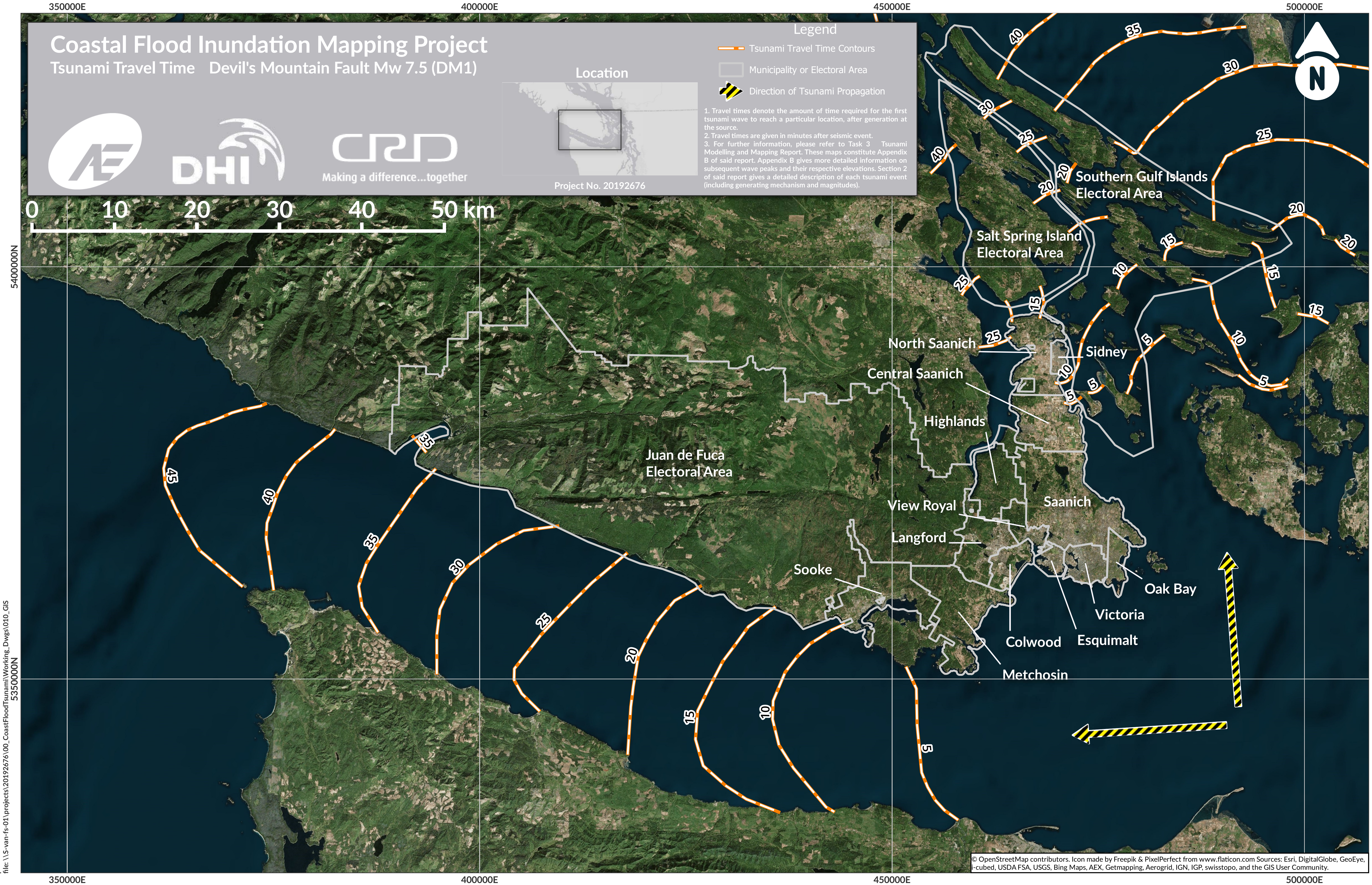

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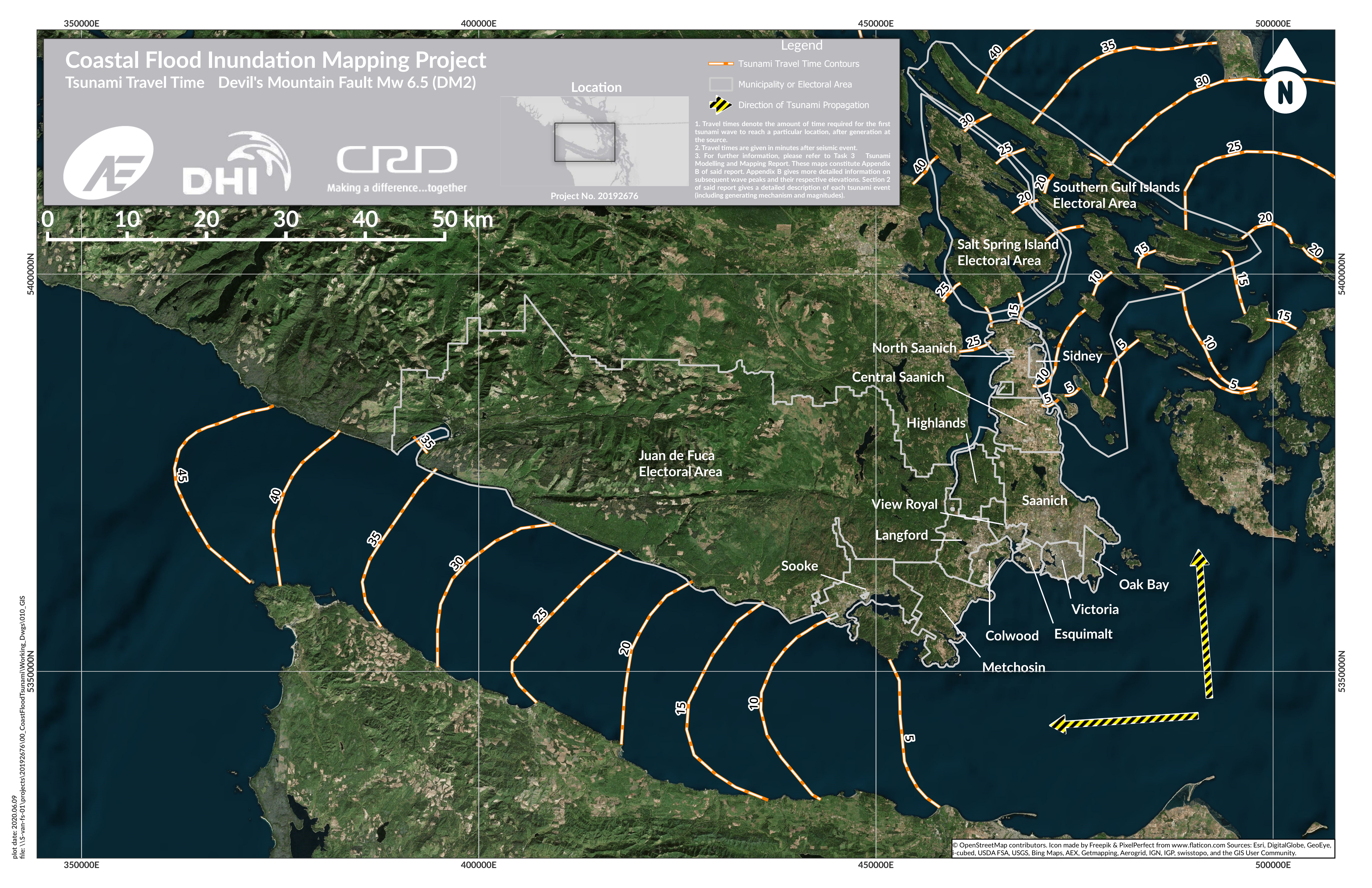
Coastal Flood Inundation Mapping Project
Tsunami Travel Time Devil's Mountain Fault Mw 6.5 (DM2)
Making a difference...together
Location
Project No. 20192676
Legend
Tsunami Travel Time Contours
Municipality or Electoral Area
Direction of Tsunami Propagation
1. Travel times denote the amount of time required for the first tsunami wave to reach a particular location, after generation at the source.
2. Travel times are given in minutes after seismic event.
3. For further information, please refer to Task 3 Tsunami Modelling and Mapping Report. These maps constitute Appendix B of said report. Appendix B gives more detailed information on subsequent wave peaks and their respective elevations. Section 2 of said report gives a detailed description of each tsunami event (including generating mechanism and magnitudes).
0 10 20 30 40 50 km
350000E
400000E
450000E
500000E
5400000N
5350000N
Southern Gulf Islands Electoral Area
Salt Spring Island Electoral Area
North Saanich
Sidney
Central Saanich
Highlands
Juan de Fuca Electoral Area
Saanich
View Royal
Langford
Sooke
Oak Bay
Victoria
Colwood
Esquimalt
Metchosin
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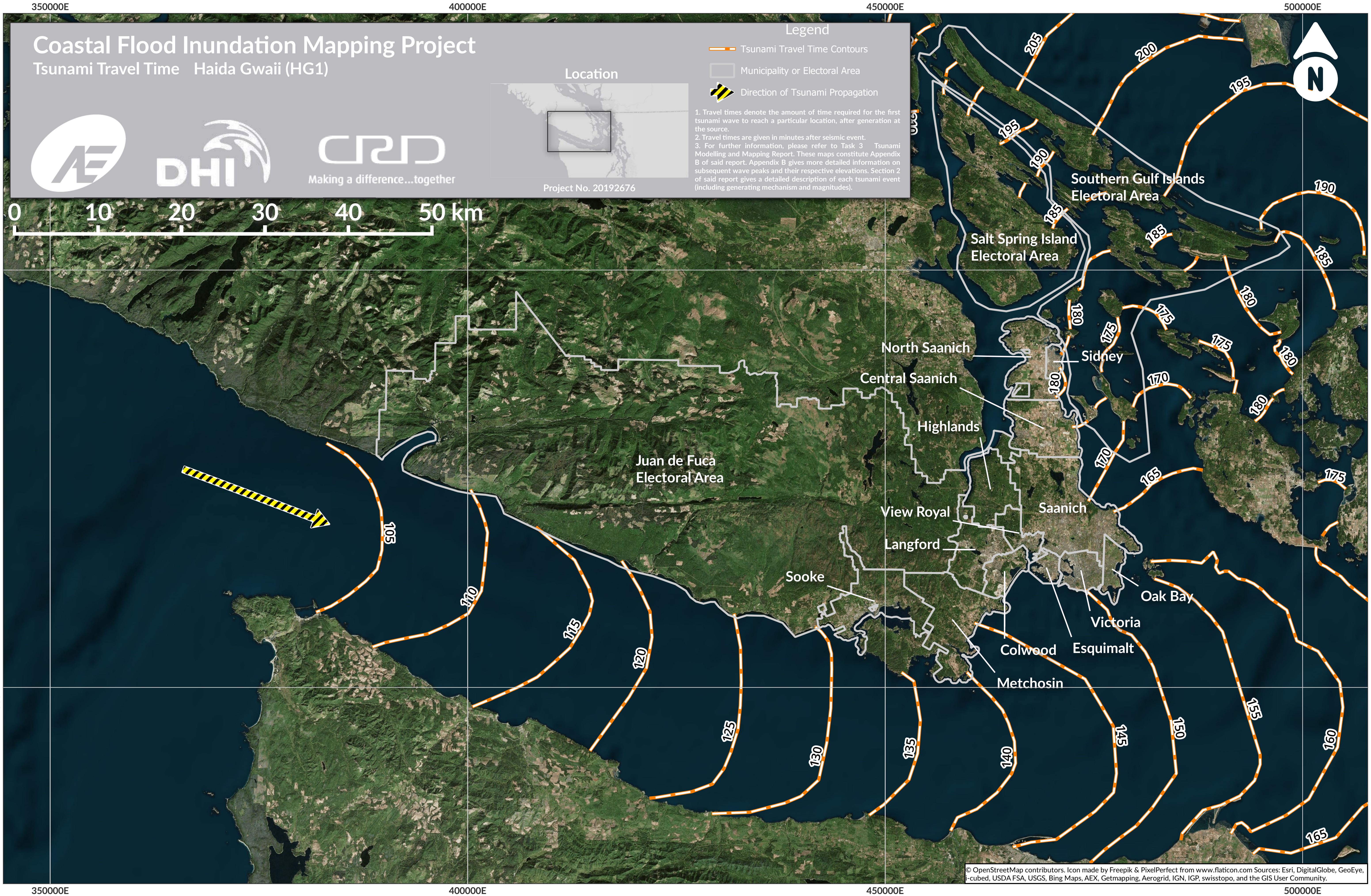
plot date: 2020.06.09
file: \\S-van-fs-01\projects\20192676\00_CoastFloodTsunami\Working_Dwgs\010_GIS



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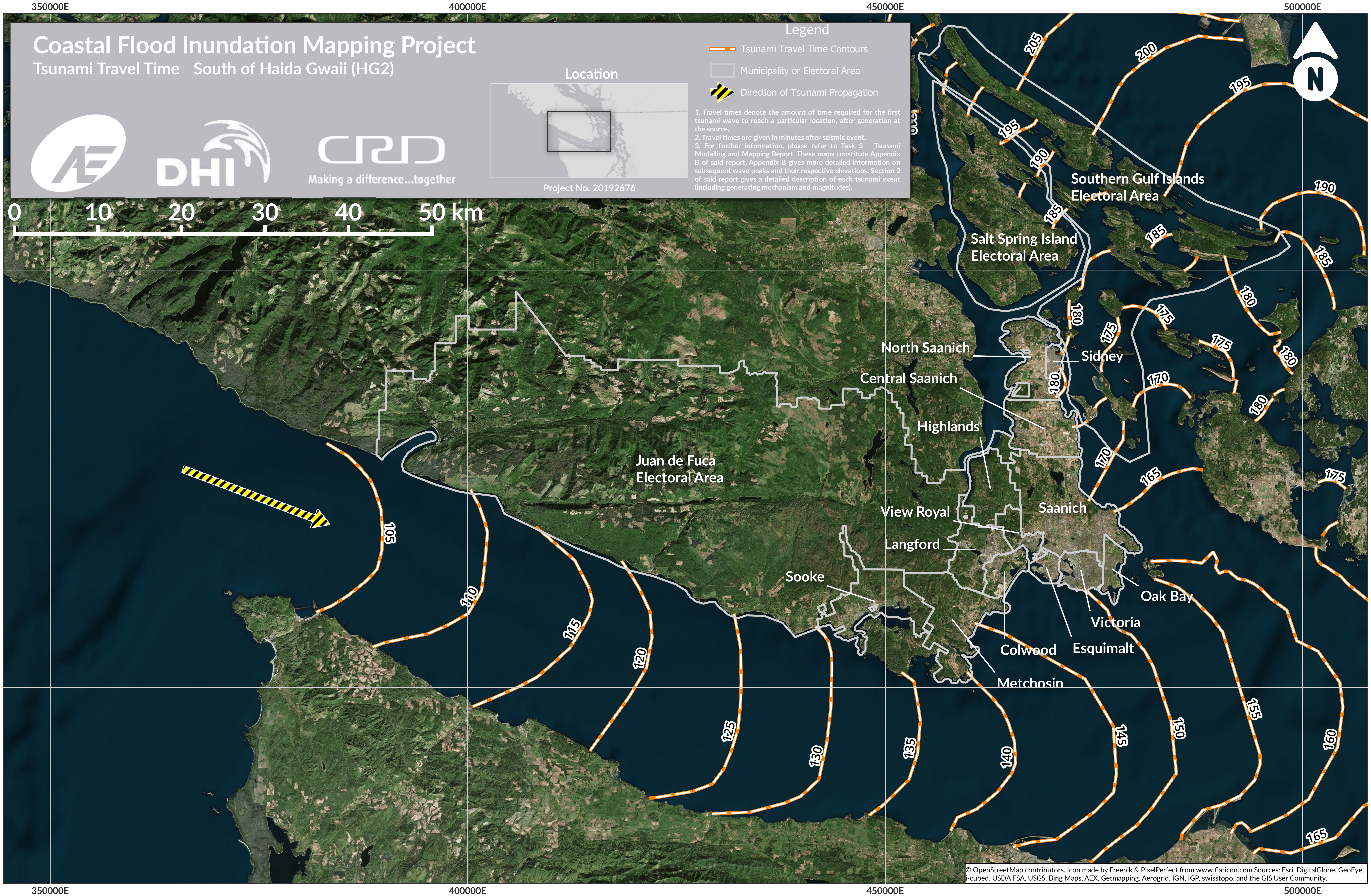

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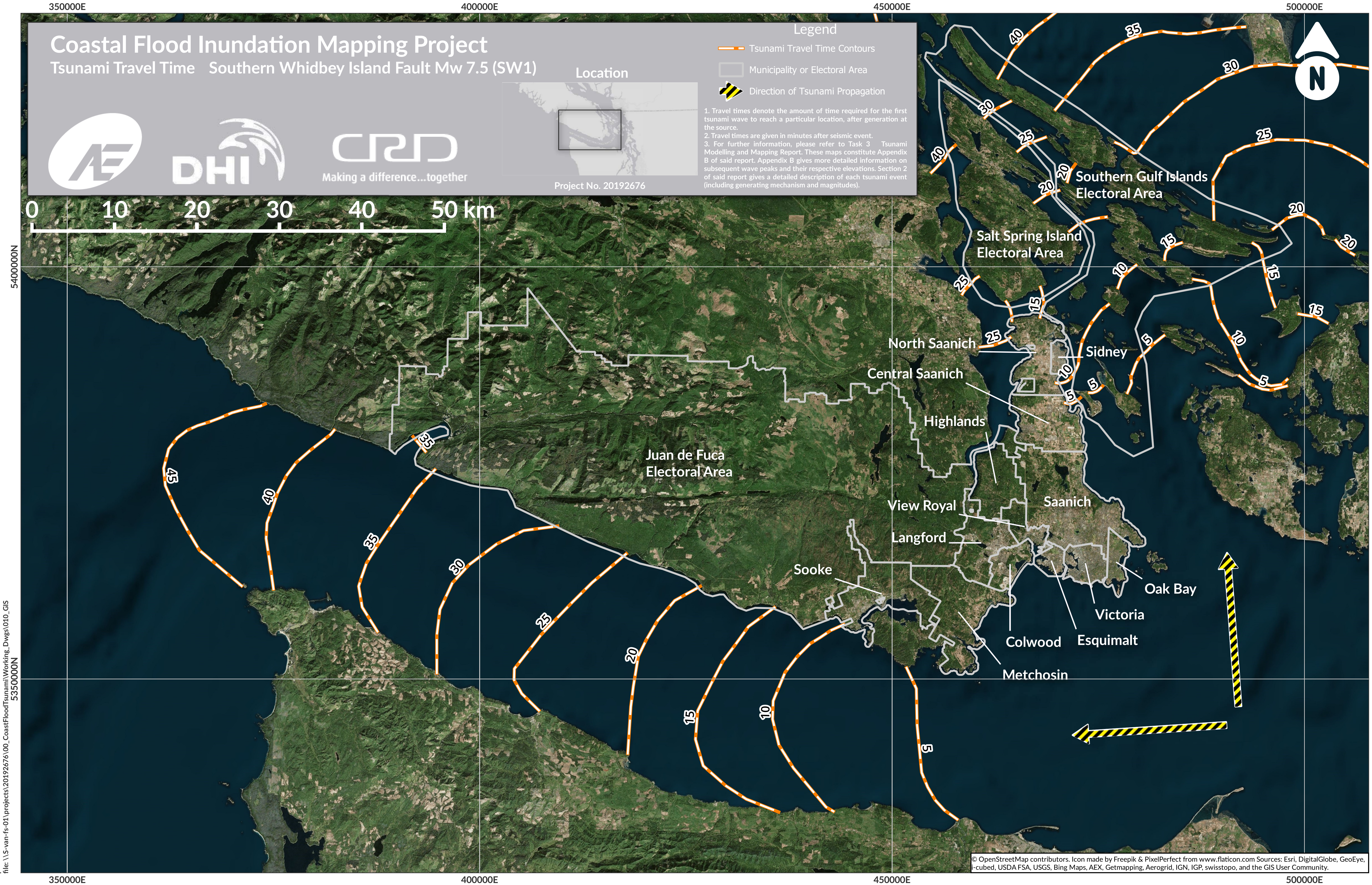
Coastal Flood Inundation Mapping Project

Tsunami Travel Time   Southern Whidbey Island Fault Mw 7.5 (SW1)



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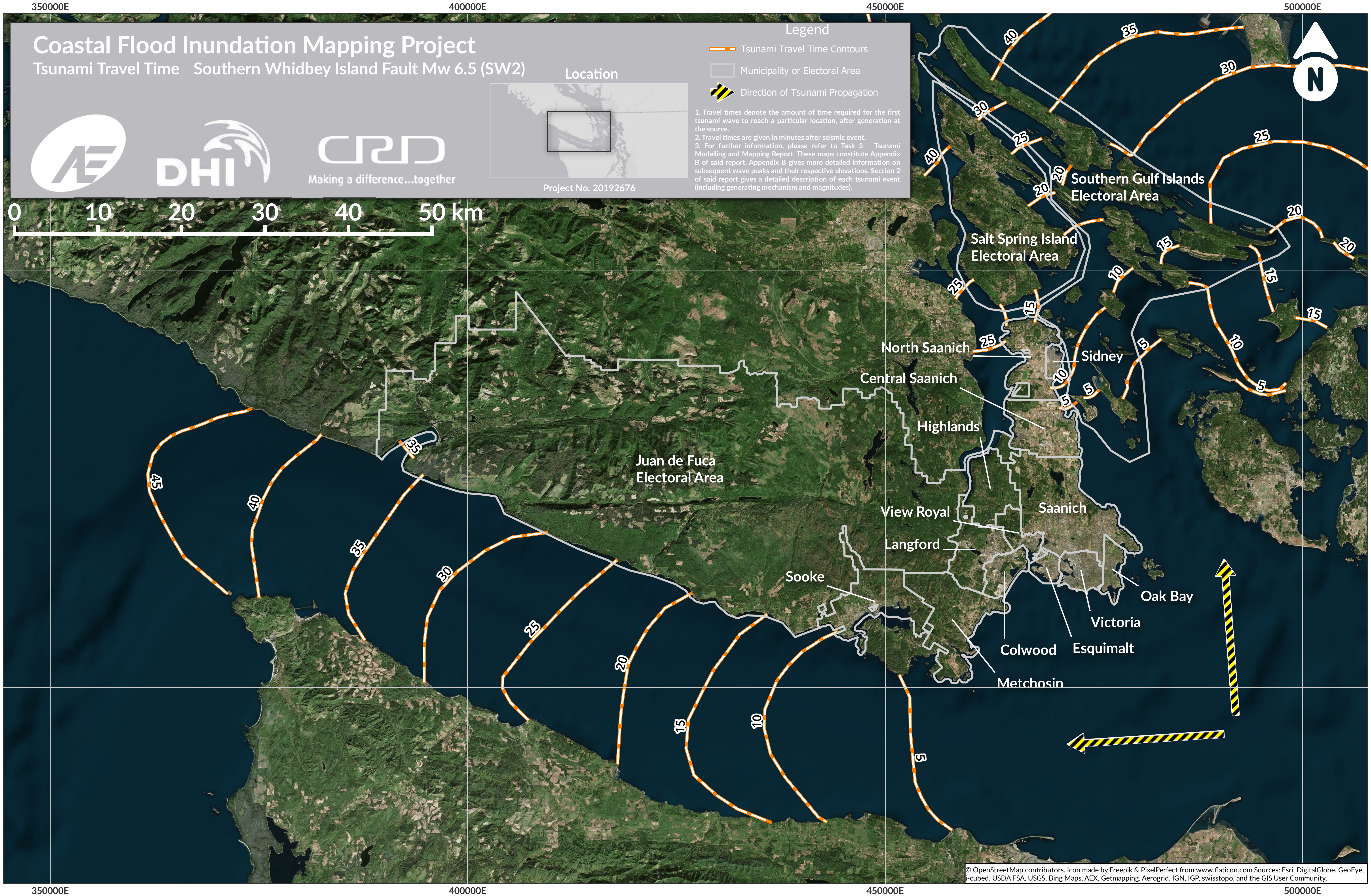

Coastal Flood Inundation Mapping Project
Tsunami Travel Time Southern Whidbey Island Fault Mw 6.5 (SW2)
Making a difference...together
Location
Project No. 20192676
Legend
Tsunami Travel Time Contours
Municipality or Electoral Area
Direction of Tsunami Propagation
1. Travel times denote the amount of time required for the first tsunami wave to reach a particular location, after generation at the source.
2. Travel times are given in minutes after seismic event.
3. For further information, please refer to Task 3 Tsunami Modelling and Mapping Report. These maps constitute Appendix B of said report. Appendix B gives more detailed information on subsequent wave peaks and their respective elevations. Section 2 of said report gives a detailed description of each tsunami event (including generating mechanism and magnitudes).
0 10 20 30 40 50 km
350000E
400000E
450000E
500000E
5400000N
5350000N
Southern Gulf Islands Electoral Area
Salt Spring Island Electoral Area
North Saanich
Sidney
Central Saanich
Highlands
Juan de Fuca Electoral Area
Saanich
View Royal
Langford
Sooke
Oak Bay
Victoria
Colwood
Esquimalt
Metchosin
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plot date: 2020.06.09
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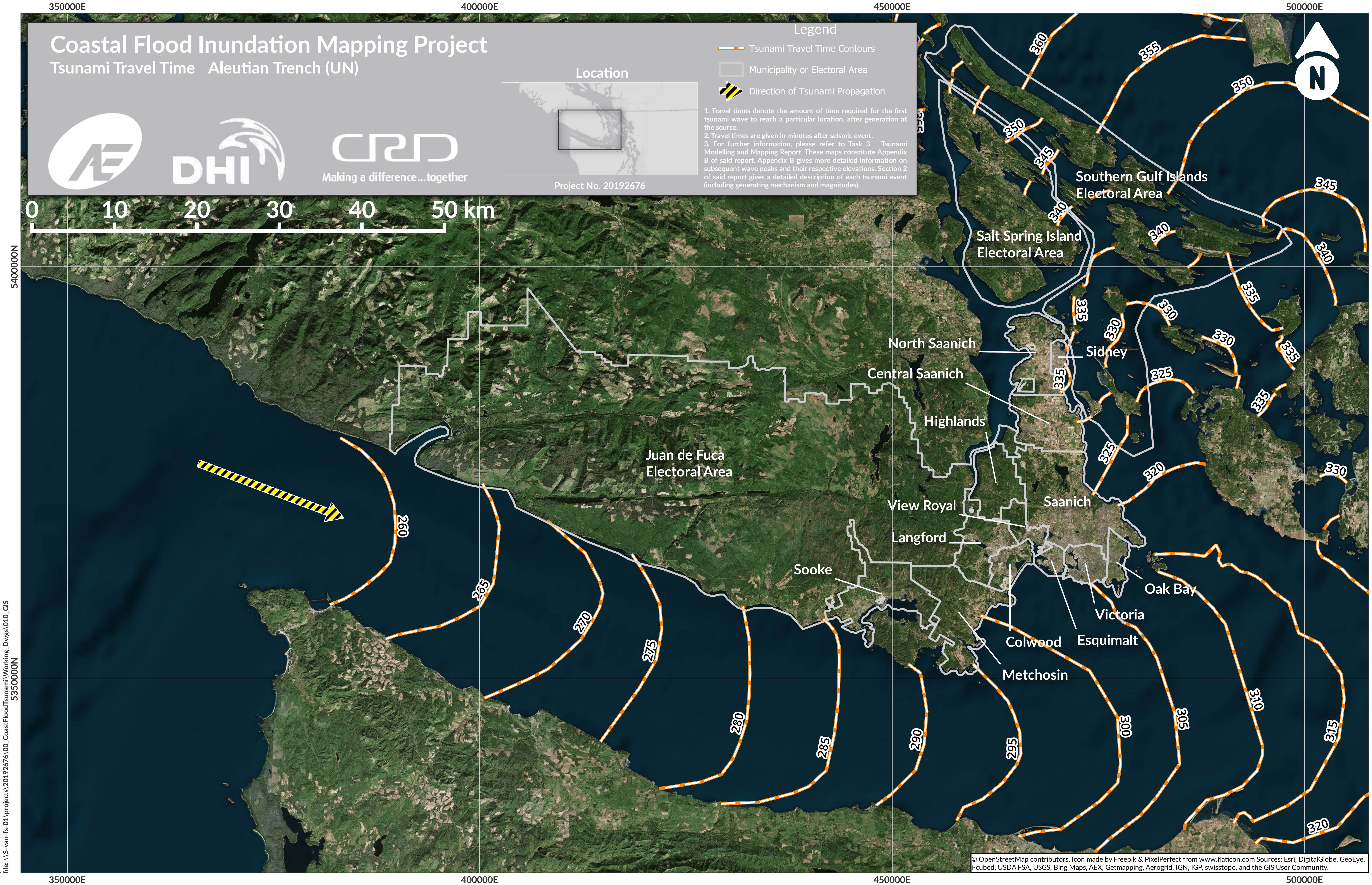

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APPENDIX C – TSUNAMI INUNDATION MAPPING

Appendix C, which contains tsunami inundation maps for the CSZ L1, CSZ-NS, SW1 and DM1 cases, is provided as a stand-alone pdf file.


350000E
400000E
450000E
500000E
5400000
5350000
N
0
10
20
30
40
50 km
1
2
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4
5
6
7
8
9
10
11
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13
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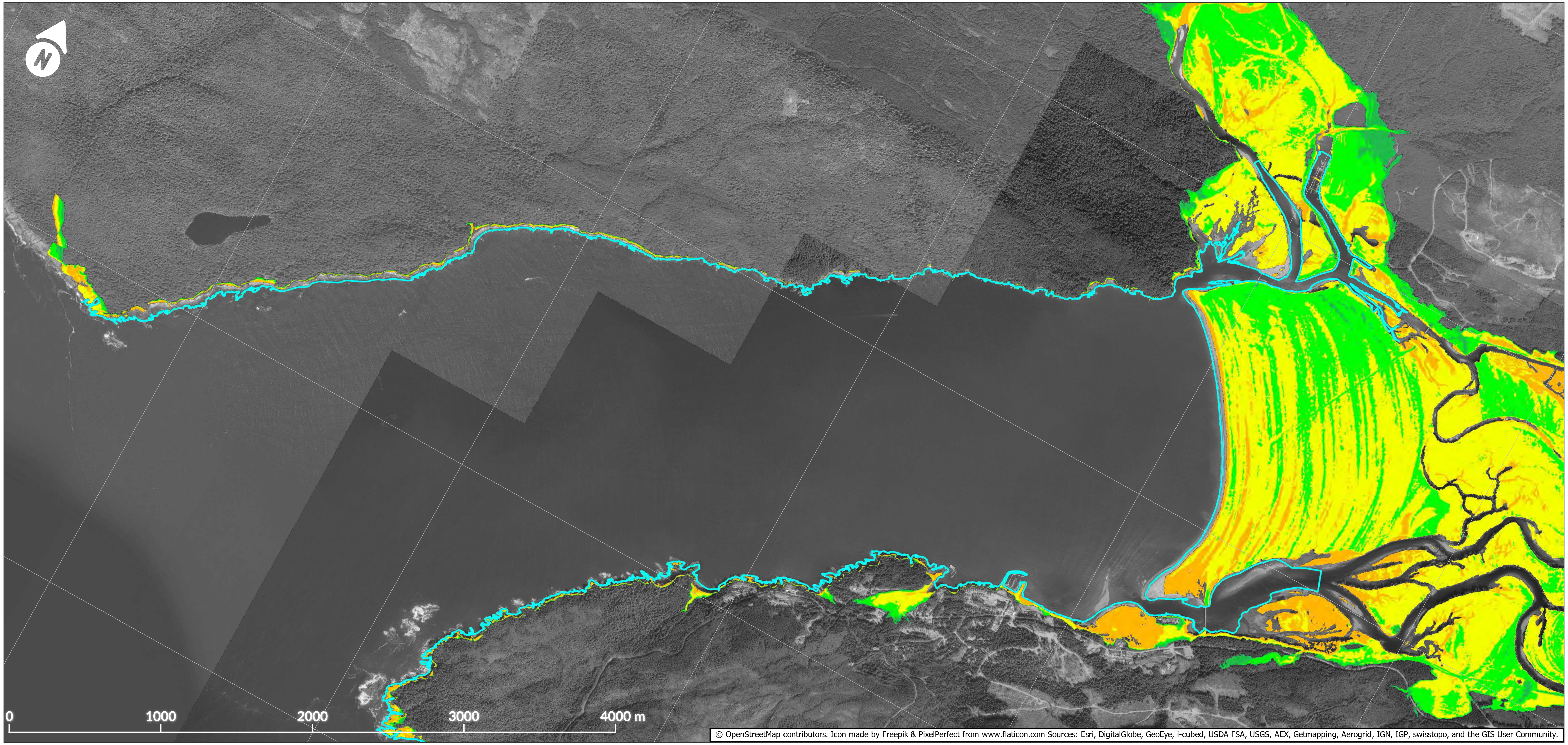
41
Coastal Flood Inundation Mapping Project
Tsunami Inundation Map Index heet
Location
Legend
CRD Boundary
DHI
Making a difference...together
1. For further information, please refer to Tas 3 – Tsunami Modelling and Mapping Report. These maps constitute Appendix C of said report.
Project o. 20192676
plot date: 2020.06.10
© O enStreetMa c ntribut rs. Ic n made by Free ik & PixelPerfect fr m www.fla c n.c m S urces: Esri, DigitalGl be, Ge Eye, i-cubed, USDA FSA, USGS, Bing Ma s, AEX, Getma ing, Aer grid, IGN, IGP, swisst , and the GIS User C mmunity.



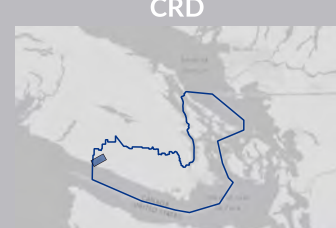
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

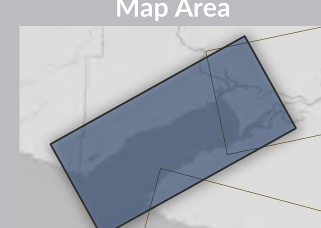
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



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DHI

Legend

Coastline

Inundation Depth (m)

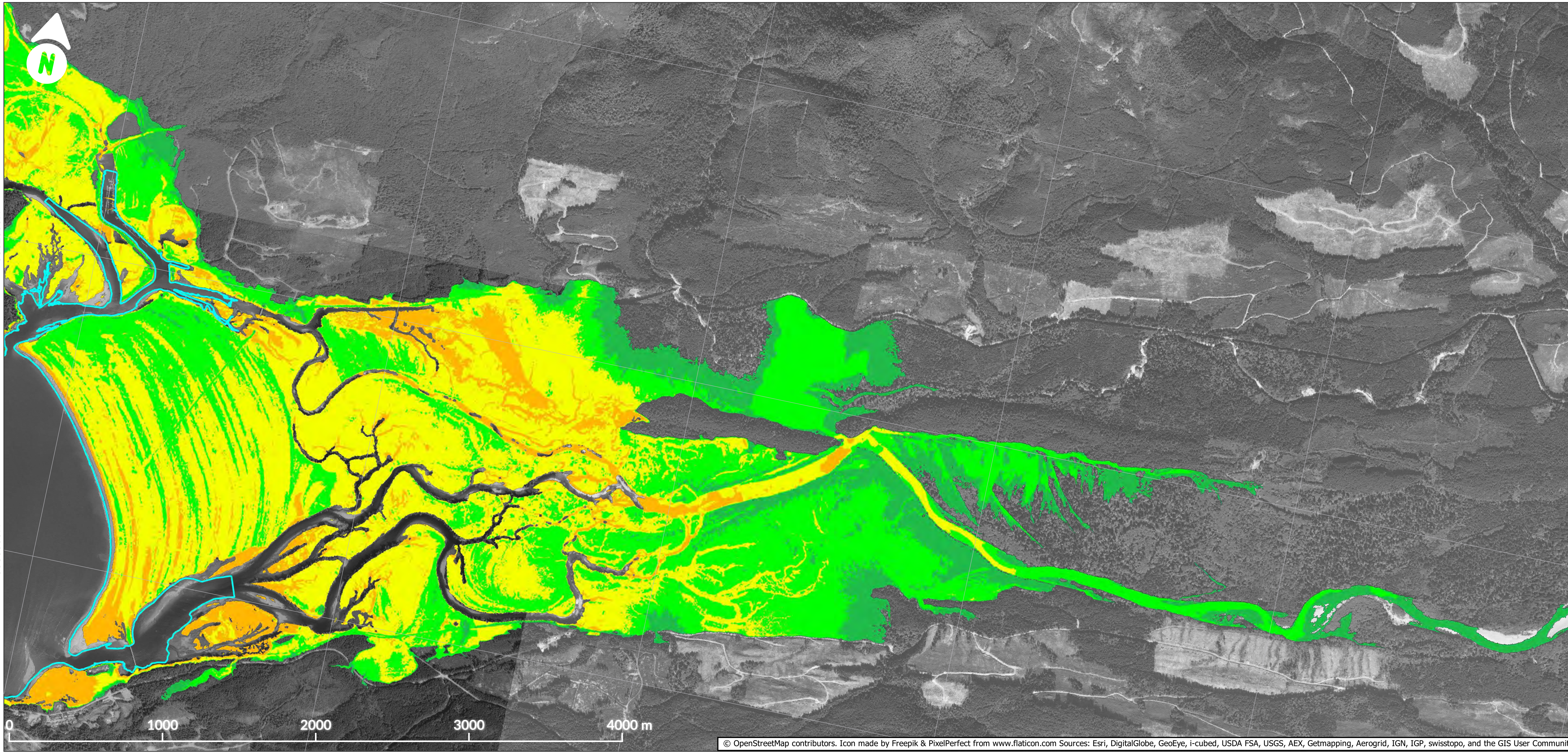
- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
2. Users must n te the dates f base mapping, aerial ph t graphy, gr und r bathymetric surveys and issue f mapping relevant t dates of devel pment in the map area. Subsequent changes al ng the c astline and/ r in the fl dplain can affect analytical results and render site-specific map inf rmati n bs lete.
3. Digital Elevati n M del includes t p graphic surface data fr m Ge BC (2019), and bathymetric surface data fr m CHS and NOAA (dates vary). Elevati ns are rep rted with reference t CGVD2013 vertical datum. Map Pr jecti n is NAD83 UTM Z ne 10N (CSRS).
4. Data s urces: Orth imagery (CRD, 2017)
5. F r further inf rmati n, please refer t Task 3 – Tsunami M delling and Mapping Rep rt. These maps c nstitute Appendix C f said rep rt.

Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 1 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



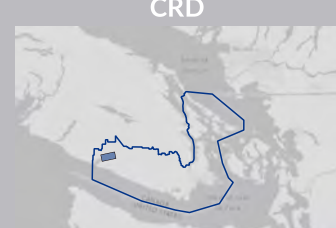
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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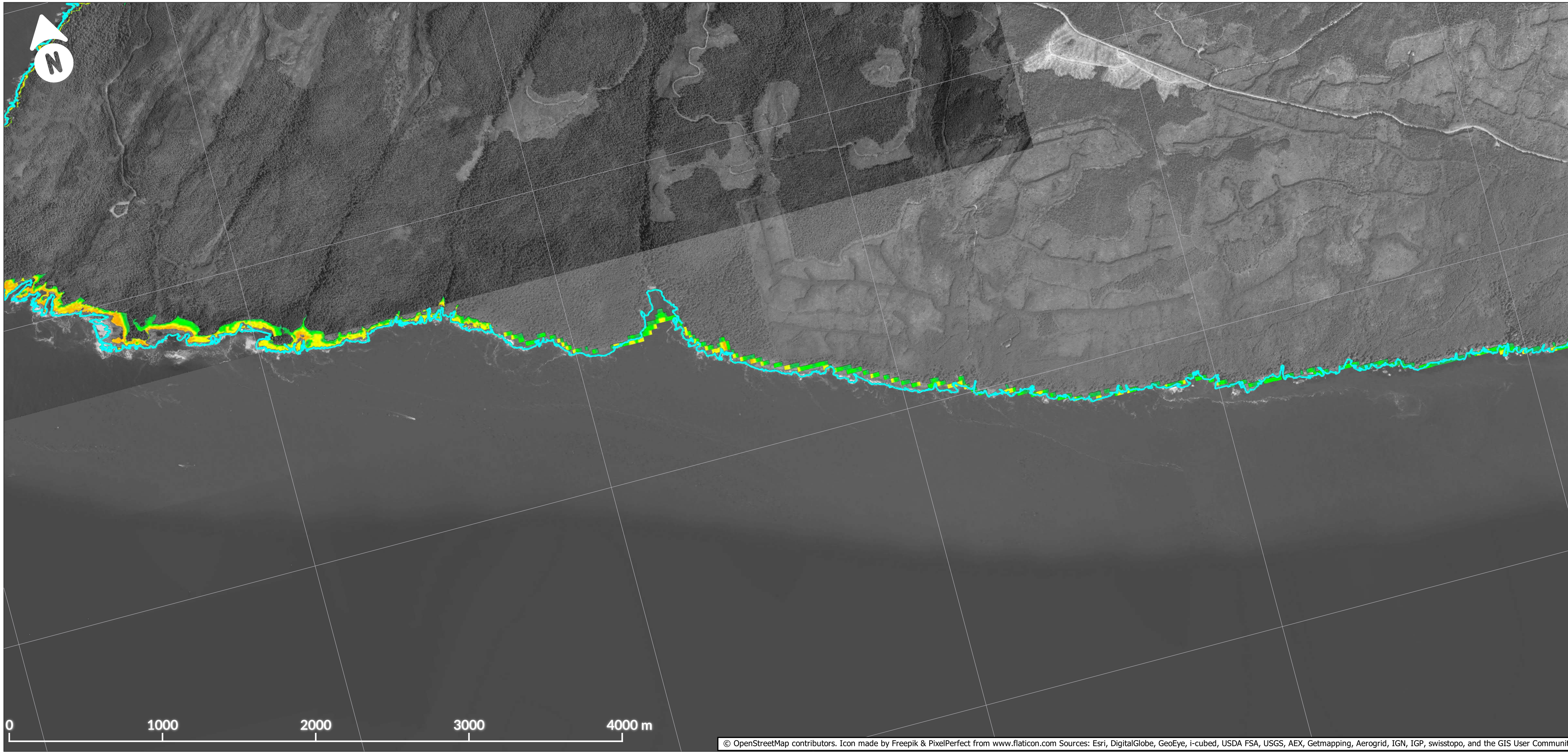
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 2 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



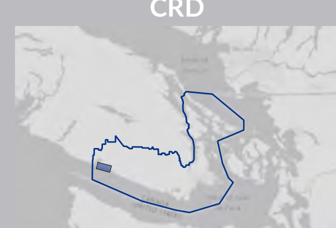
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

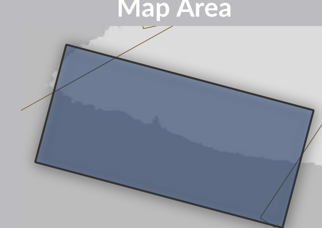
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Making a difference...together

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 3 f 41

pl t date: 2020.06.10
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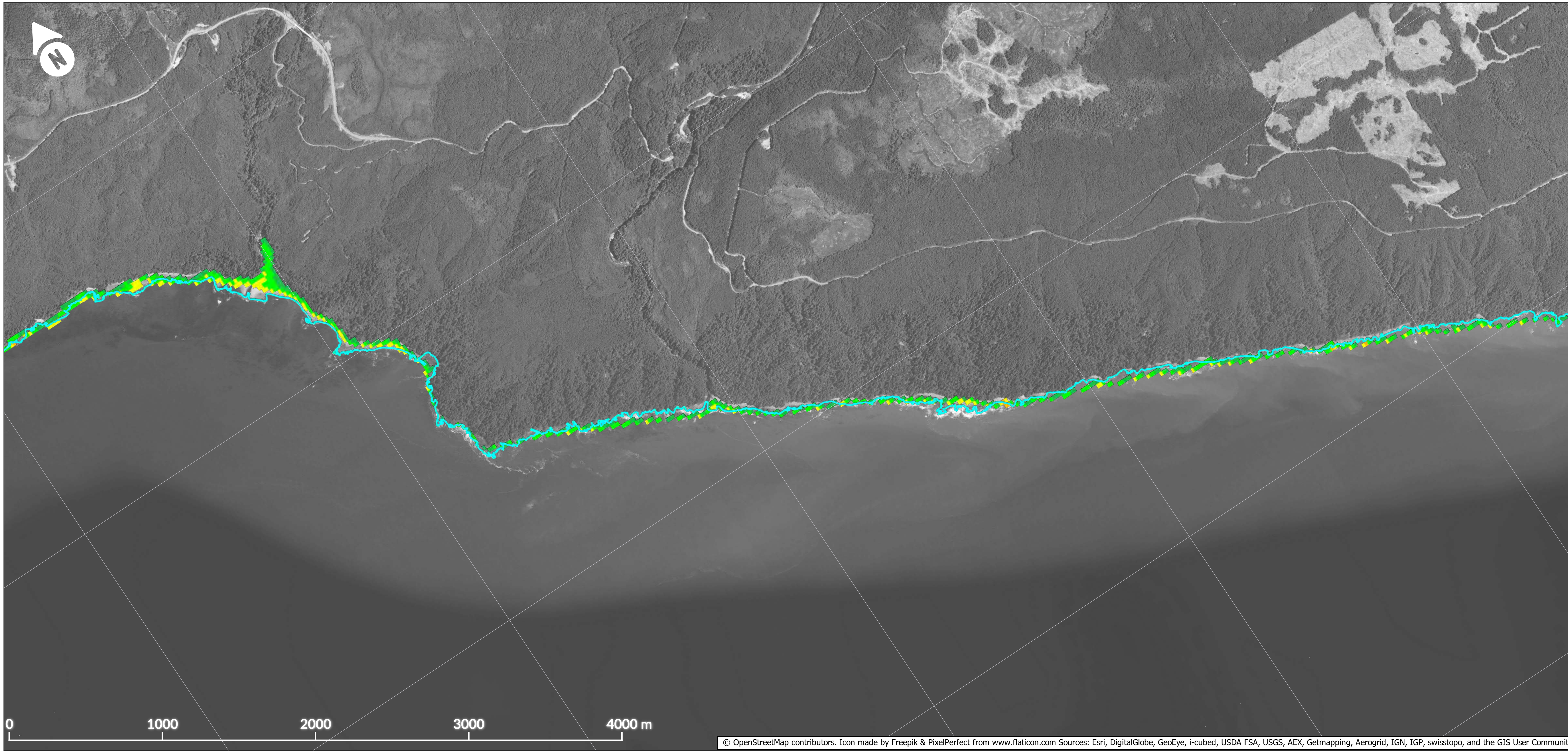


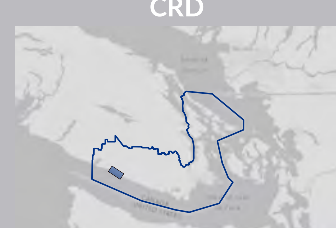
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

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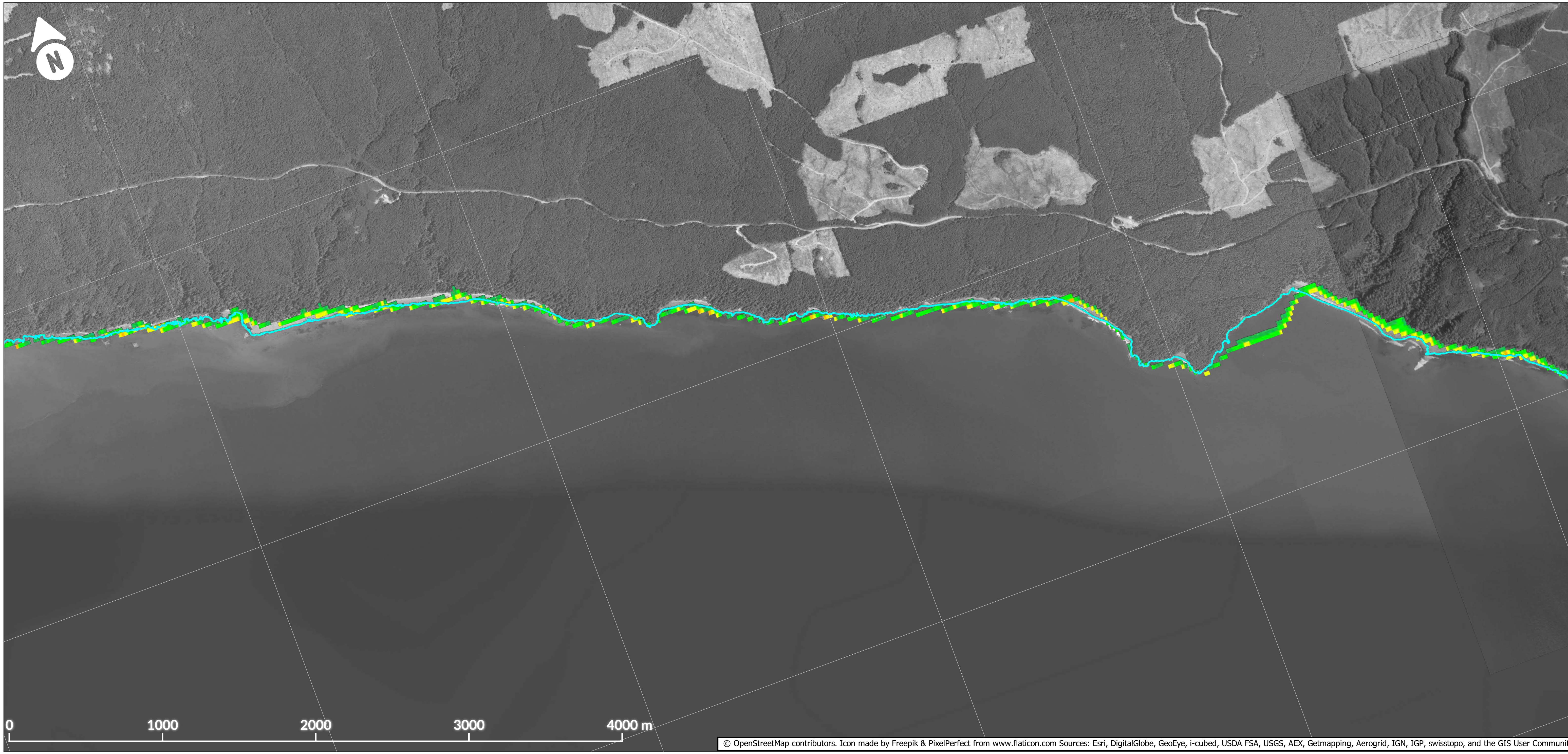
pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



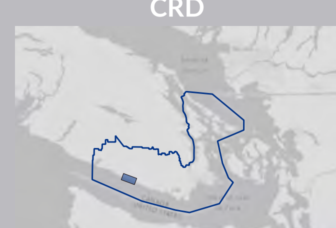
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 5 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

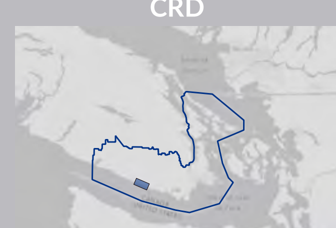
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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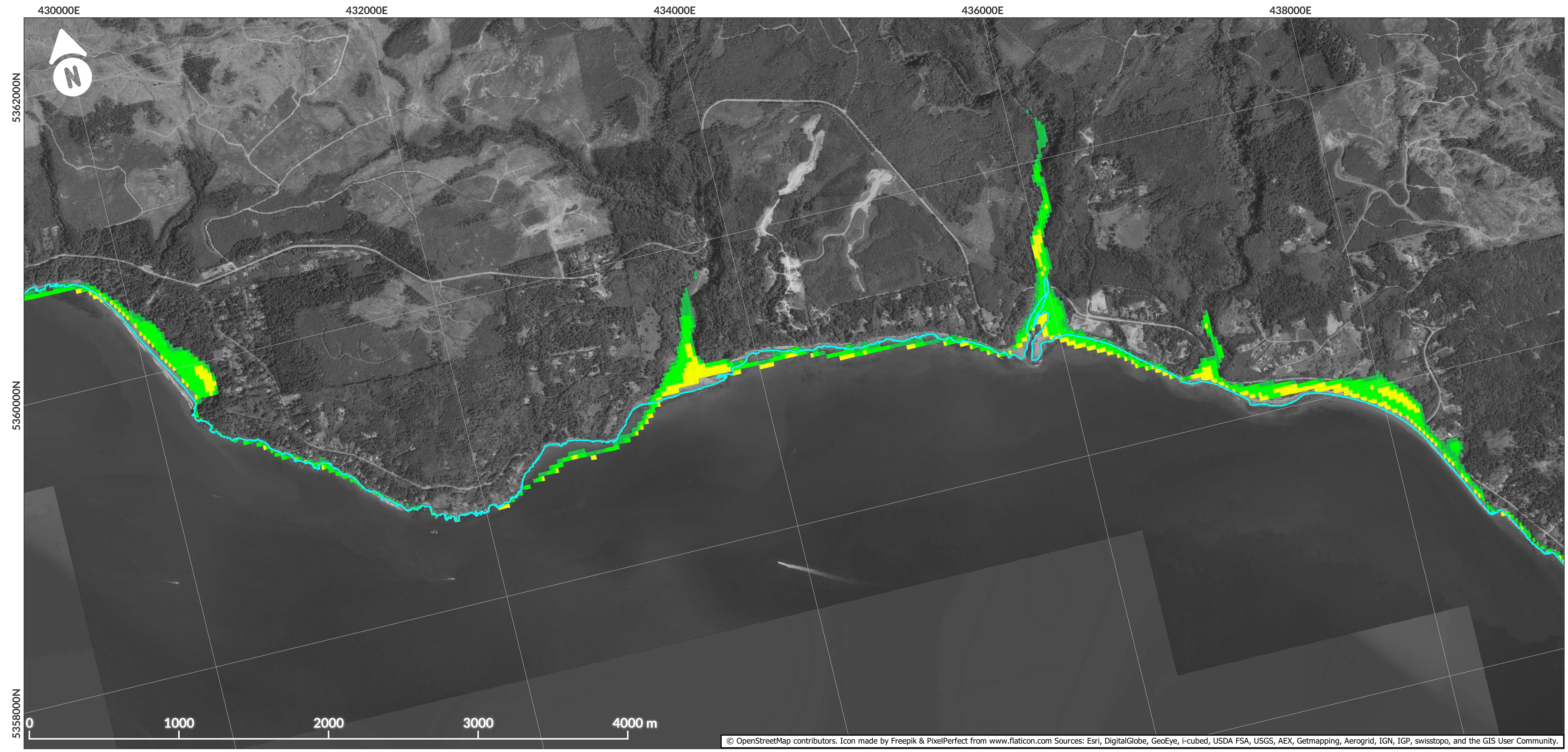
Map Sheet 6 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



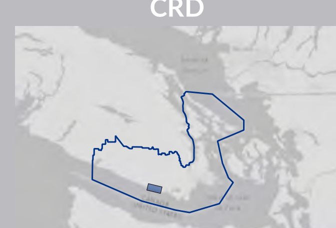
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 7 f 41

pl t date: 2020.06.10
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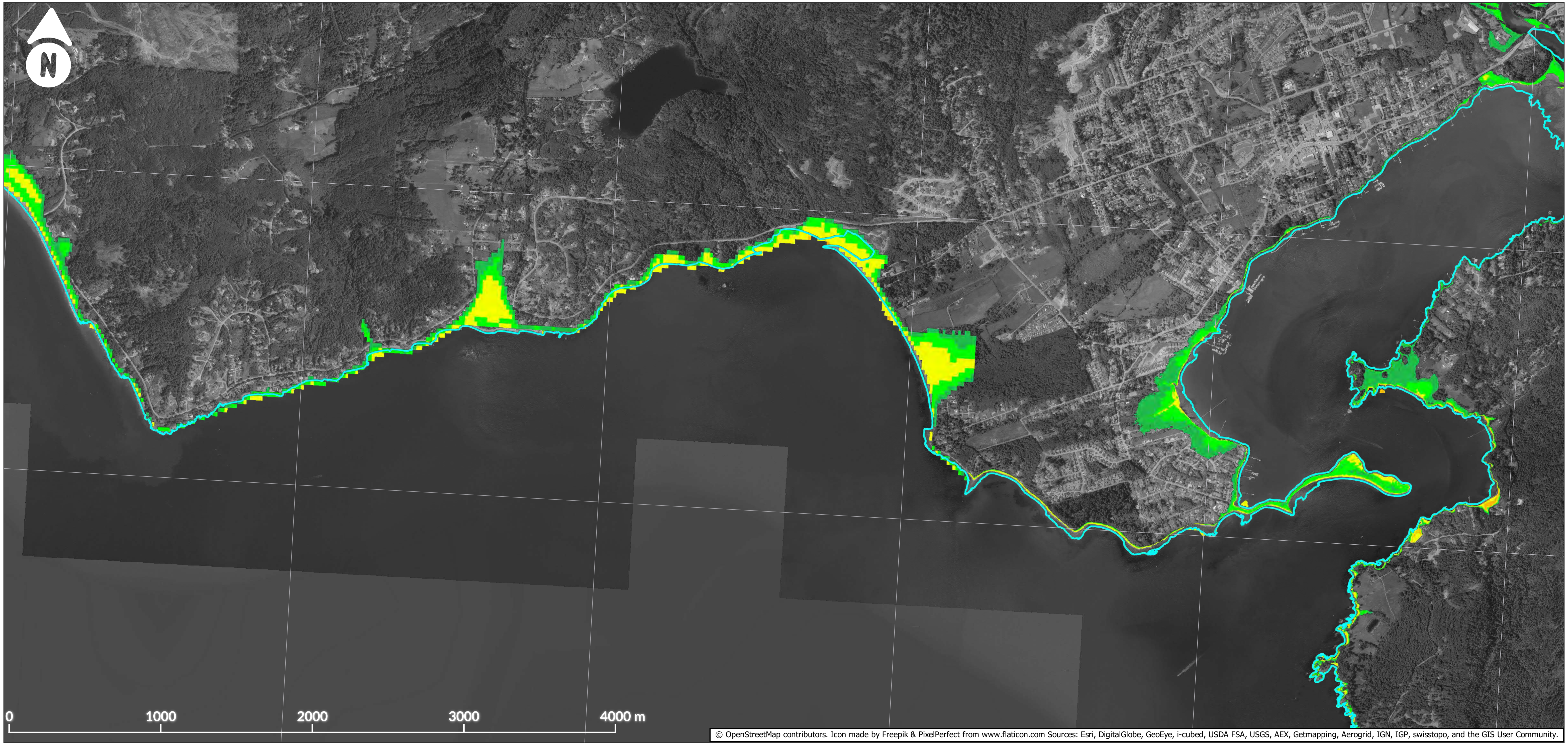


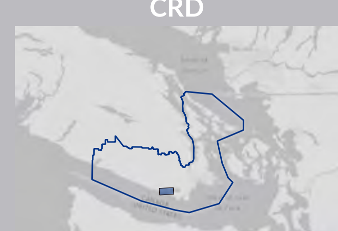
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

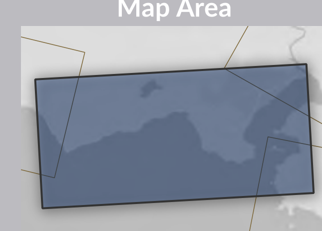
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 8 f 41

pl t date: 2020.06.11
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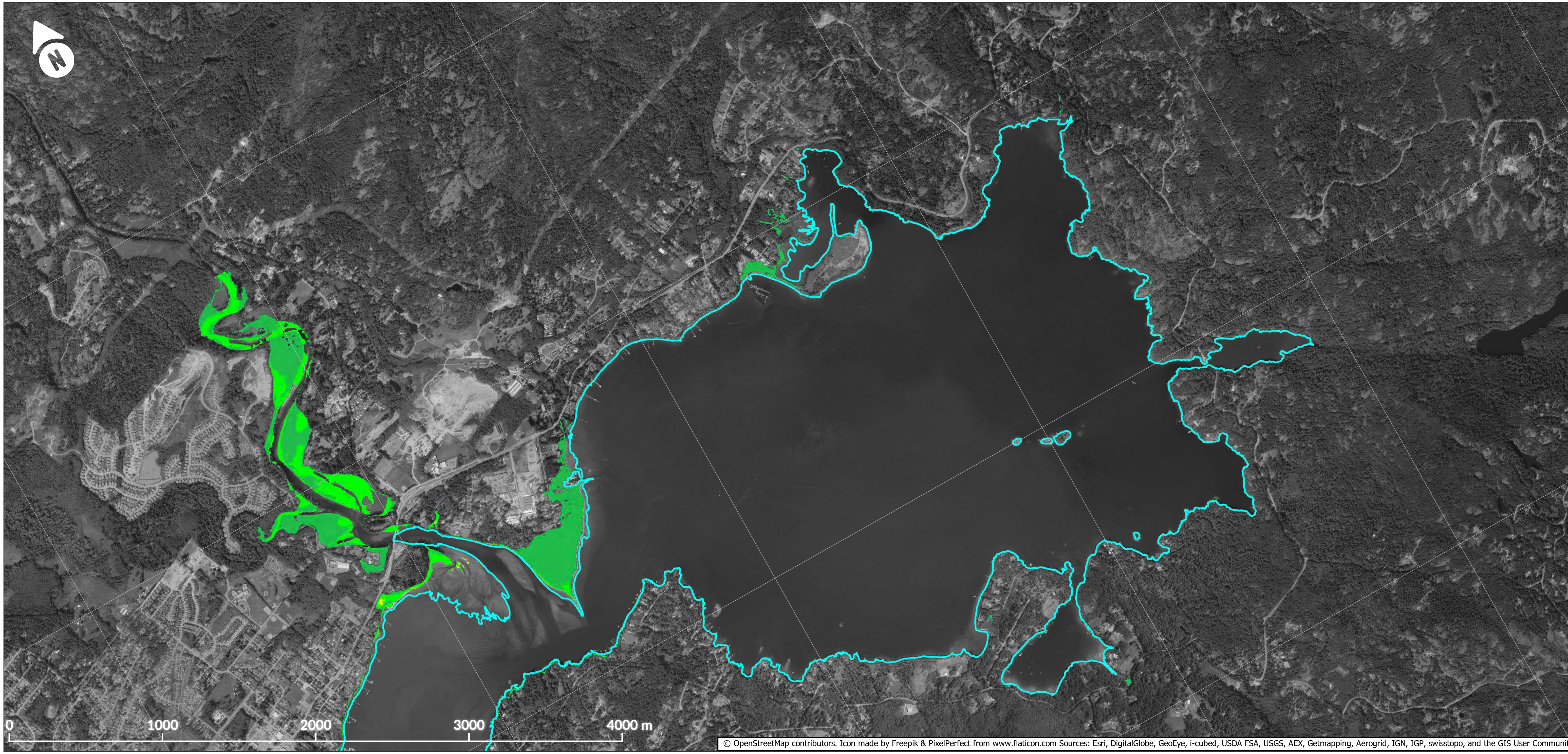


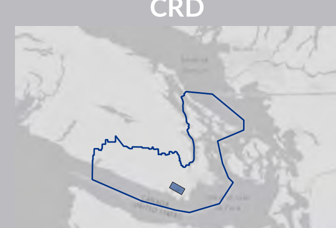
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

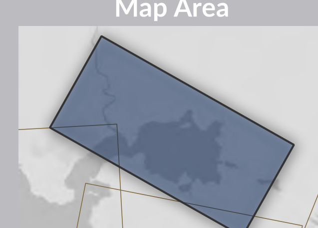
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Making a difference...together

DHI

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 9 f 41

pl t date: 2020.06.11
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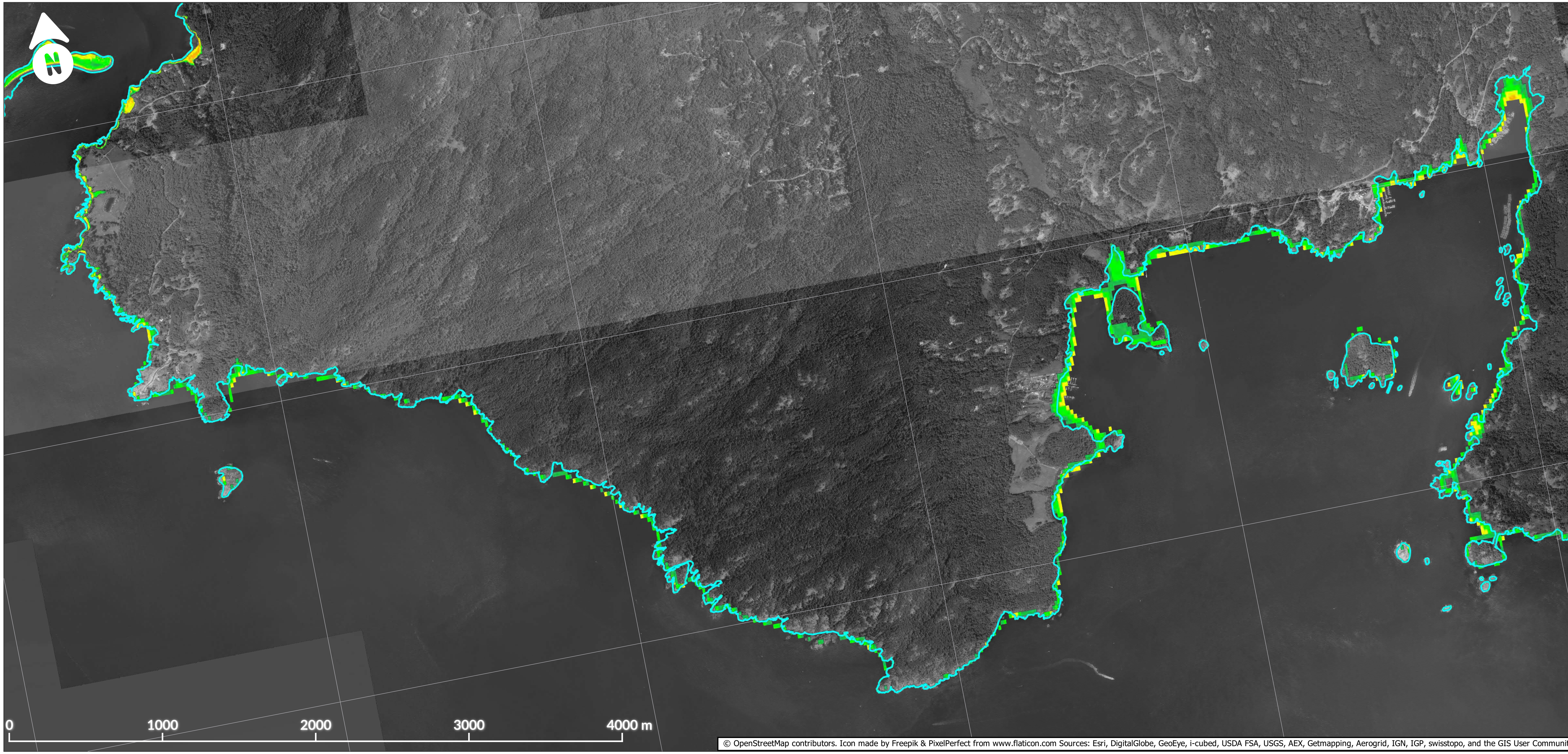


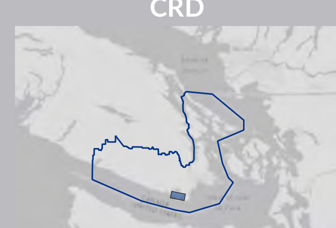
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

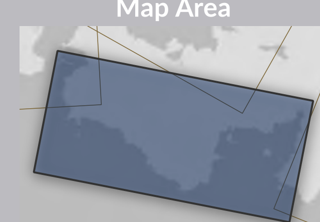
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Legend

Coastline

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Pr ject N . 20192676
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Map Sheet 10 f 41

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pl t date: 2020.06.11
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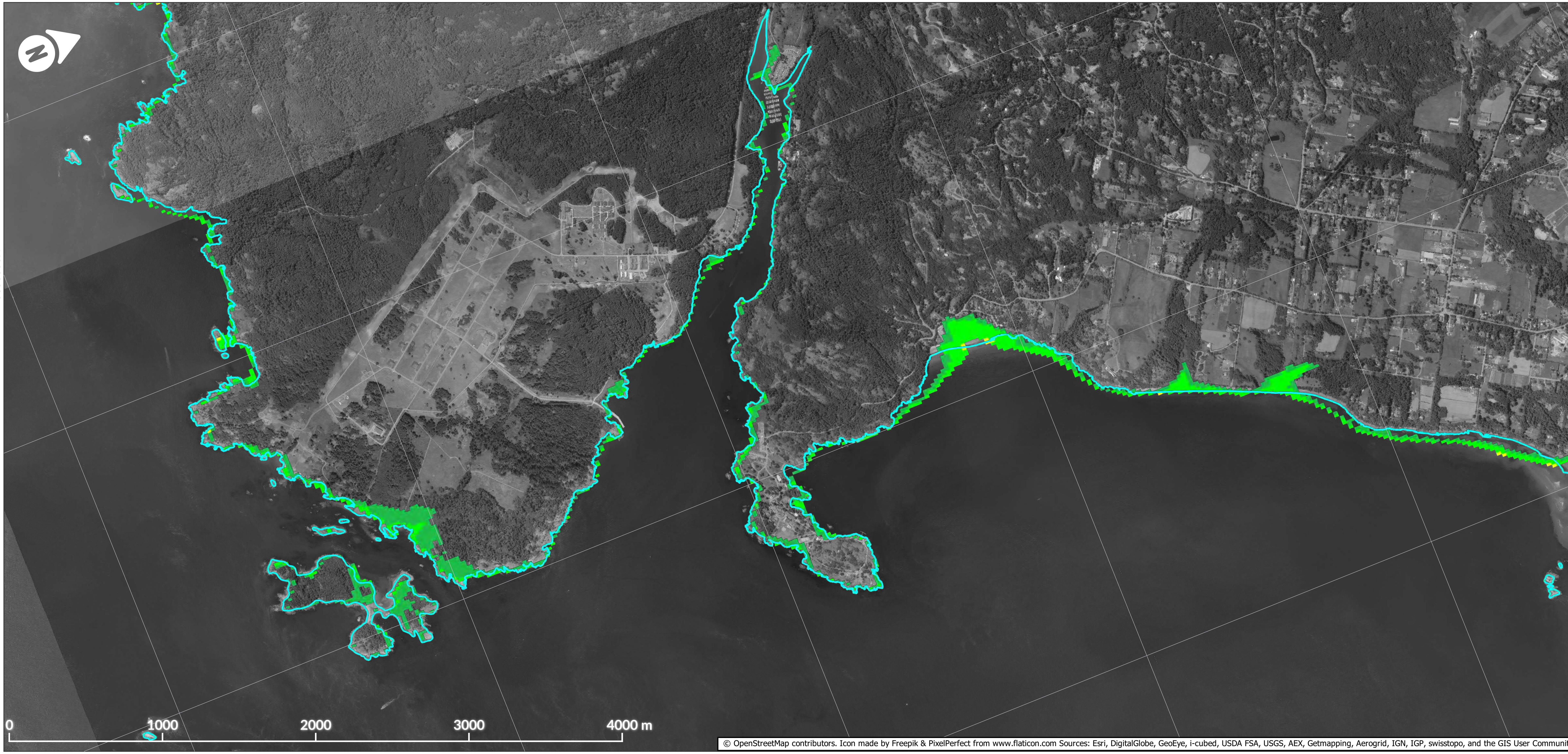


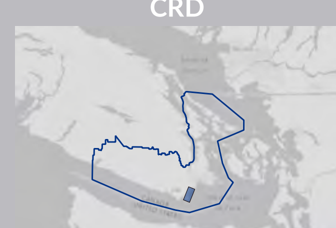
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Legend

Coastline

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Map Sheet 11 f 41

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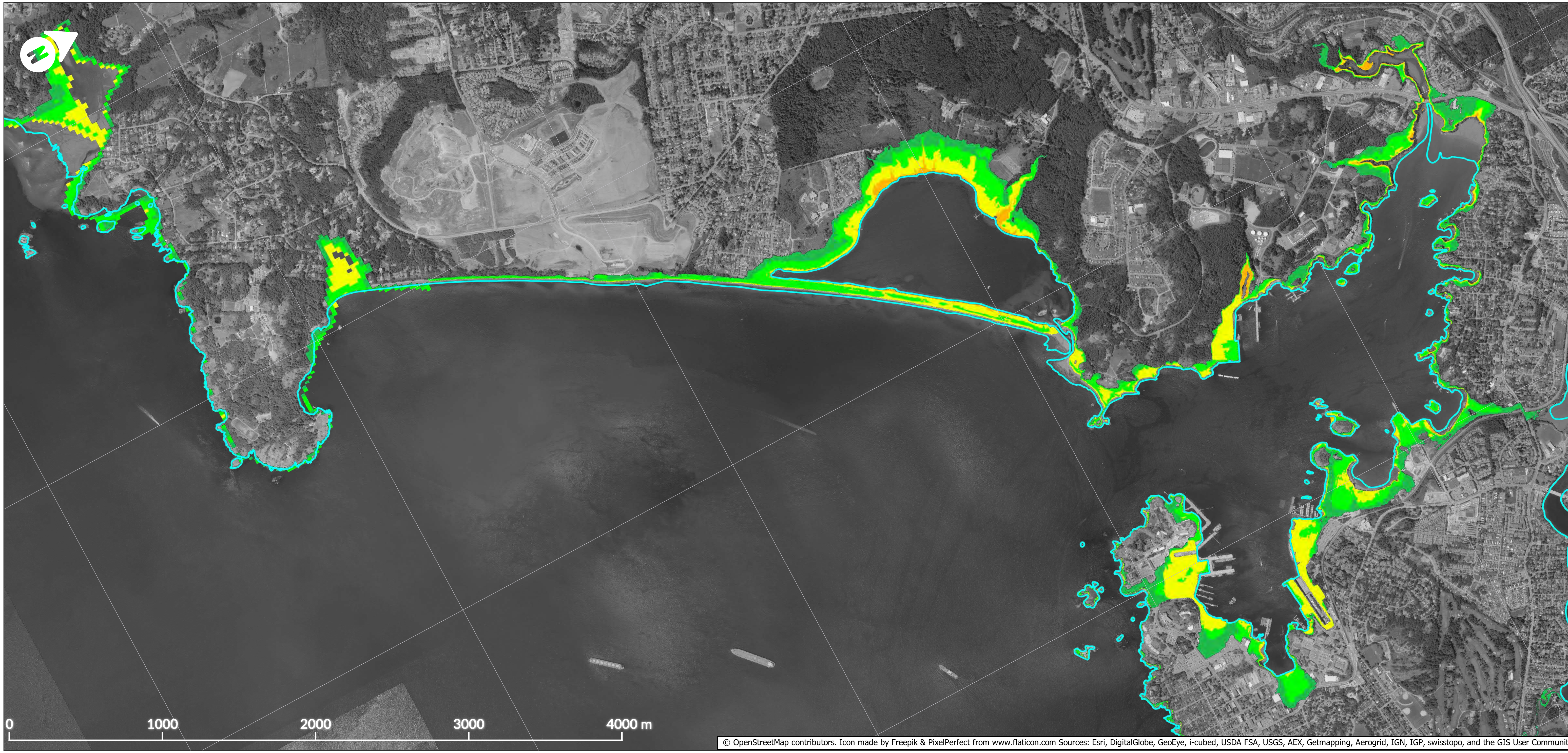


C astal Fl d Inundati n Mapping Pr ject

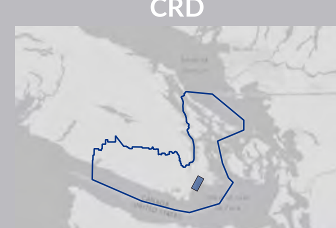
Capital Regi nal District

March 2020

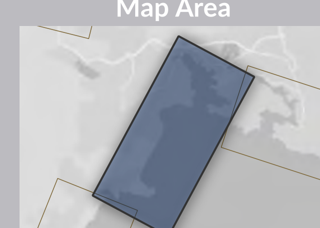
Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

Making a difference...together

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 12 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

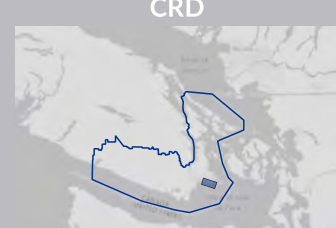
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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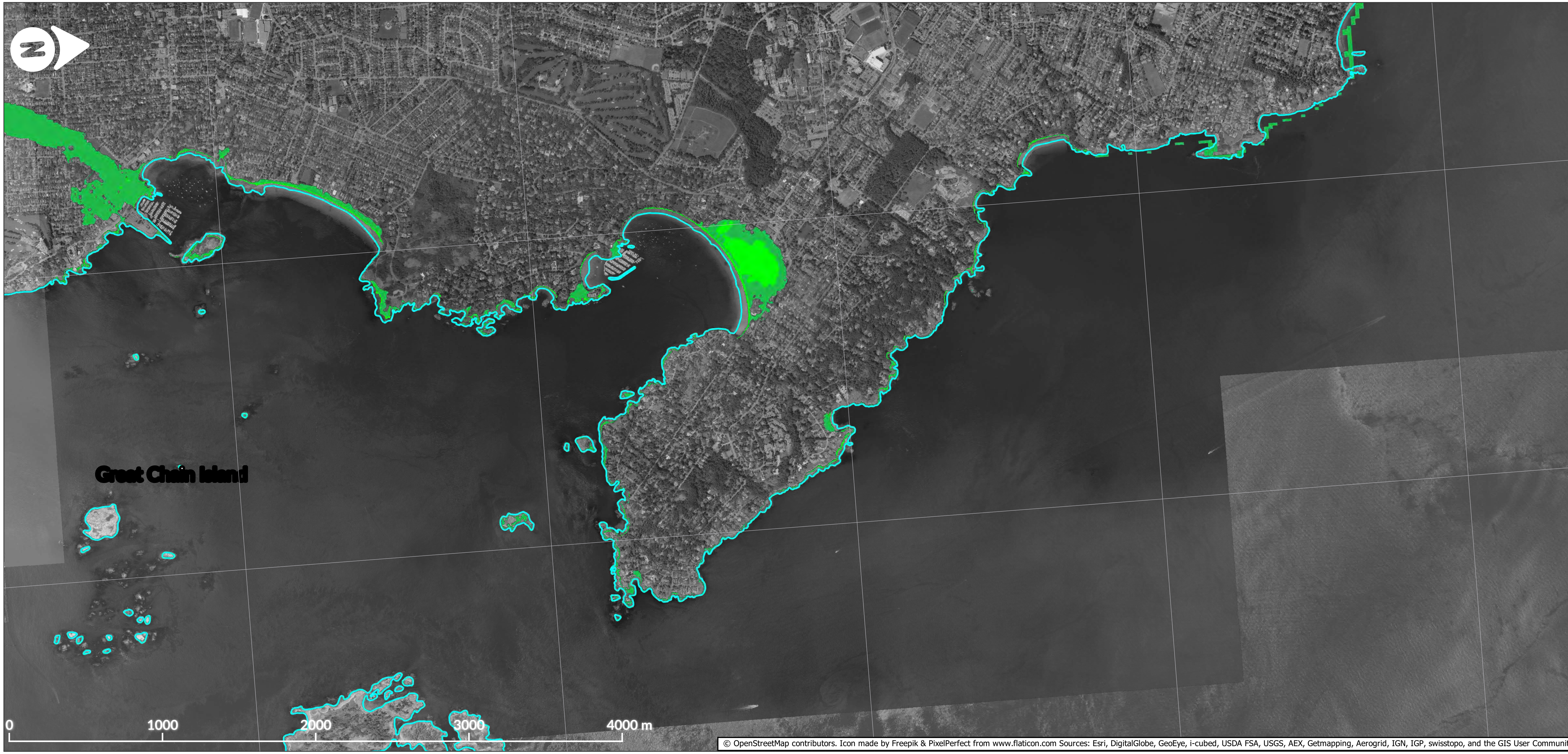
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 13 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



C astal Fl d Inundati n Mapping Pr ject

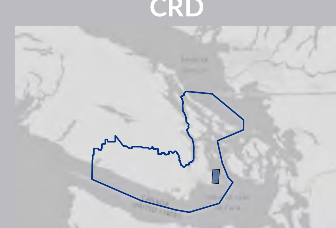
Capital Regi nal District

March 2020

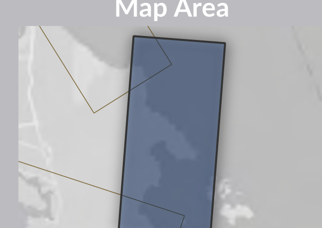
Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

Making a difference...together

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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pl t date: 2020.06.11
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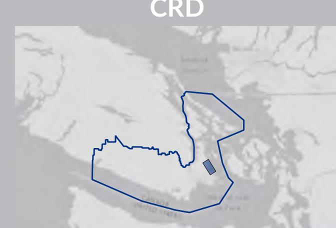
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

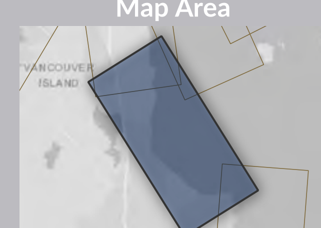
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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Map Sheet 15 f 41

pl t date: 2020.06.11
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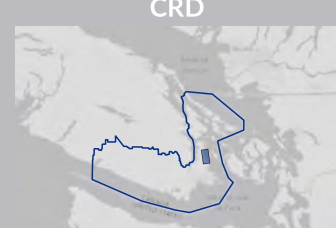
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

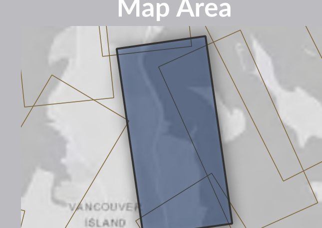
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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Map Sheet 16 f 41

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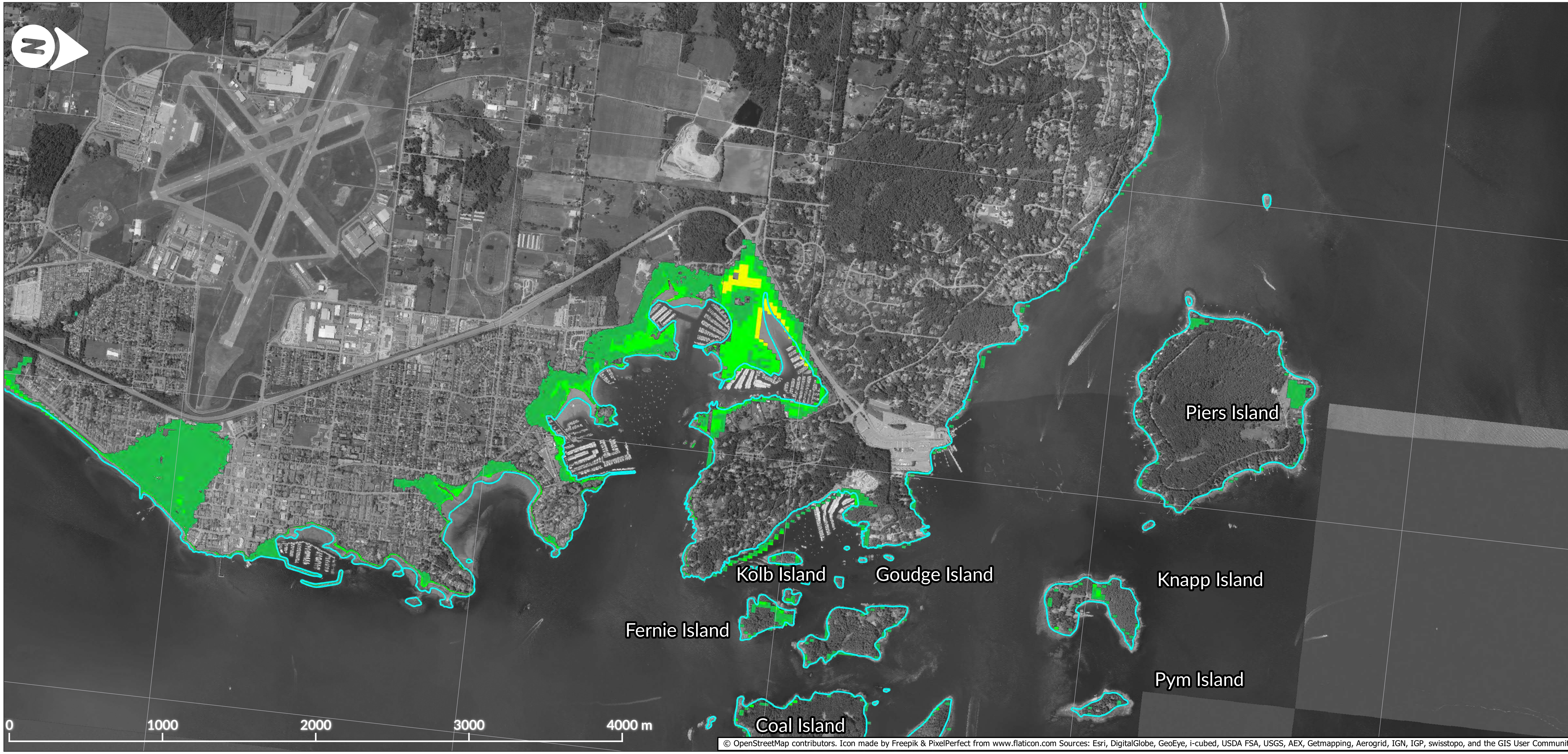
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



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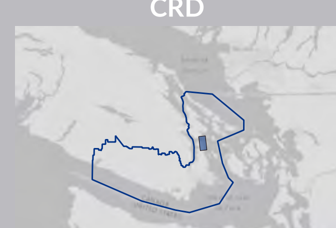
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

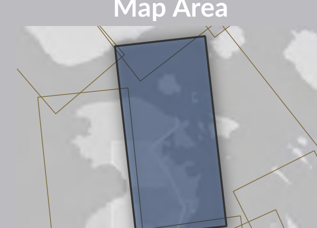
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 17 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

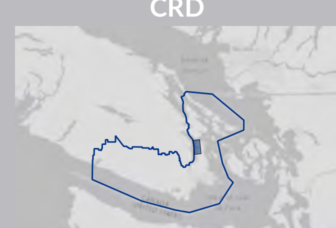
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

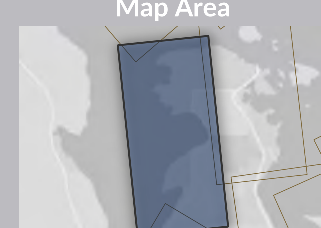
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 18 f 41

pl t date: 2020.06.11
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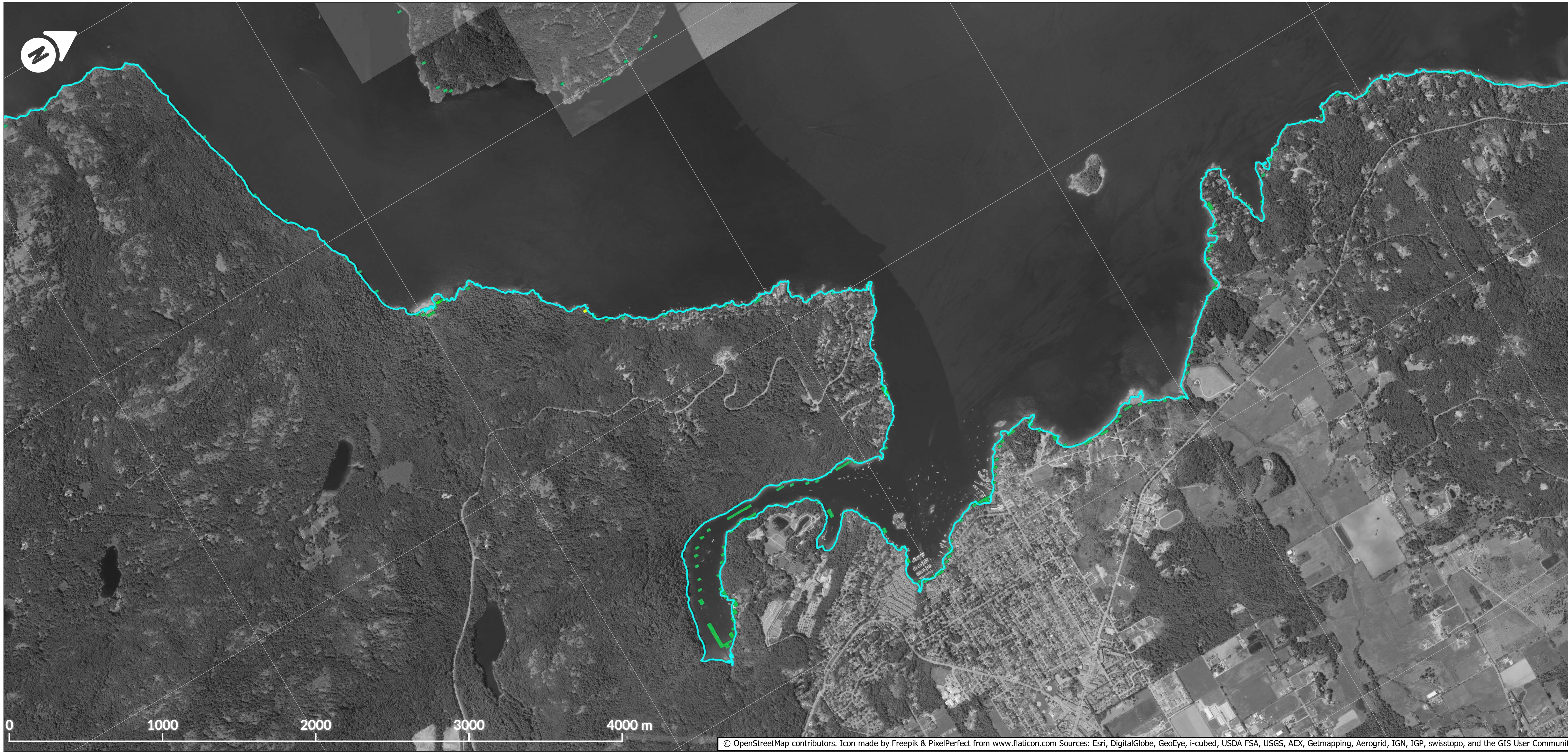


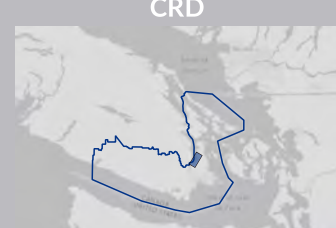
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

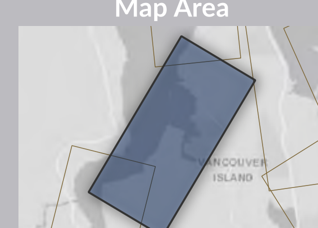
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
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Map Sheet 19 f 41

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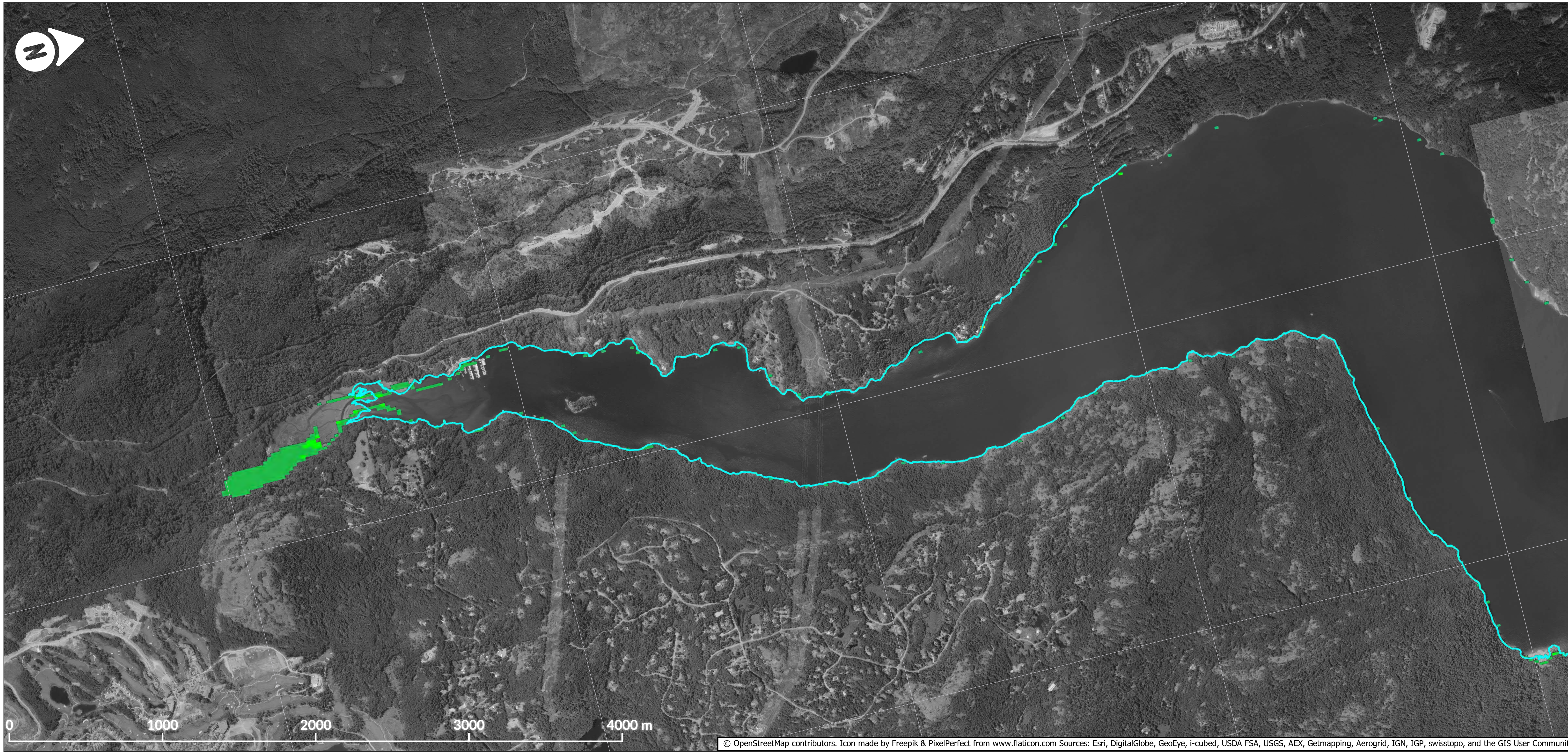


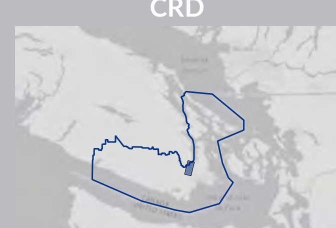
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

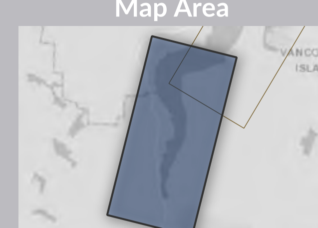
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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Map Sheet 20 f 41

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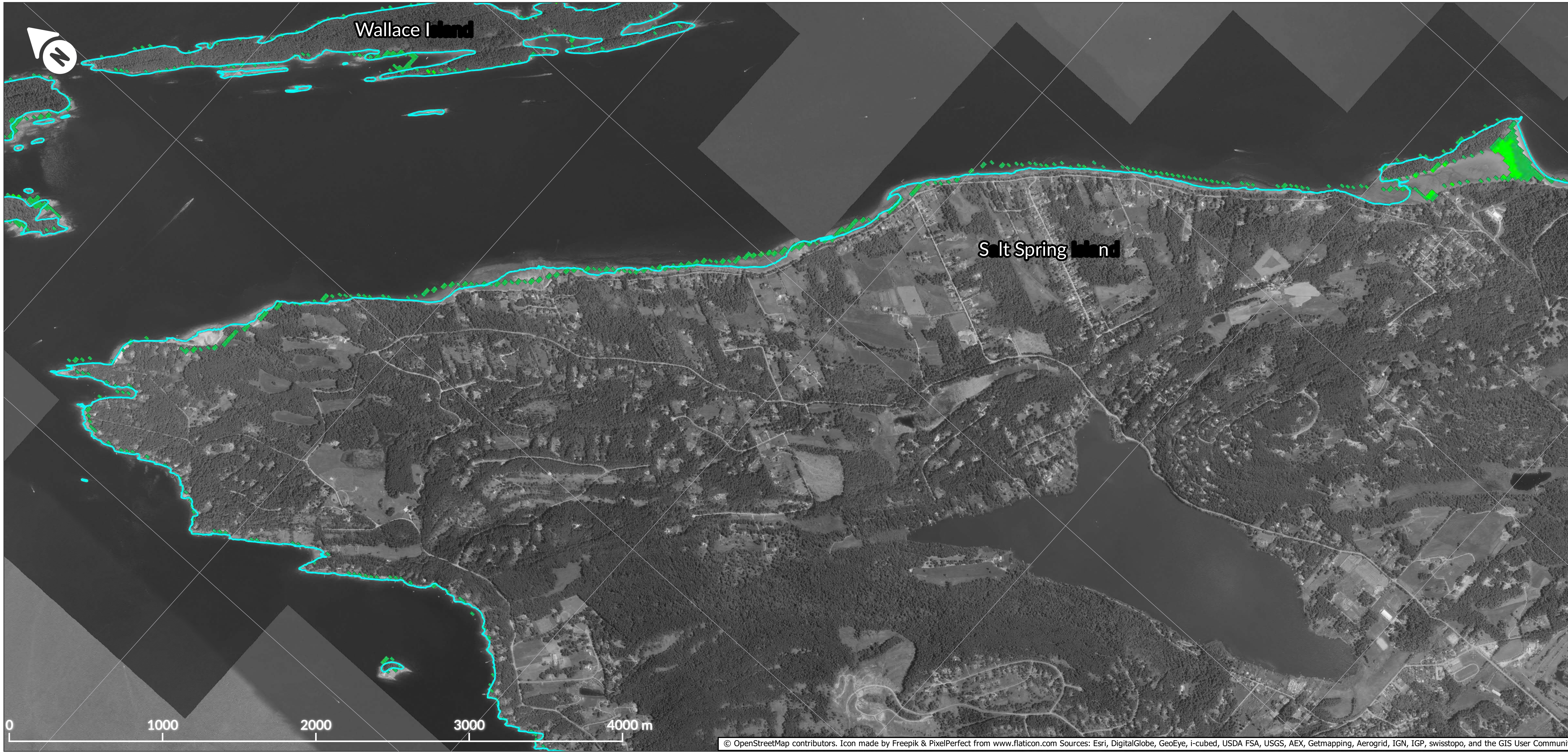
pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



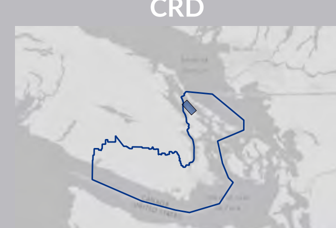
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

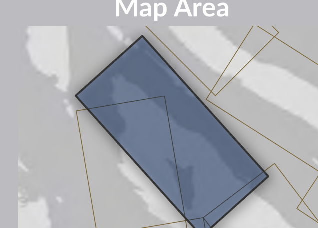
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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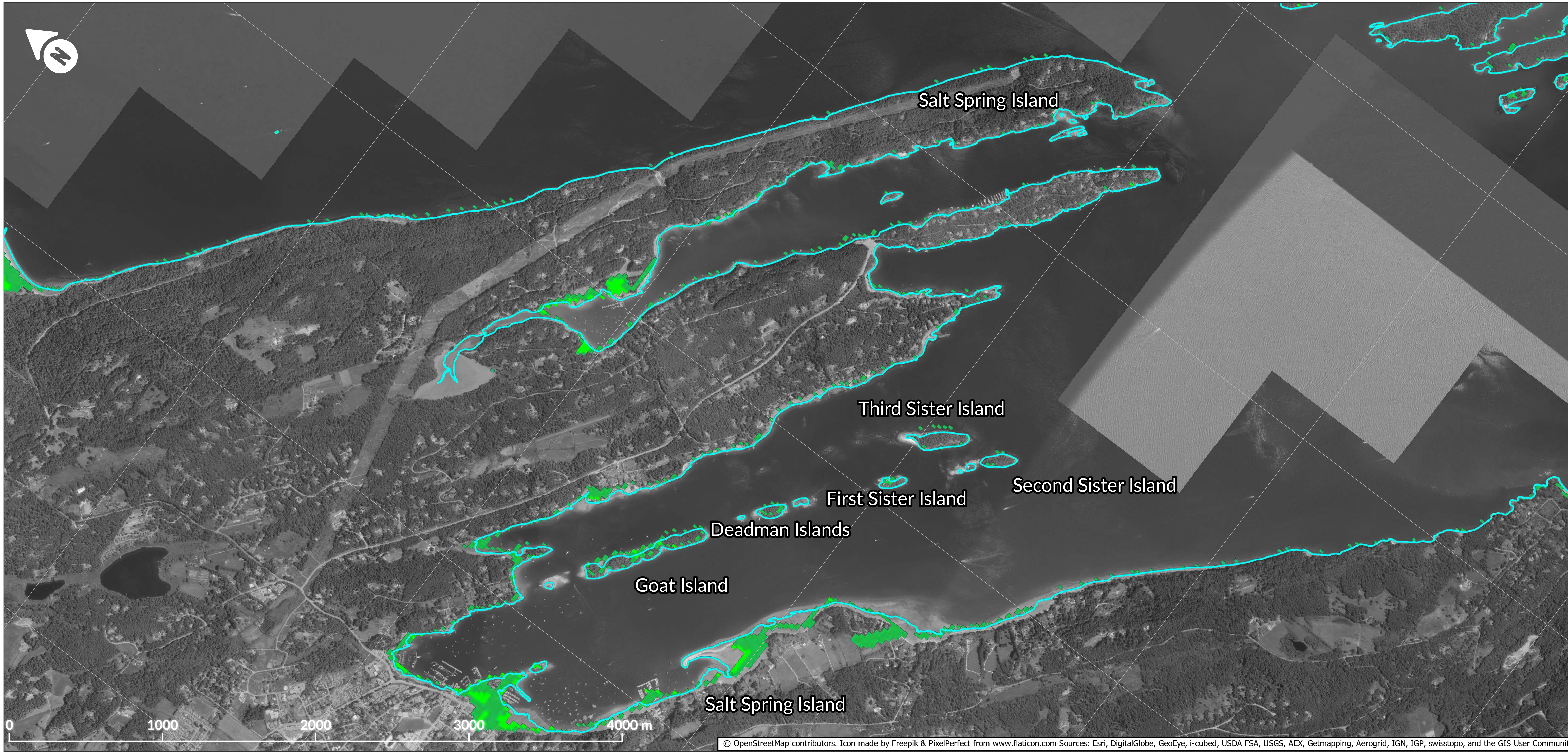
Map Sheet 21 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

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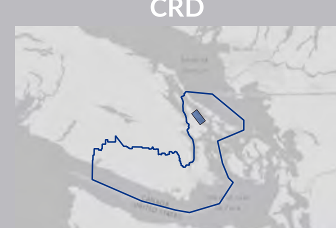
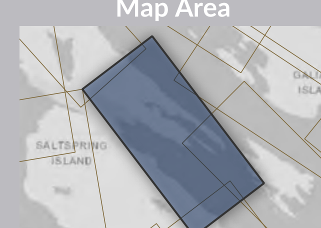
Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



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Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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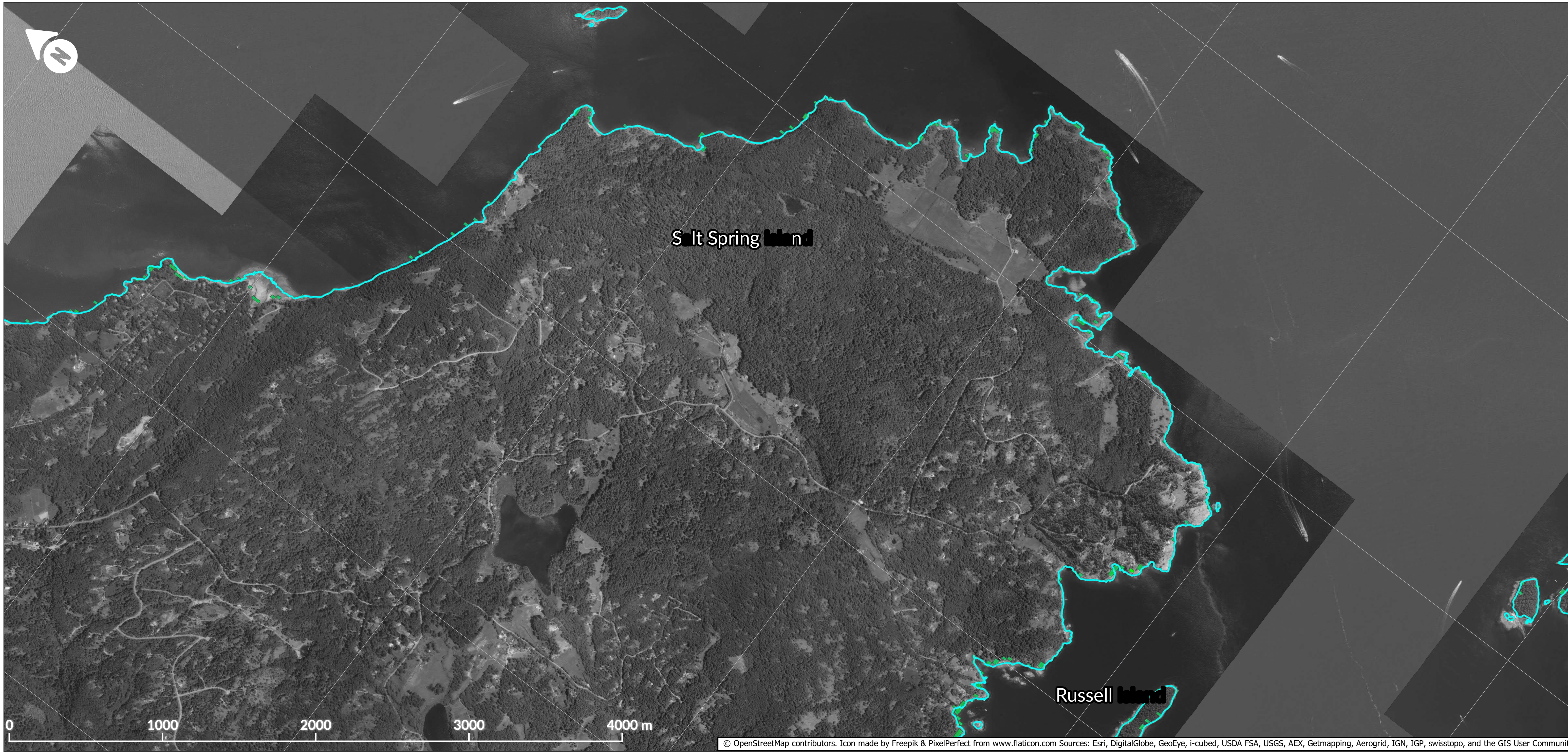
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 22 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



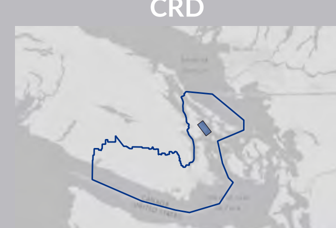
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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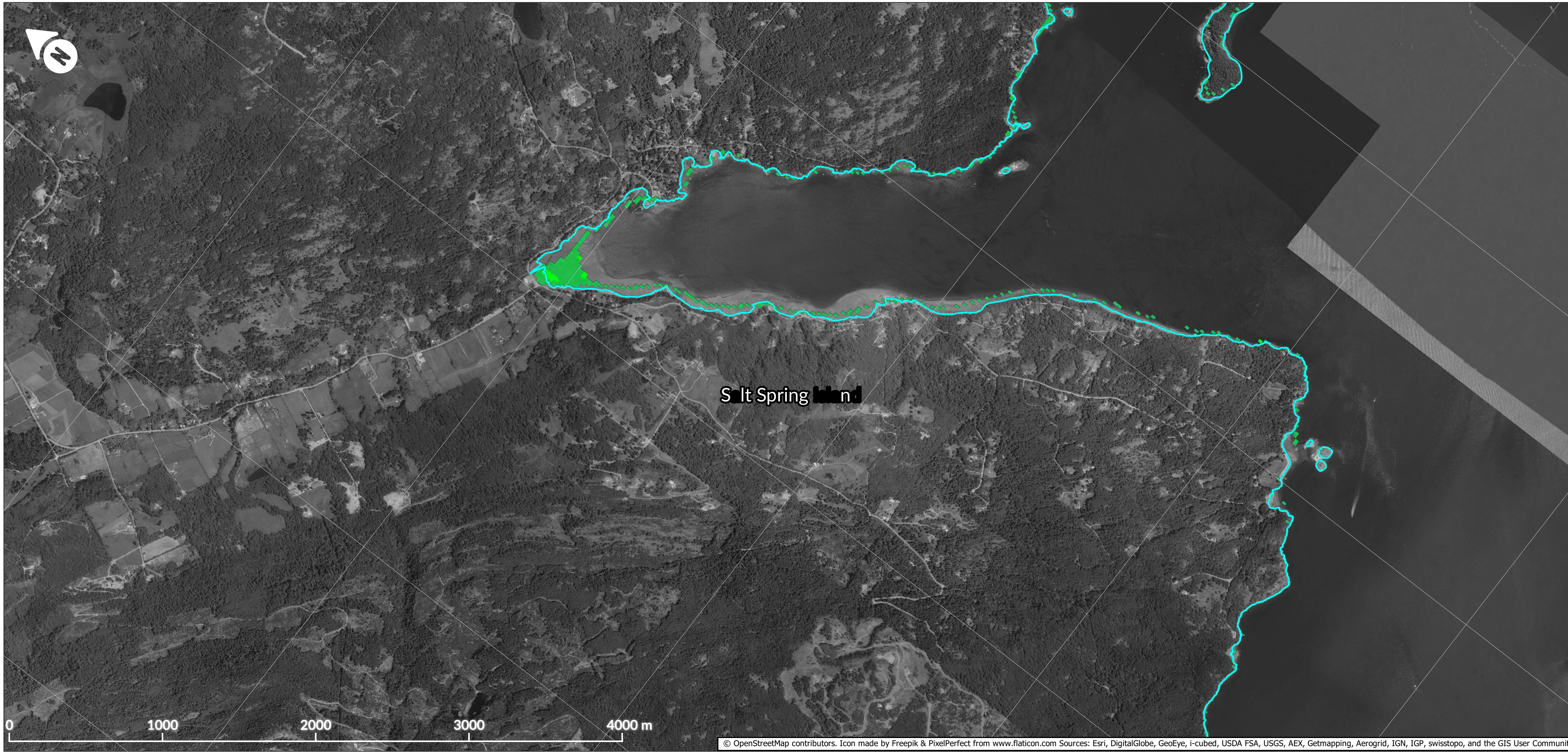
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 23 f 41

Making a difference...together

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



C astal Fl d Inundati n Mapping Pr ject

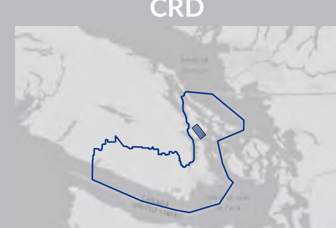
Capital Regi nal District

March 2020

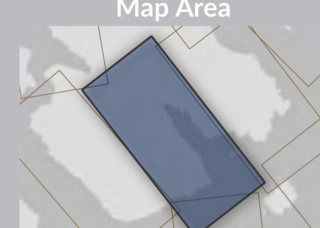
Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

Making a difference...together

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 24 f 41

pl t date: 2020.06.11
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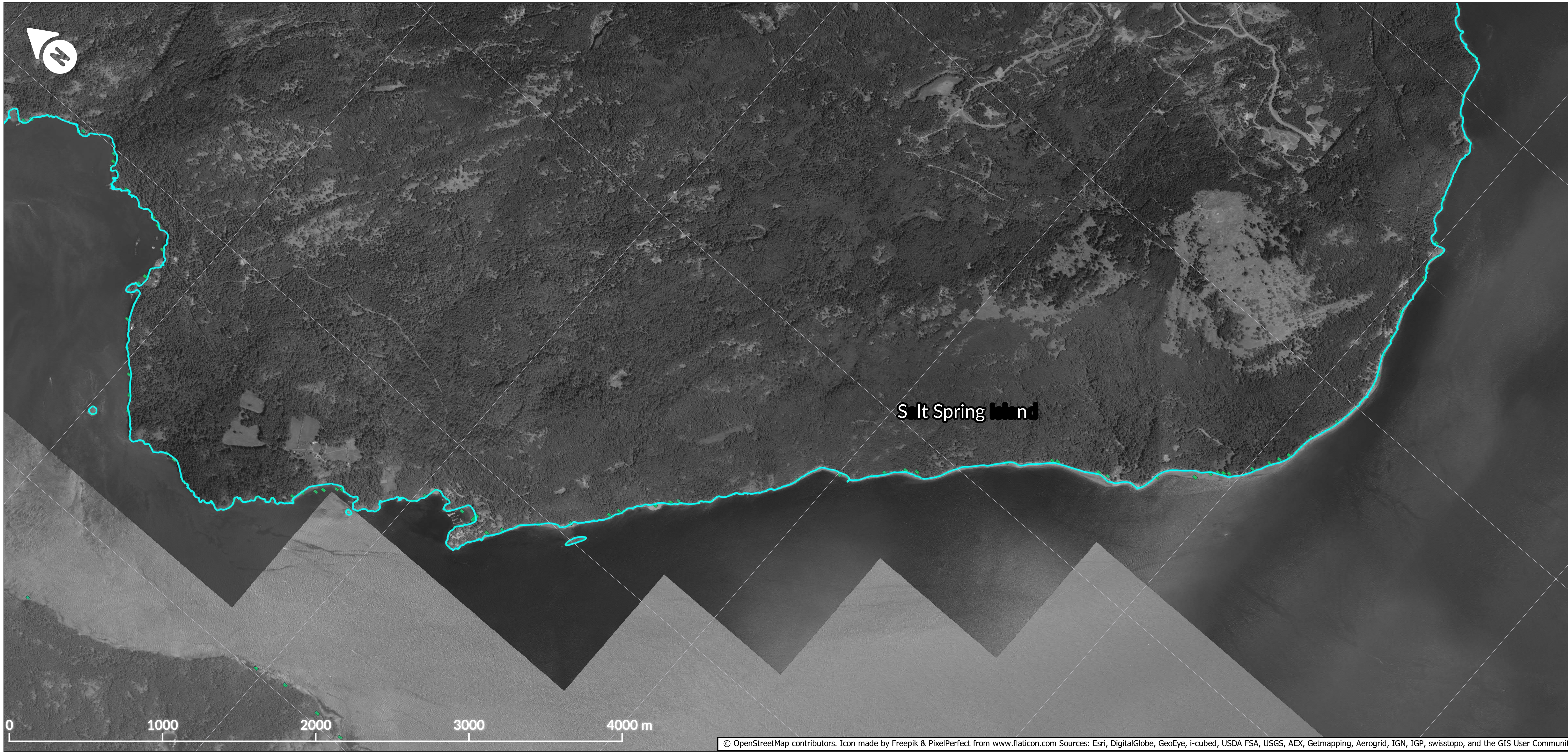


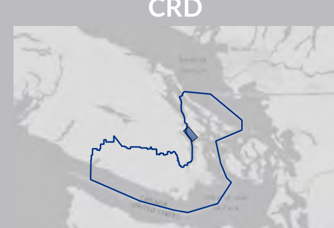
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 25 f 41

Making a difference...together

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

462000E

458000E

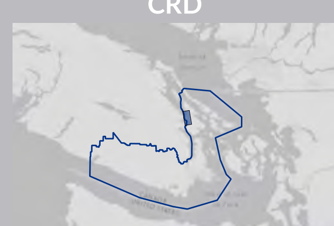
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Making a difference...together

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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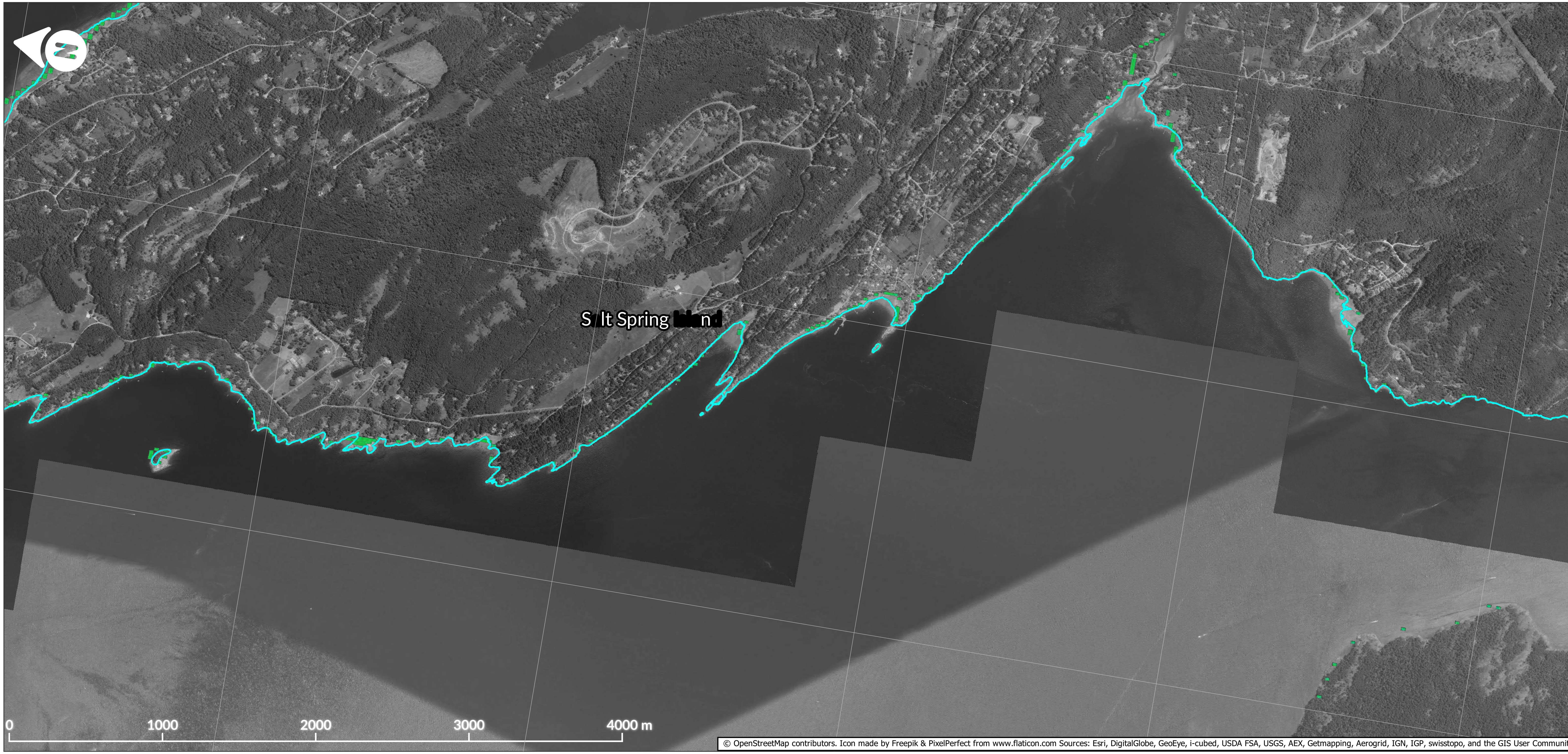
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 26 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



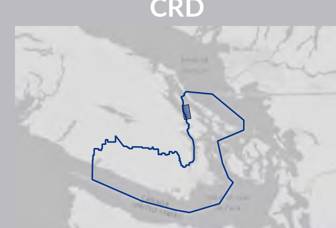
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

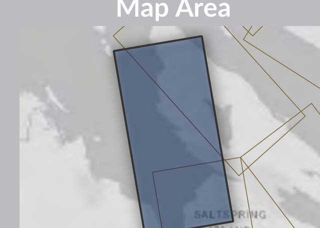
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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Drawn by C. Duncan and S. Haley

Map Sheet 27 f 41

pl t date: 2020.06.11
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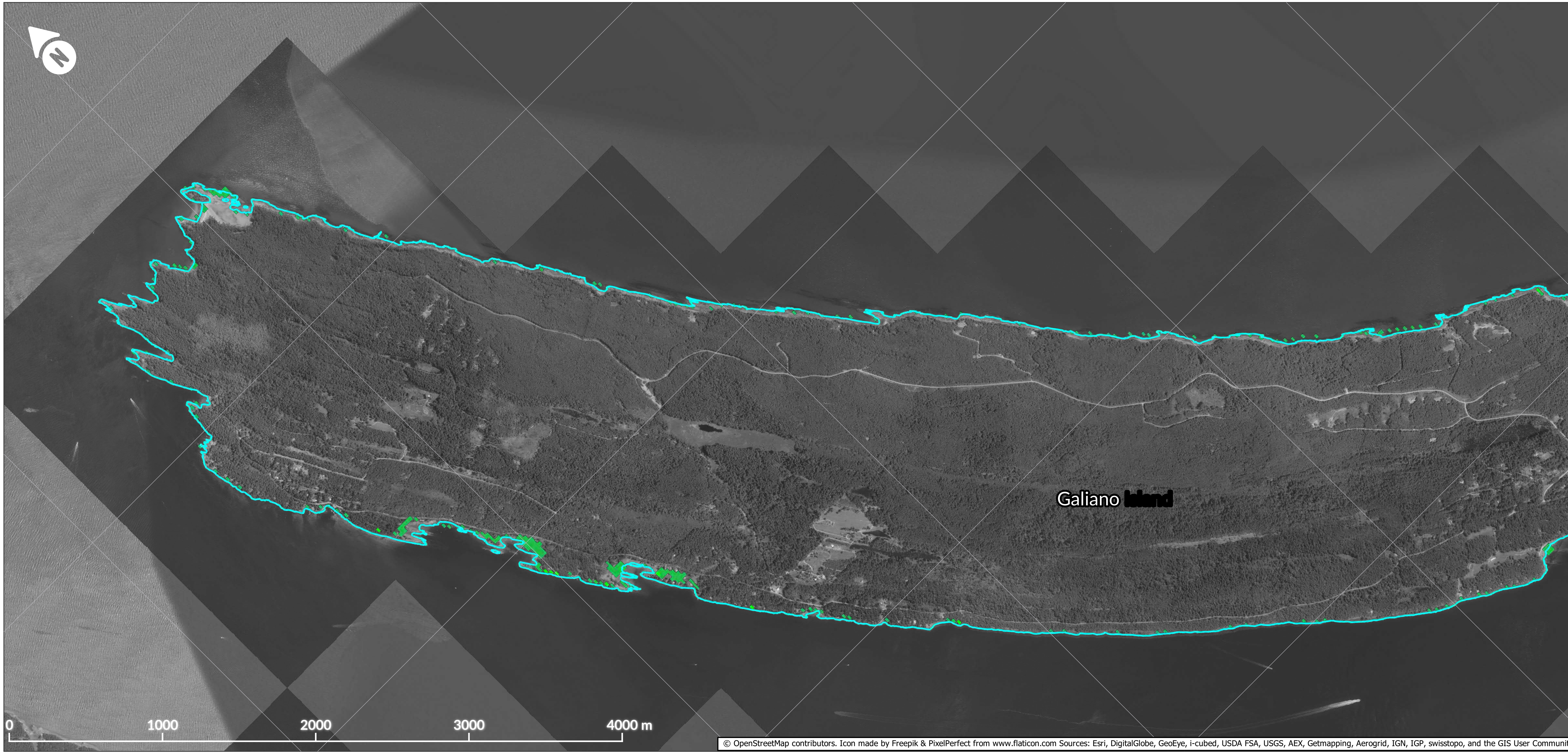


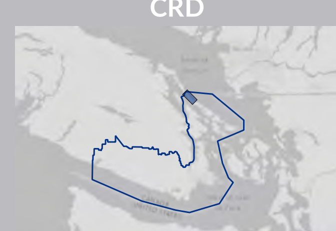
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
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Map Sheet 28 f 41

pl t date: 2020.06.11
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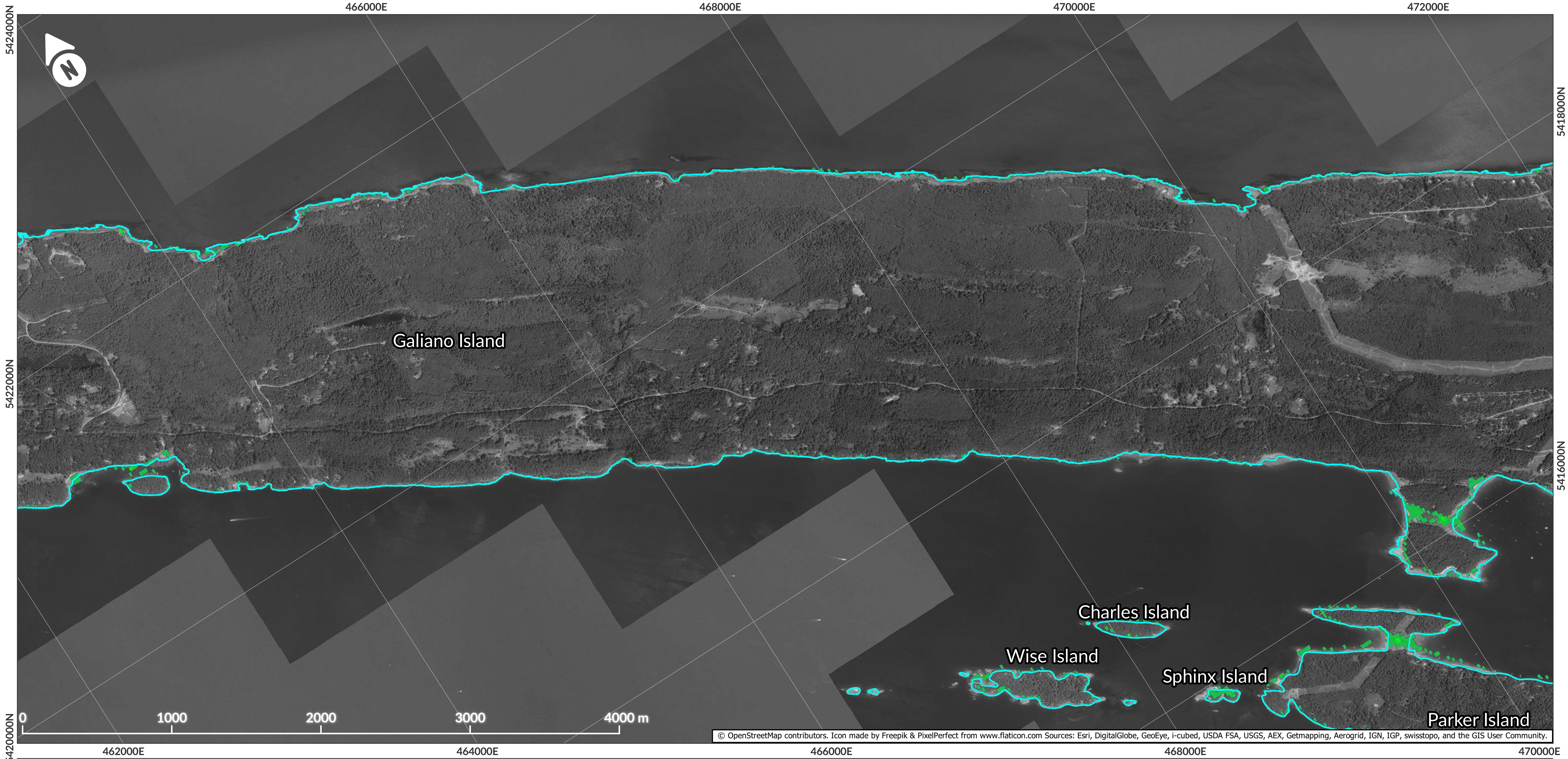


C astal Fl d Inundati n Mapping Pr ject

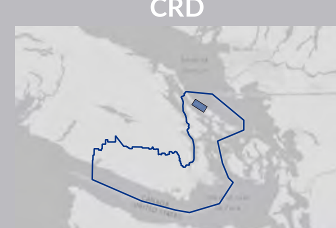
Capital Regi nal District

March 2020

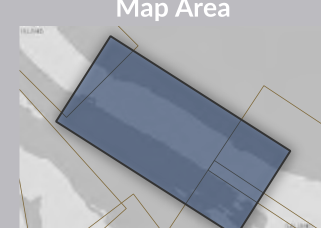
Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

Making a difference...together

CRD



Map Area



Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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Map Sheet 29 f 41

pl t date: 2020.06.11
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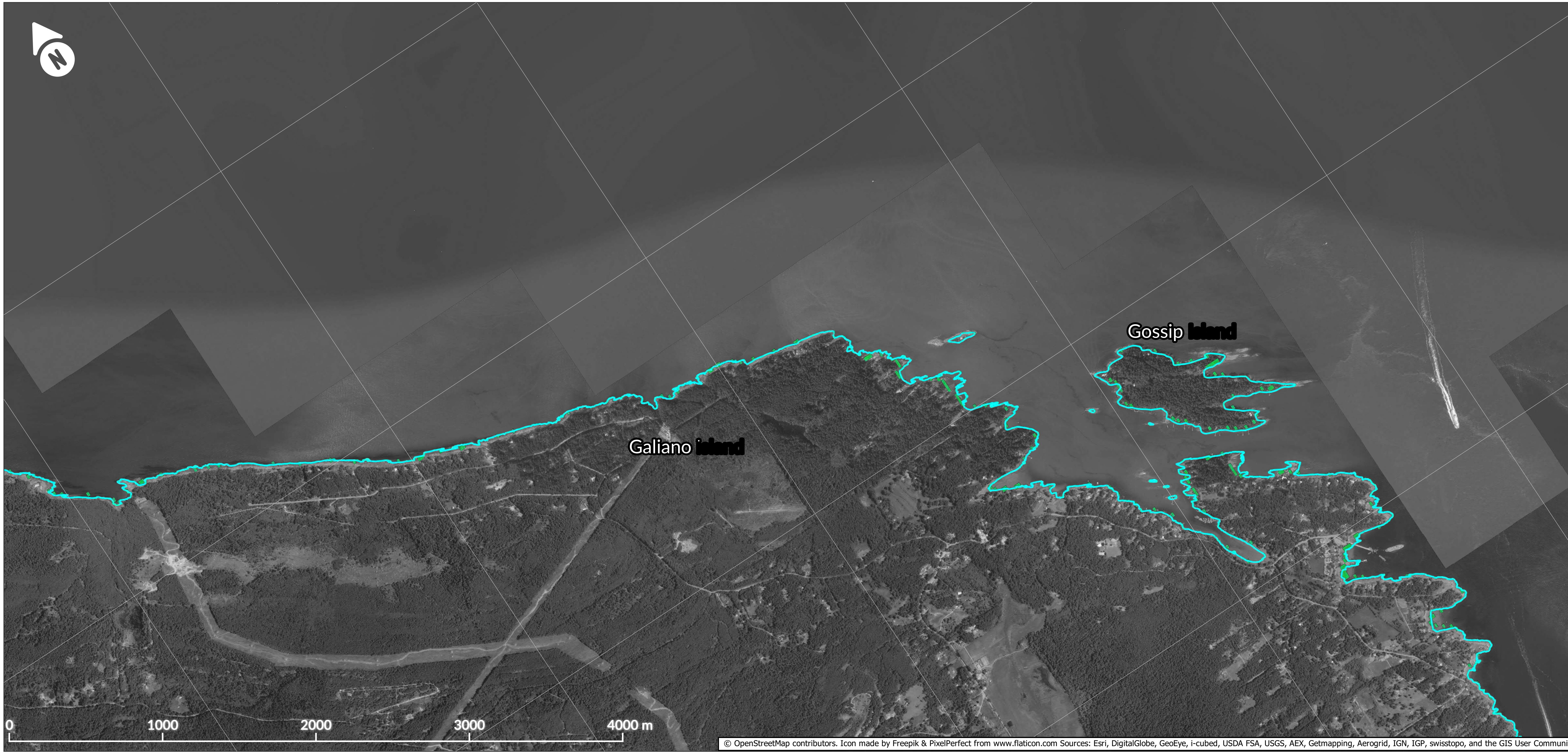


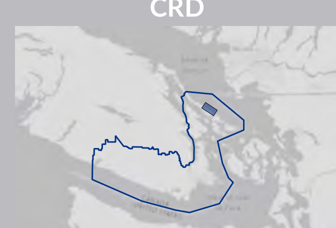
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

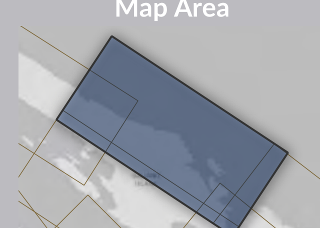
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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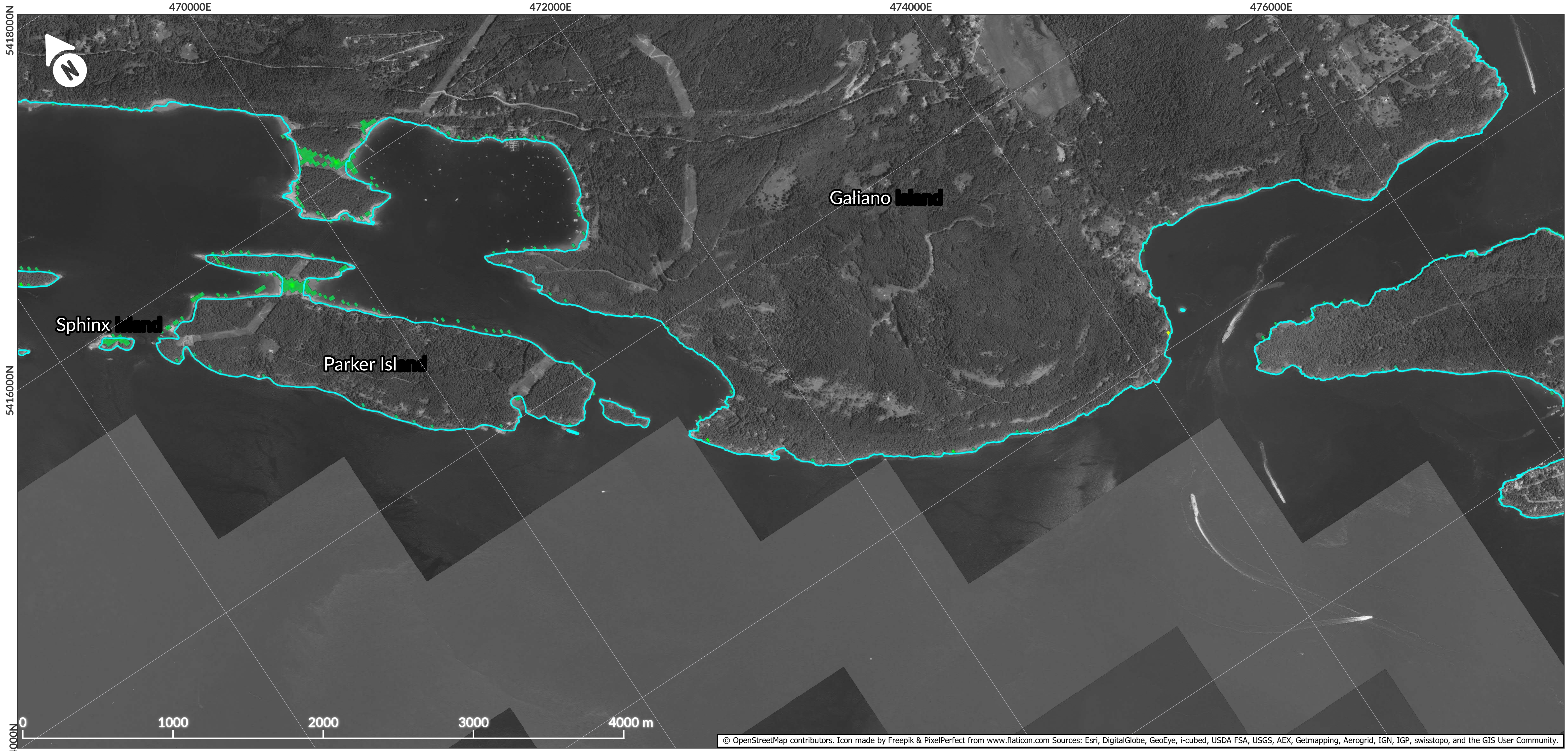
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 30 f 41

Making a difference...together



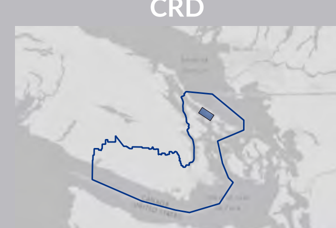
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

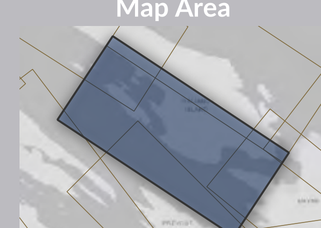
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Making a difference...together

DHI

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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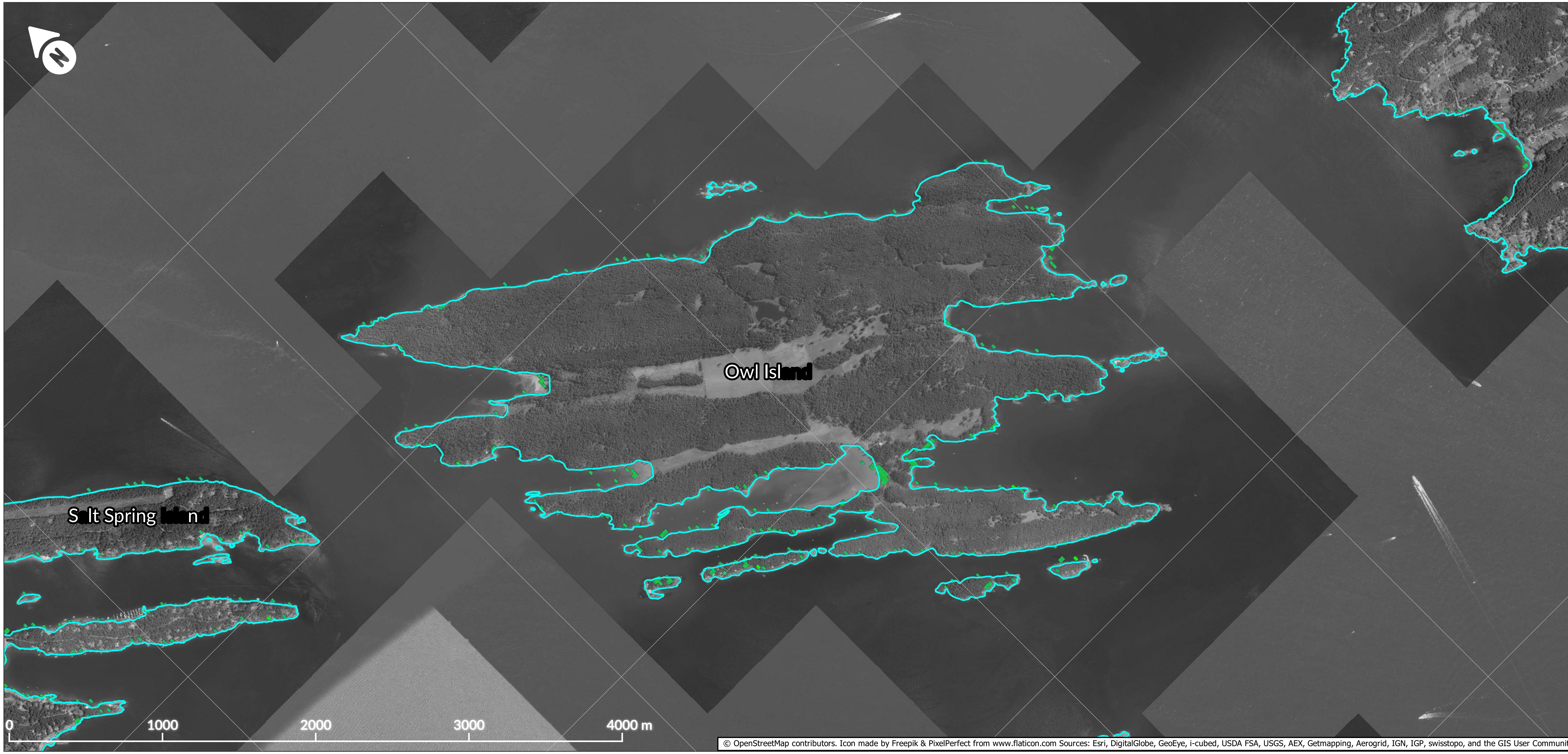
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 31 f 41



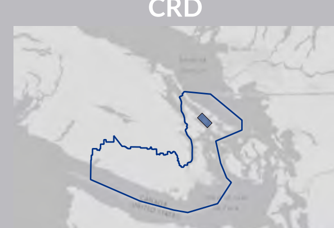
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

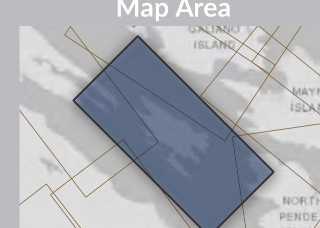
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 32 f 41

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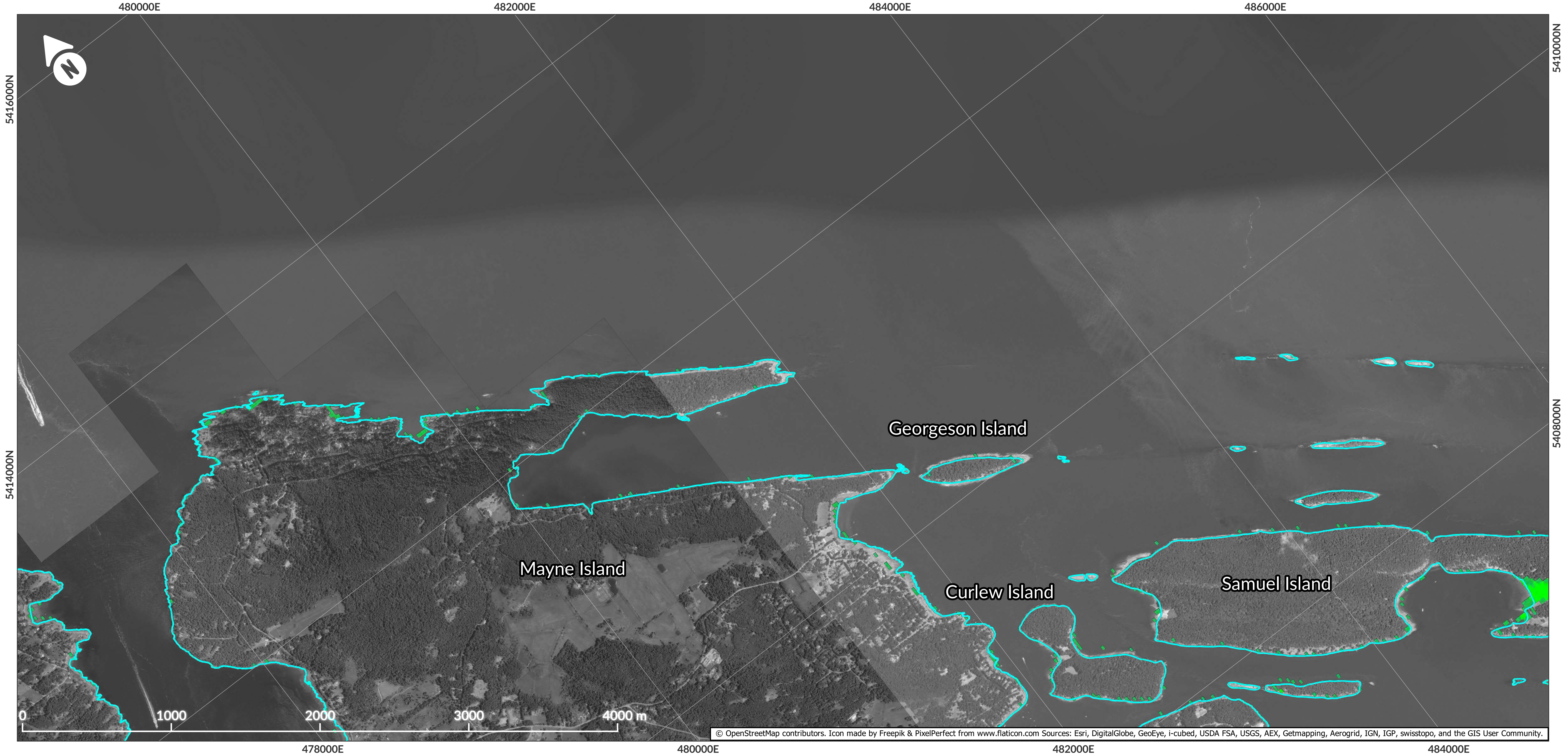
pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



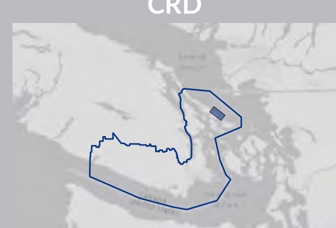
C astal Fl   d Inundati n Mapping Pr ject

Capital Regi nal District

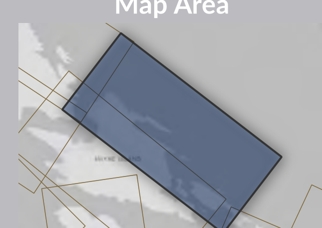
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0   2.0
- 2.0   4.0
- 4.0   6.0
- 6.0   8.0
- >8.0

1. Under the pr visi ns   f the Fl   d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl   dplain devel pment practices, including decisi ns ab ut fl   dplain bylaws within their c mmunities. nf rmati n   n fl   dplain management guidelines can be f und in the BC Fl   d Ha ard Area Land Use Management Guidelines.
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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 33   f 41

pl t date: 2020.06.11
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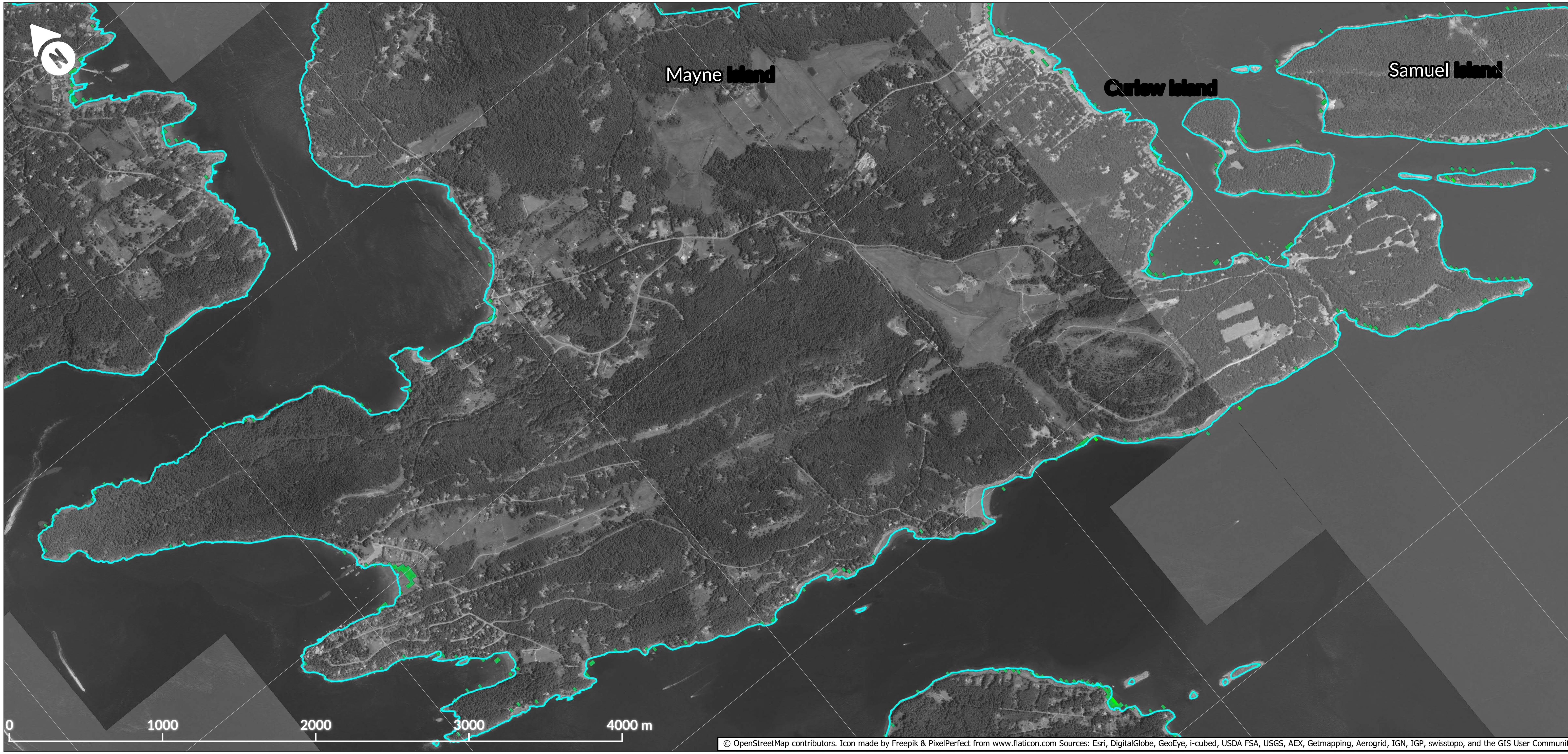


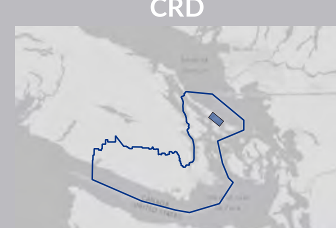
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

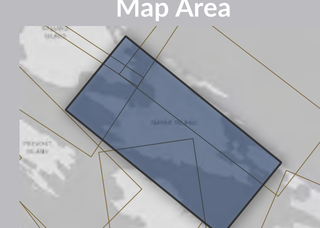
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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pl t date: 2020.06.11
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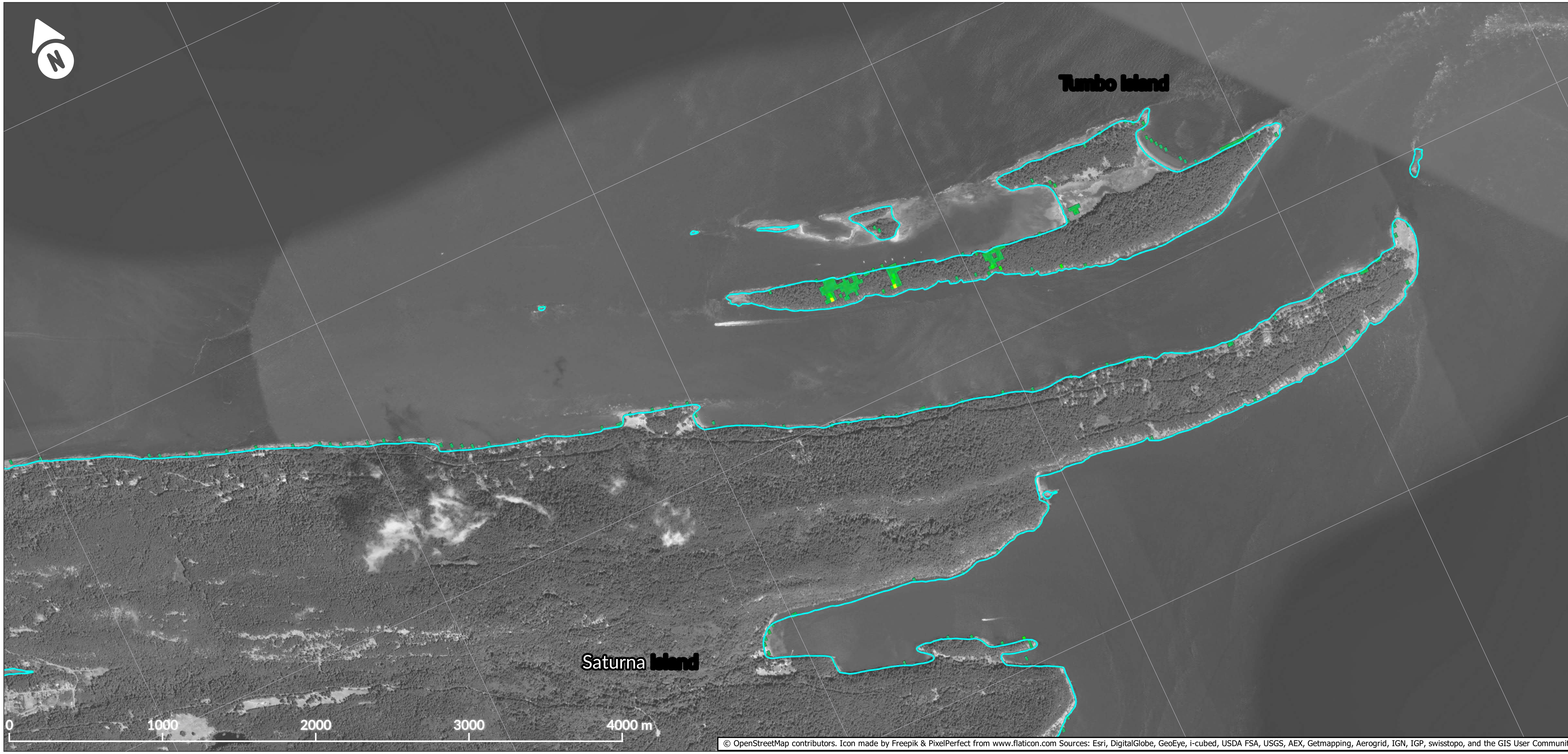


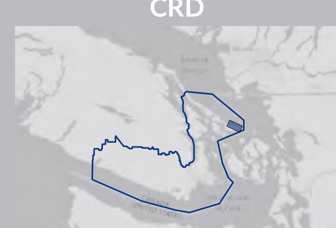
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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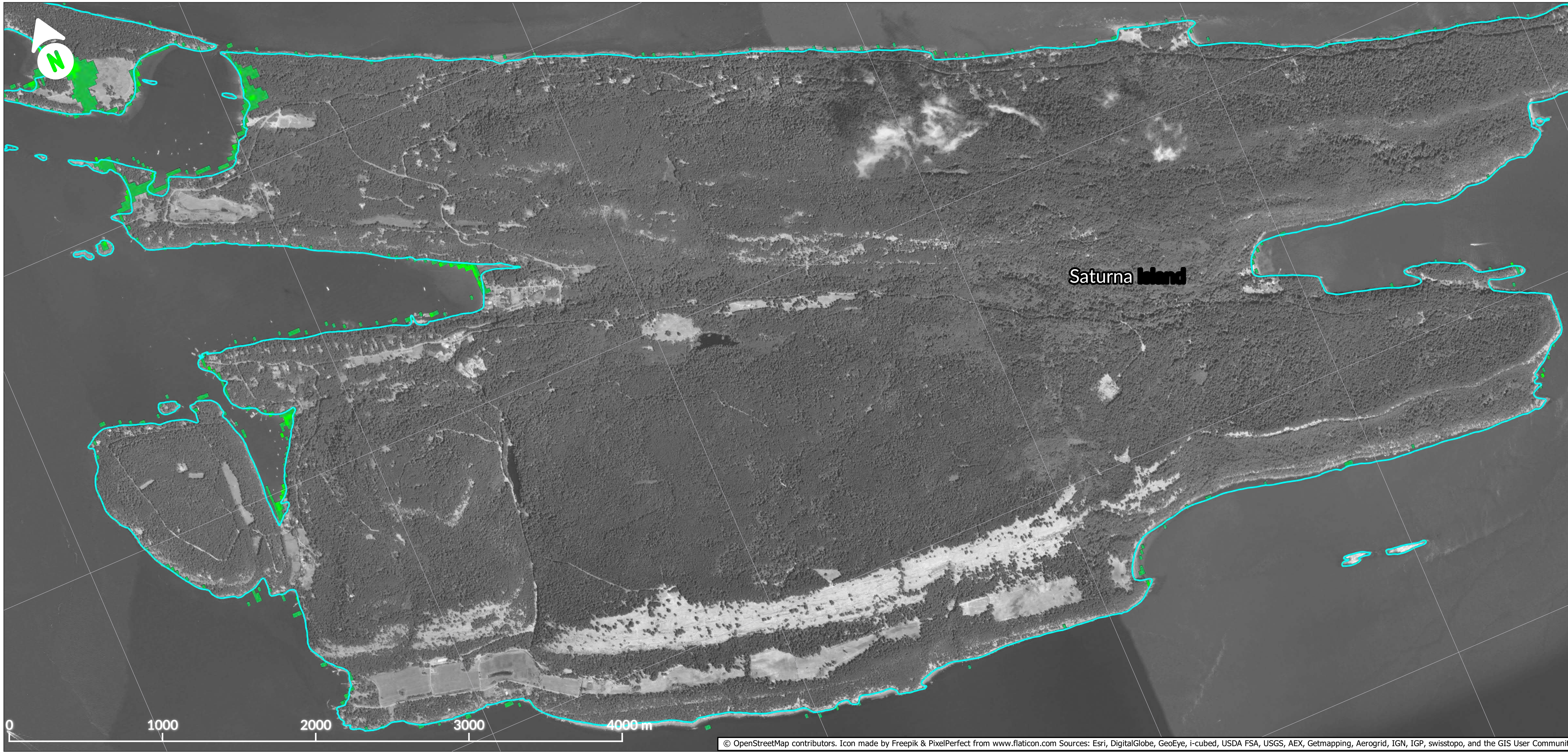


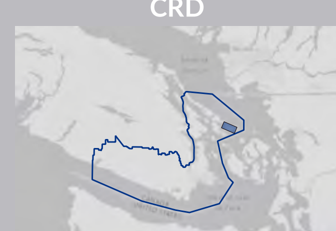
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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Map Sheet 36 f 41

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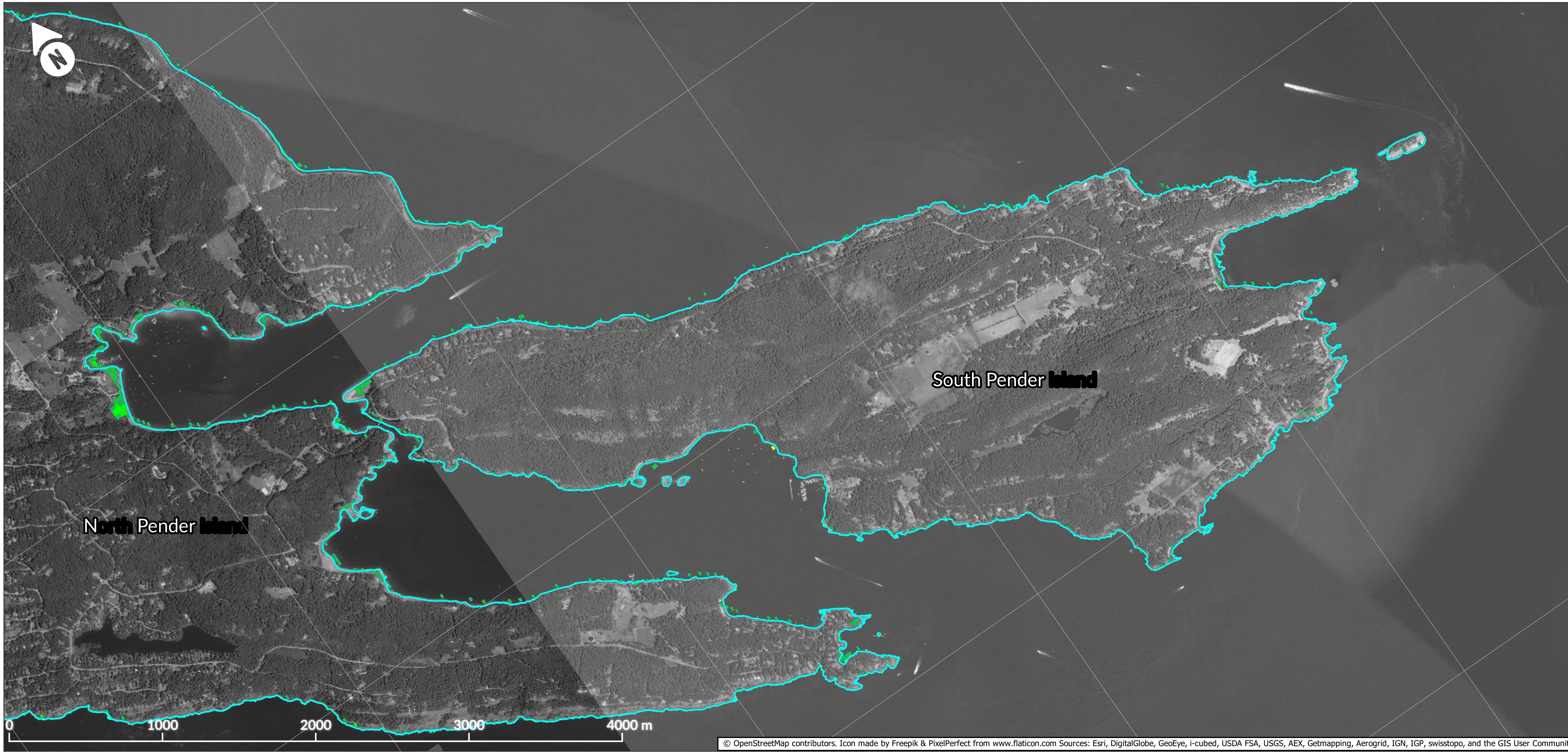


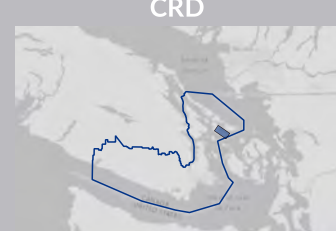
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Making a difference...together

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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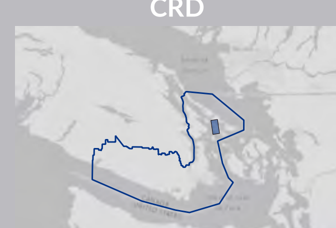
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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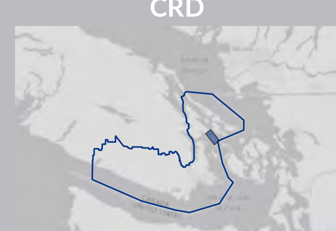
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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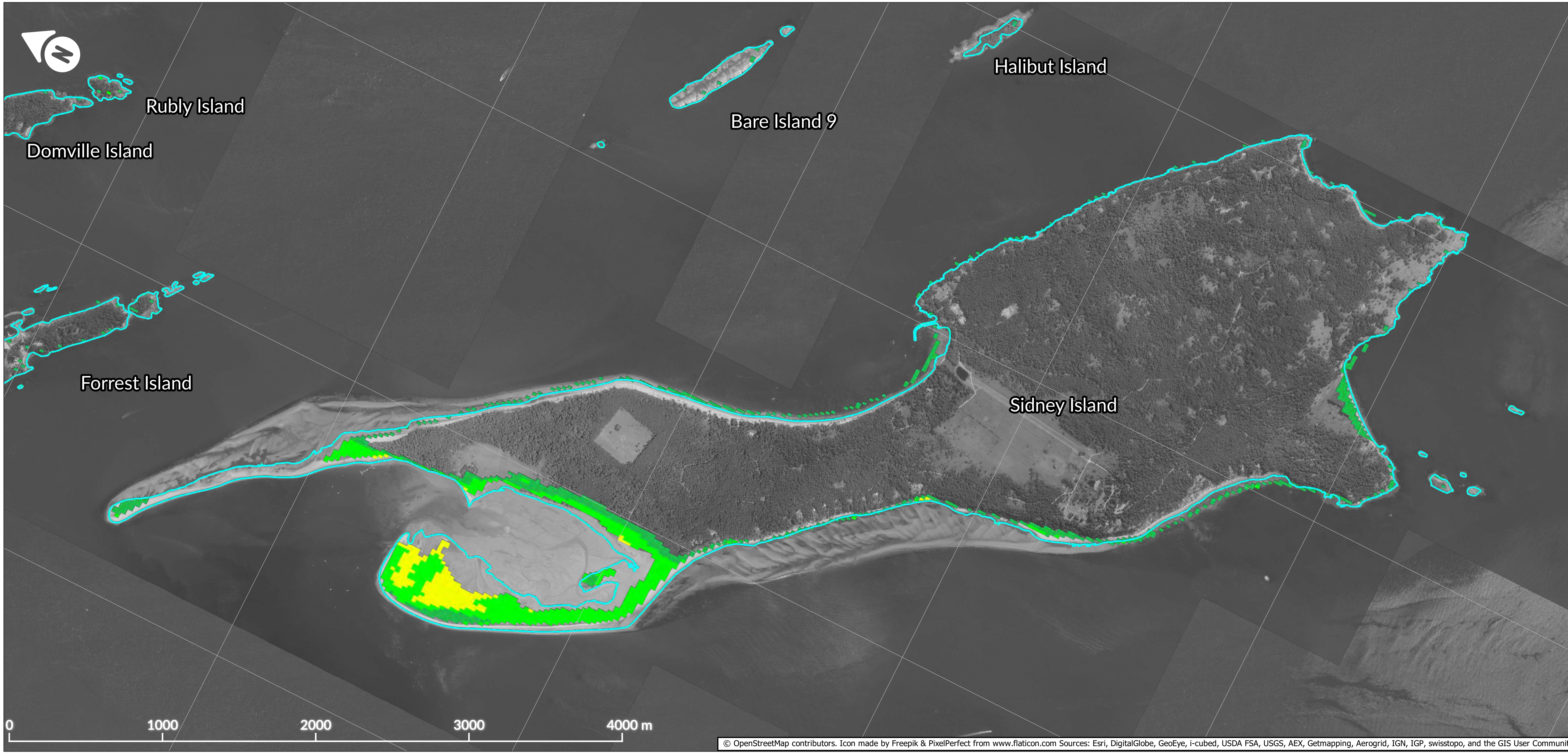
Map Sheet 39 f 41



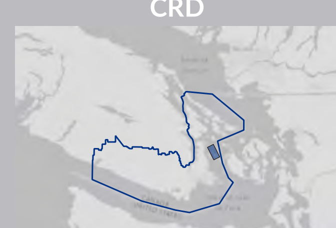
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

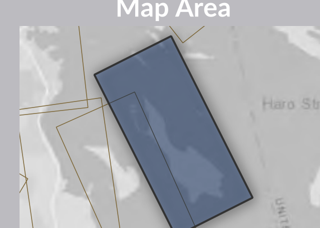
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Ha ard Statutes Amendment Act, 2003 (Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Ha ard Area Land Use Management Guidelines.
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Map Sheet 40 f 41

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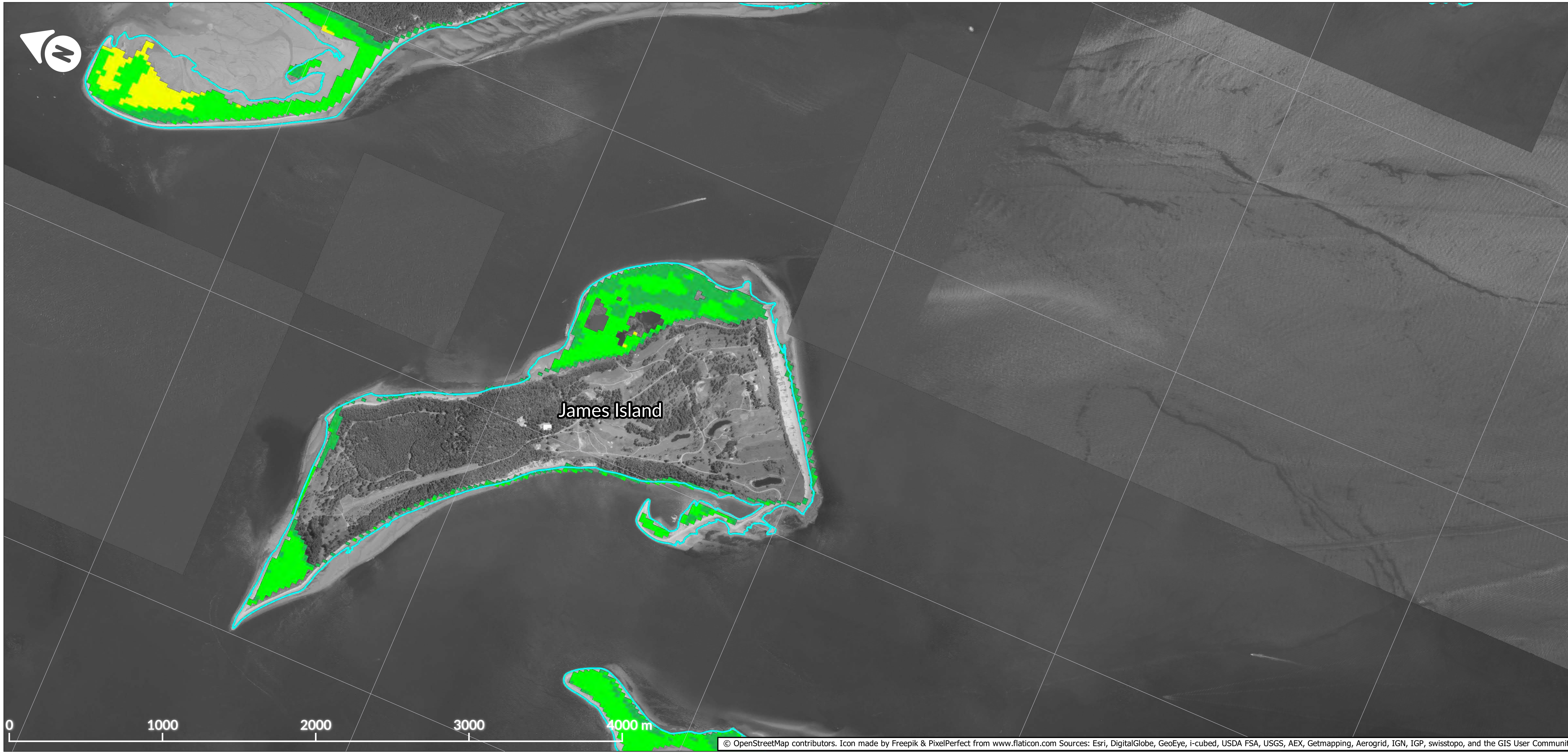


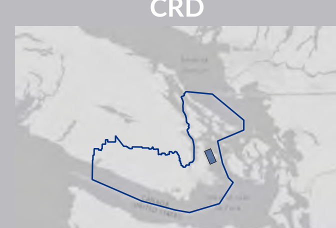
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

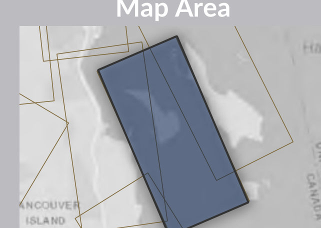
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - L1 S urce

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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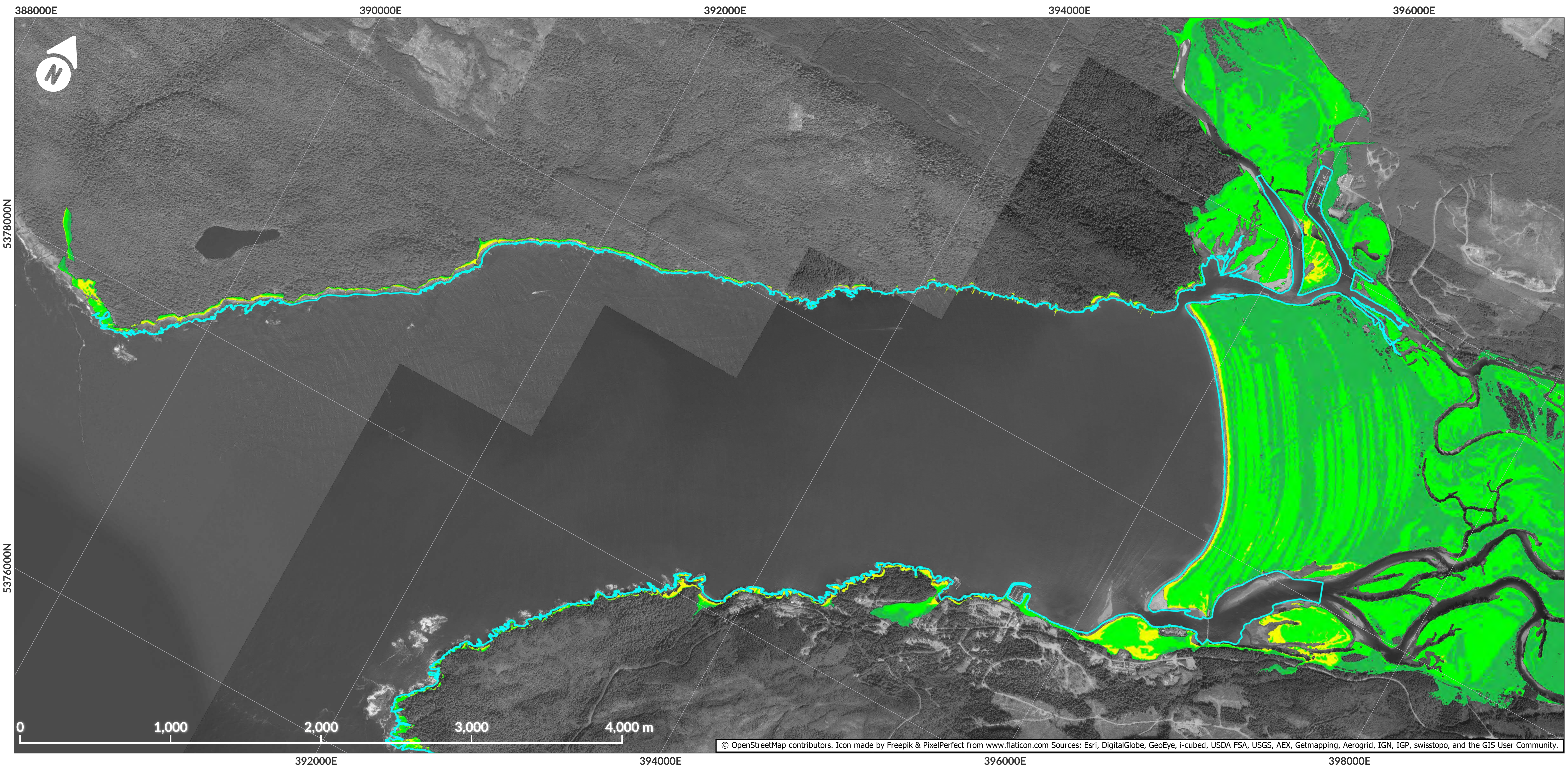


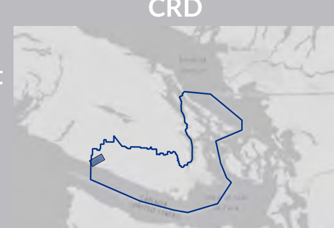
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

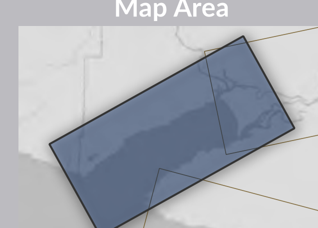
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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4. Data s urces: Orth imagery CRD, 2017)
5. F r further inf rmati n, please refer t Task 3 – Tsunami M delling and Mapping Rep rt. These maps c nstitute Appendix C f said rep rt.

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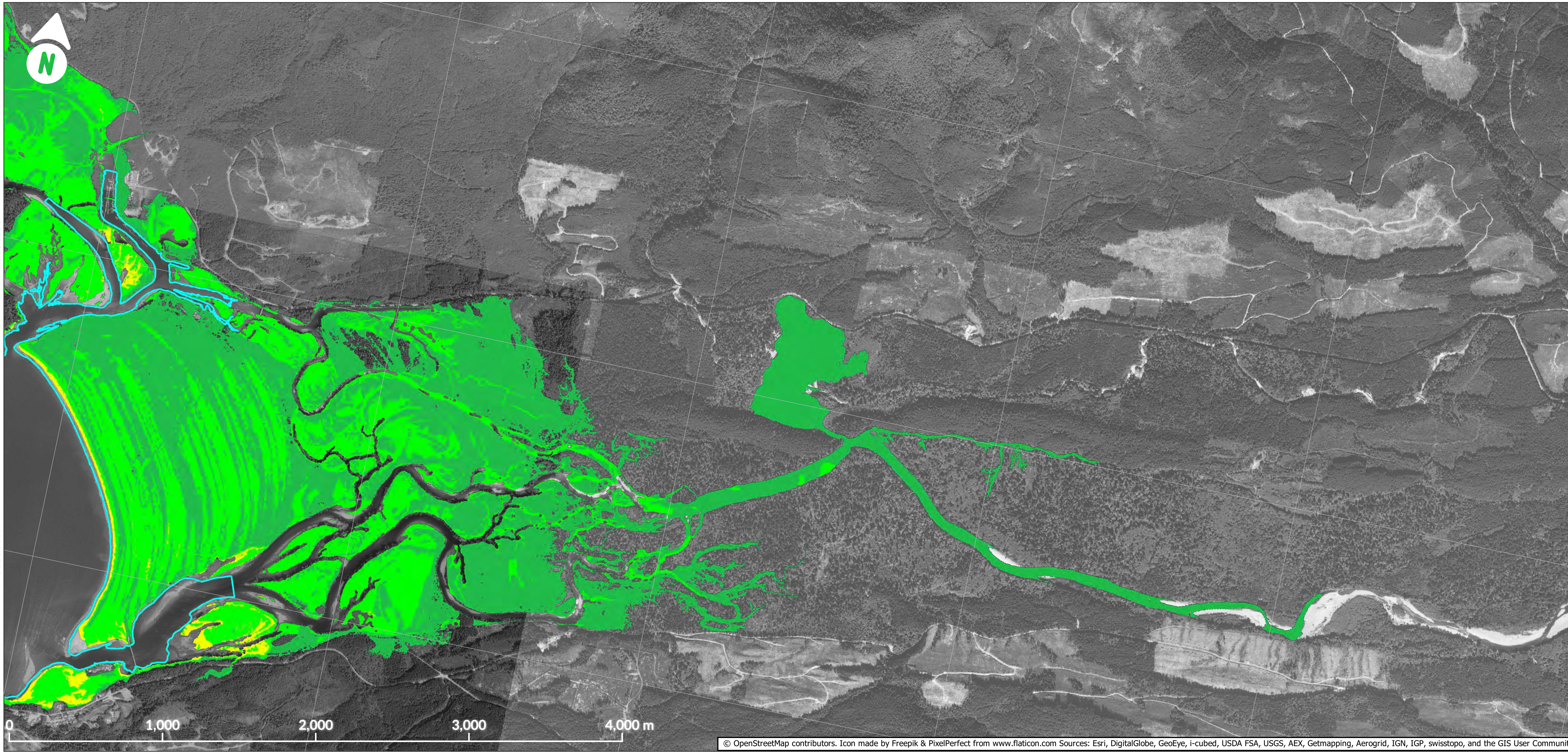


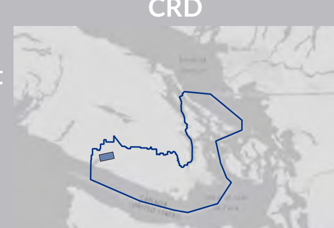
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 2 f 41

pl t date: 2020.06.11
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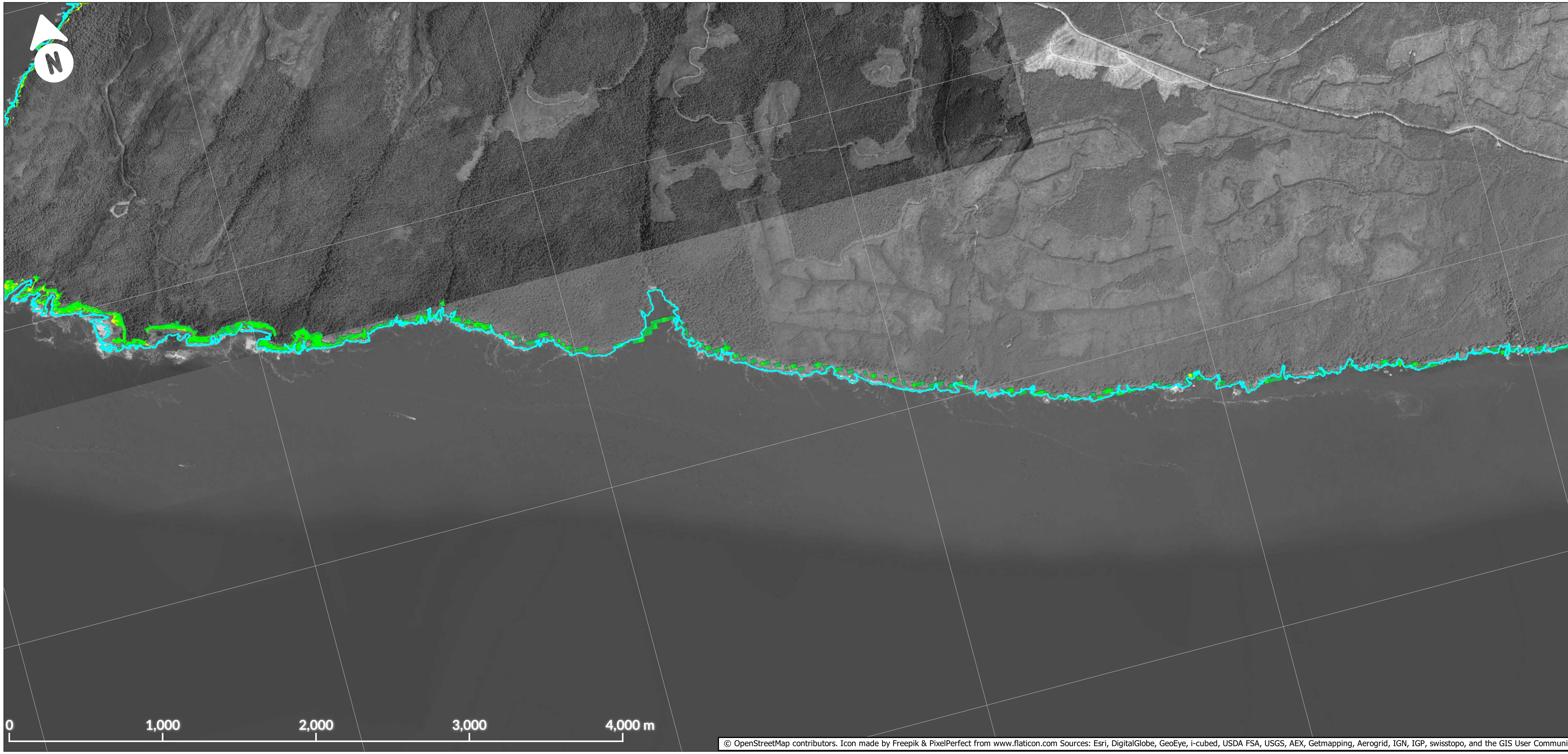


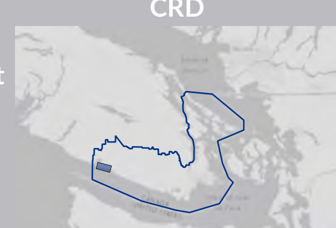
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

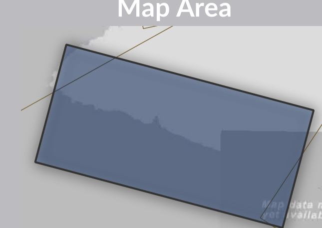
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0   2.0
- 2.0   4.0
- 4.0   6.0
- 6.0   8.0
- >8.0

1. Under the pr visi ns   f the Fl   d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl   dplain devel pment practices, including decisi ns ab ut fl   dplain bylaws within their c mmunities. nf rmati n   n fl   dplain management guidelines can be f und in the BC Fl   d Hazard Area Land Use Management Guidelines.
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Map Sheet 3   f 41

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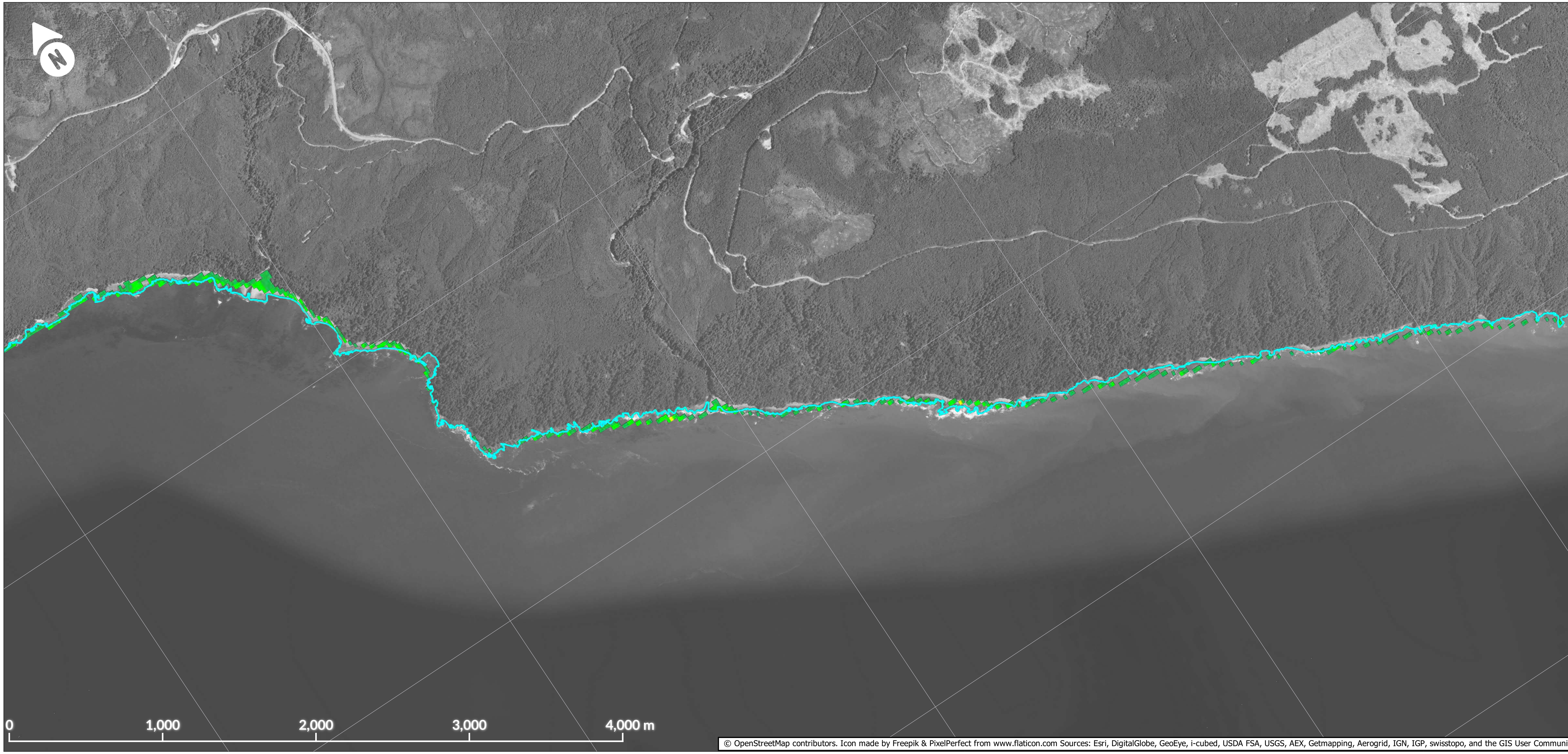
file: P:\20192676\00_C astFl   dTsunami\W rking_Dwgs\010_GIS



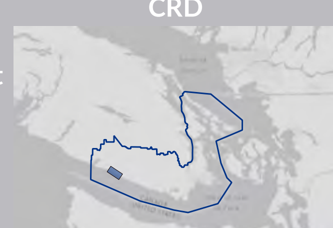
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

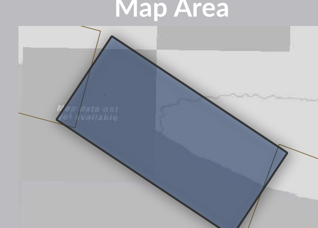
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 4 f 41

pl t date: 2020.06.11
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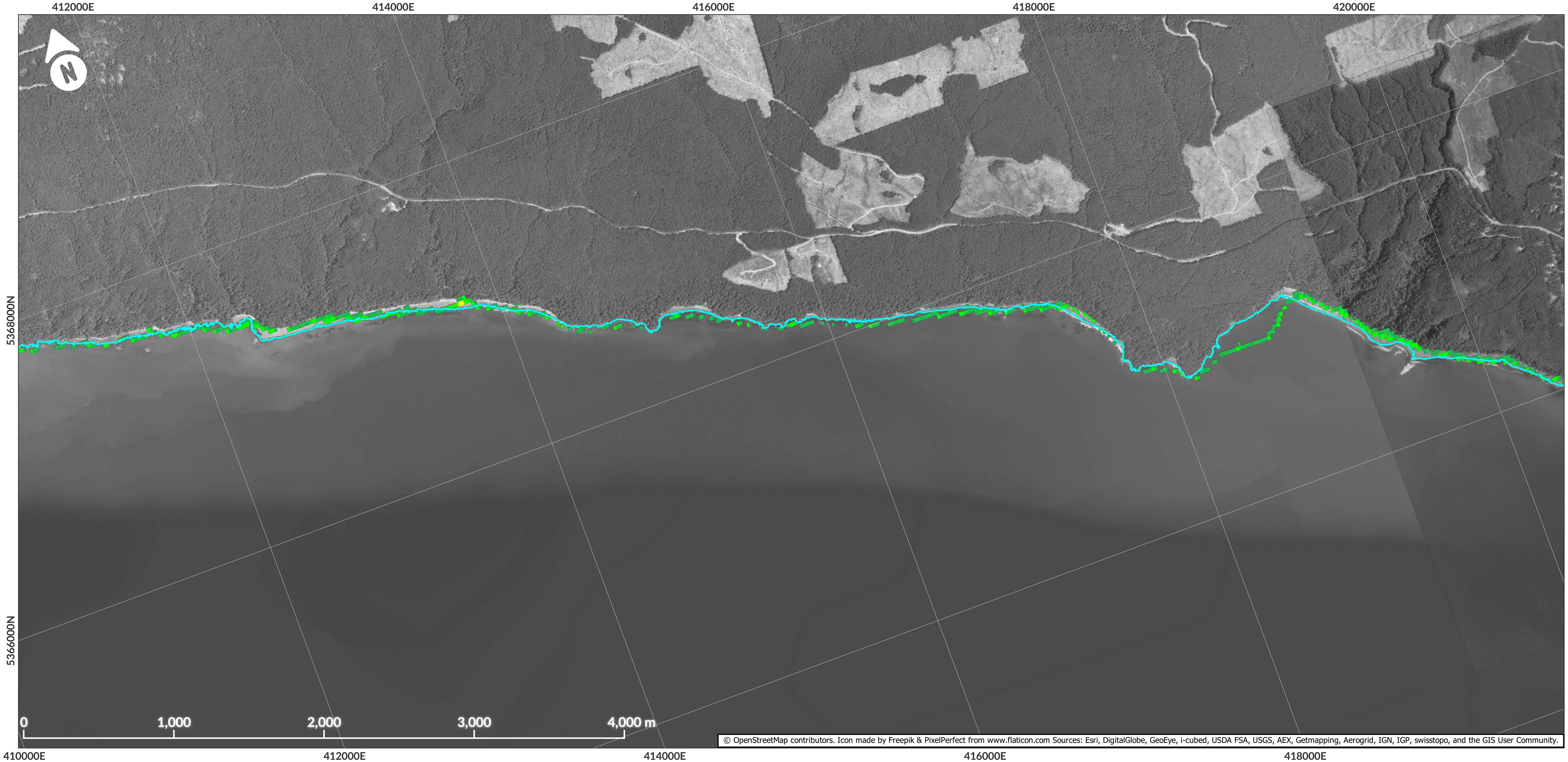


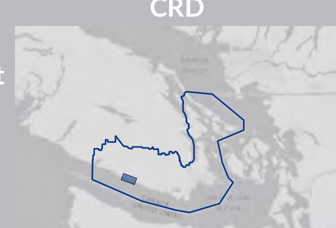
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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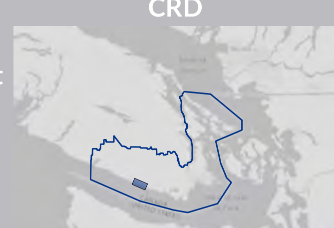
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Making a difference...together

DHI

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 6 f 41

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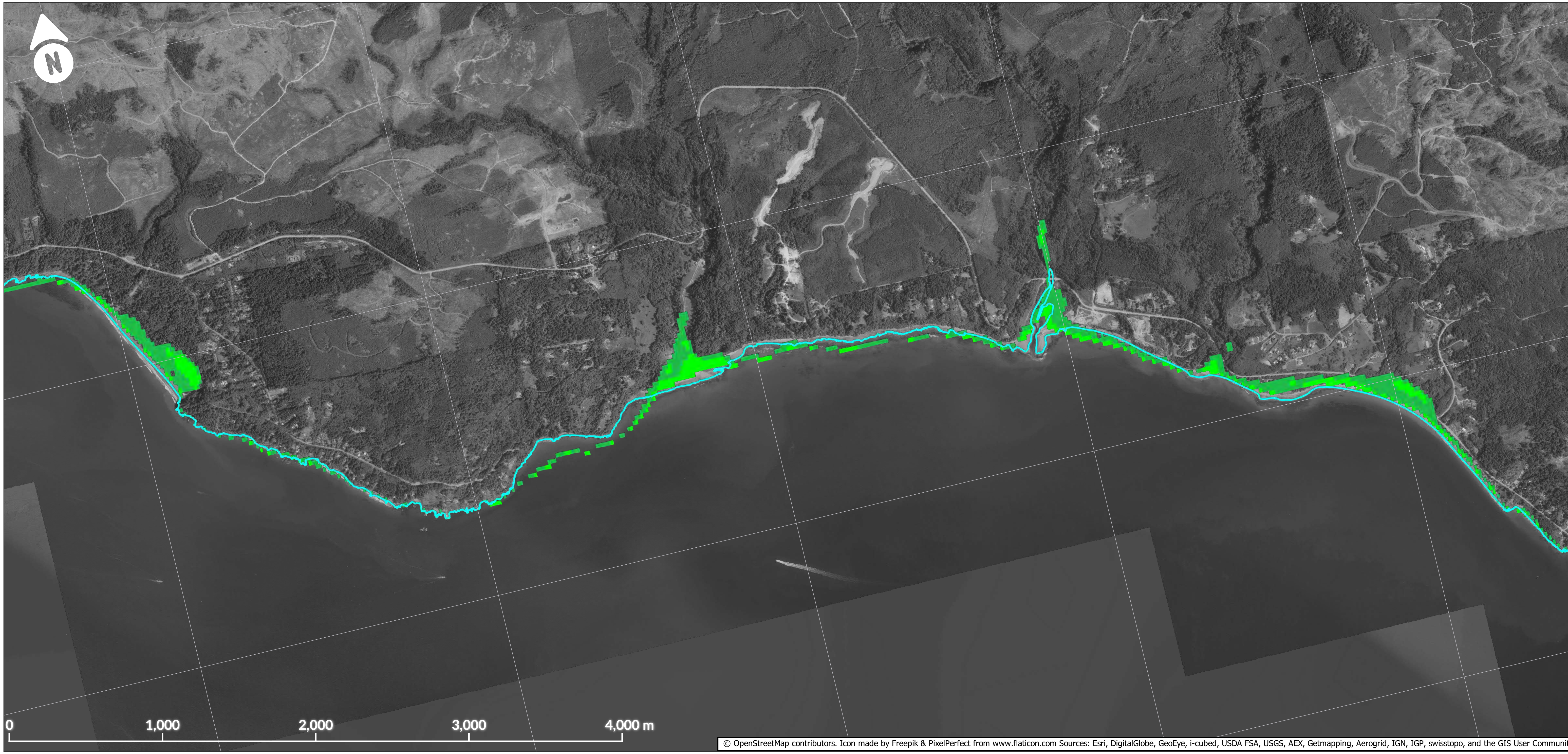


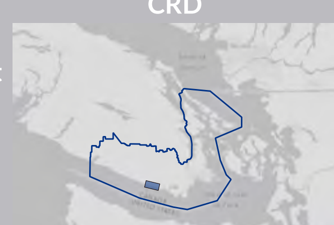
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Making a difference...together

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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Map Sheet 7 f 41

pl t date: 2020.06.11
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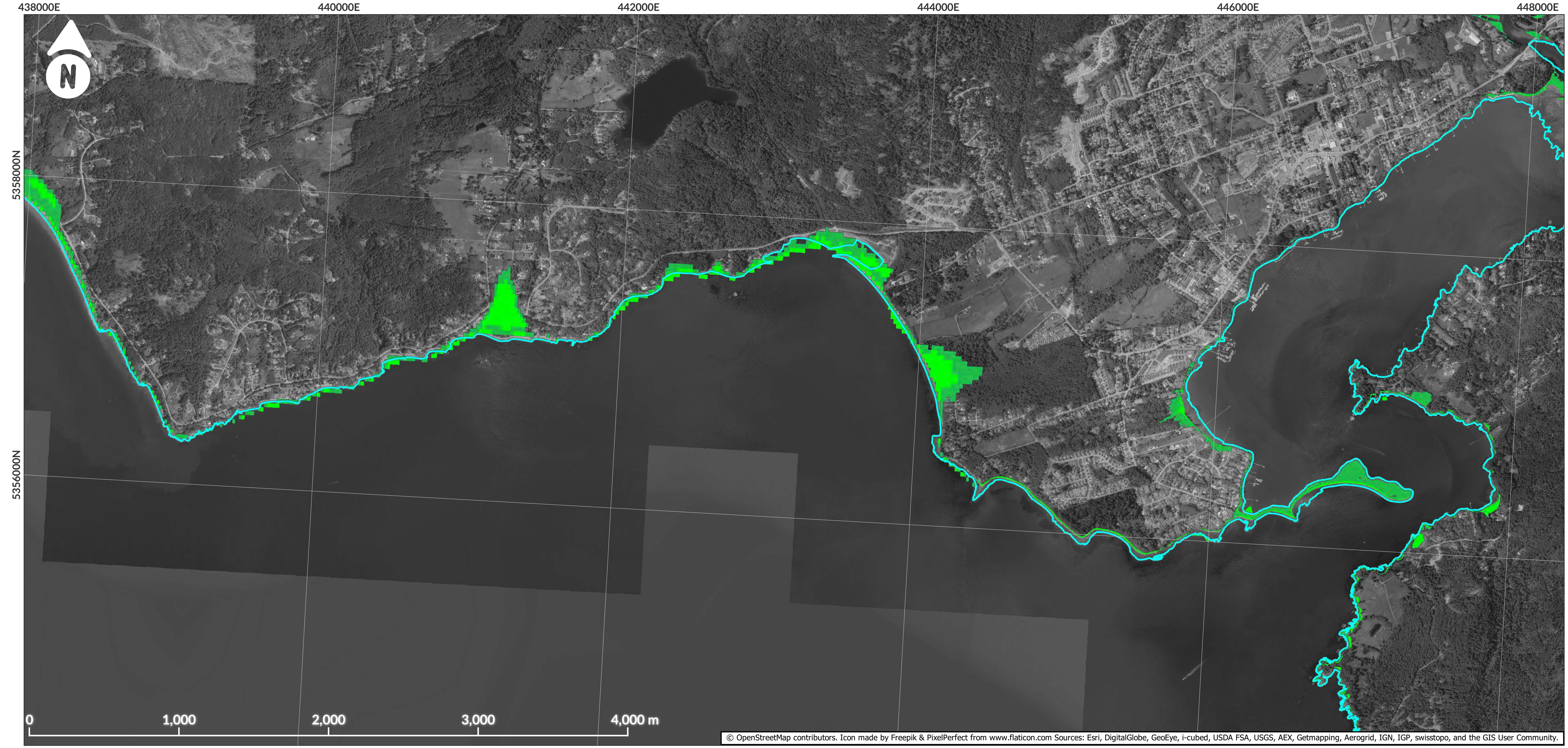


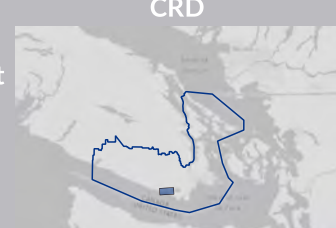
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

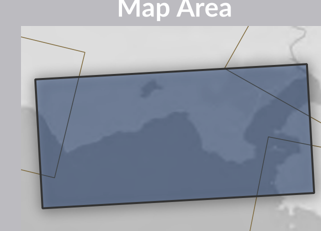
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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DHI

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 8 f 41

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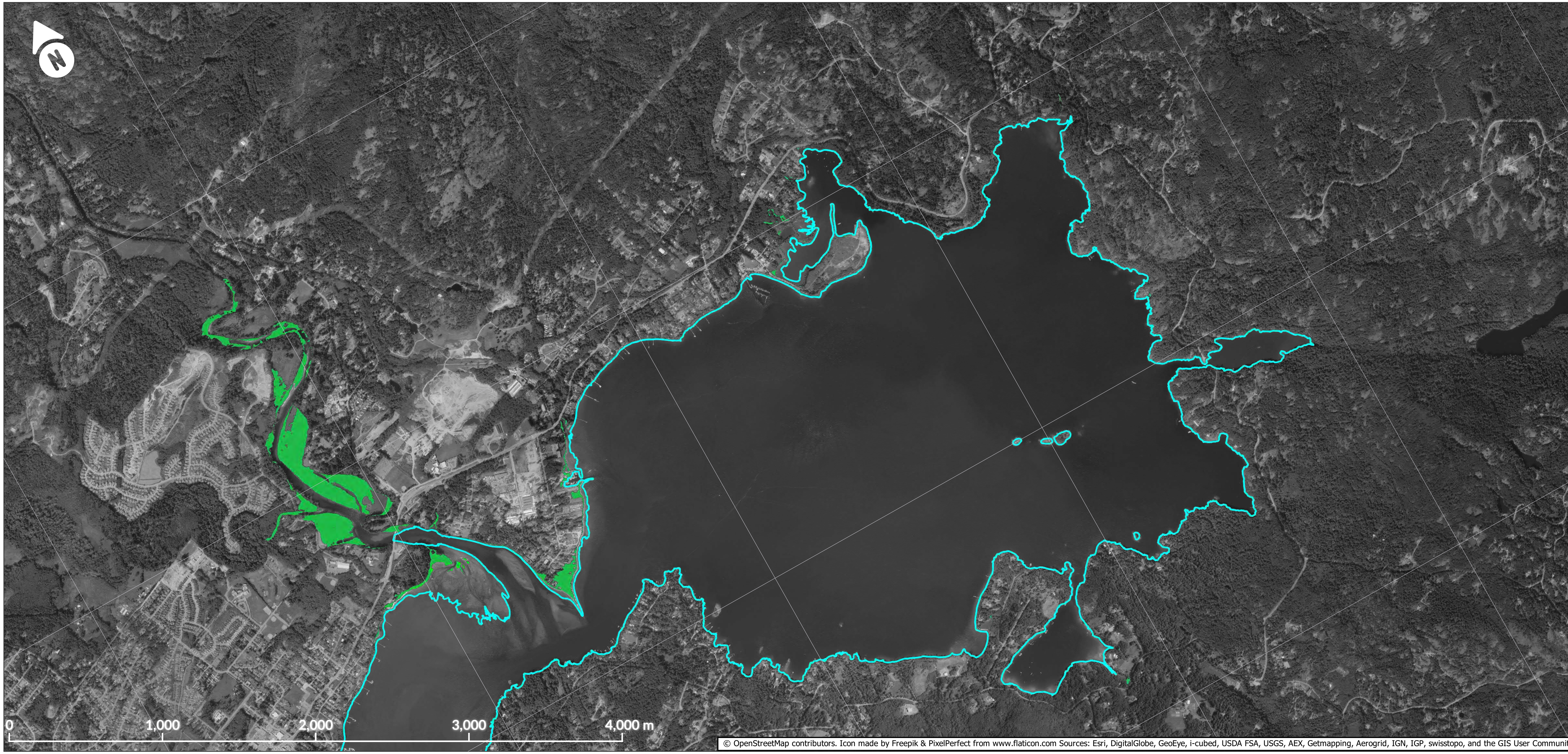


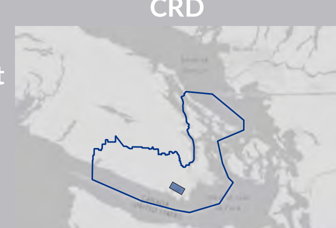
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

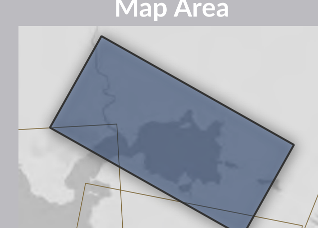
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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Legend

Coastline

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Map Sheet 9 f 41

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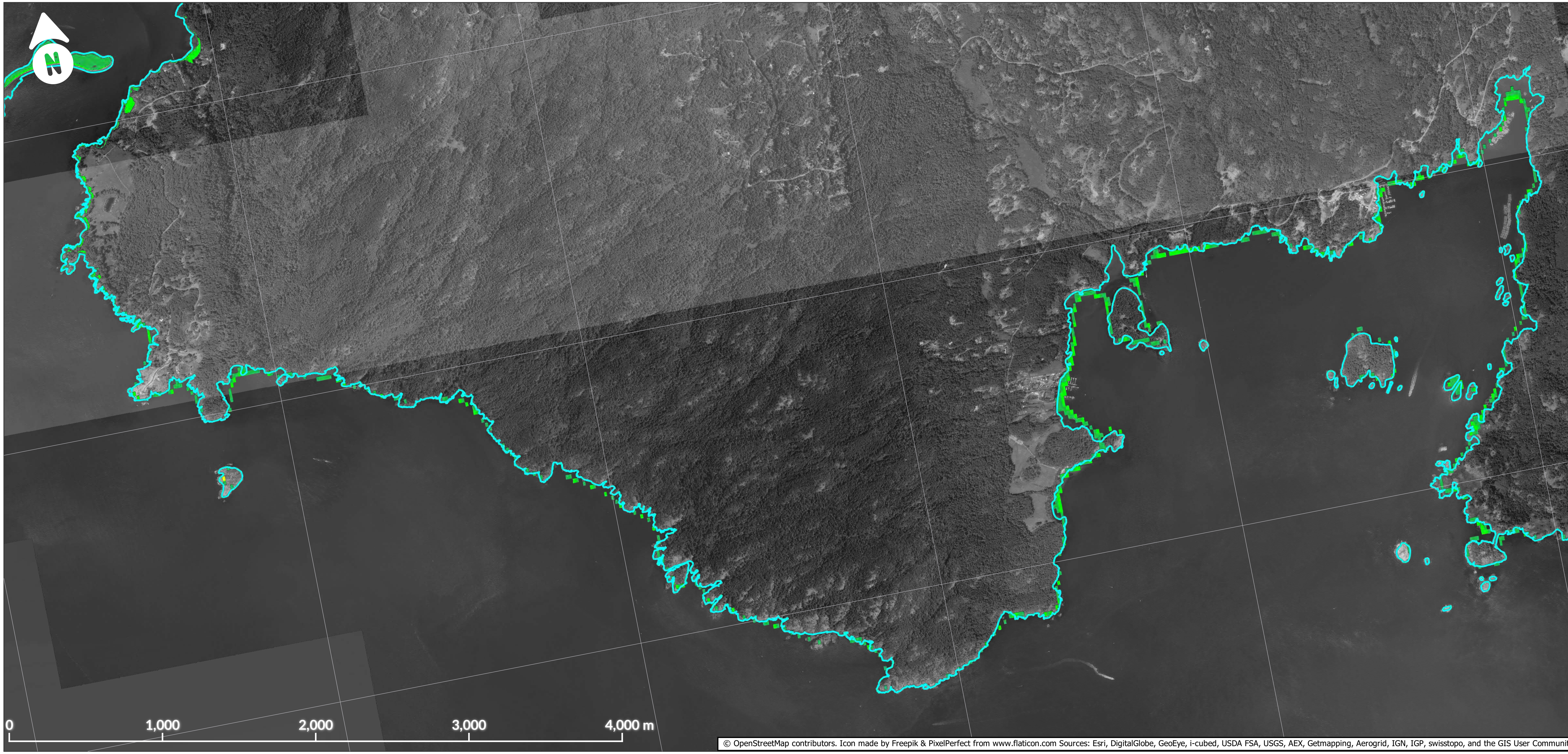


C astal Fl d Inundati n Mapping Pr ject

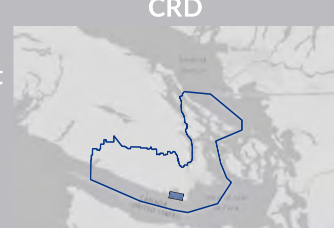
Capital Regi nal District

March 2020

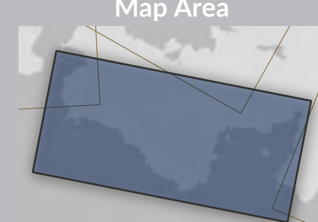
Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

Making a difference...together

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

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- 2.0 4.0
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Map Sheet 10 f 41

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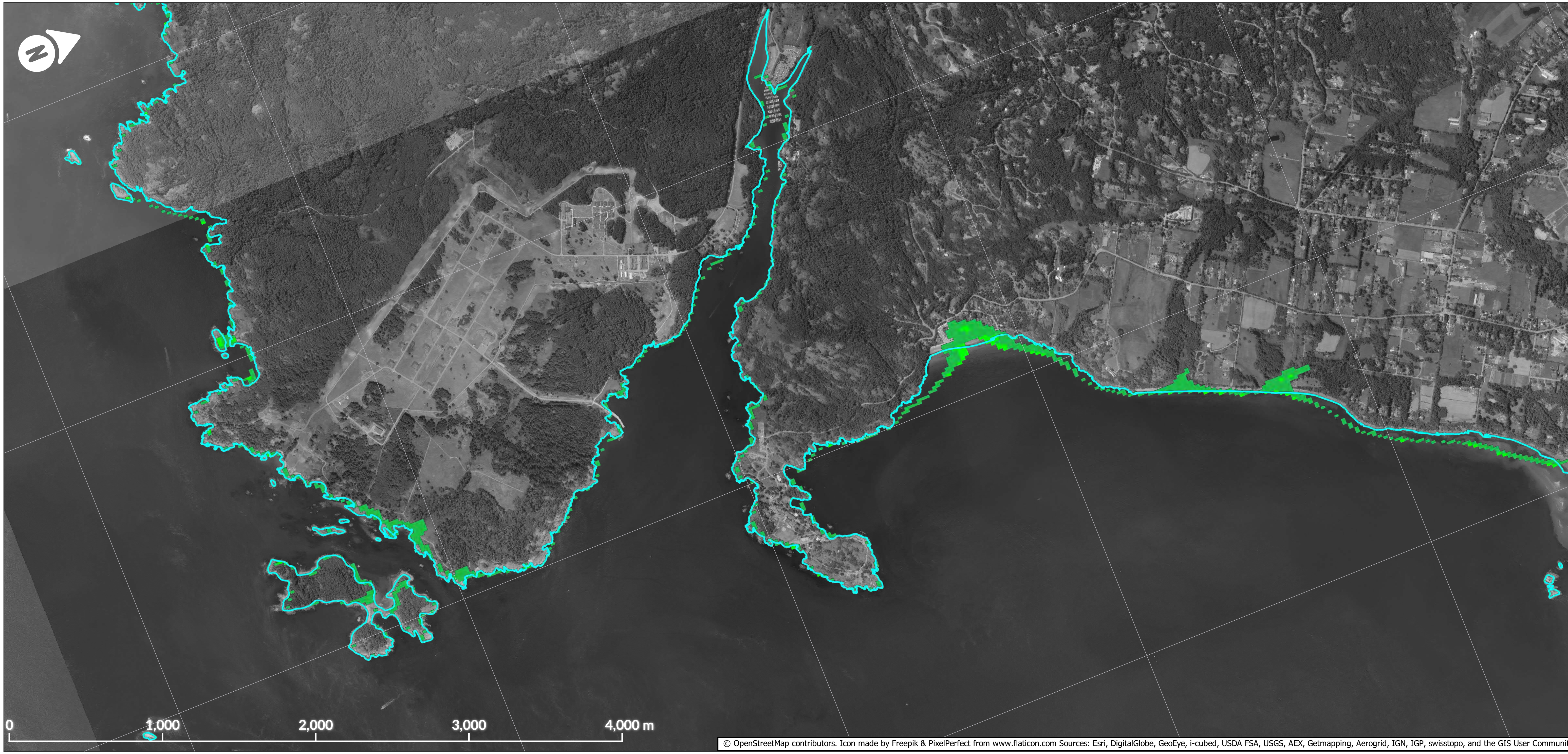

C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

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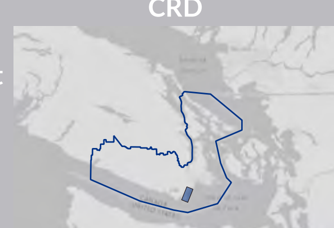
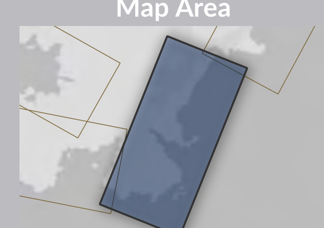


Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
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Map Sheet 11 f 41

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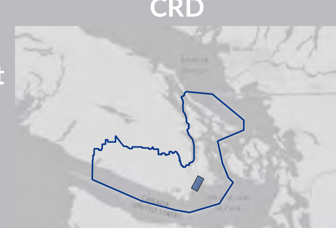
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

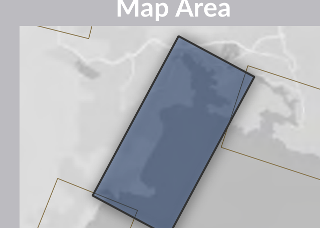
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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4. Data s urces: Orth imagery CRD, 2017)
5. F r further inf rmati n, please refer t Task 3 – Tsunami M delling and Mapping Rep rt. These maps c nstitute Appendix C f said rep rt.

Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 12 f 41

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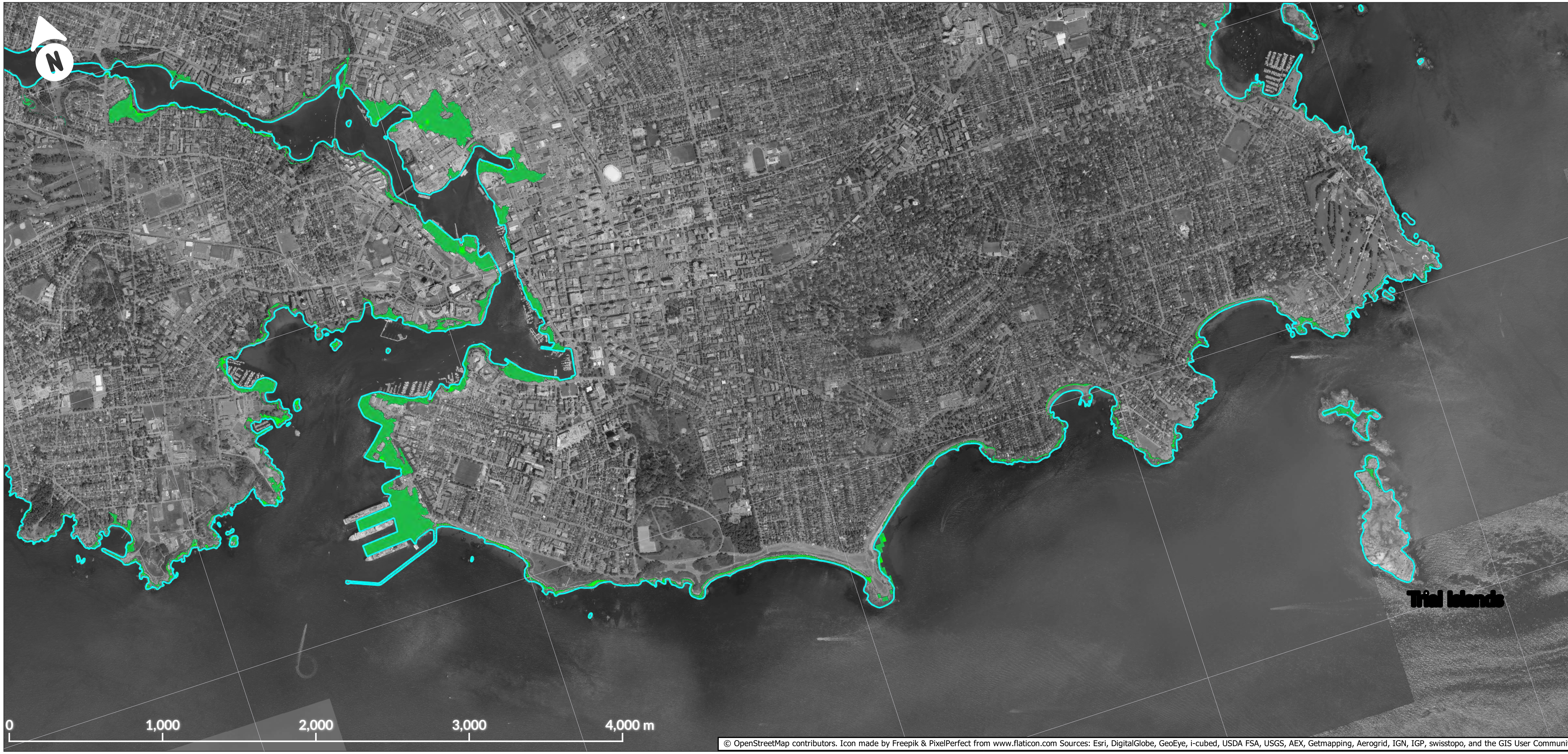
pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



C astal Fl d Inundati n Mapping Pr ject

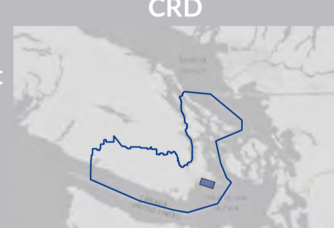
Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

Making a difference...together

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 13 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

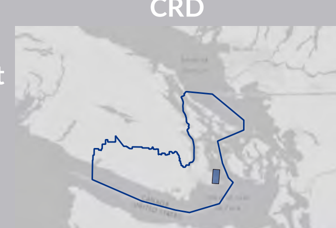
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

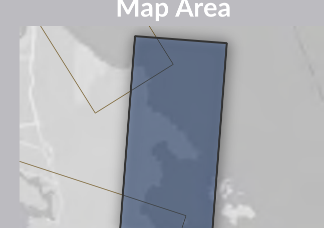
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 14 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

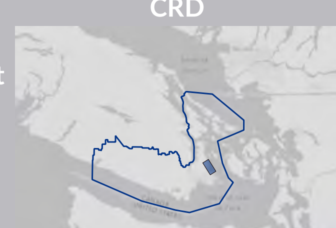
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

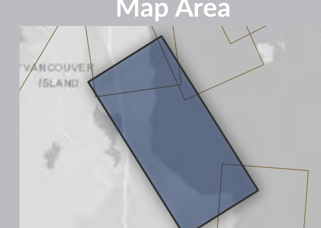
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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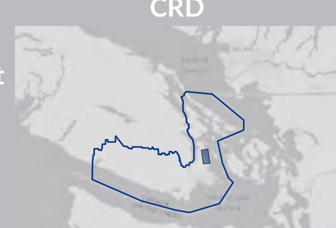
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

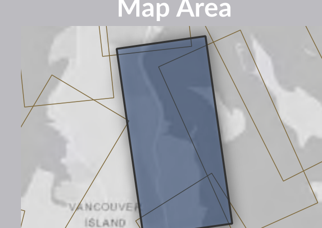
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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5. F r further inf rmati n, please refer t Task 3 – Tsunami M delling and Mapping Rep rt. These maps c nstitute Appendix C f said rep rt.

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Map Sheet 16 f 41

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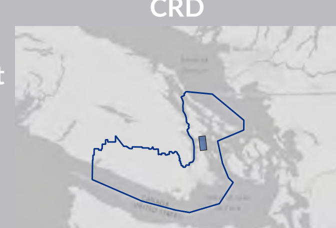
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

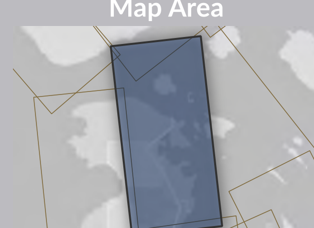
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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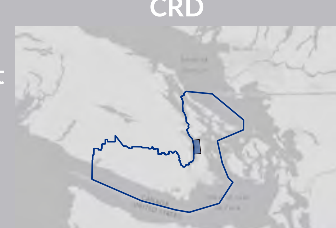
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

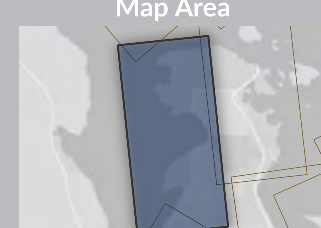
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 18 f 41

pl t date: 2020.06.11
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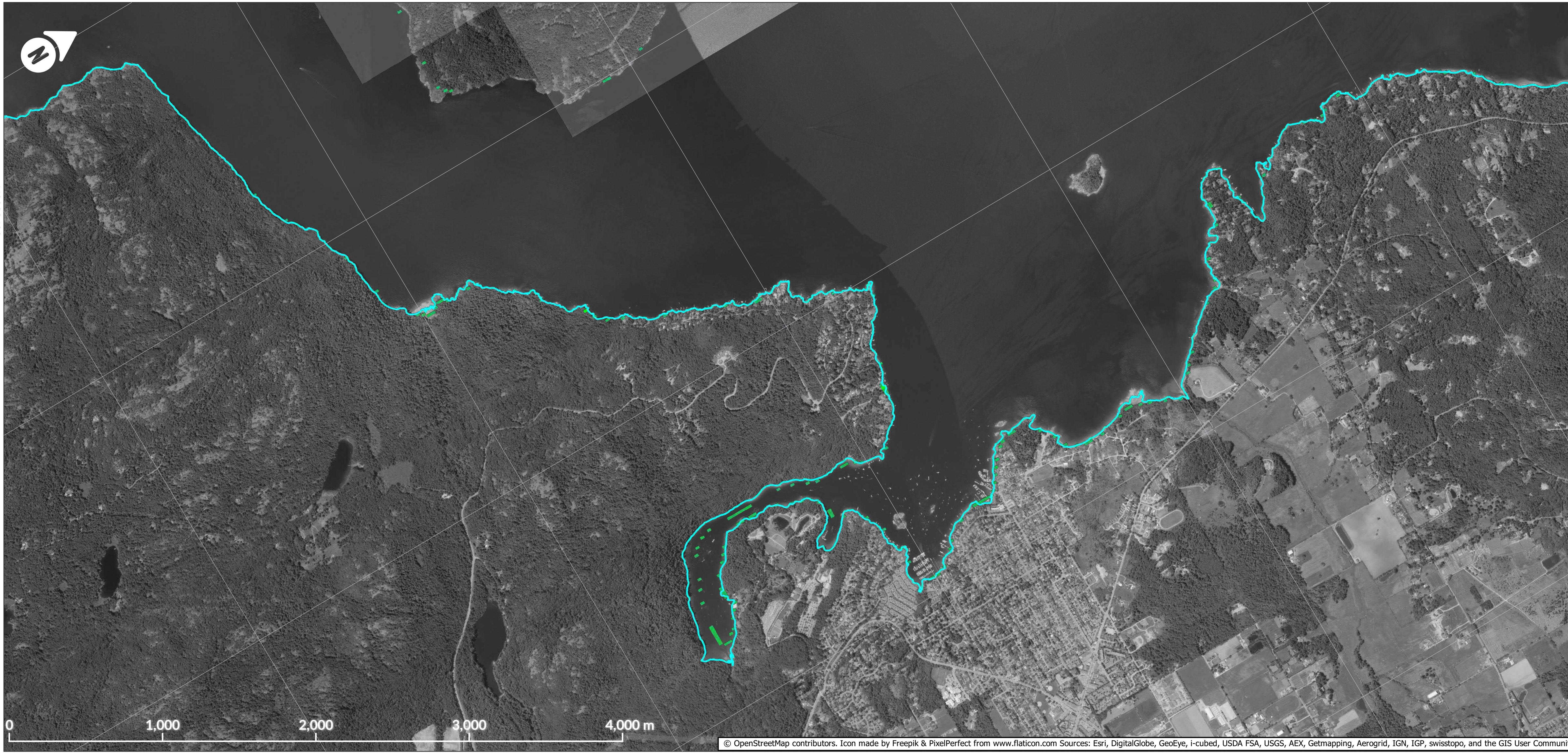


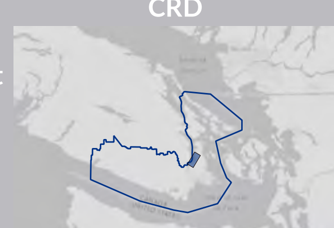
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

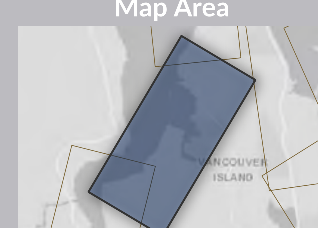
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 19 f 41

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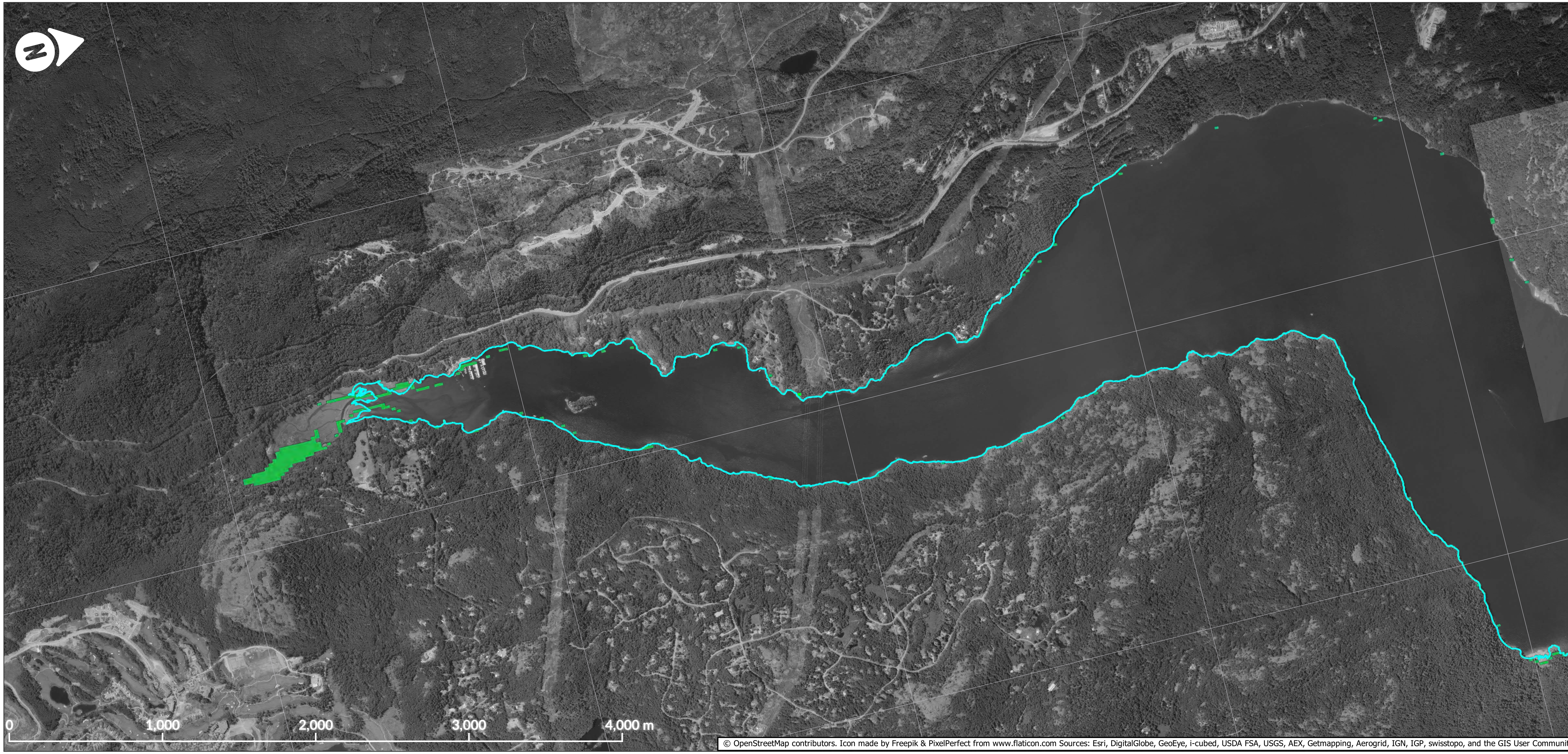
458000E



462000E

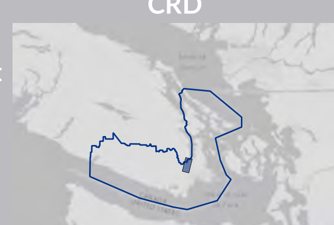
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

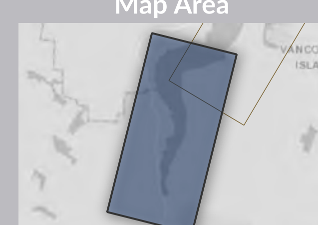
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 20 f 41

pl t date: 2020.06.11
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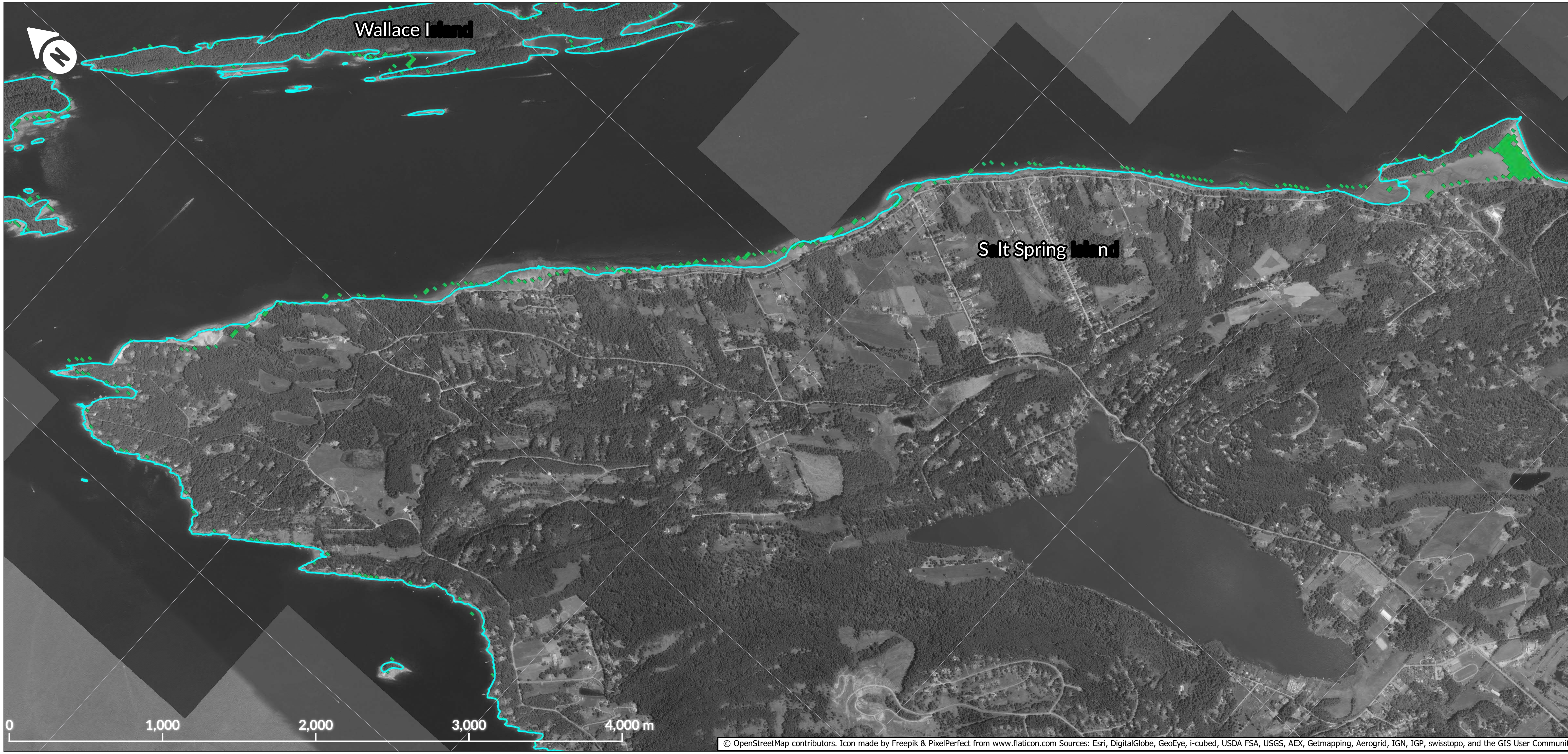


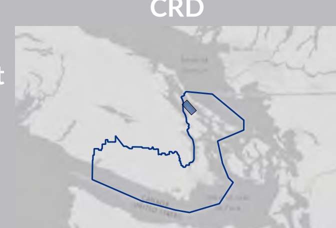
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

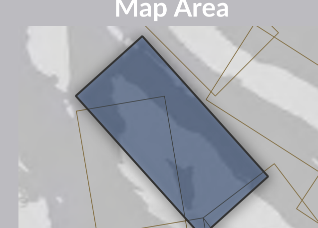
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Drawn by C. Duncan and S. Haley

Map Sheet 21 f 41

pl t date: 2020.06.11
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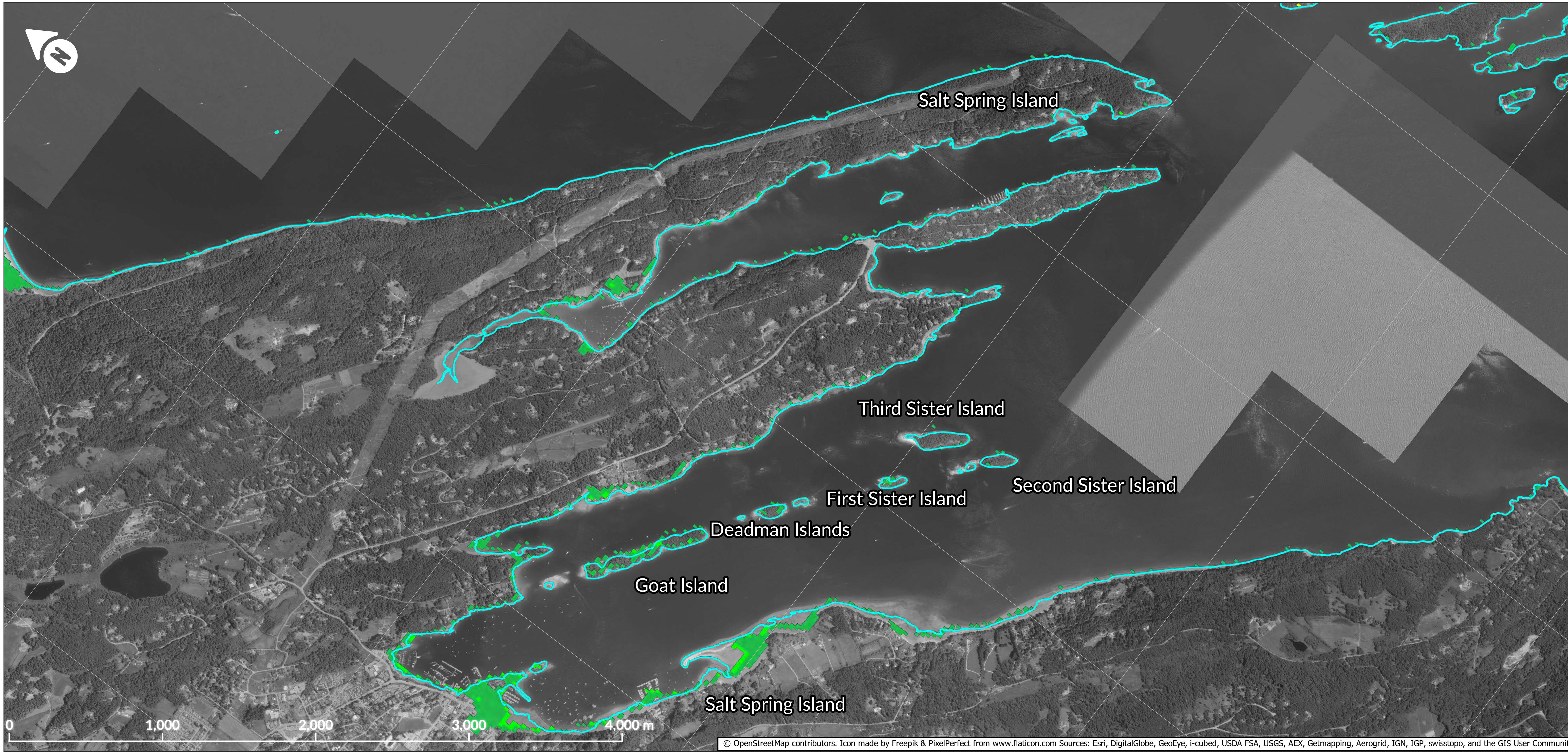


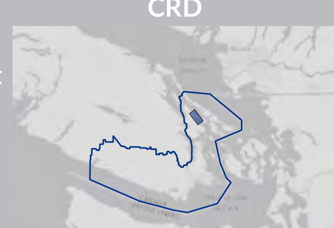
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

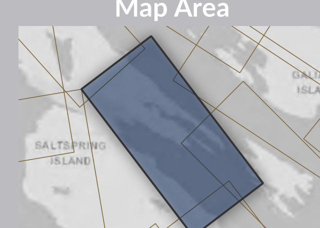
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 22 f 41

pl t date: 2020.06.11
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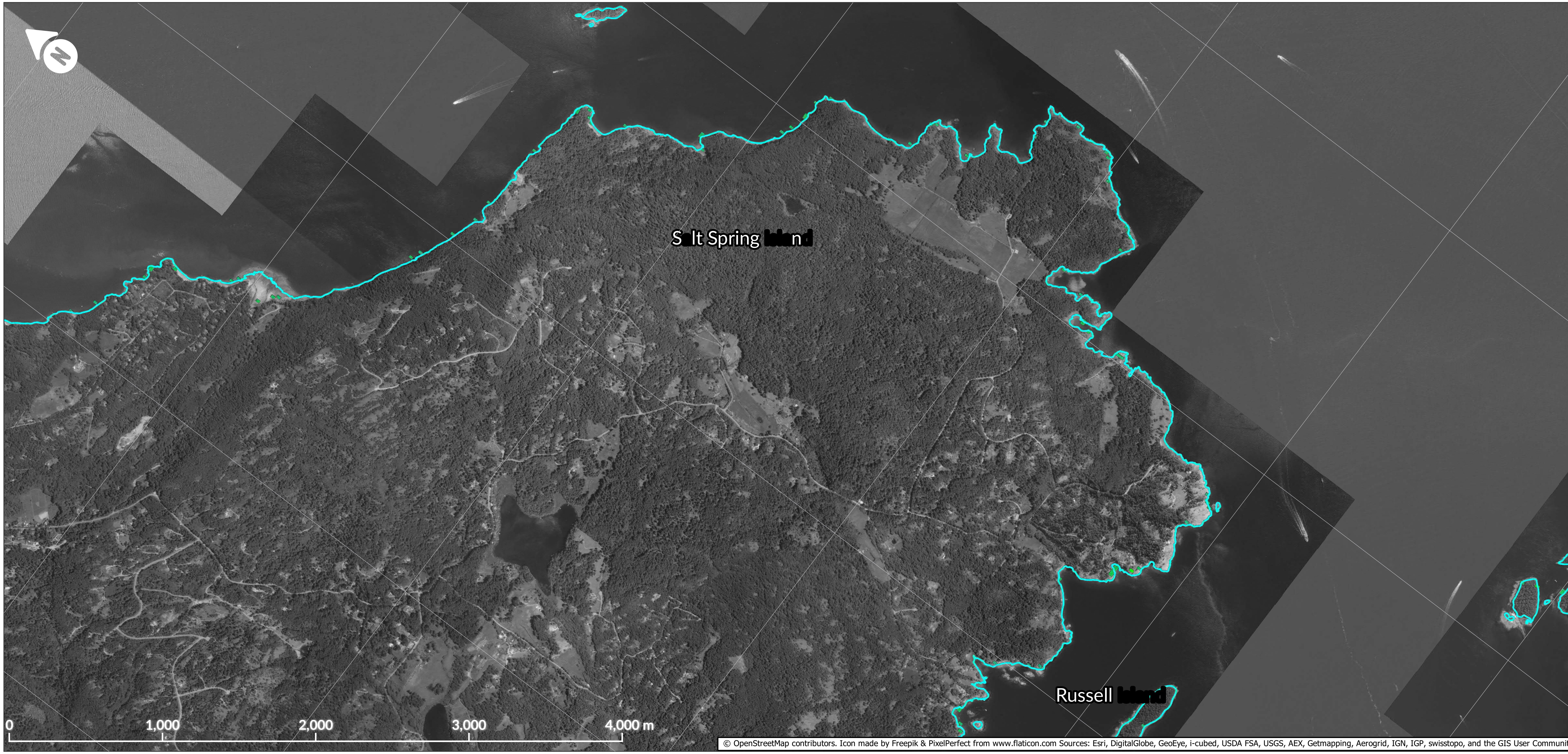


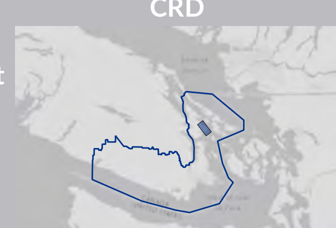
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 23 f 41

pl t date: 2020.06.11
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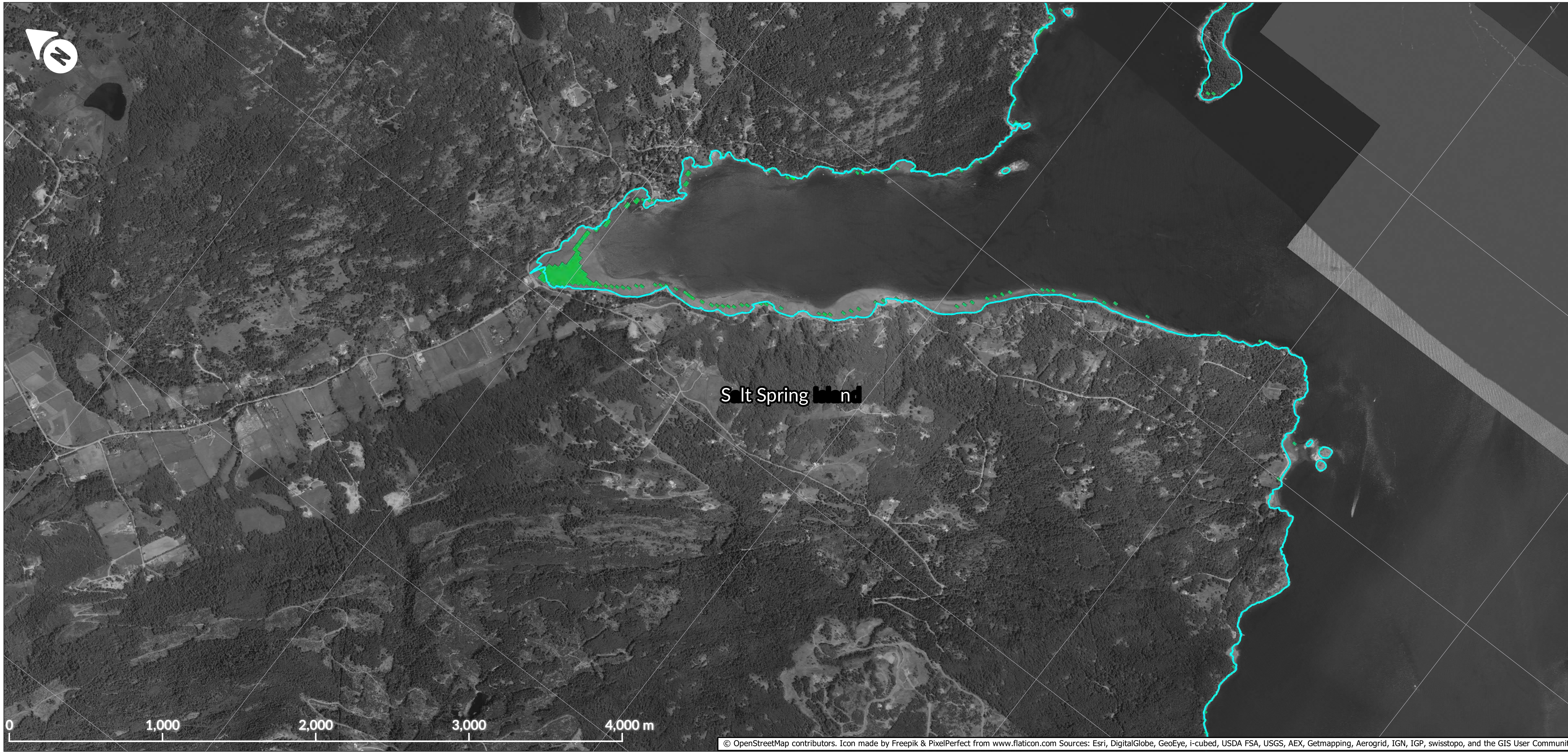
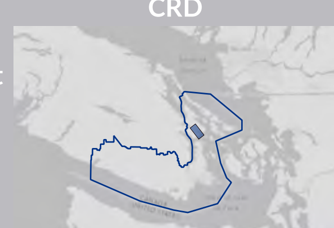


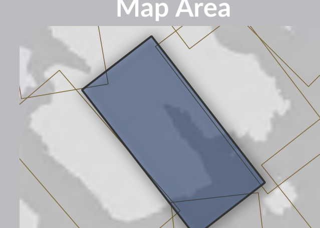
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment





Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 24 f 41

pl t date: 2020.06.11
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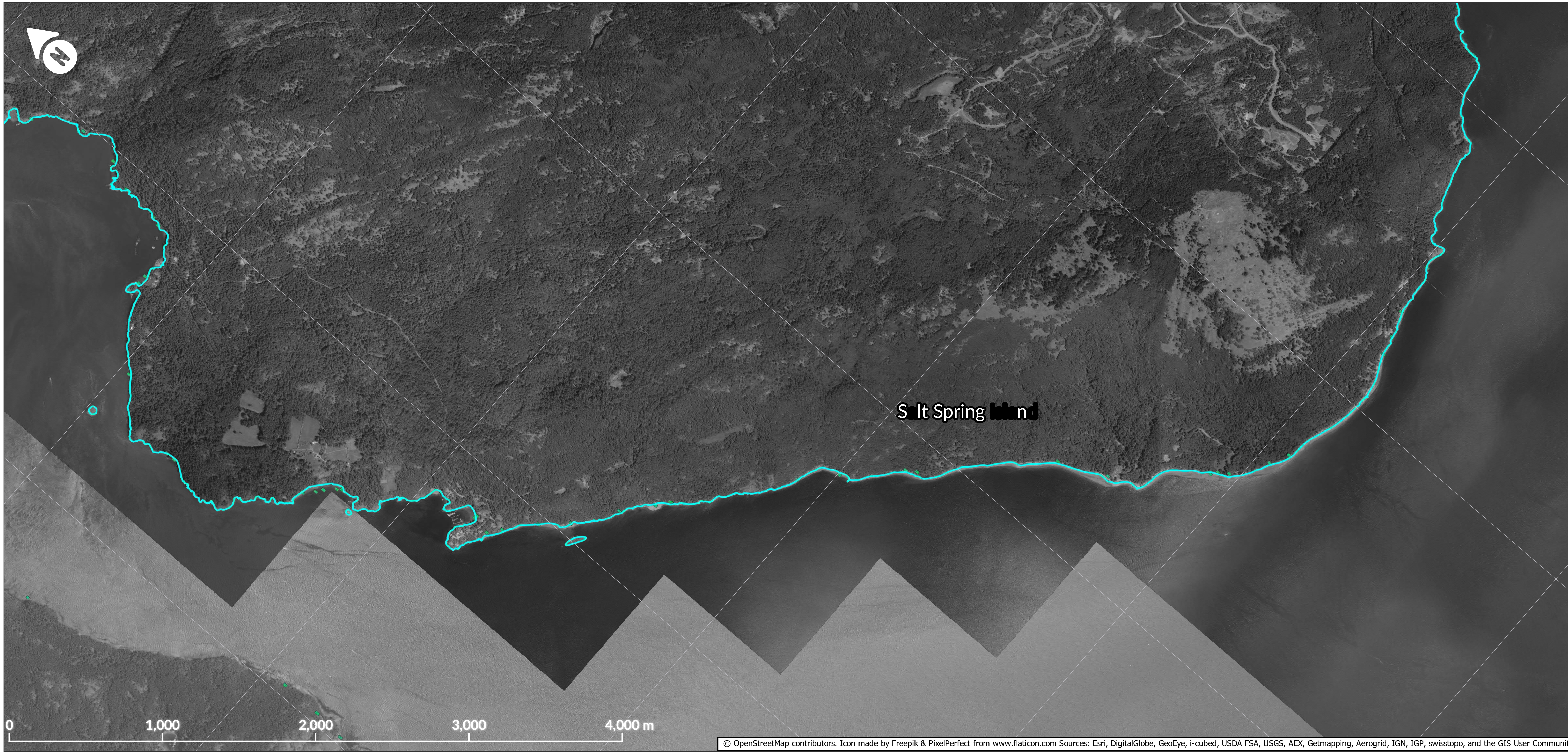


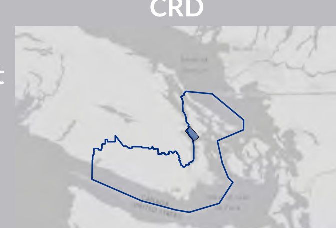
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 25 f 41

pl t date: 2020.06.11
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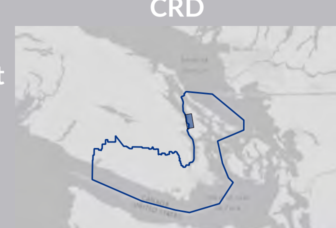
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

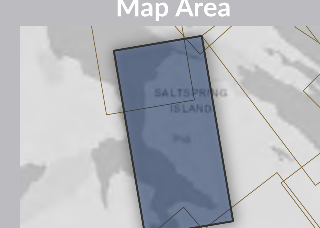
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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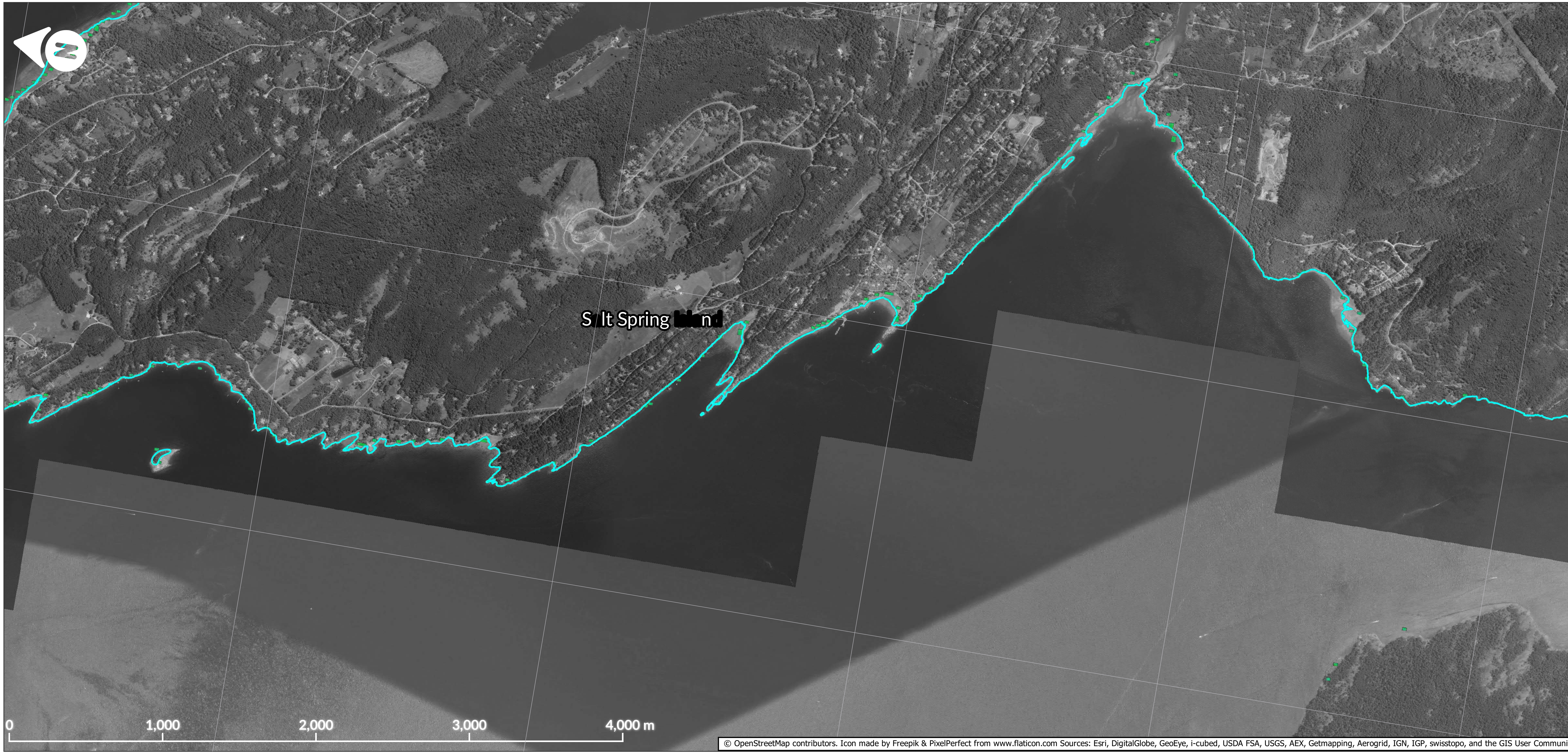
Map Sheet 26 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



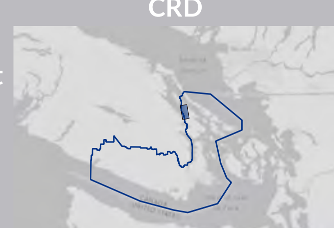
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

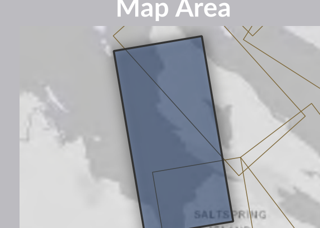
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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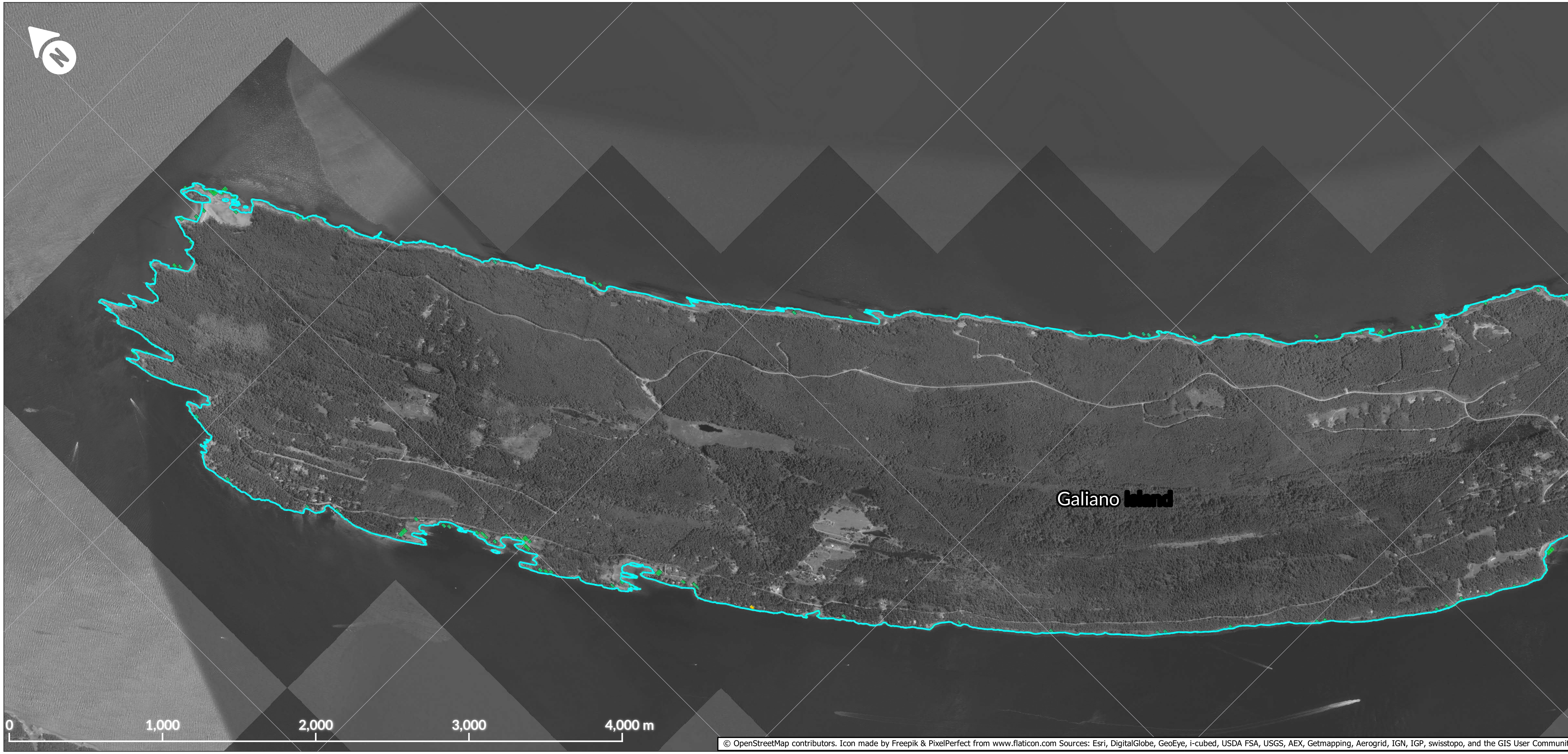
Map Sheet 27 f 41



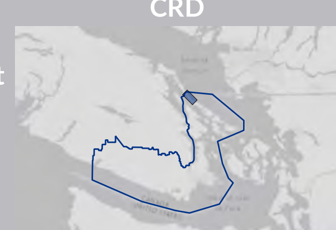
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 28 f 41

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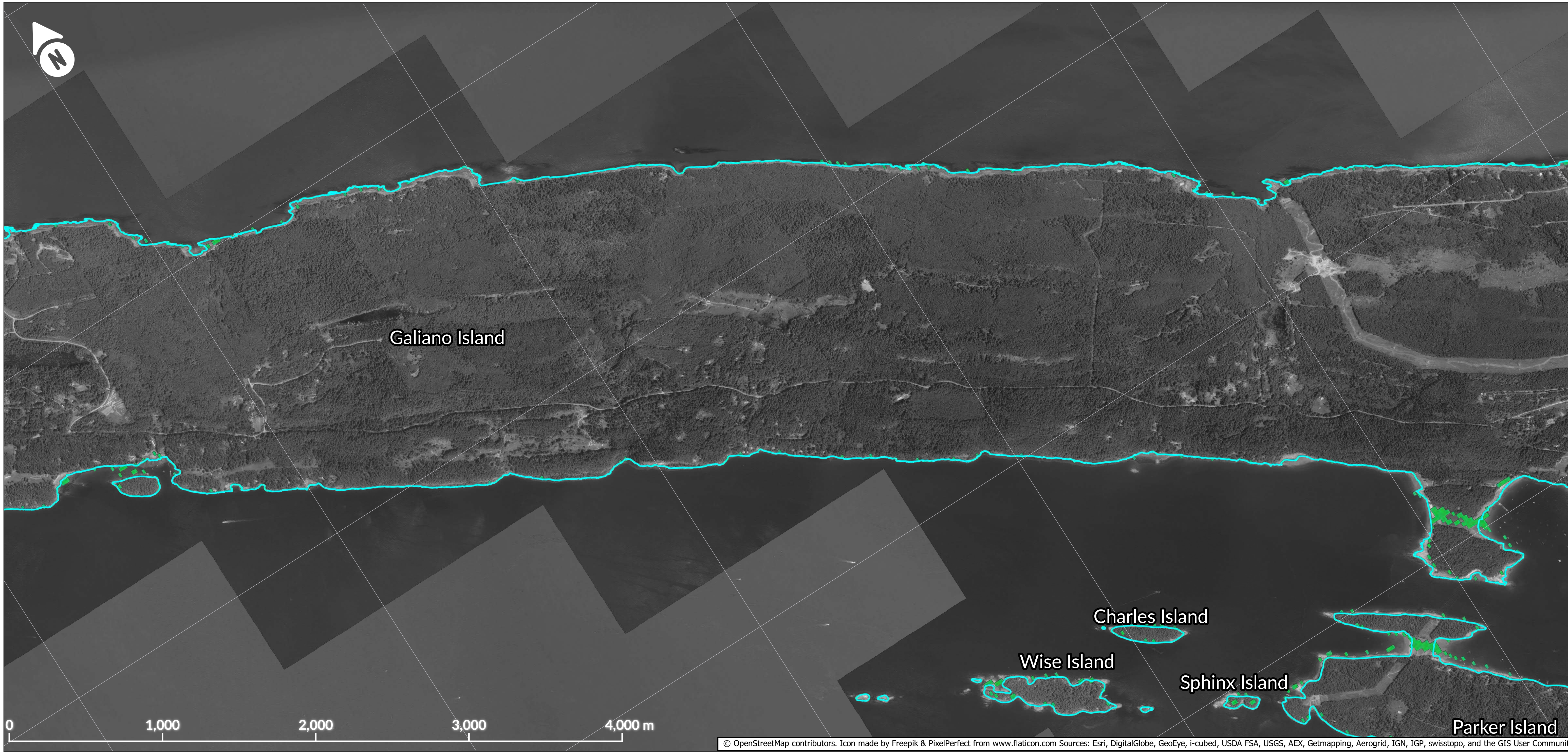
pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



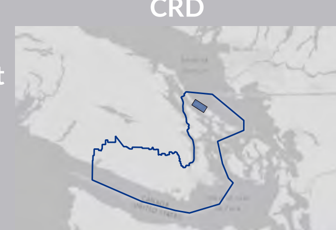
C astal Fl   d Inundati n Mapping Pr ject

Capital Regi nal District

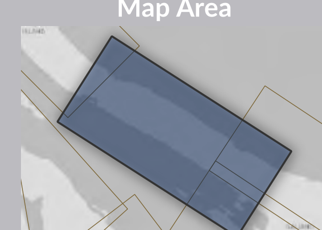
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0   2.0
- 2.0   4.0
- 4.0   6.0
- 6.0   8.0
- >8.0

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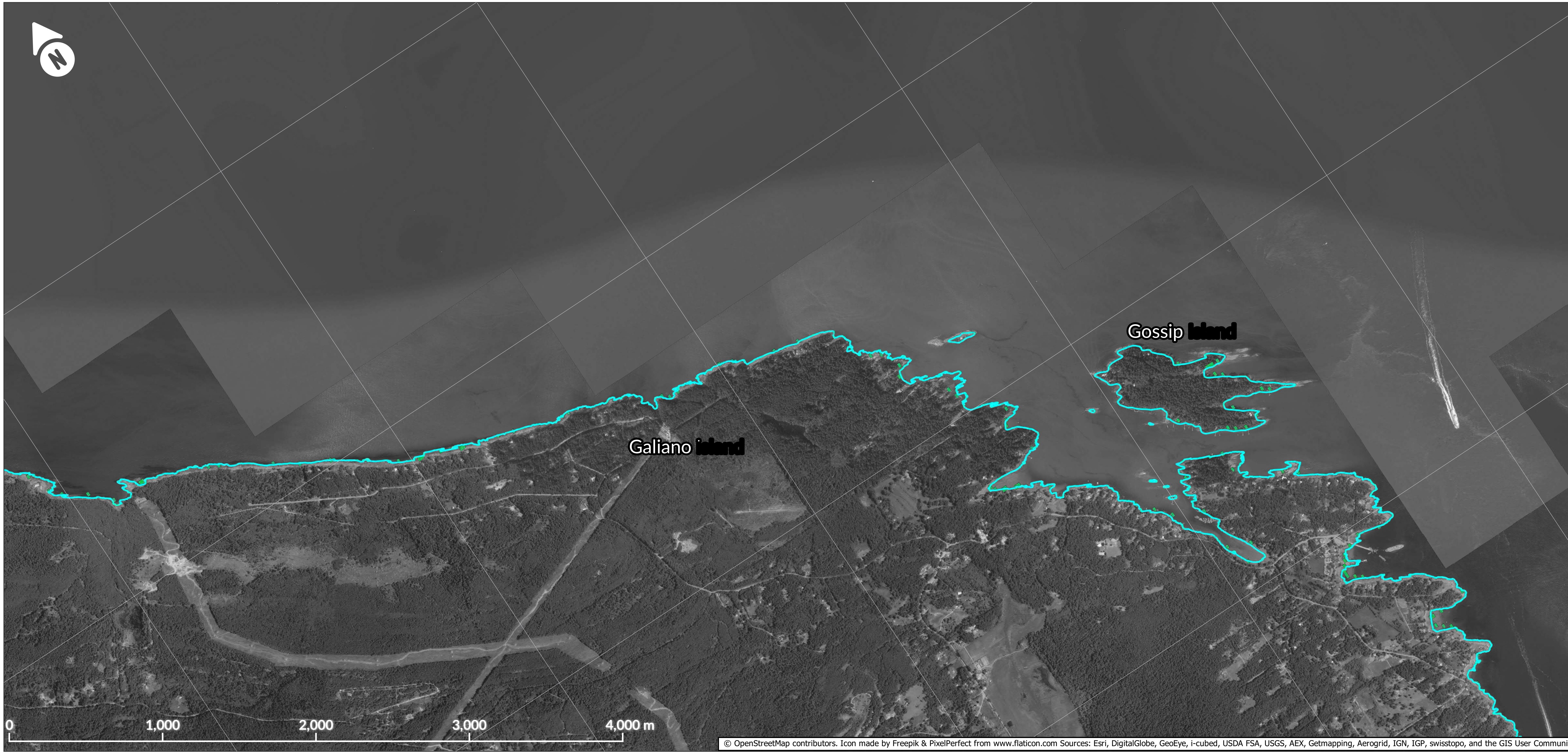
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 29   f 41



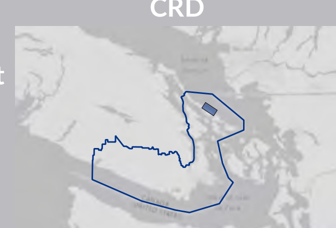
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

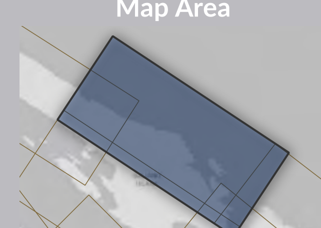
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



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Legend

Coastline

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Pr ject N . 20192676
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Map Sheet 30 f 41

pl t date: 2020.06.11
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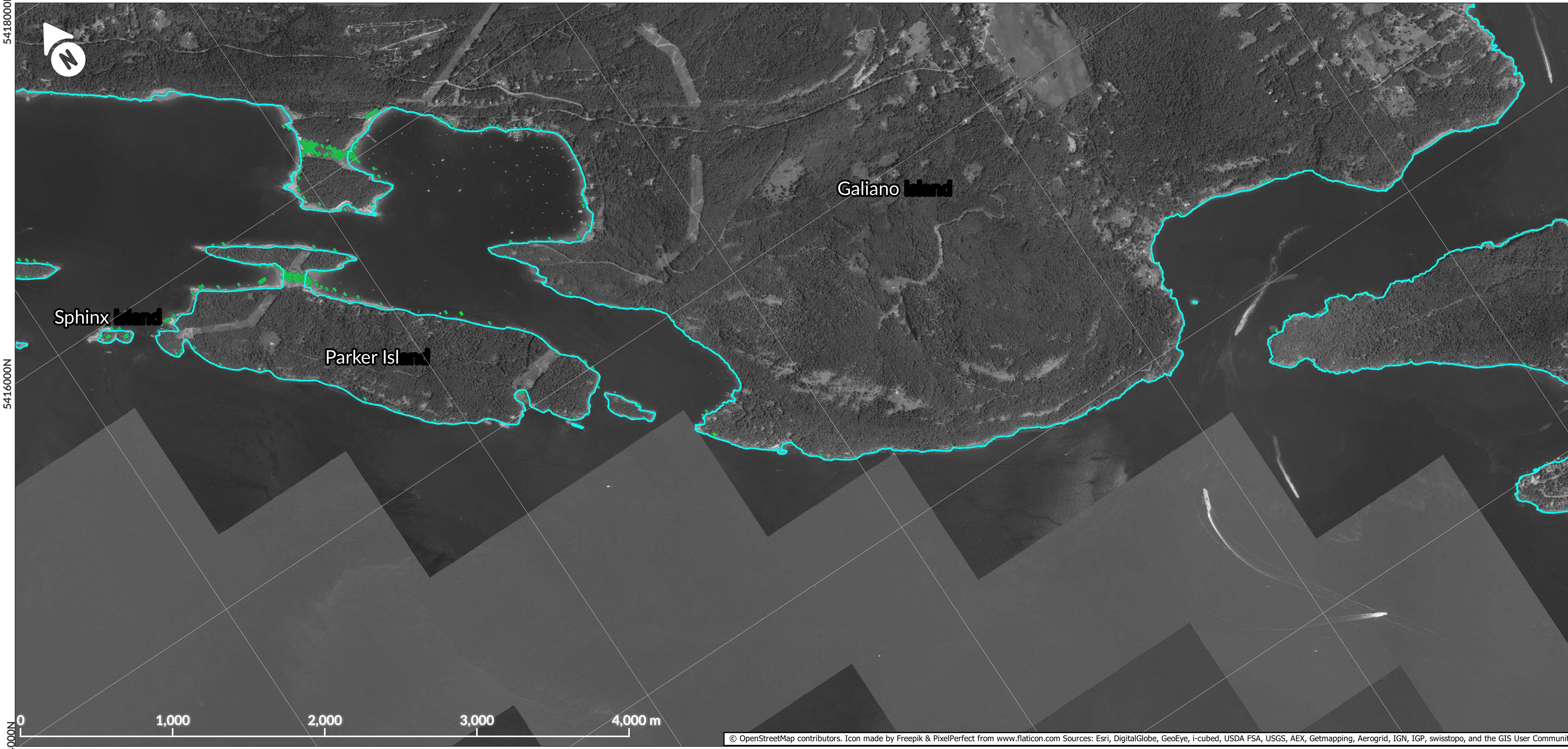


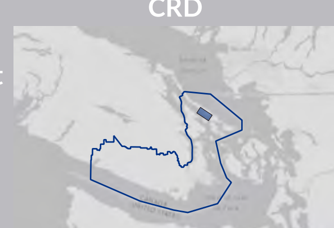
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

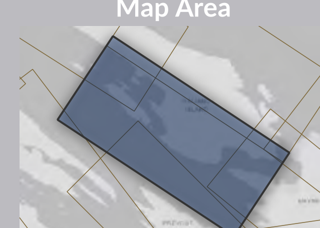
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
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Map Sheet 31 f 41

pl t date: 2020.06.11
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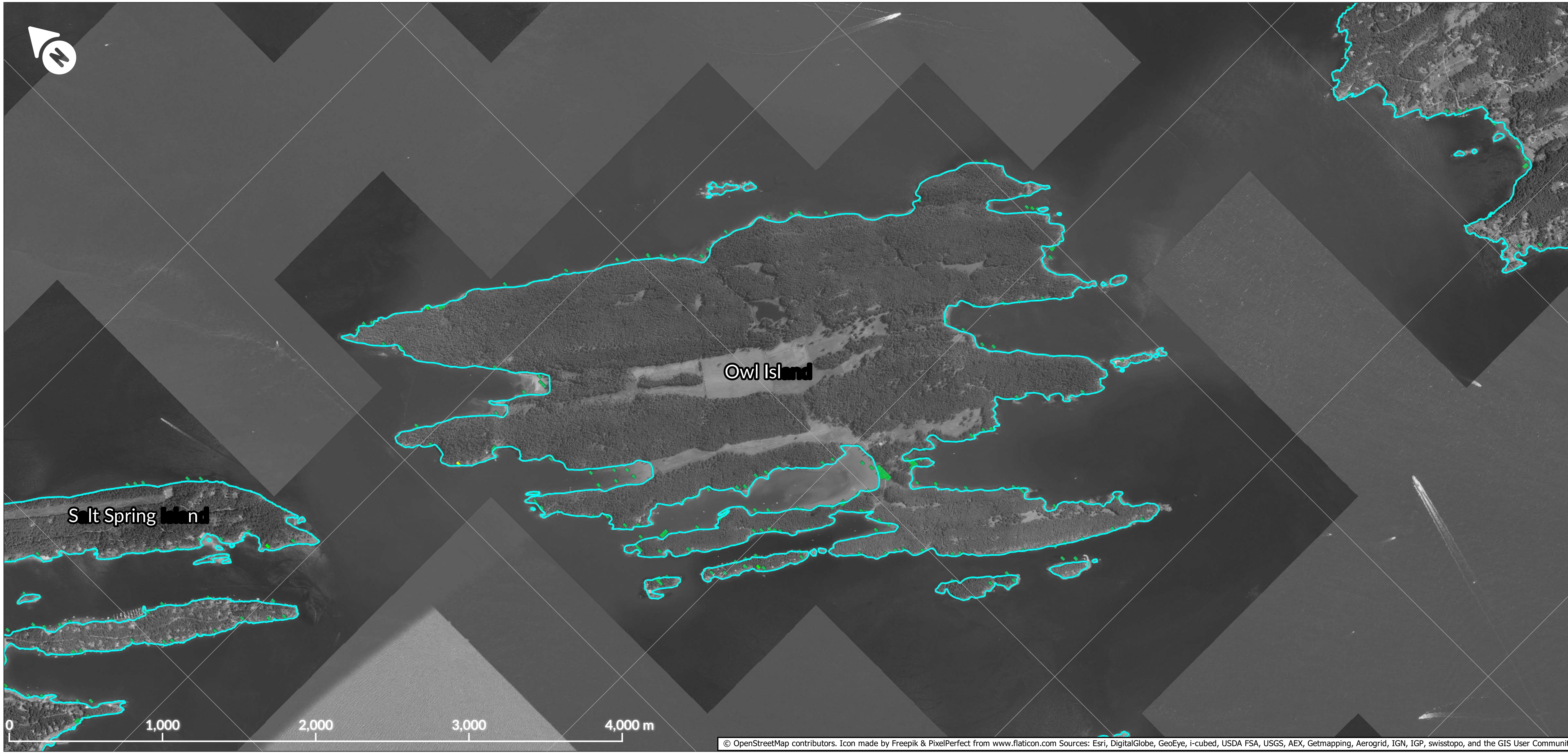


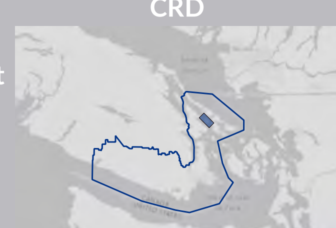
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



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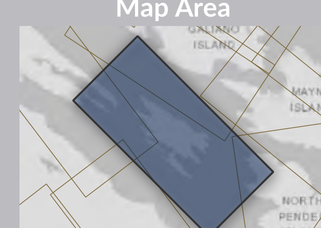

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Coastline

Inundation Depth (m)

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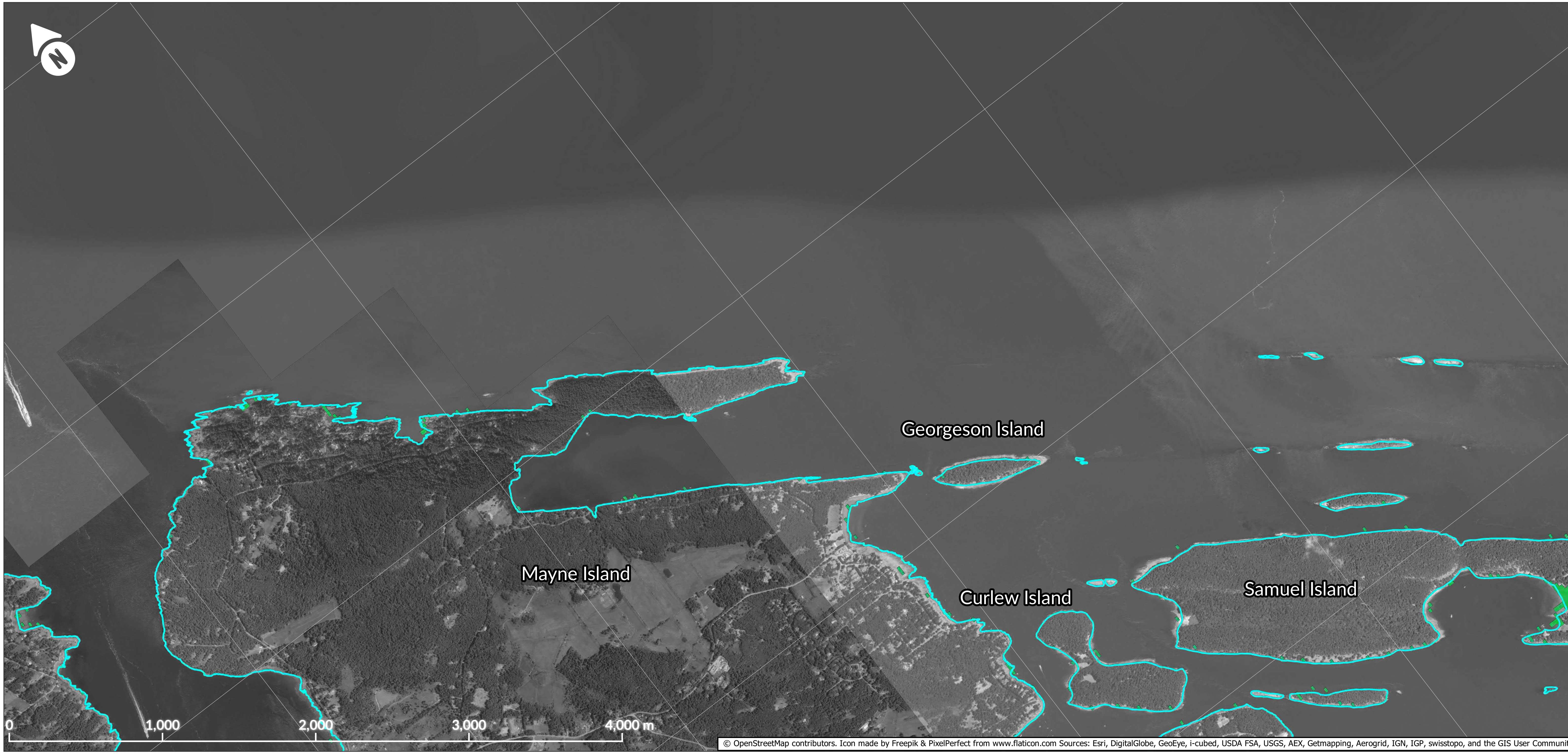
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 32 f 41



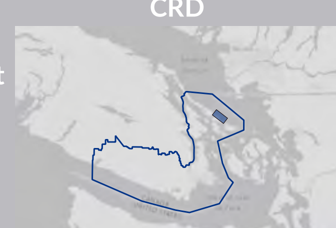
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

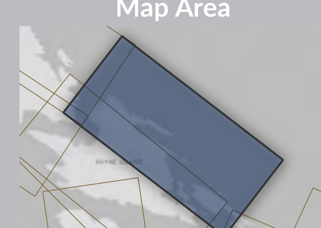
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
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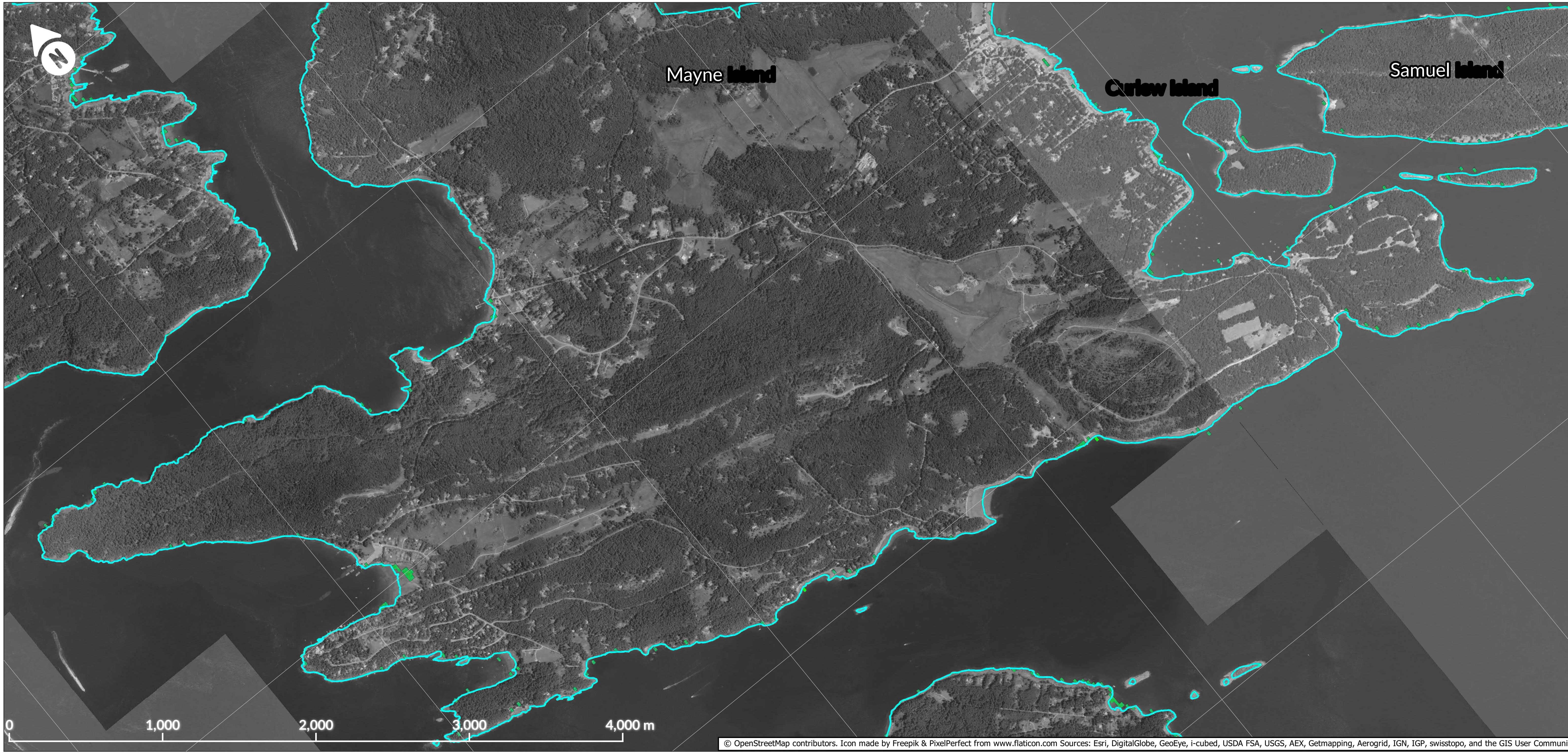
Map Sheet 33 f 41



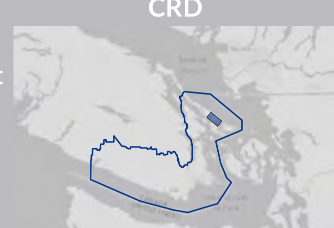
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

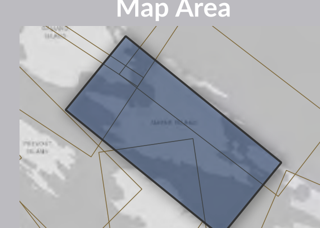
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
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Map Sheet 34 f 41

pl t date: 2020.06.11
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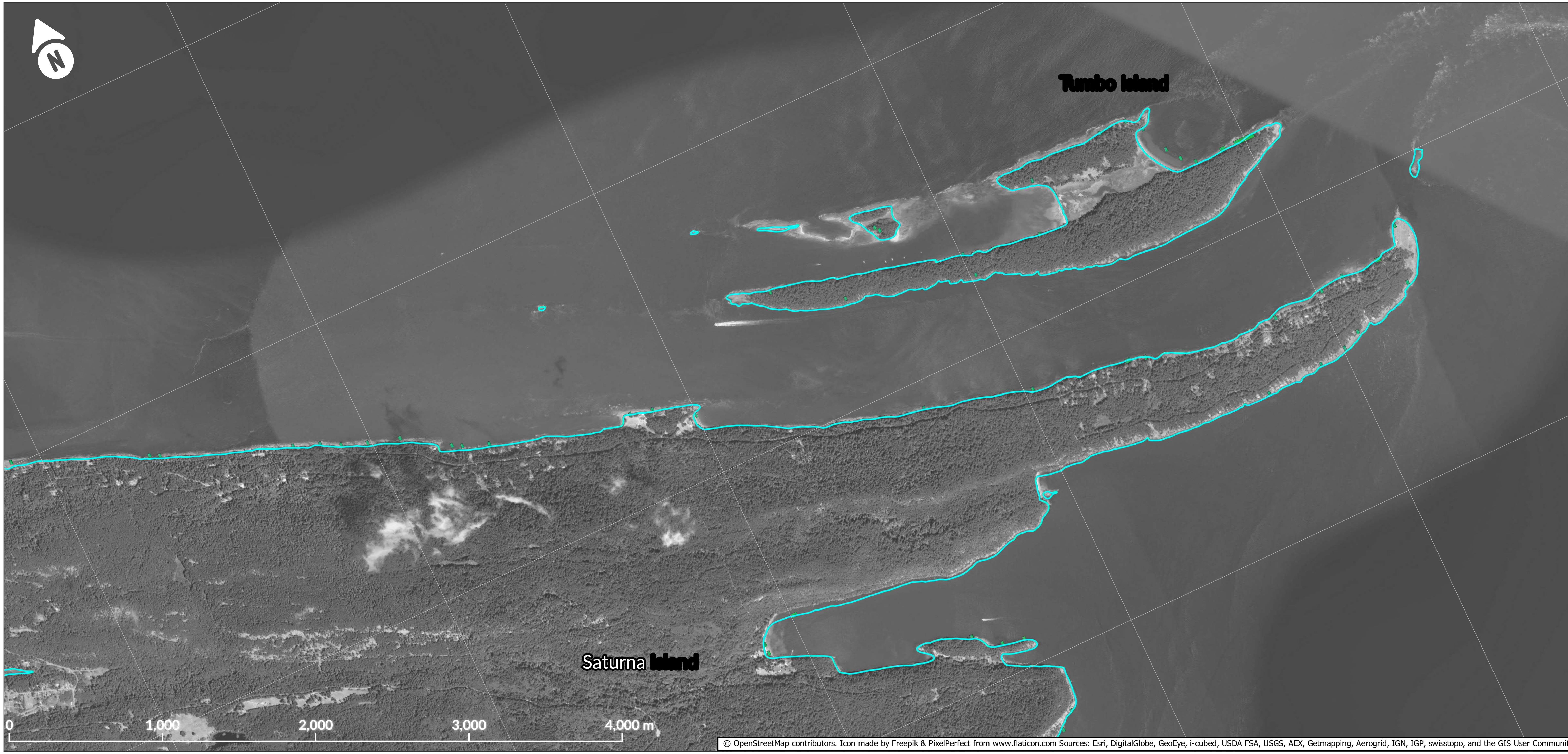


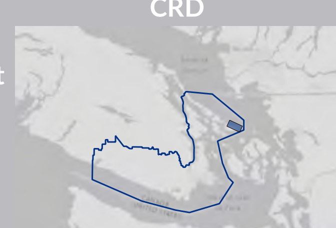
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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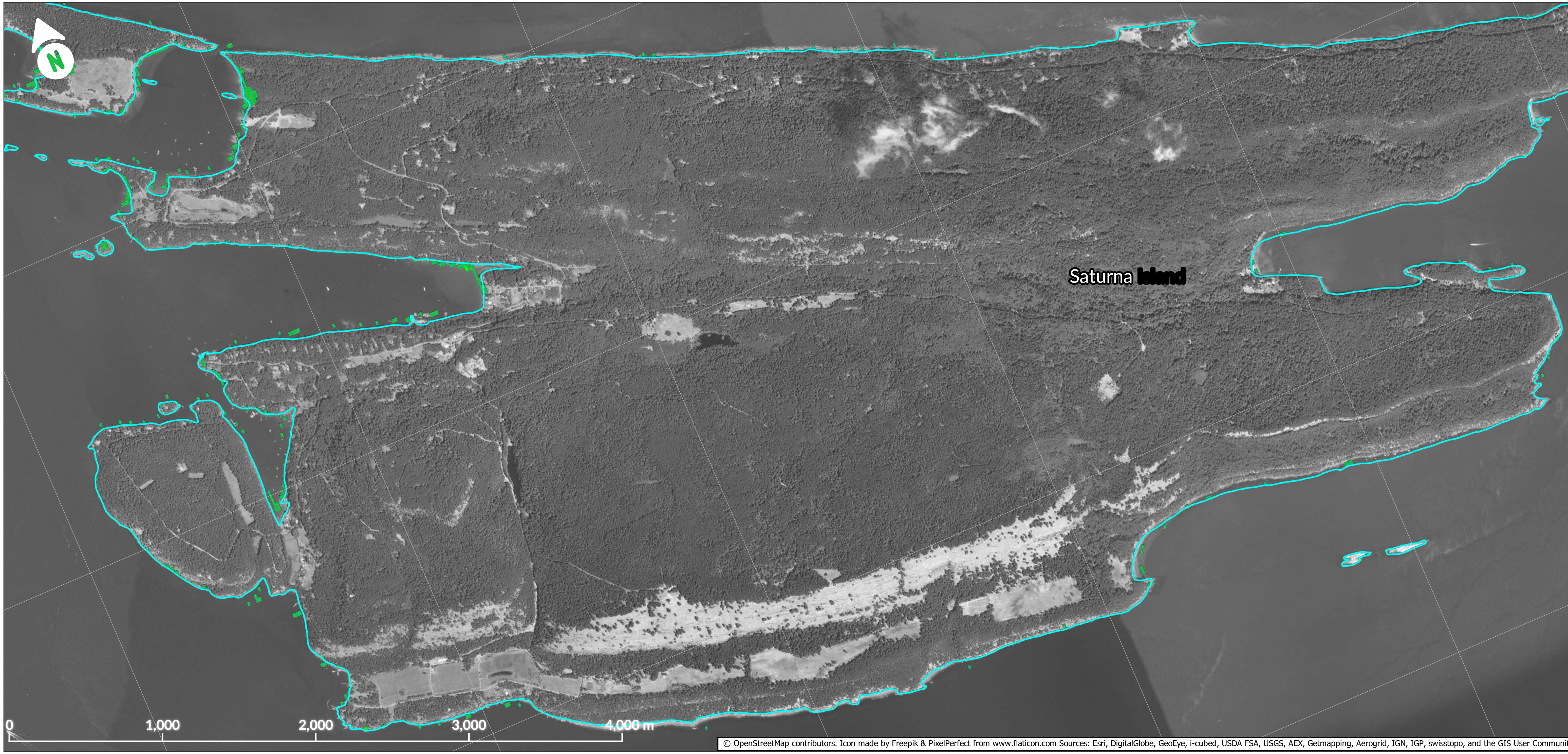
Map Sheet 35 f 41

pl t date: 2020.06.11
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



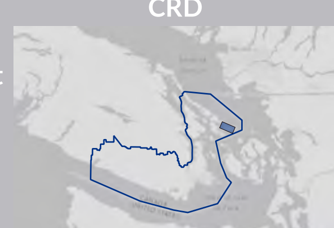
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 36 f 41

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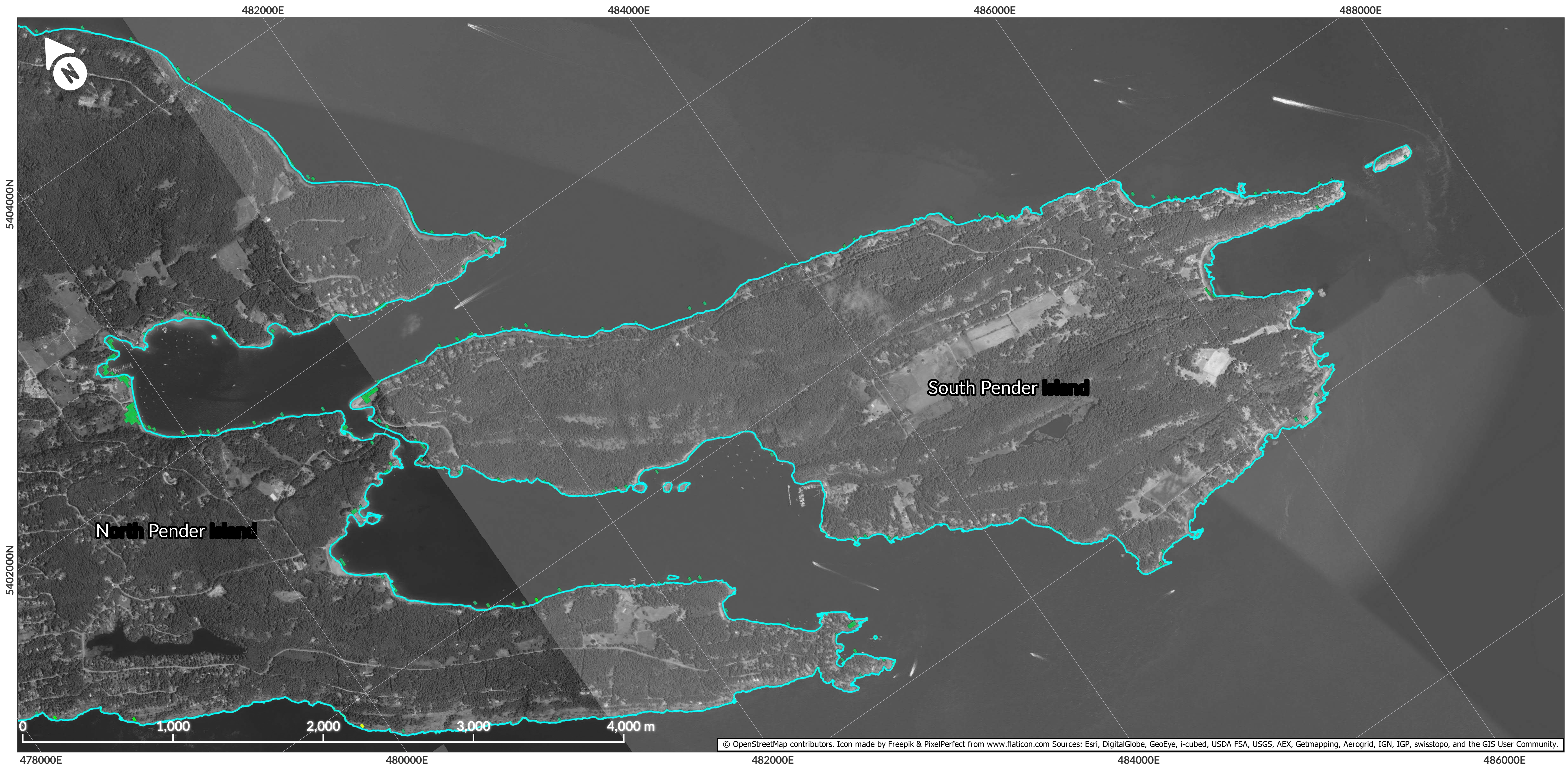


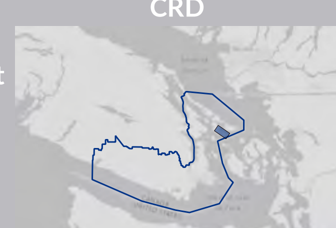
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 Bill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 37 f 41

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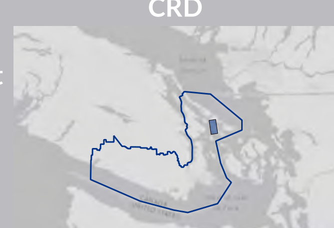
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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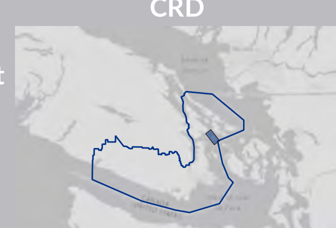
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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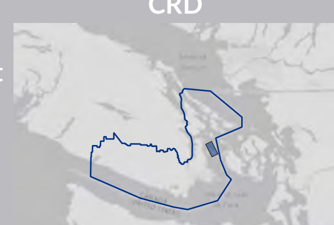
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

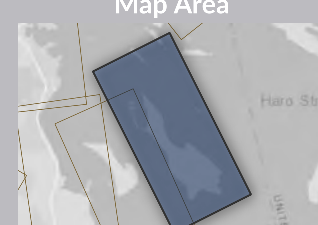
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

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- 0 2.0
- 2.0 4.0
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- 6.0 8.0
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 40 f 41

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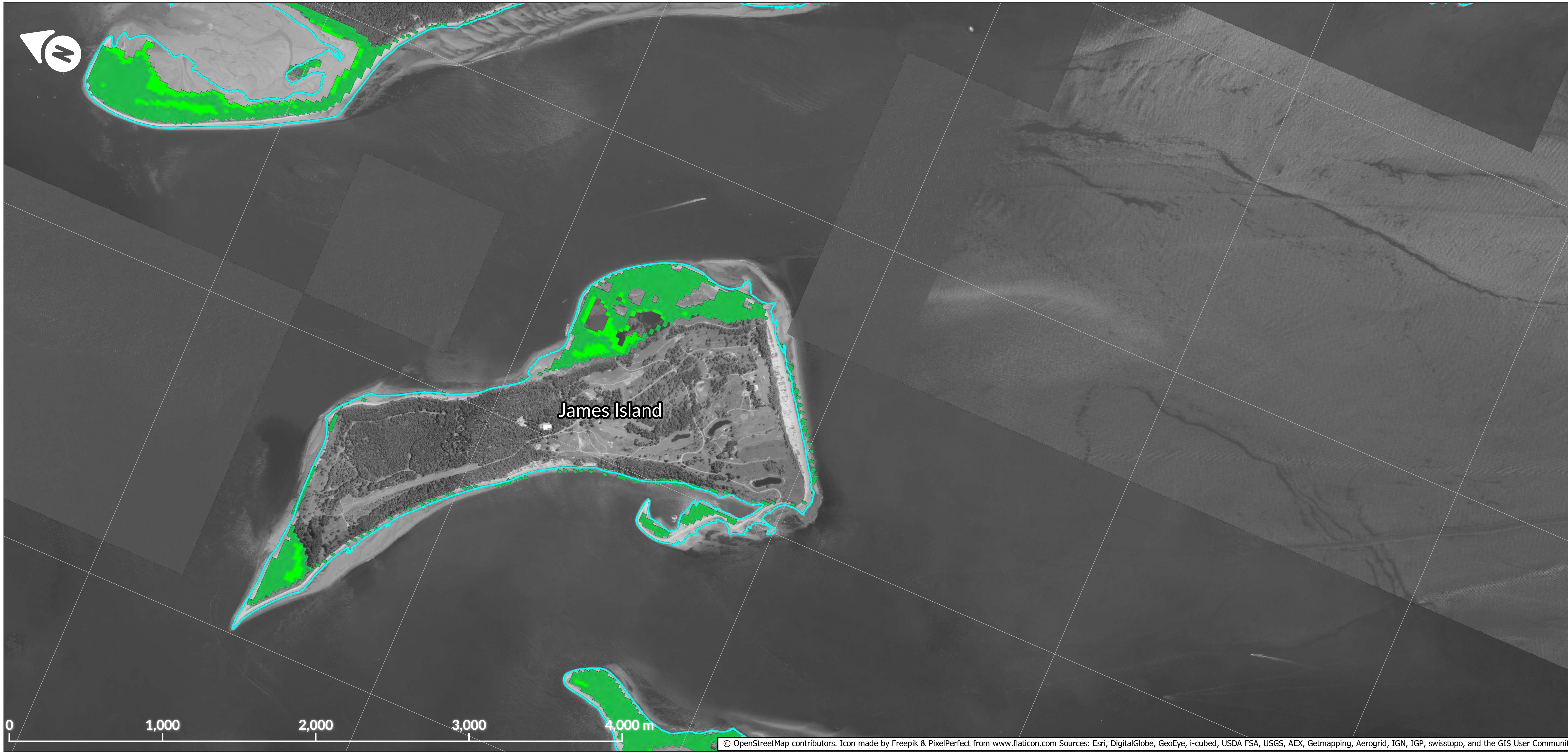


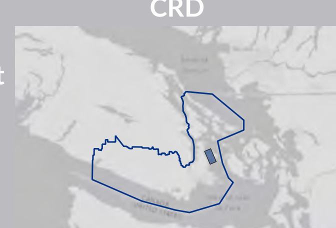
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

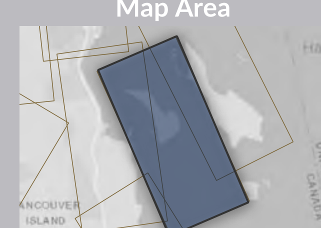
March 2020

Tsunami nundati n Map
Cascadia Subducti n Z ne - N rthern Segment

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 41 f 41

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pl t date: 2020.06.11
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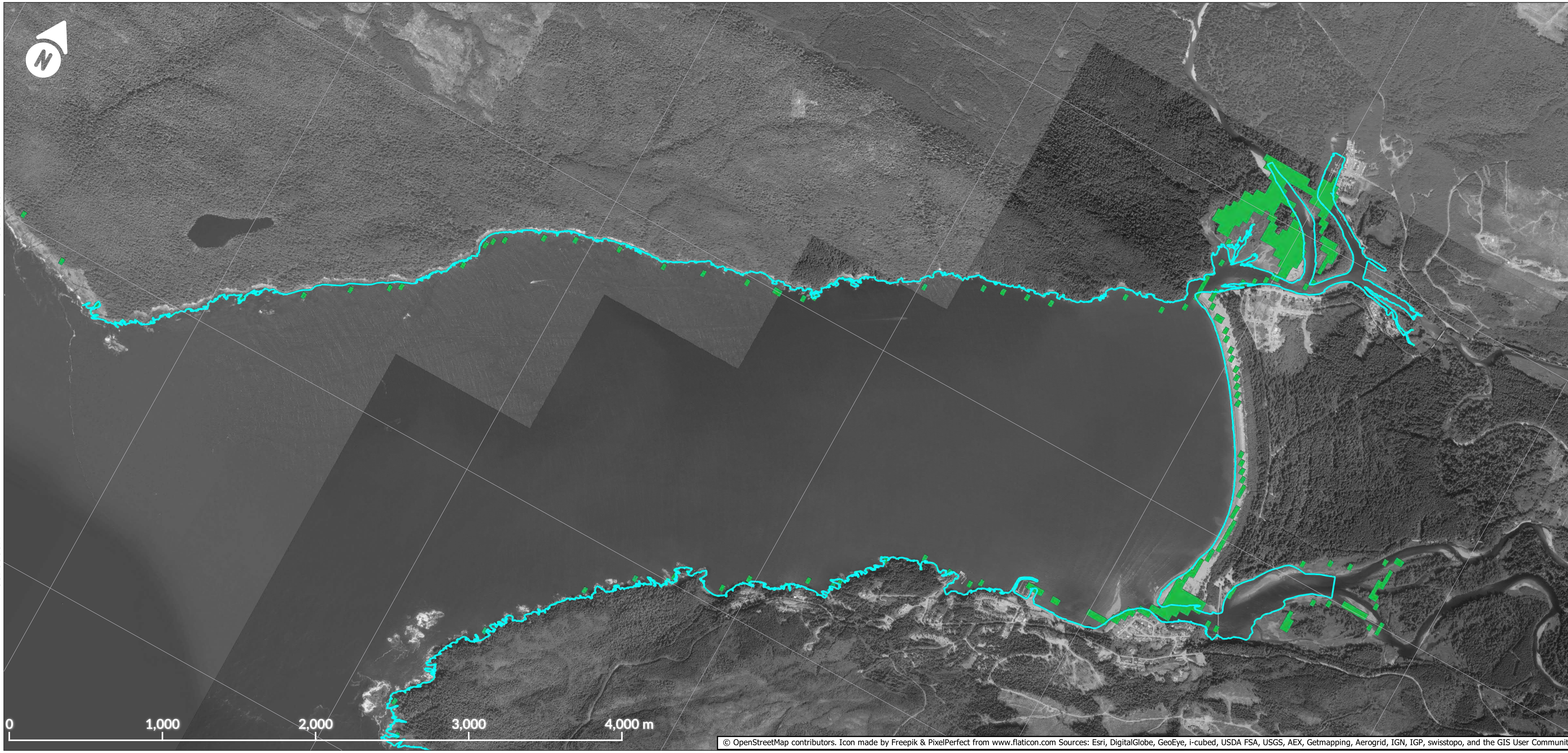


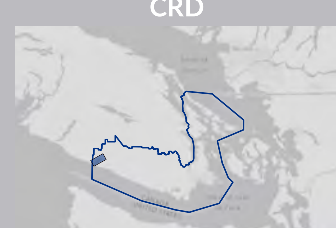
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

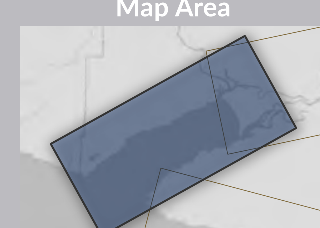
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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4. Data s urces: Orth imagery (CRD, 2017
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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 1 f 41

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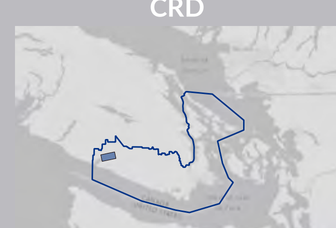
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 2 f 41

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pl t date: 2020.06.10
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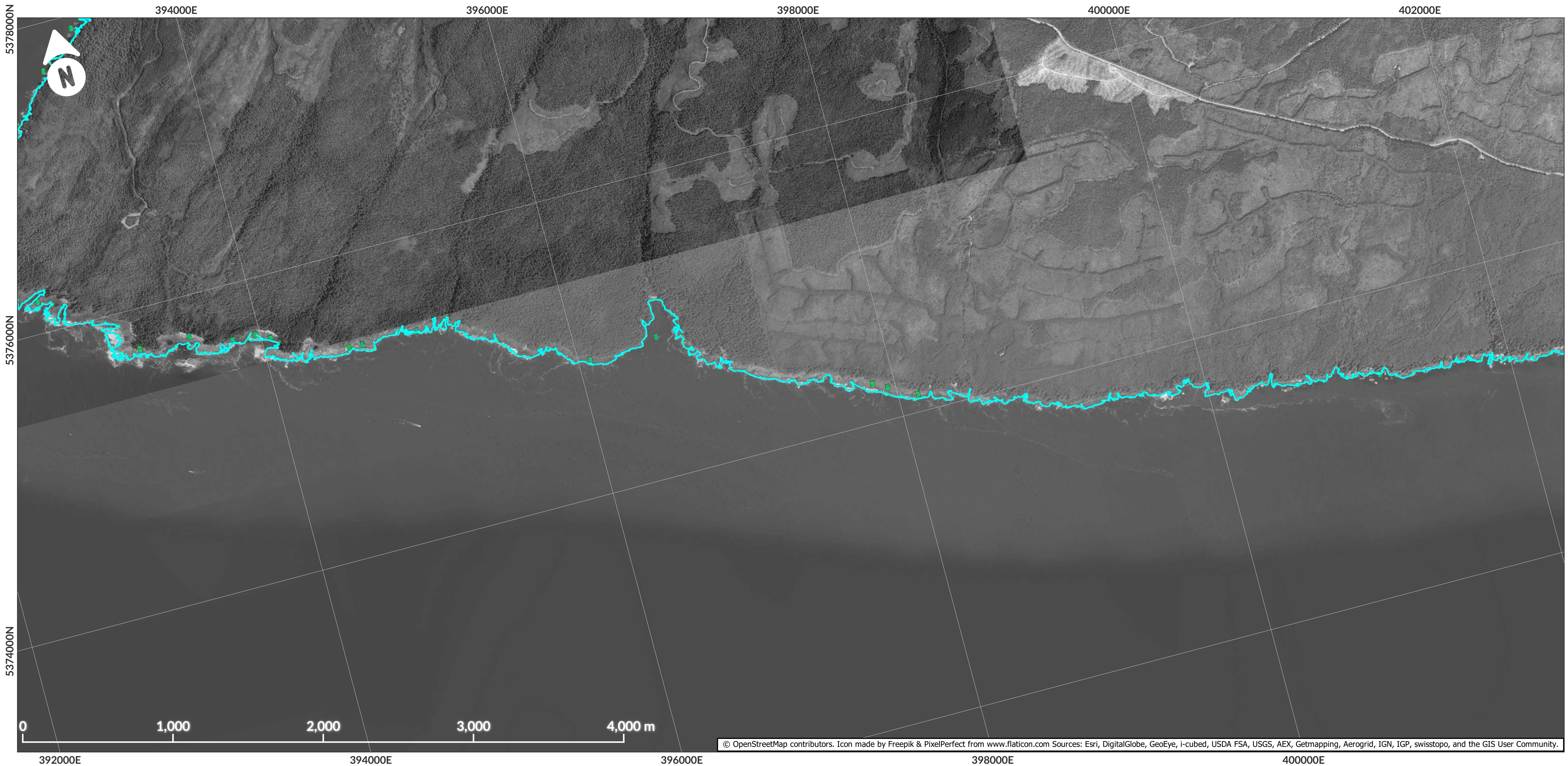


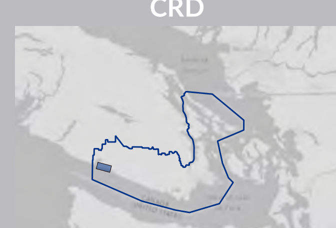
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

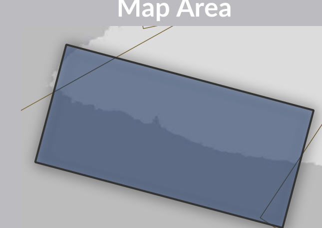
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 3 f 41

pl t date: 2020.06.10
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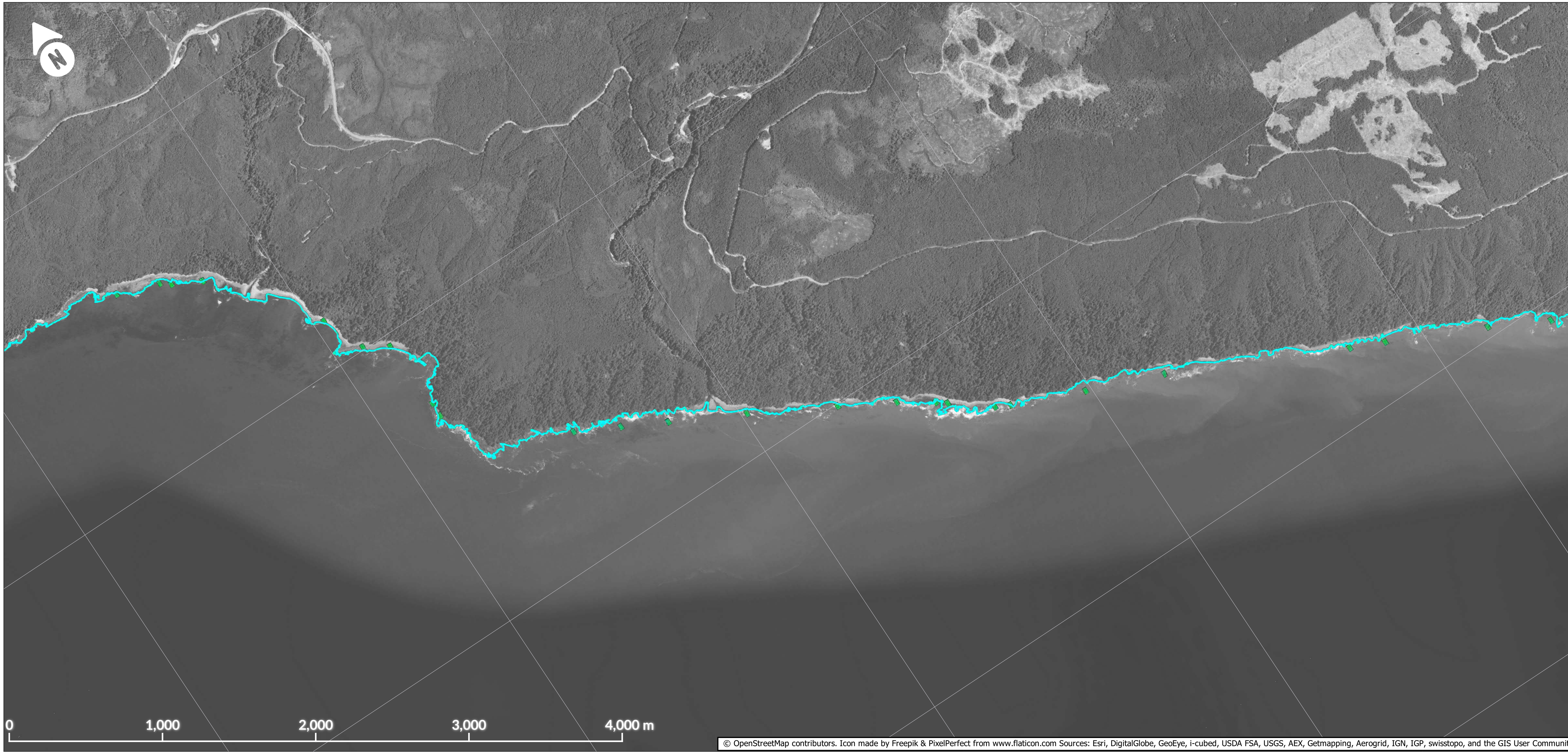

C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

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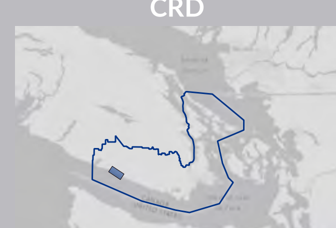
CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 4 f 41

pl t date: 2020.06.10
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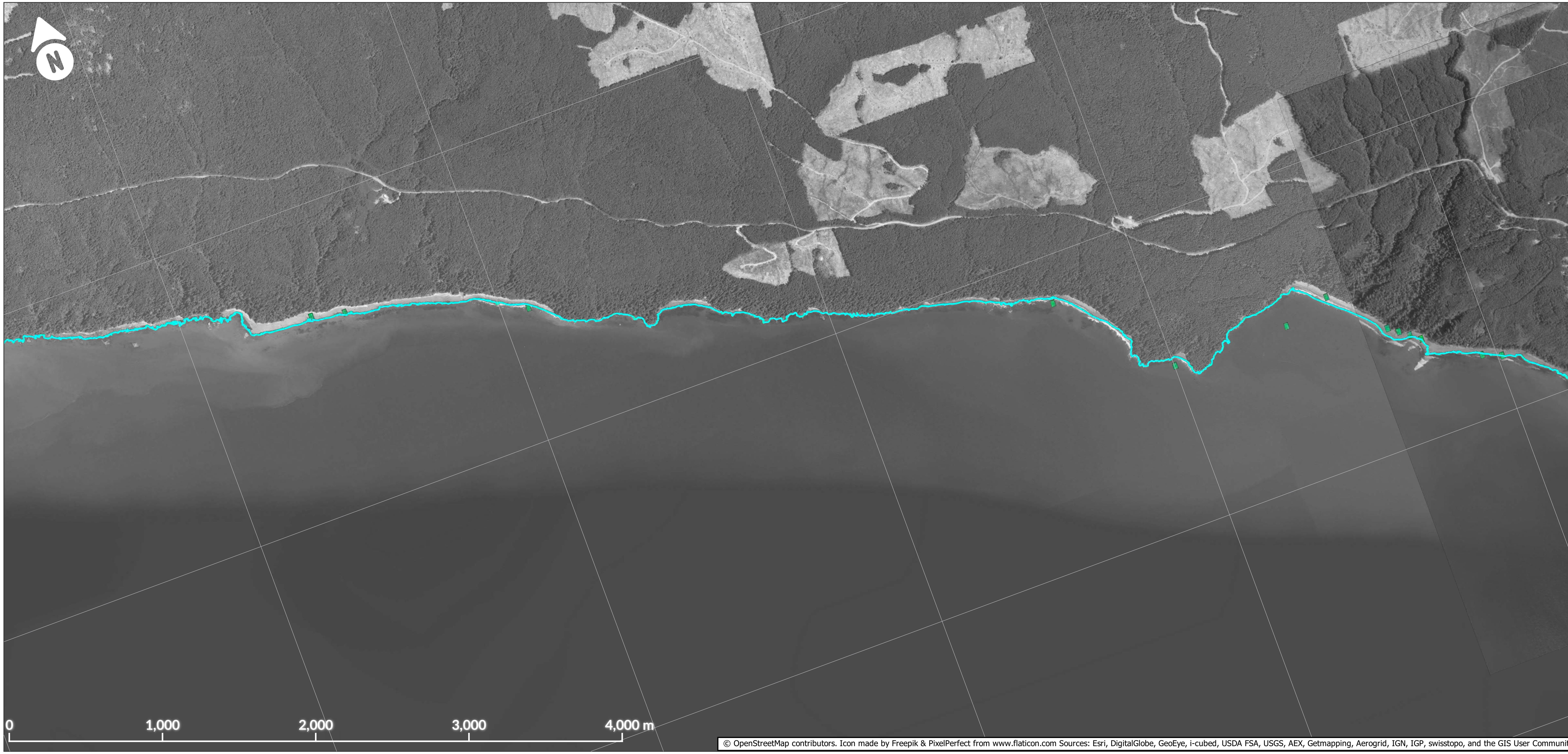


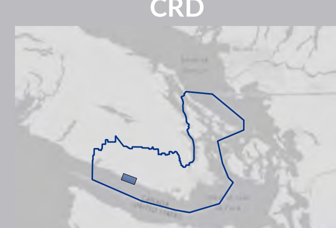
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

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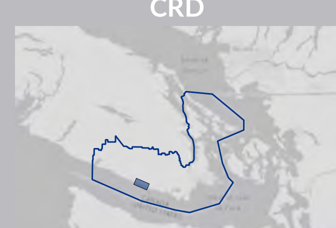
CRD



Map Area

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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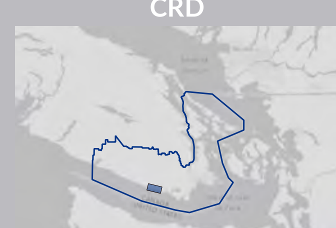
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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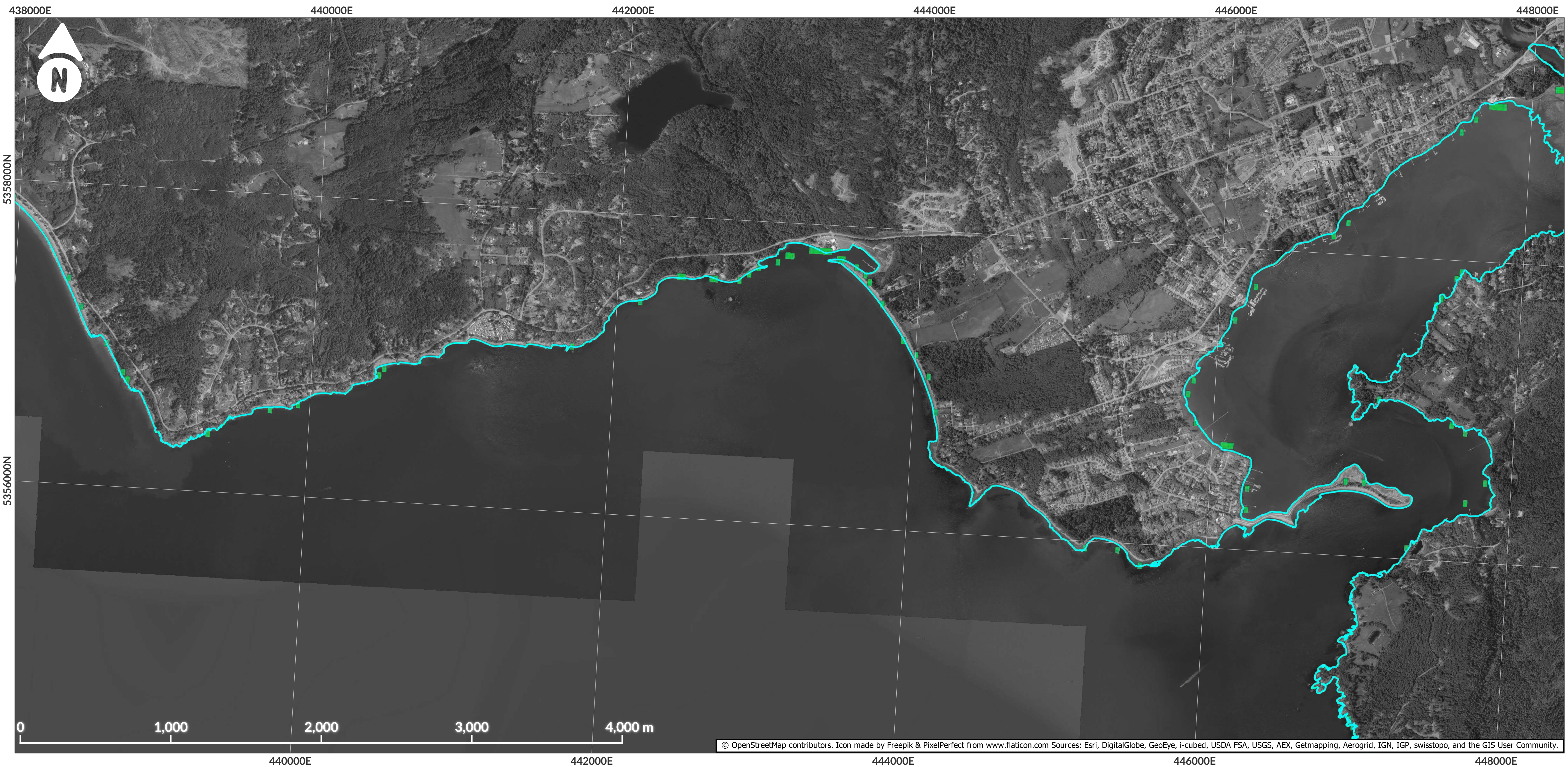


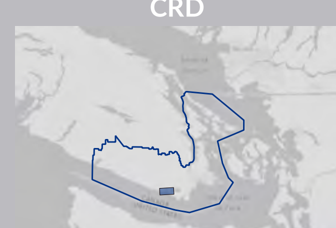
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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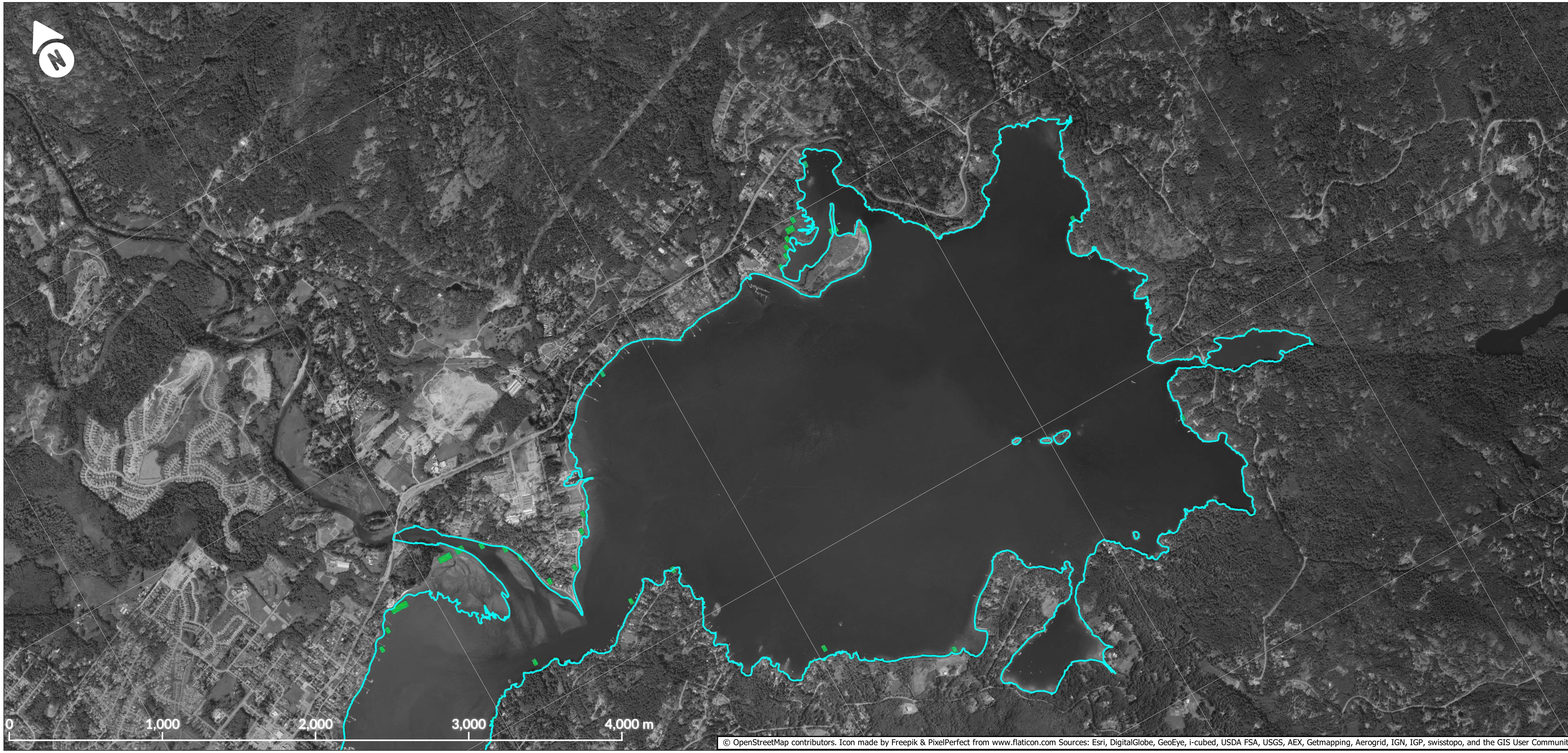


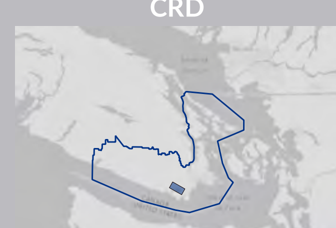
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

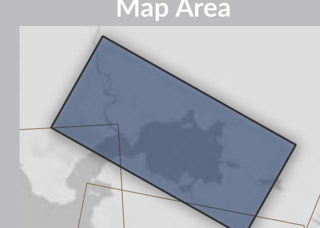
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 9 f 41

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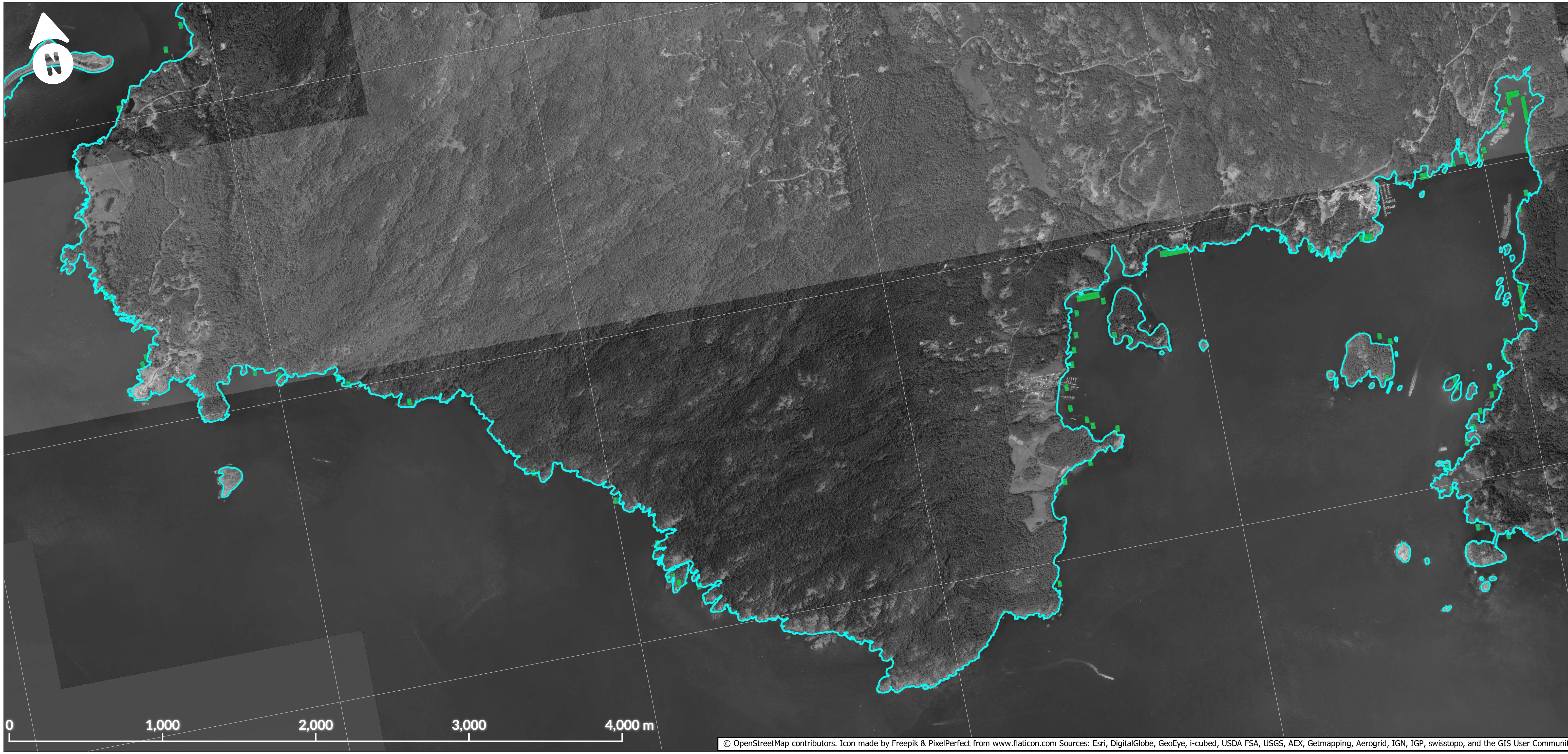


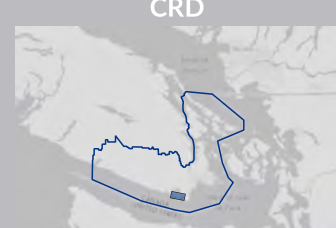
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

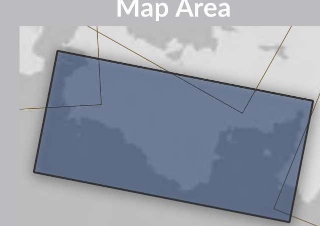
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 10 f 41

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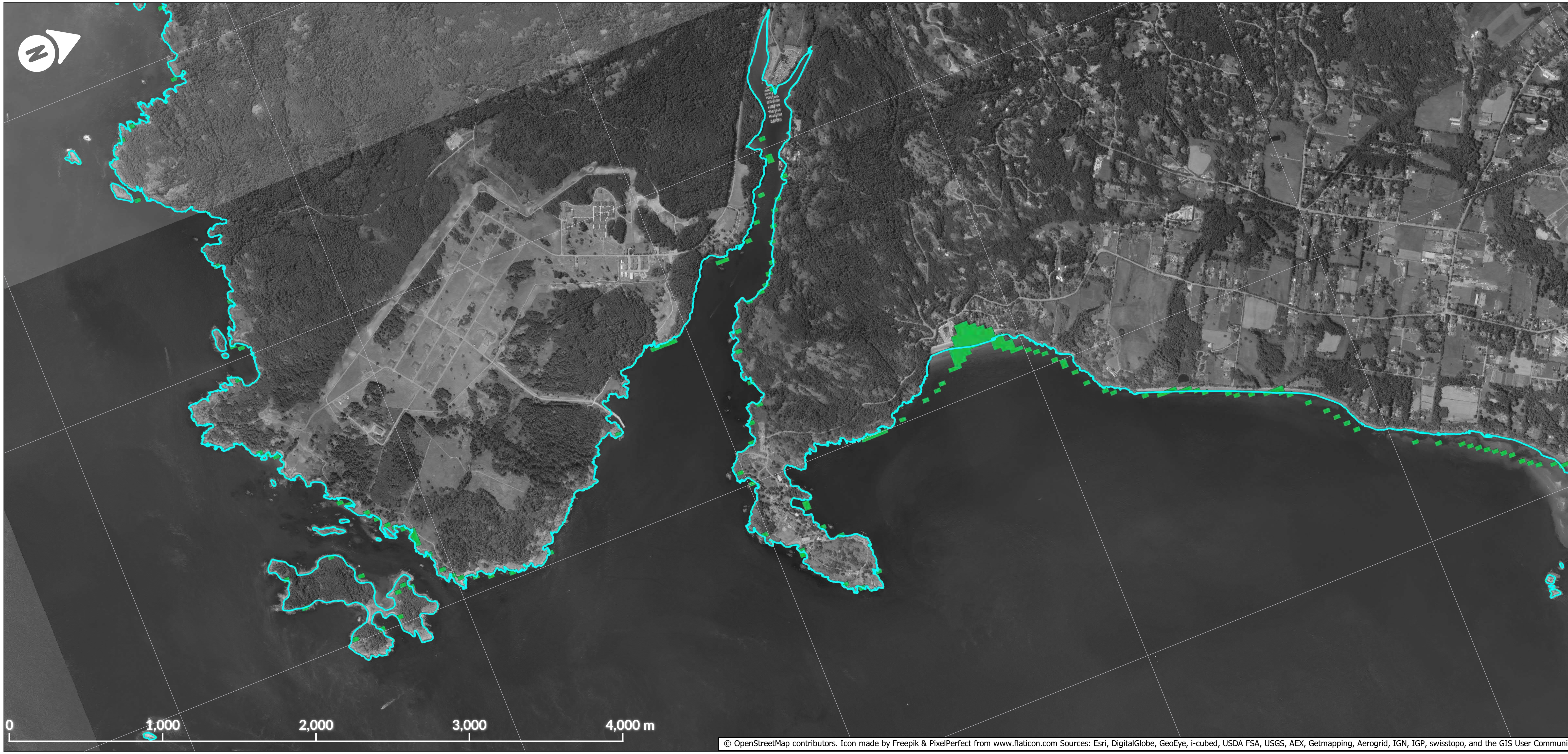


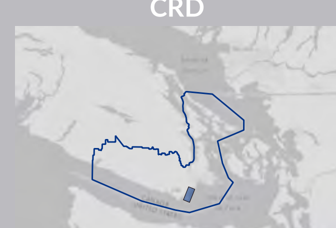
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



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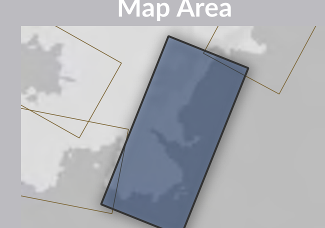

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
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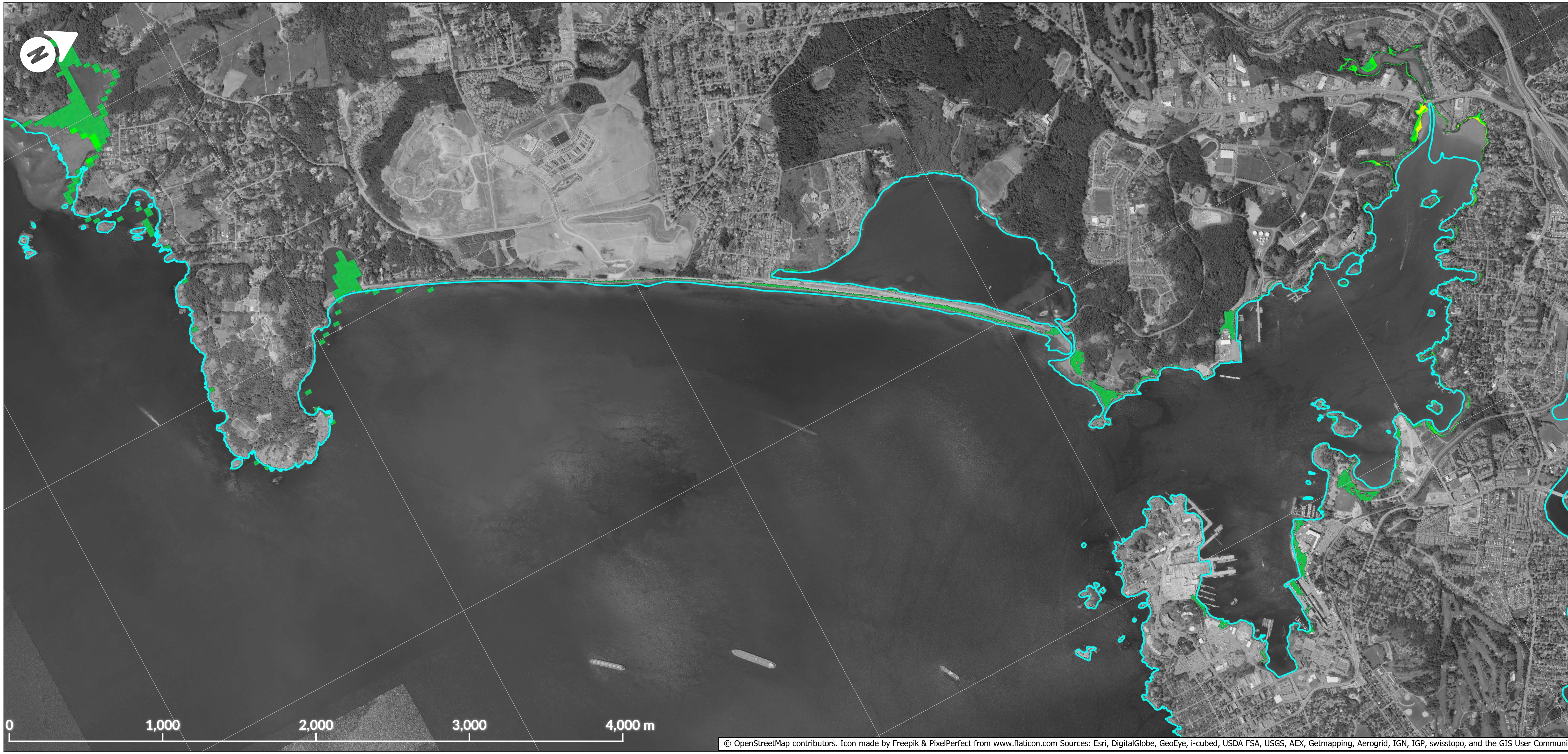
Map Sheet 11 f 41



C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

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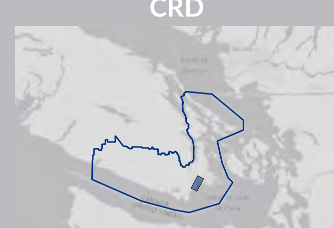
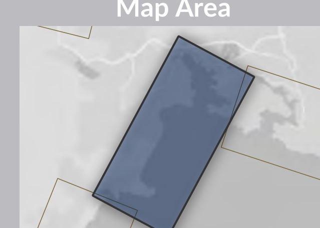
CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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pl t date: 2020.06.10
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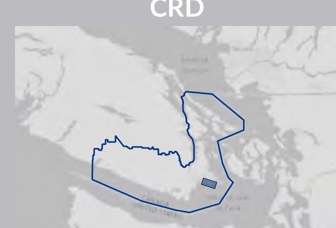
Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 13 f 41

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C astal Fl d Inundati n Mapping Pr ject

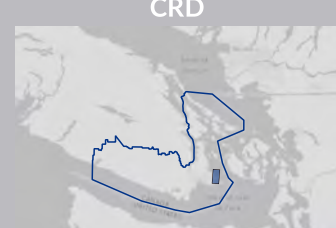
Capital Regi nal District

March 2020

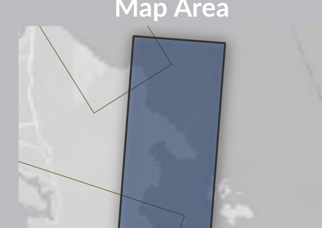
Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

Making a difference...together

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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pl t date: 2020.06.10
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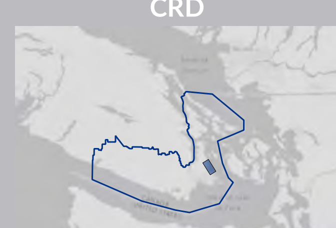
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

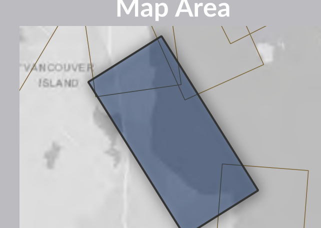
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

- Coastline
- Inundation Depth (m)
  - 0 2.0
  - 2.0 4.0
  - 4.0 6.0
  - 6.0 8.0
  - >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 15 f 41

pl t date: 2020.06.10
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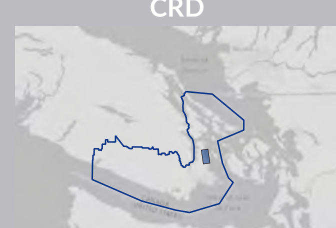
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

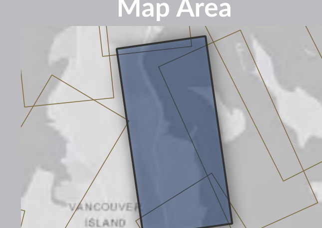
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Making a difference...together

DHI

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 16 f 41

pl t date: 2020.06.10
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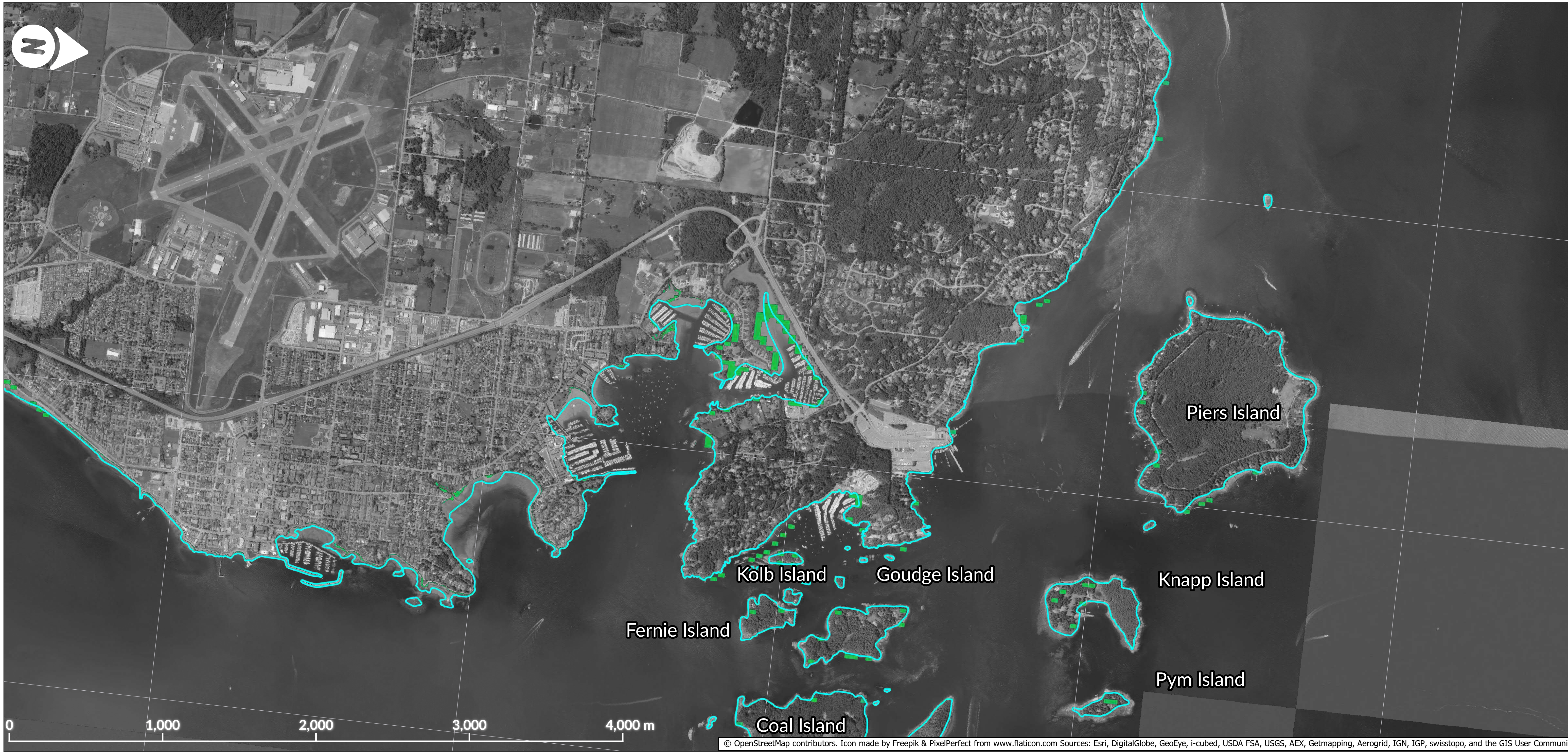

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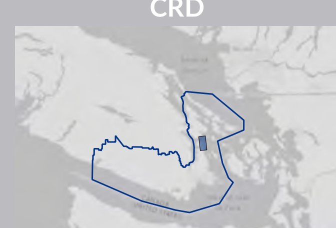
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



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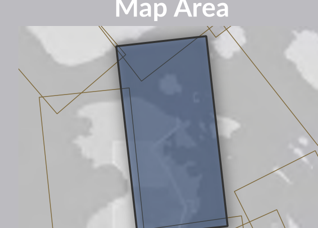

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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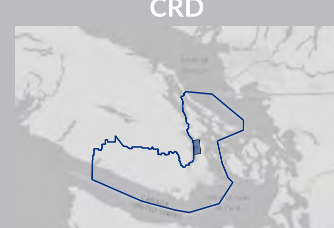
Capital Regi nal District

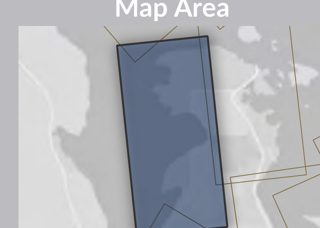
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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pl t date: 2020.06.10
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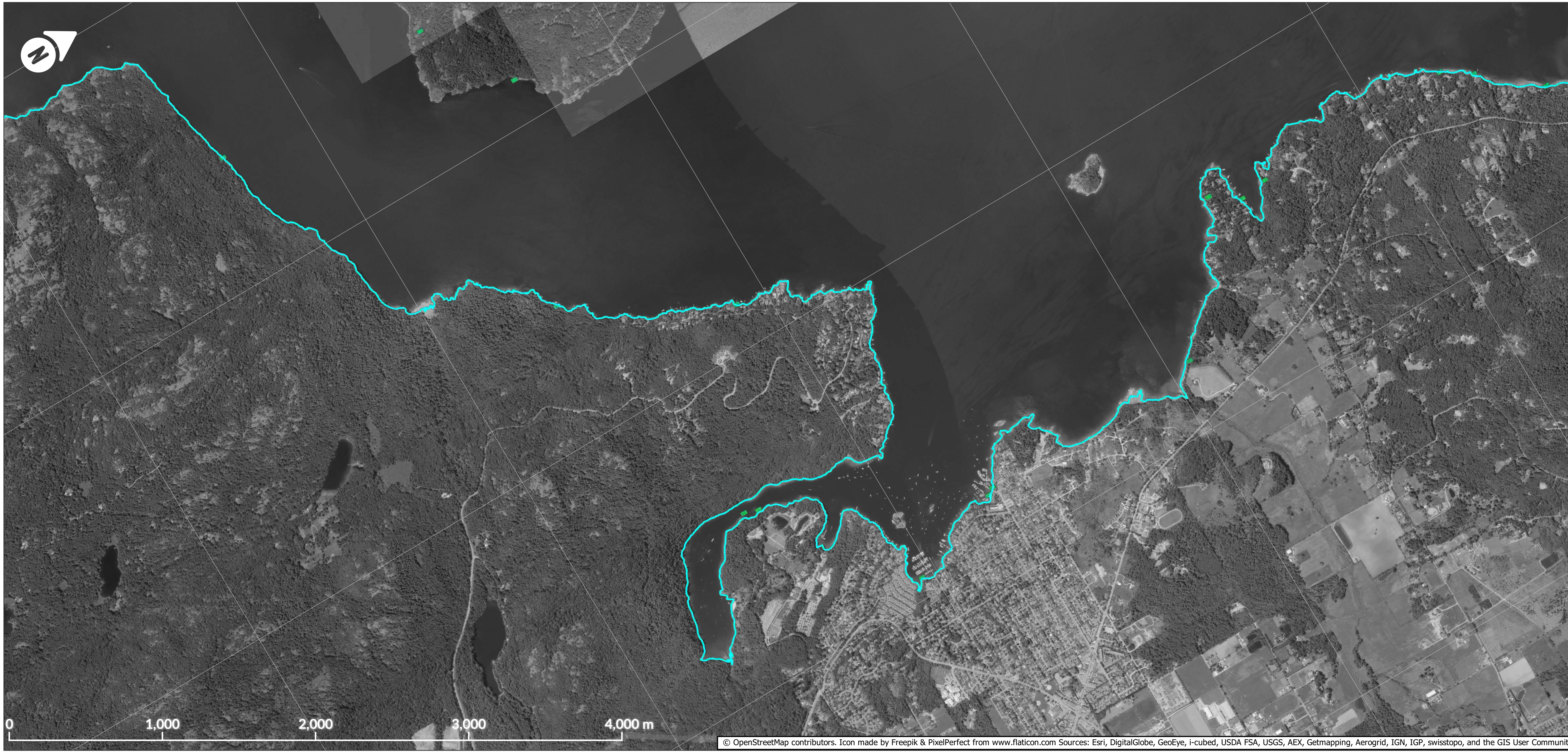

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Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

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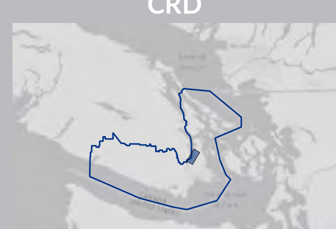

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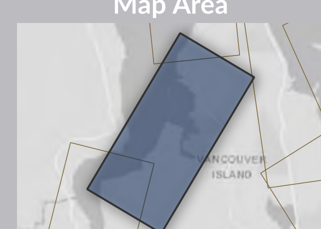

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
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Map Sheet 19 f 41

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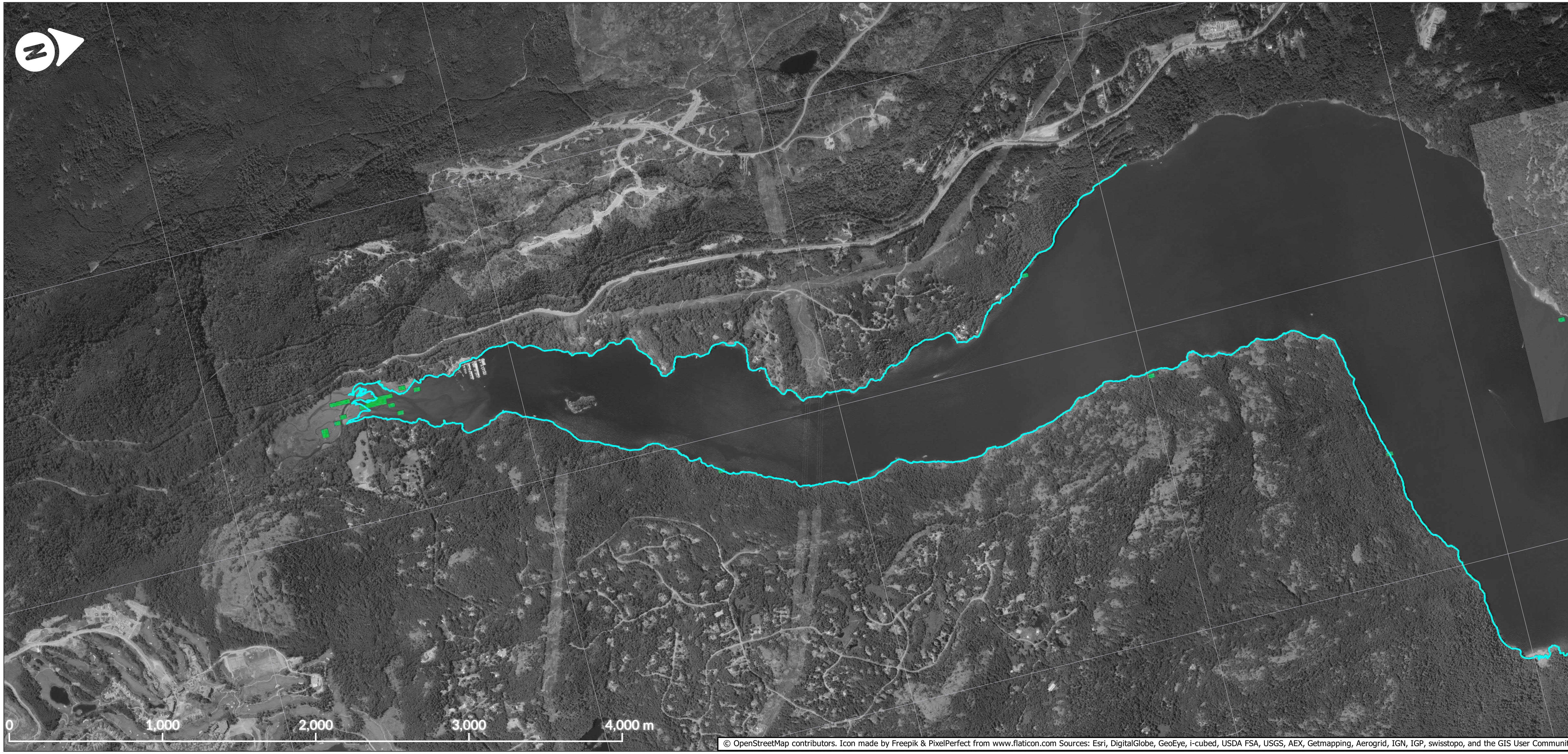

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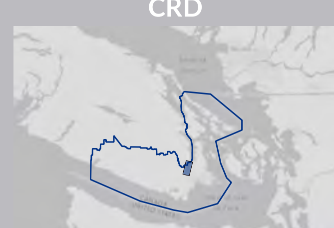
Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



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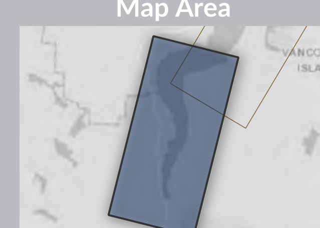

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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pl t date: 2020.06.10
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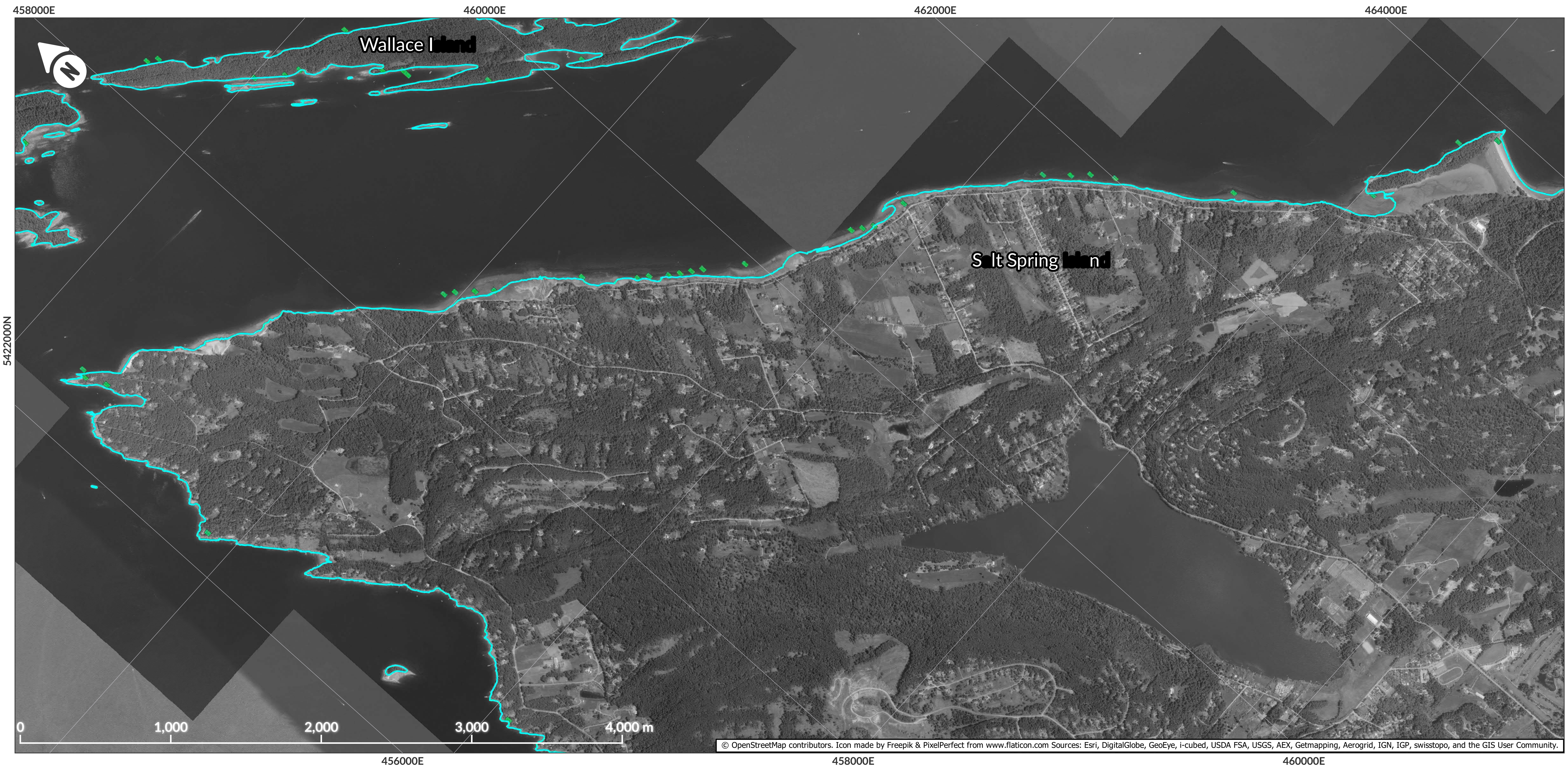


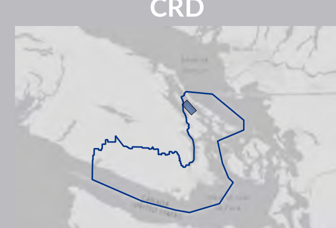
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



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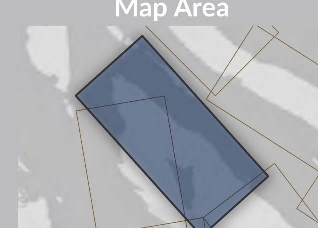

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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 21 f 41

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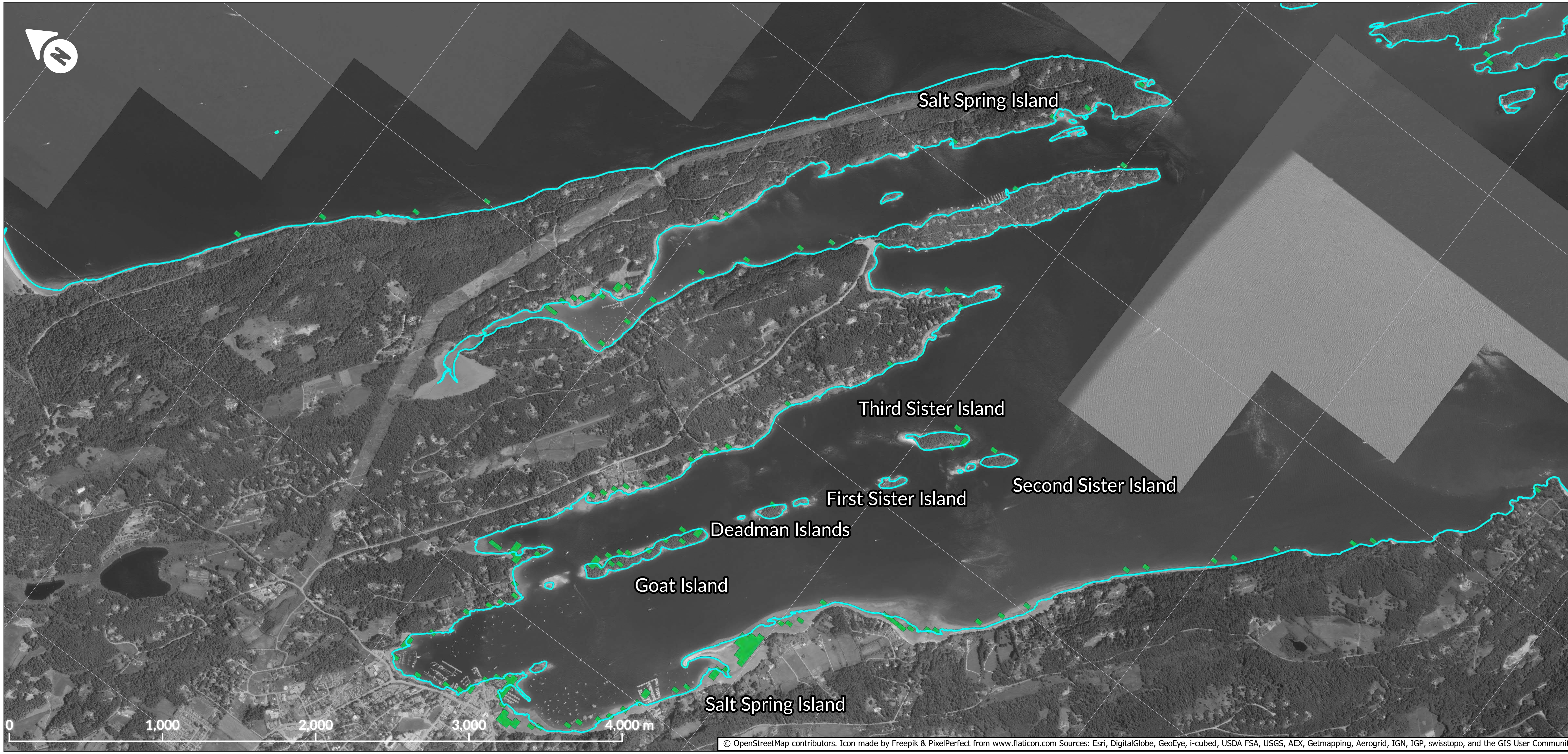


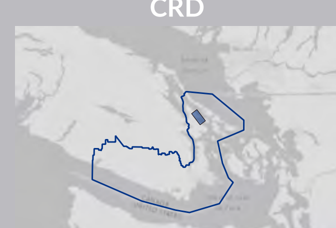
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

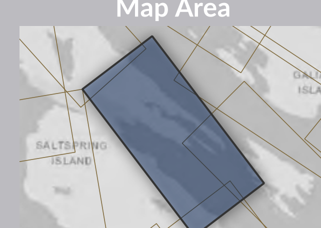
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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pl t date: 2020.06.10
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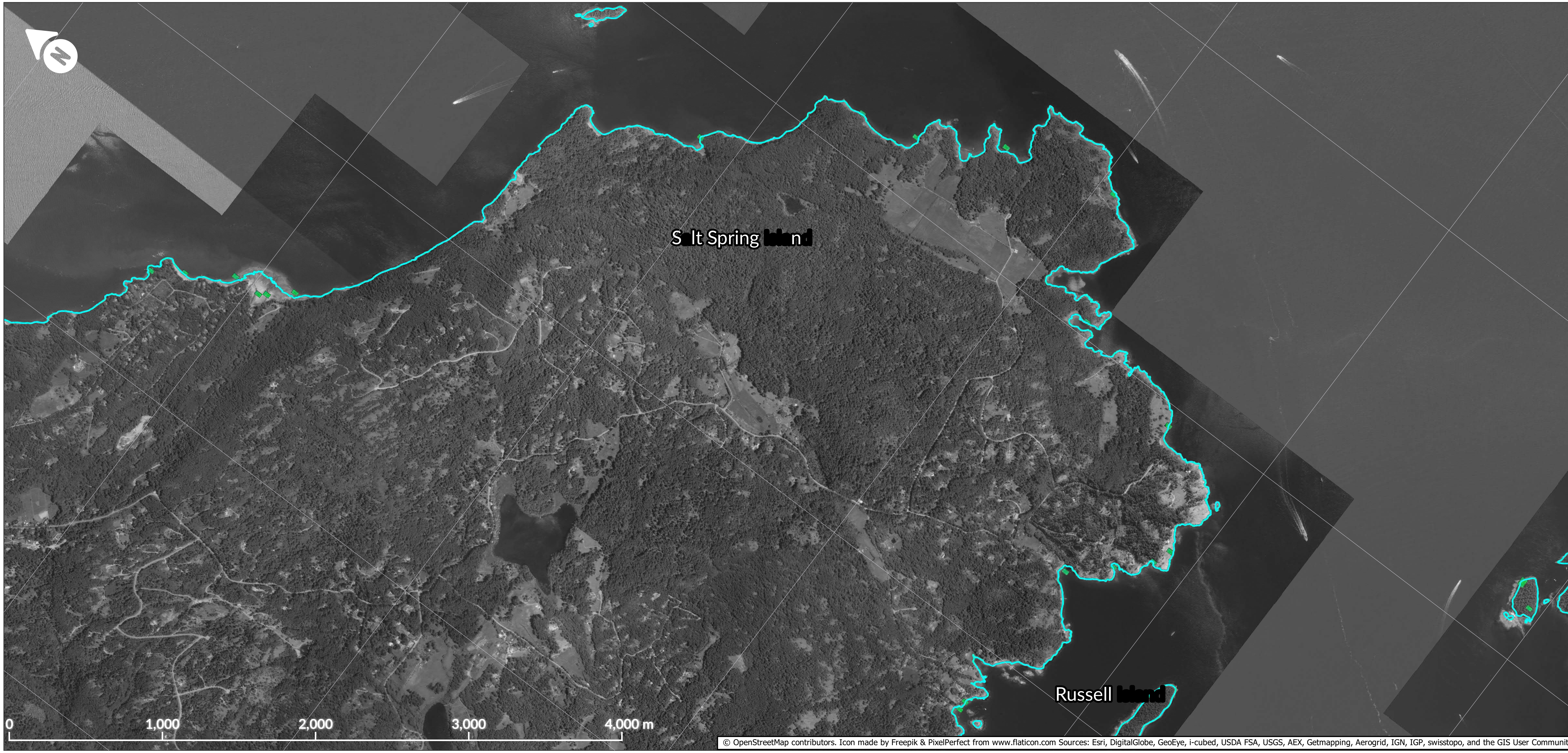

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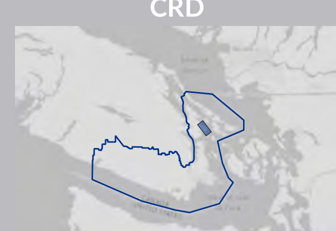
Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Making a difference...together

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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4. Data s urces: Orth imagery (CRD, 2017
5. F r further inf rmati n, please refer t Task 3 – Tsunami M delling and Mapping Rep rt. These maps c nstitute Appendix C f said rep rt.

Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 23 f 41

pl t date: 2020.06.10
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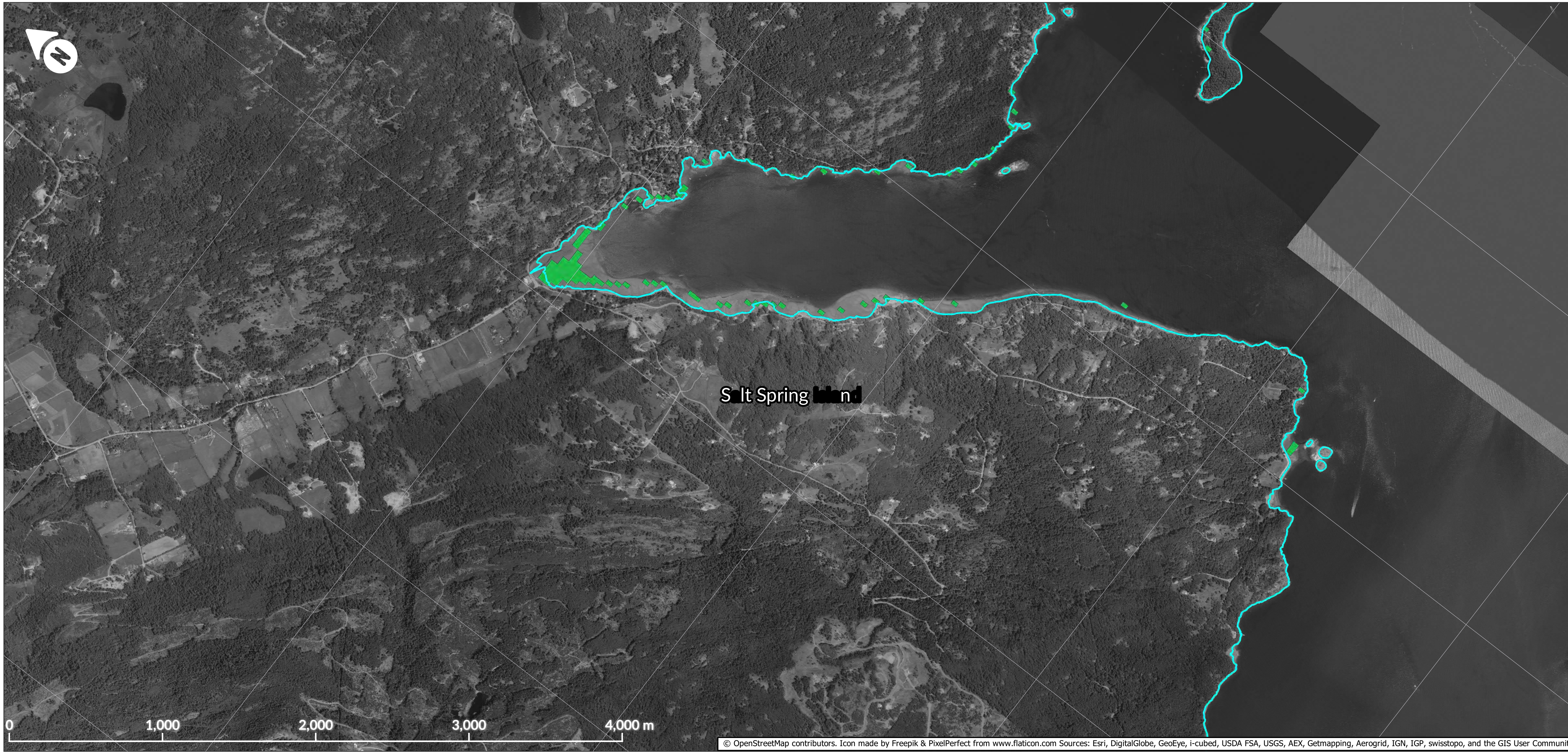

C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

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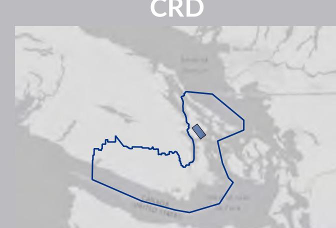
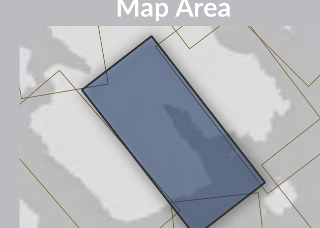
CRD



Map Area



Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
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Map Sheet 24 f 41

pl t date: 2020.06.10
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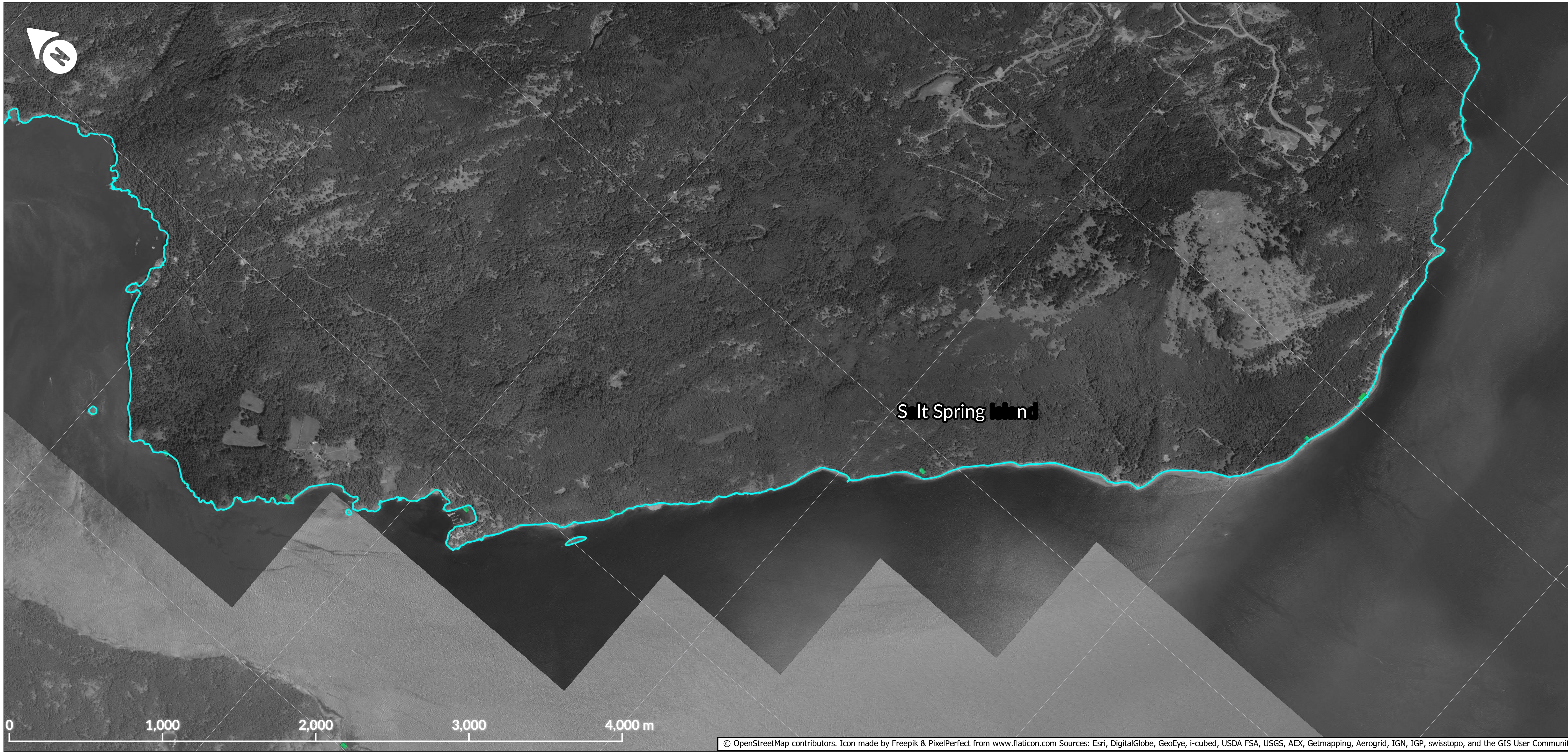


C astal Fl d Inundati n Mapping Pr ject

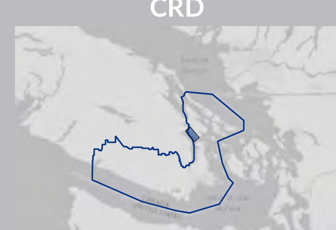
Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

Making a difference...together

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
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Map Sheet 25 f 41

pl t date: 2020.06.10
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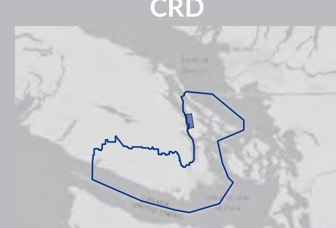
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

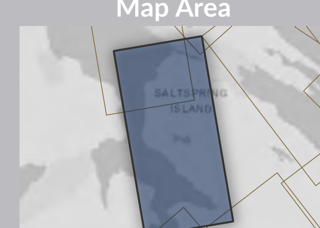
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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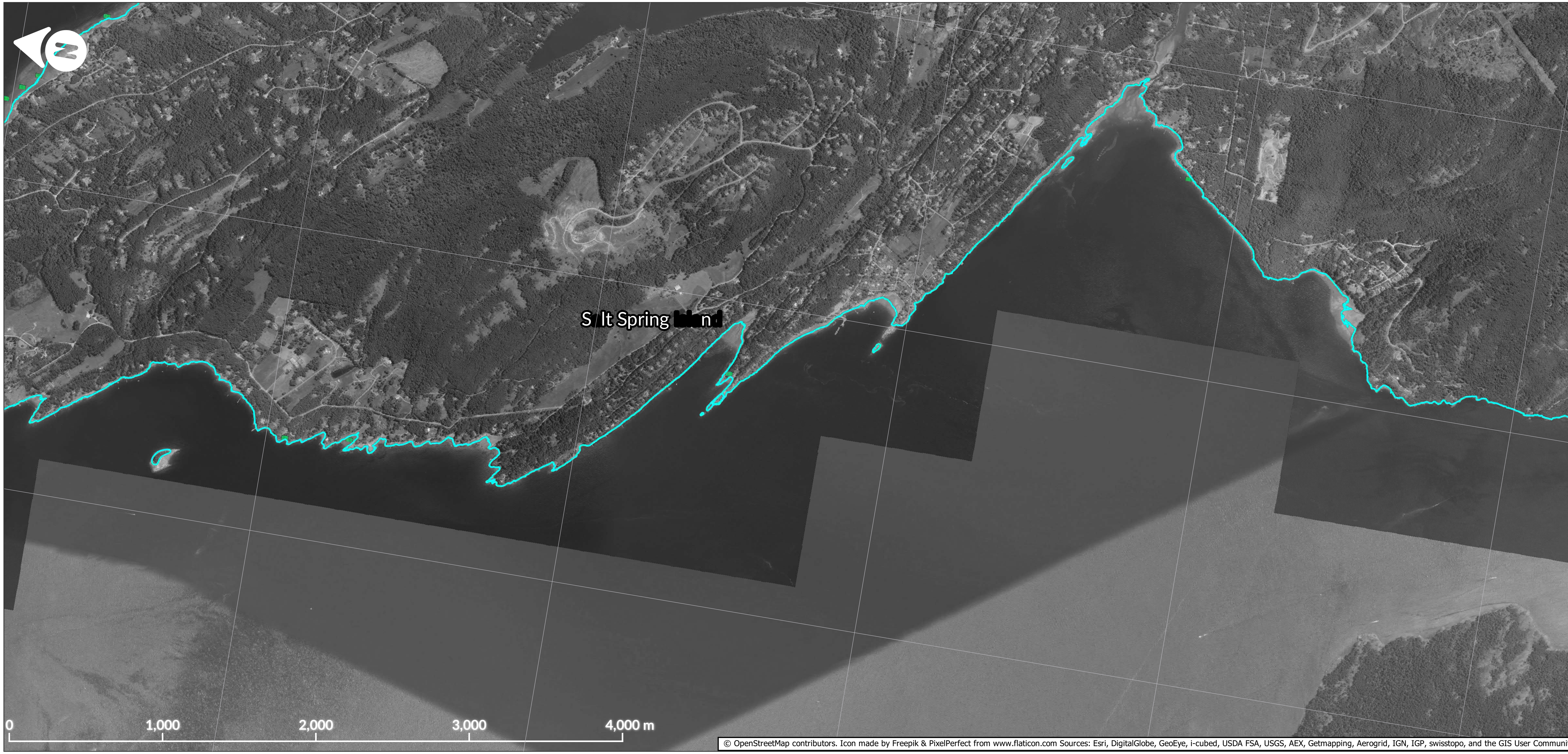


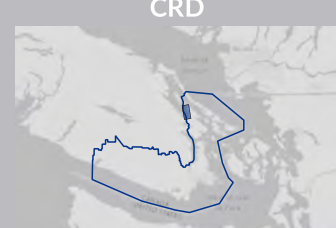
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

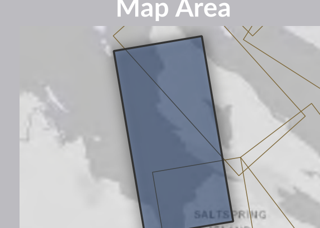
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 27 f 41

CRD Making a difference...together
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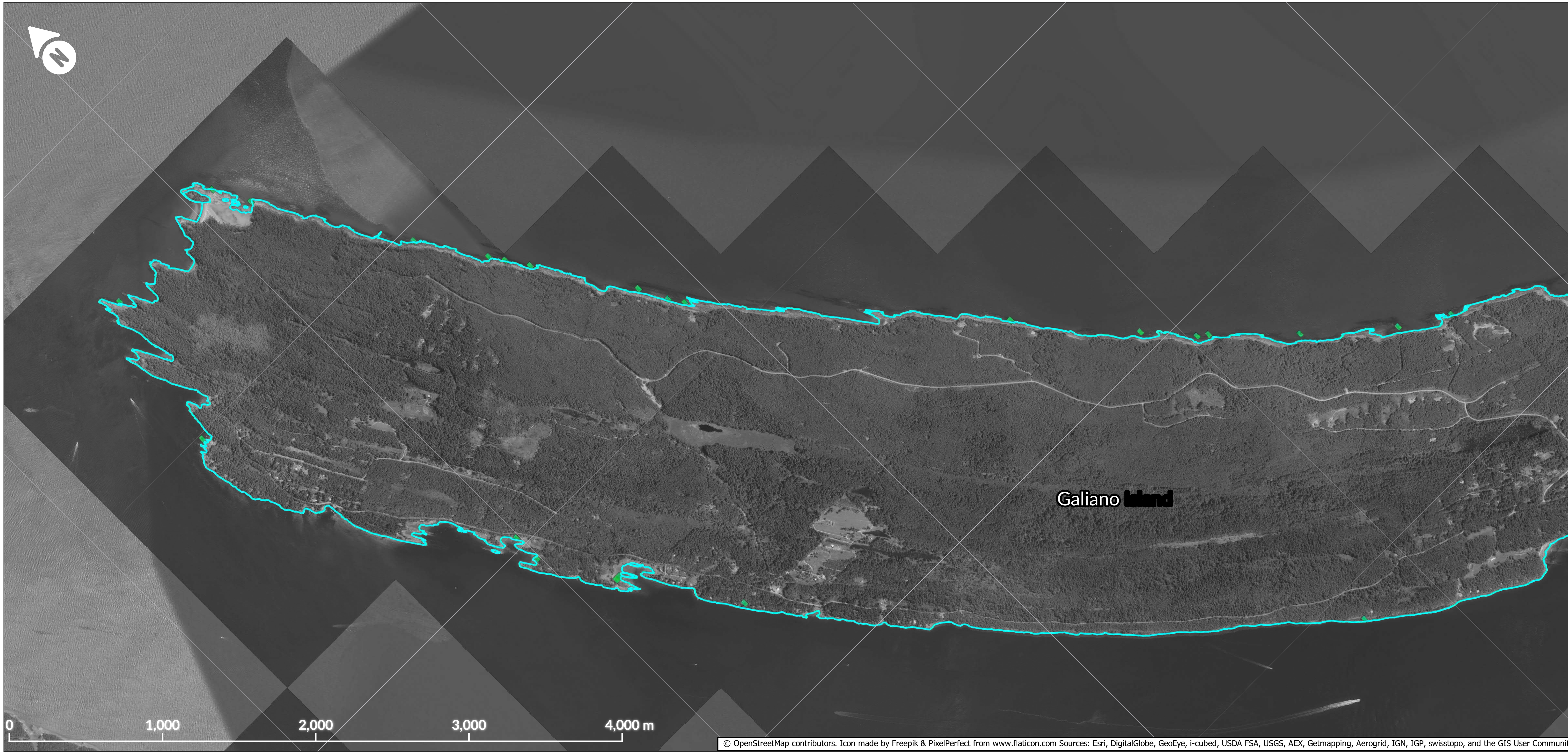


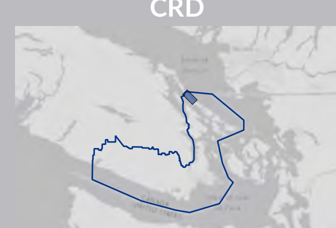
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 28 f 41

pl t date: 2020.06.10
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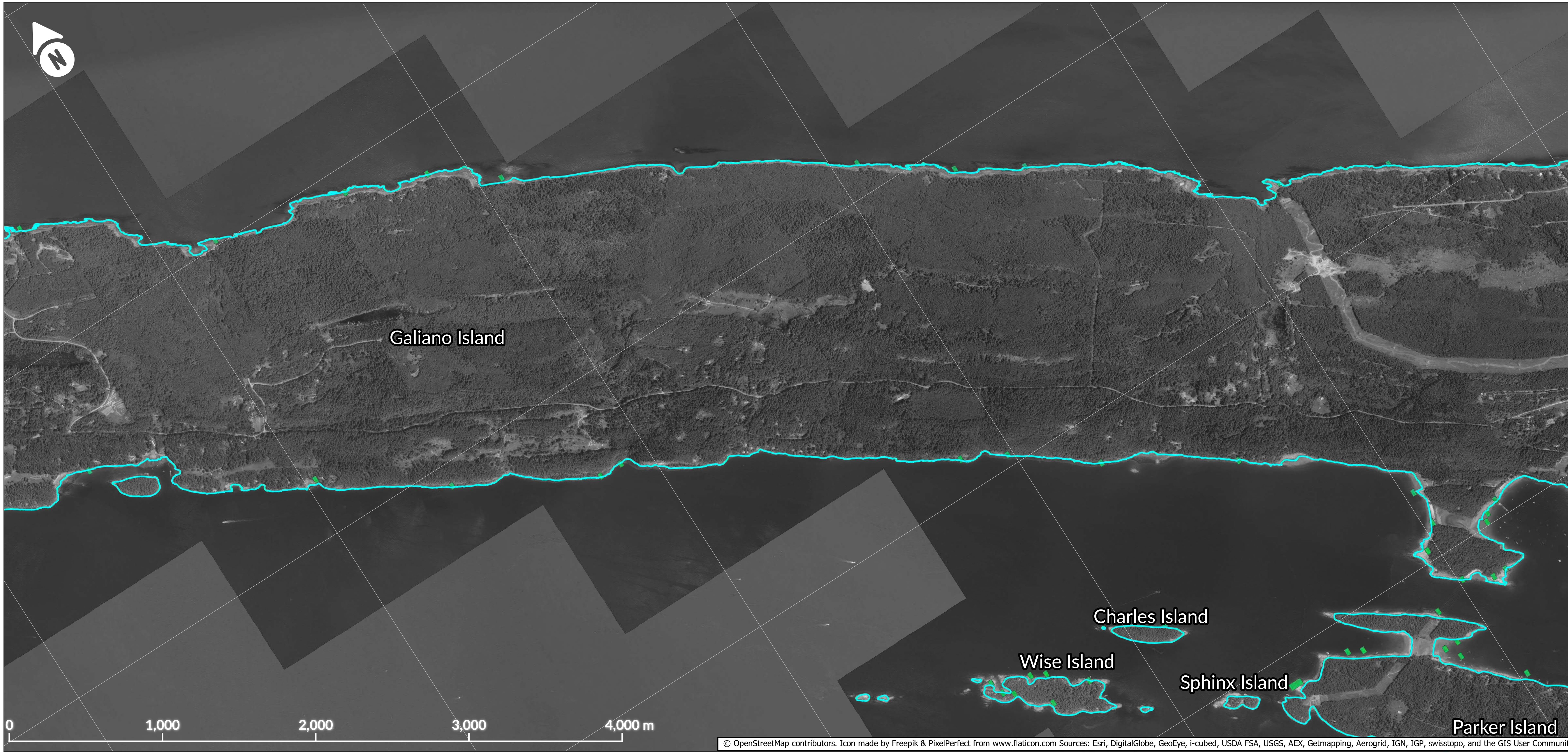


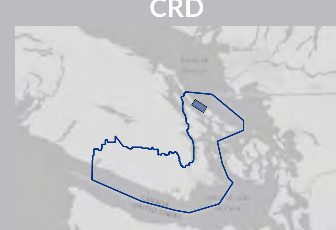
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

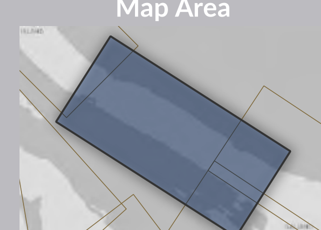
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
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Map Sheet 29 f 41

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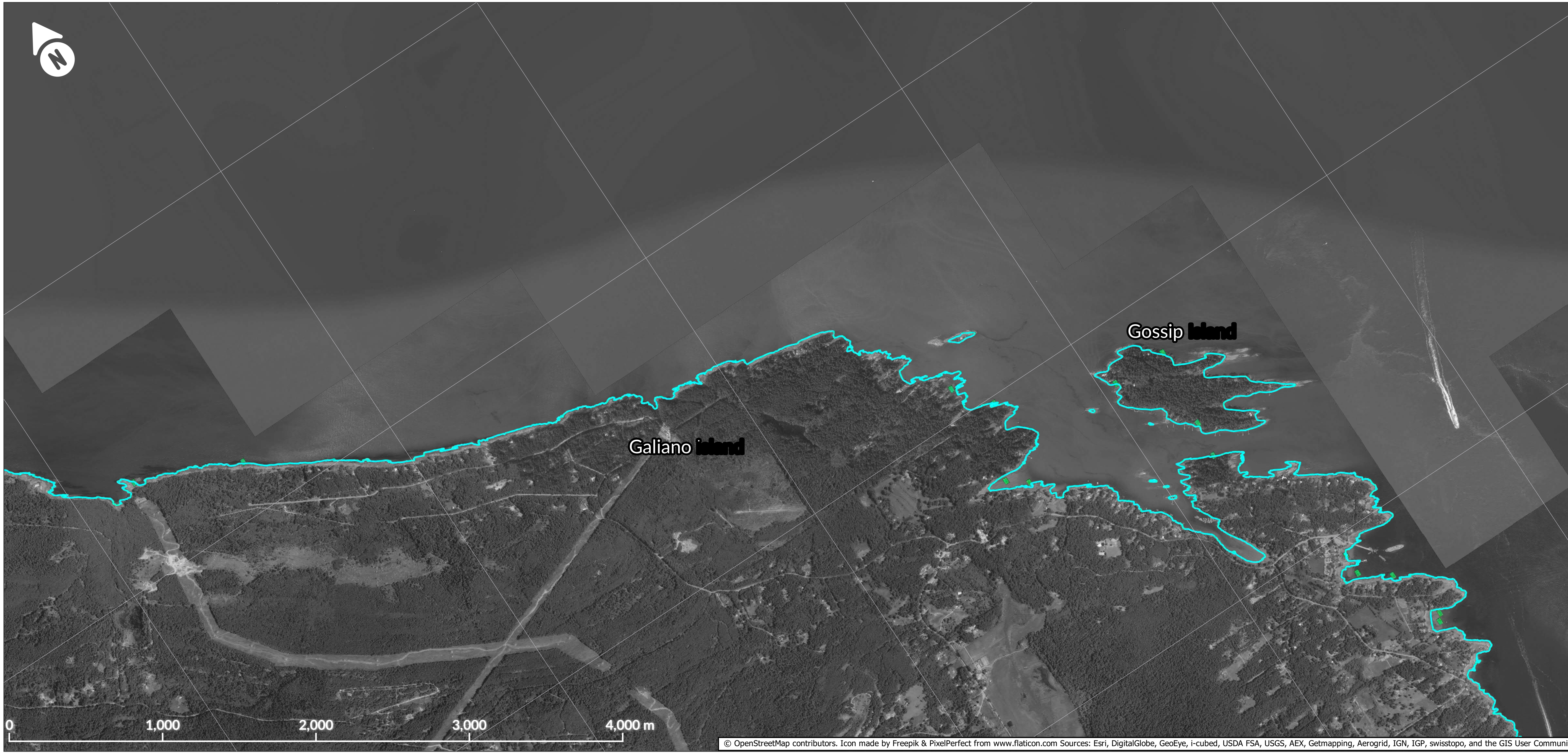


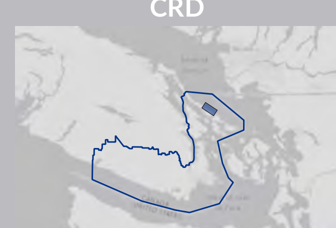
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

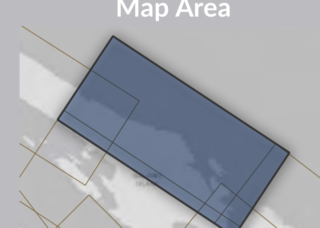
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
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Map Sheet 30 f 41

pl t date: 2020.06.10
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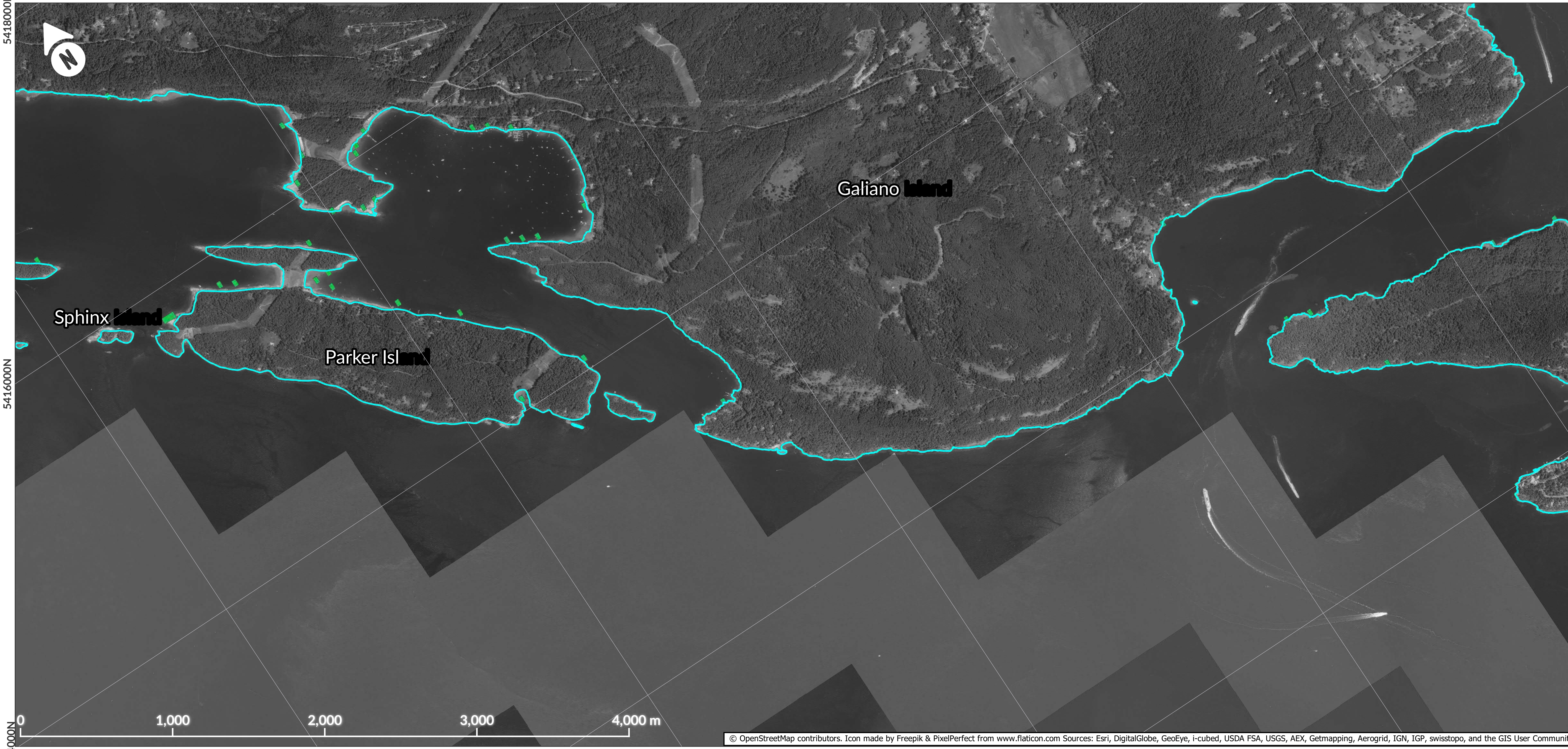


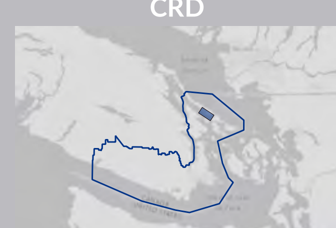
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

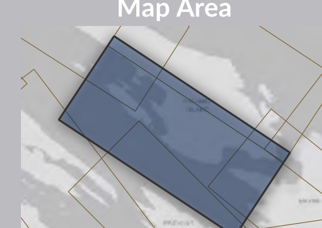
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
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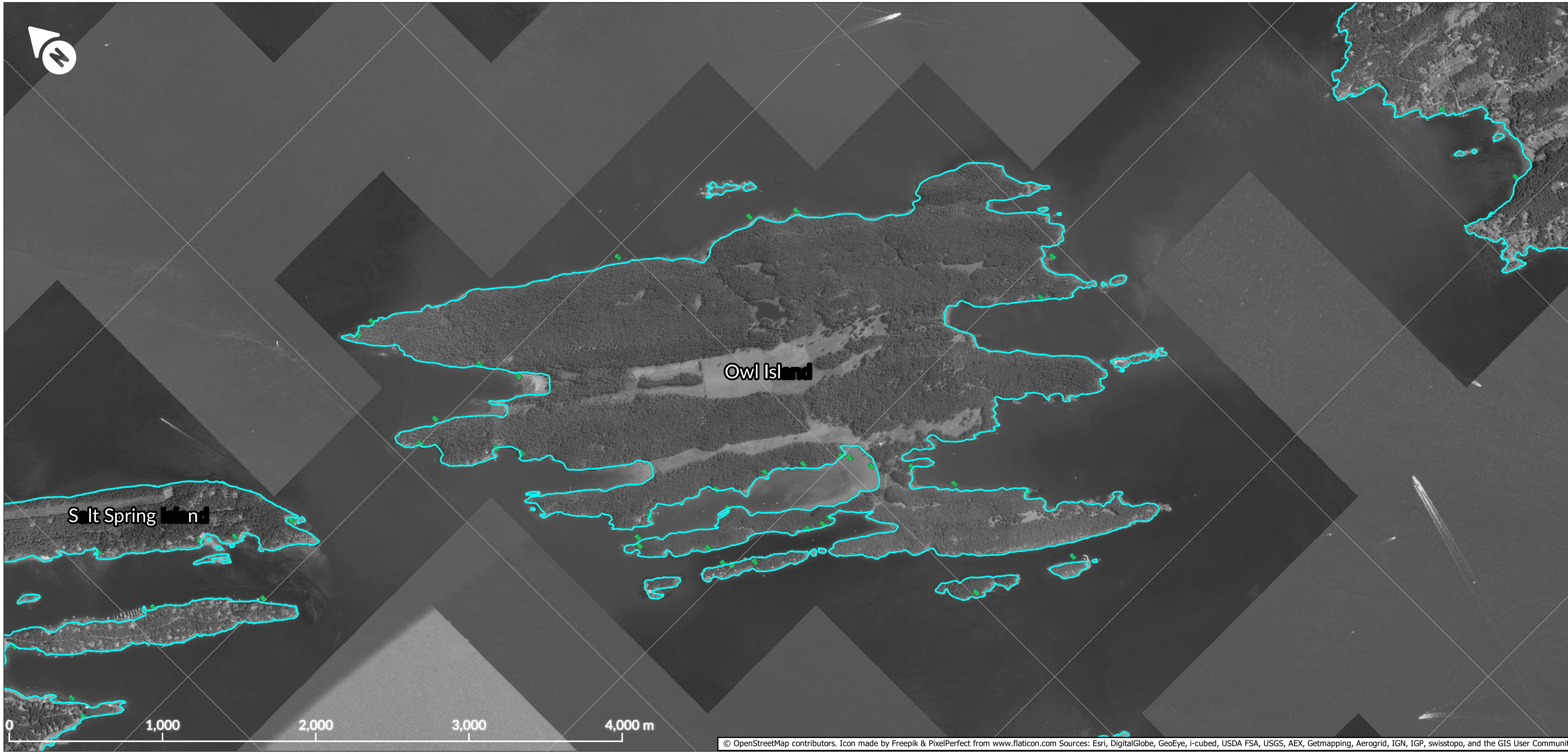


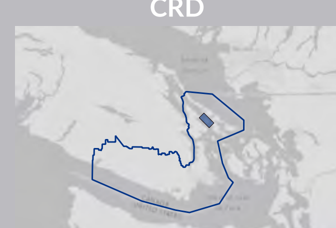
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



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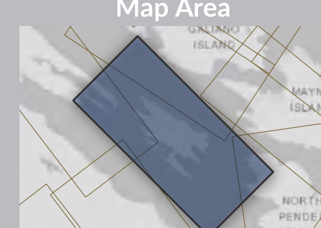

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Legend

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- 0 2.0
- 2.0 4.0
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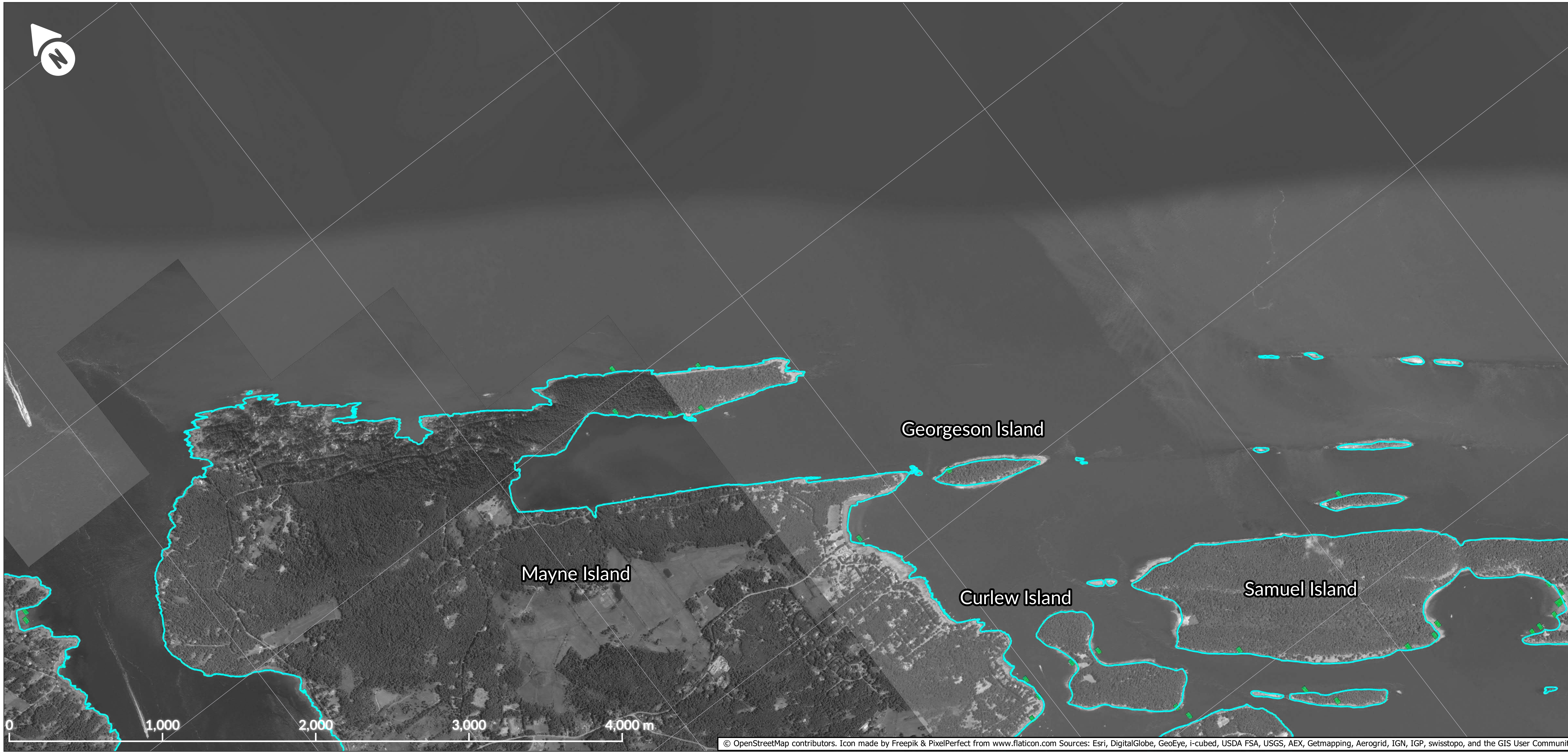
Map Sheet 32 f 41



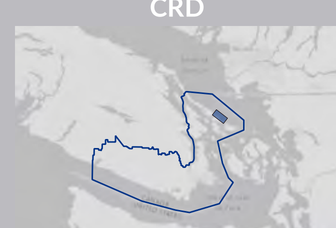
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



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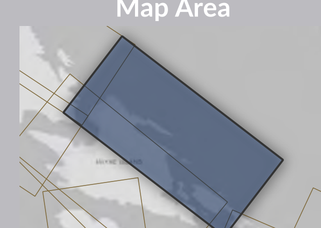

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Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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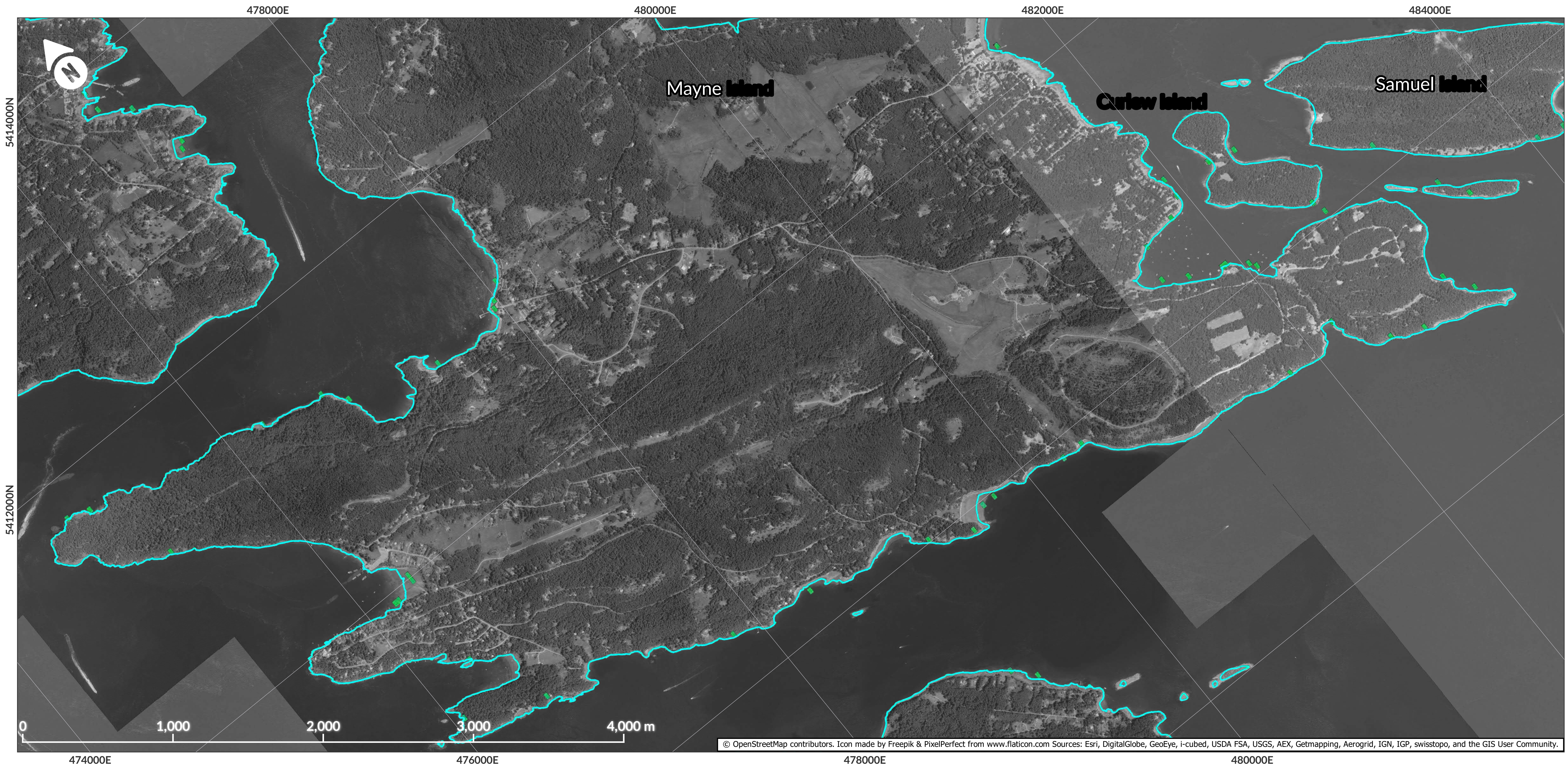
4. Data s urces: Orth imagery (CRD, 2017
5. F r further inf rmati n, please refer t Task 3 – Tsunami M delling and Mapping Rep rt. These maps c nstitute Appendix C f said rep rt.

Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 33 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



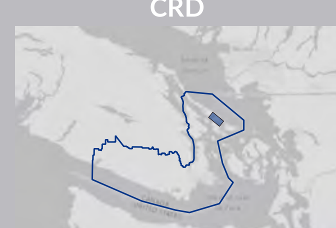
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

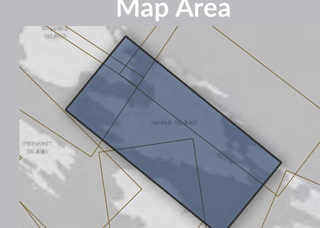
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
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Map Sheet 34 f 41

pl t date: 2020.06.10
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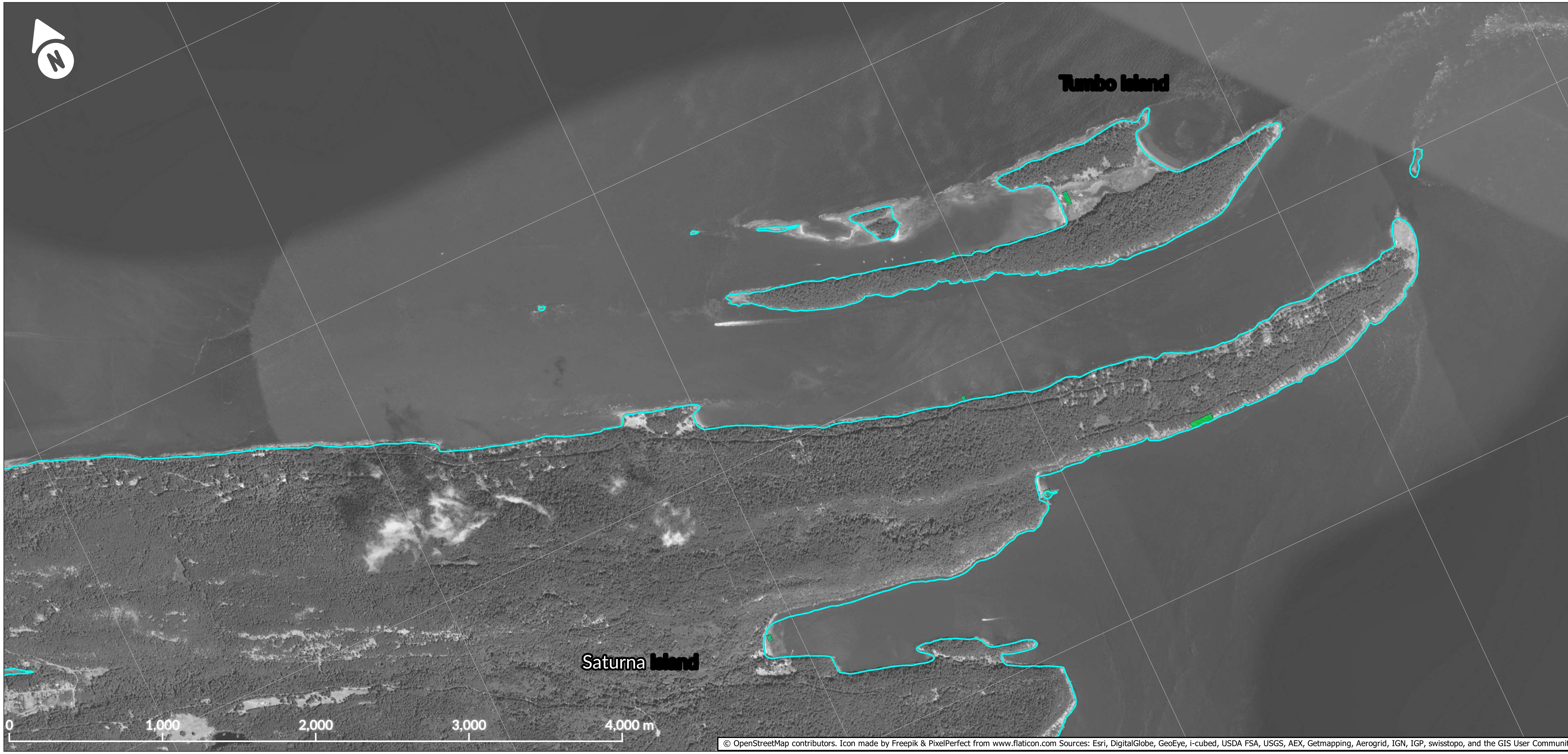


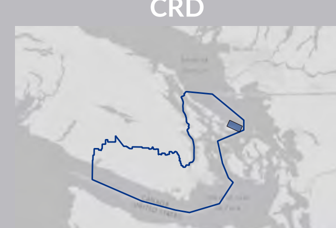
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 35 f 41

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pl t date: 2020.06.10
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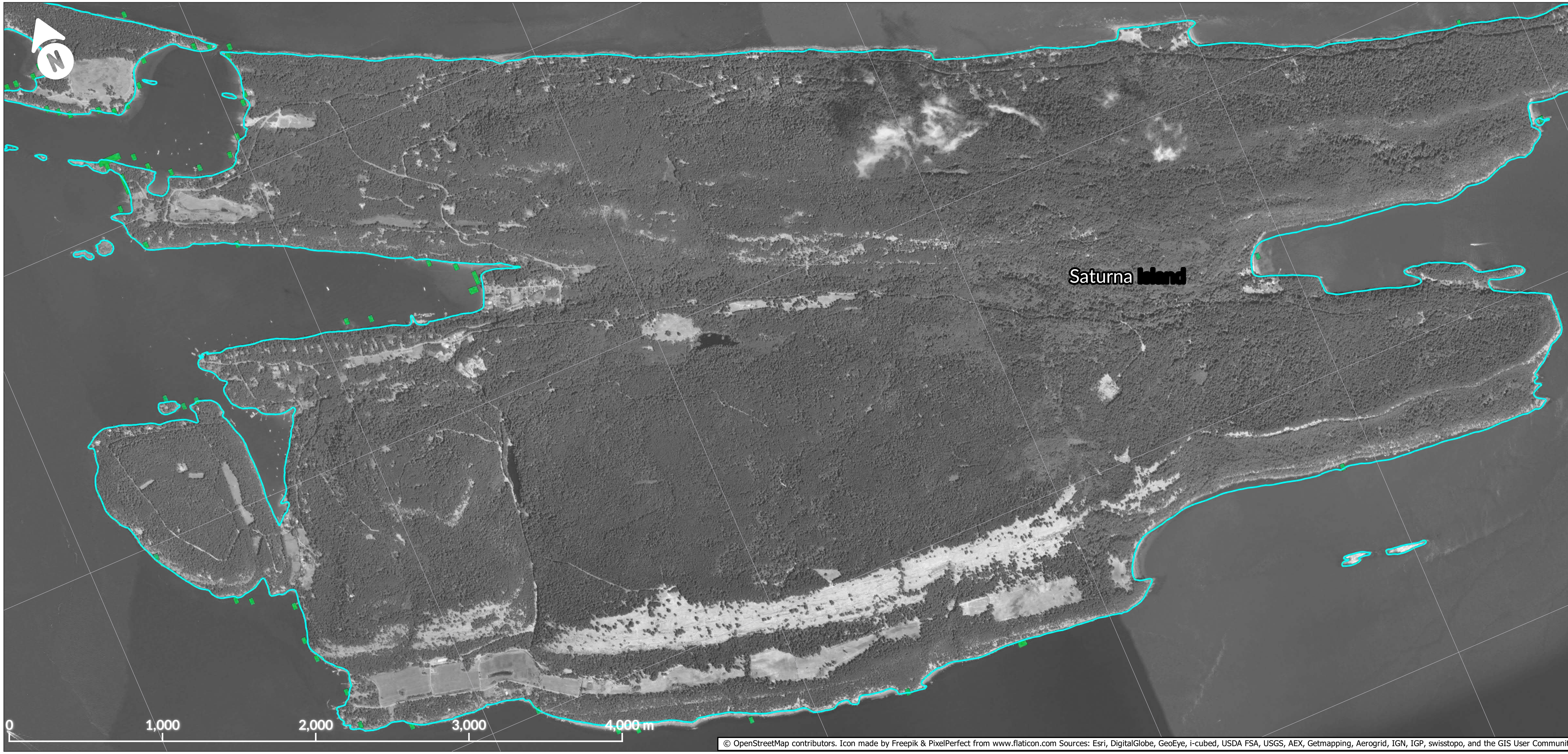


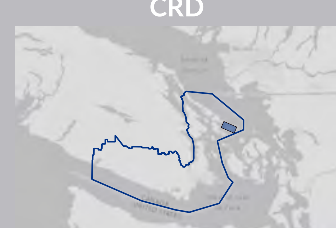
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 36 f 41

pl t date: 2020.06.10
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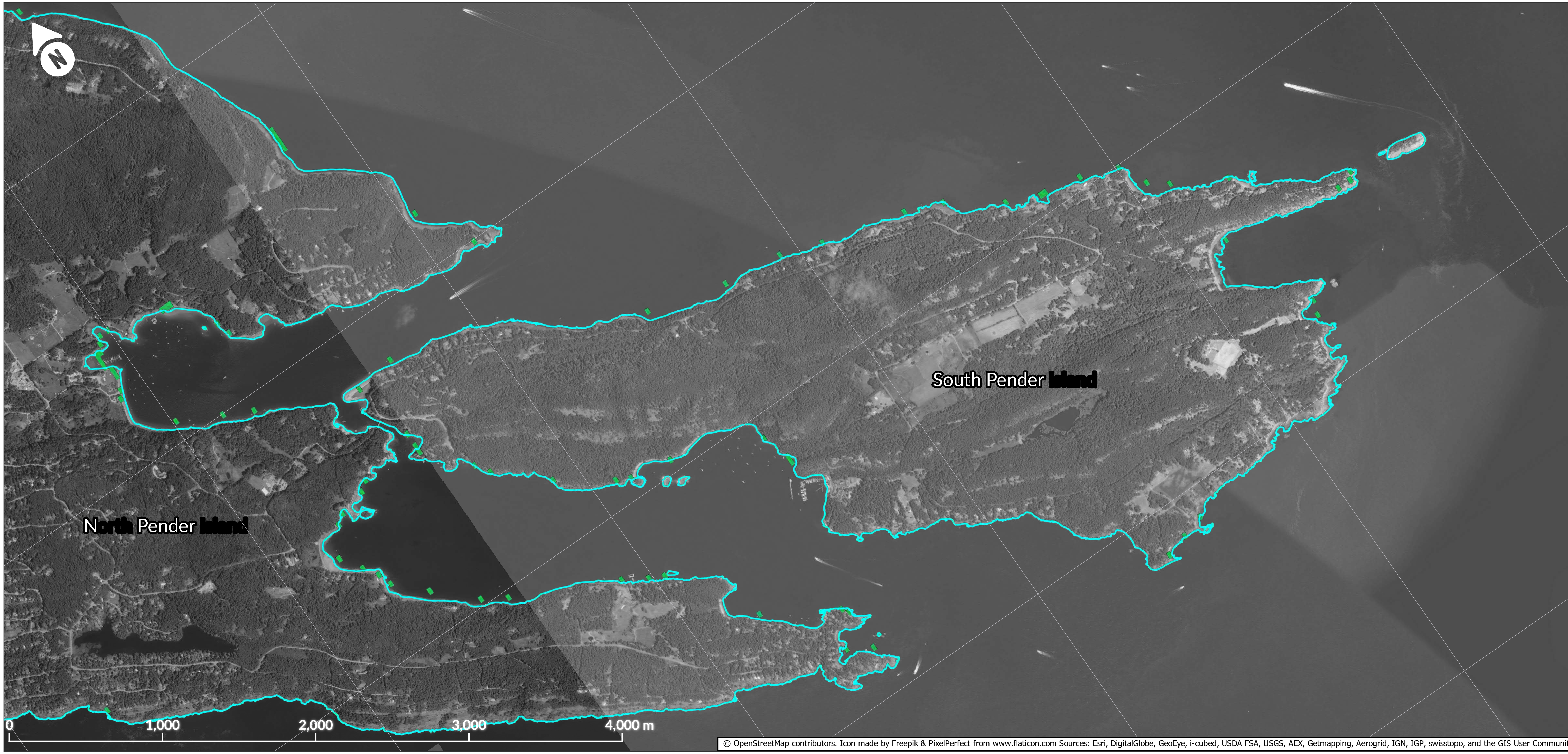


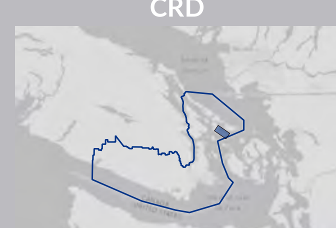
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 37 f 41

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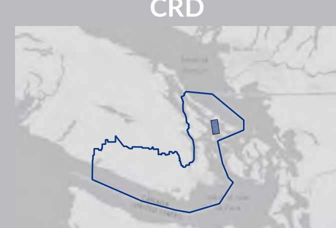
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the BC Fl d Hazard Area Land Use Management Guidelines.
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Map Sheet 38 f 41

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file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

C astal Fl d Inundati n Mapping Pr ject

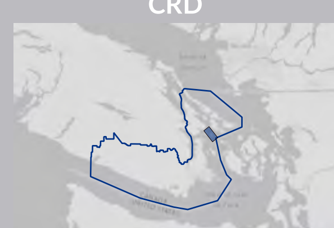
Capital Regi nal District

March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

Making a difference...together

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0   2.0
- 2.0   4.0
- 4.0   6.0
- 6.0   8.0
- >8.0

1. Under the pr visi ns   f the Fl   d Hazard Statutes Amendment Act, 2003 (Bill 56 , l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl   dplain devel pment practices, including decisi ns ab ut fl   dplain bylaws within their c mmunities. nf rmati n   n fl   dplain management guidelines can be f und in the BC Fl   d Hazard Area Land Use Management Guidelines.
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Map Sheet 39   f 41

pl t date: 2020.06.10
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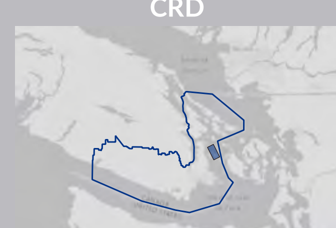
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

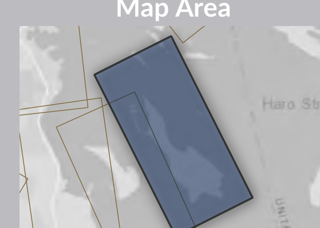
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
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Map Sheet 40 f 41

pl t date: 2020.06.10
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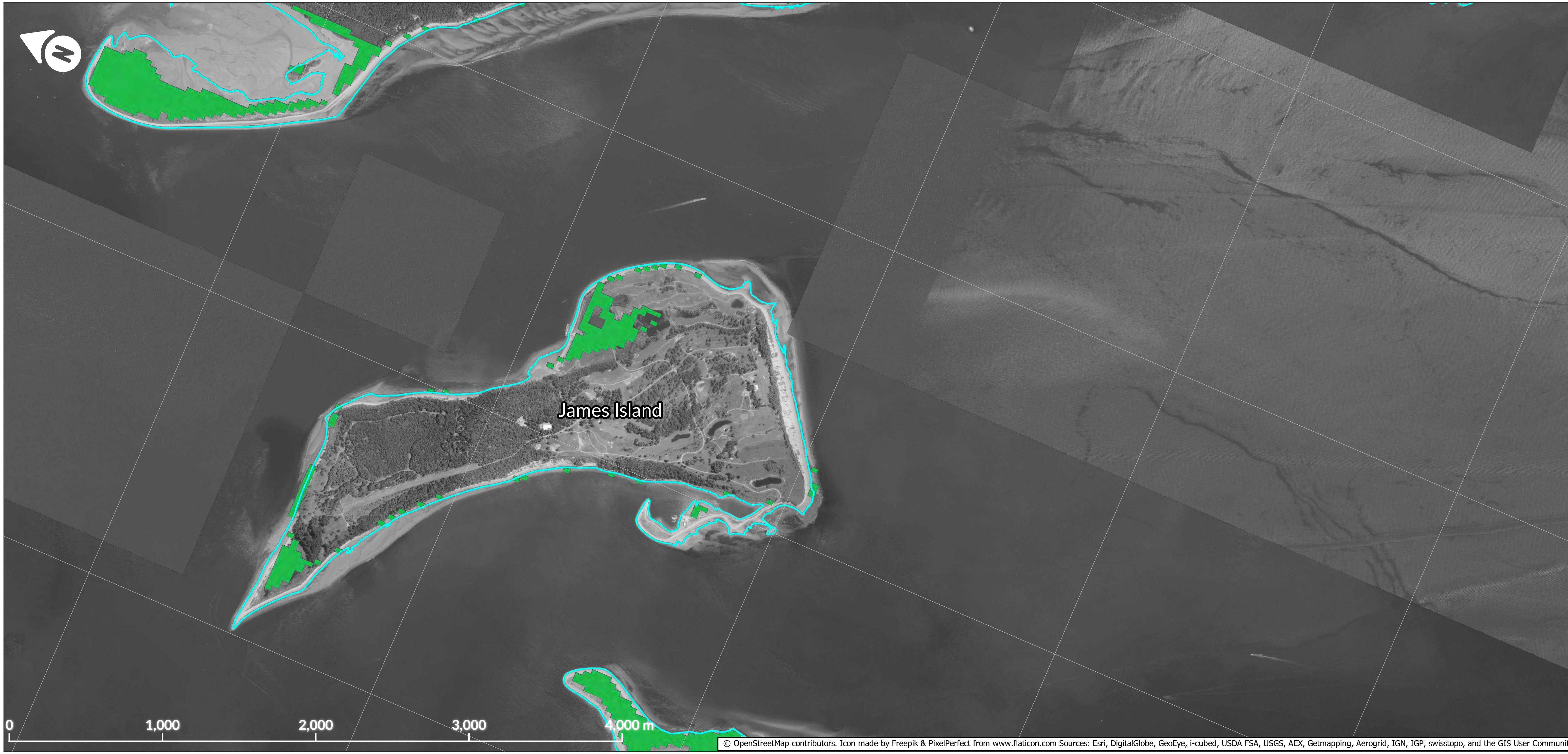


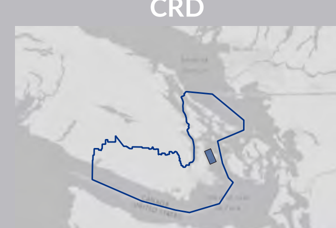
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

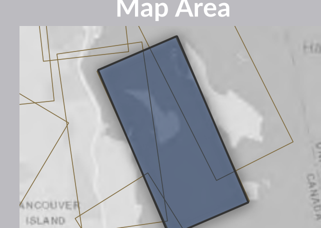
March 2020

Tsunami nundati n Map
S uthern Whidbey sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
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Map Sheet 41 f 41

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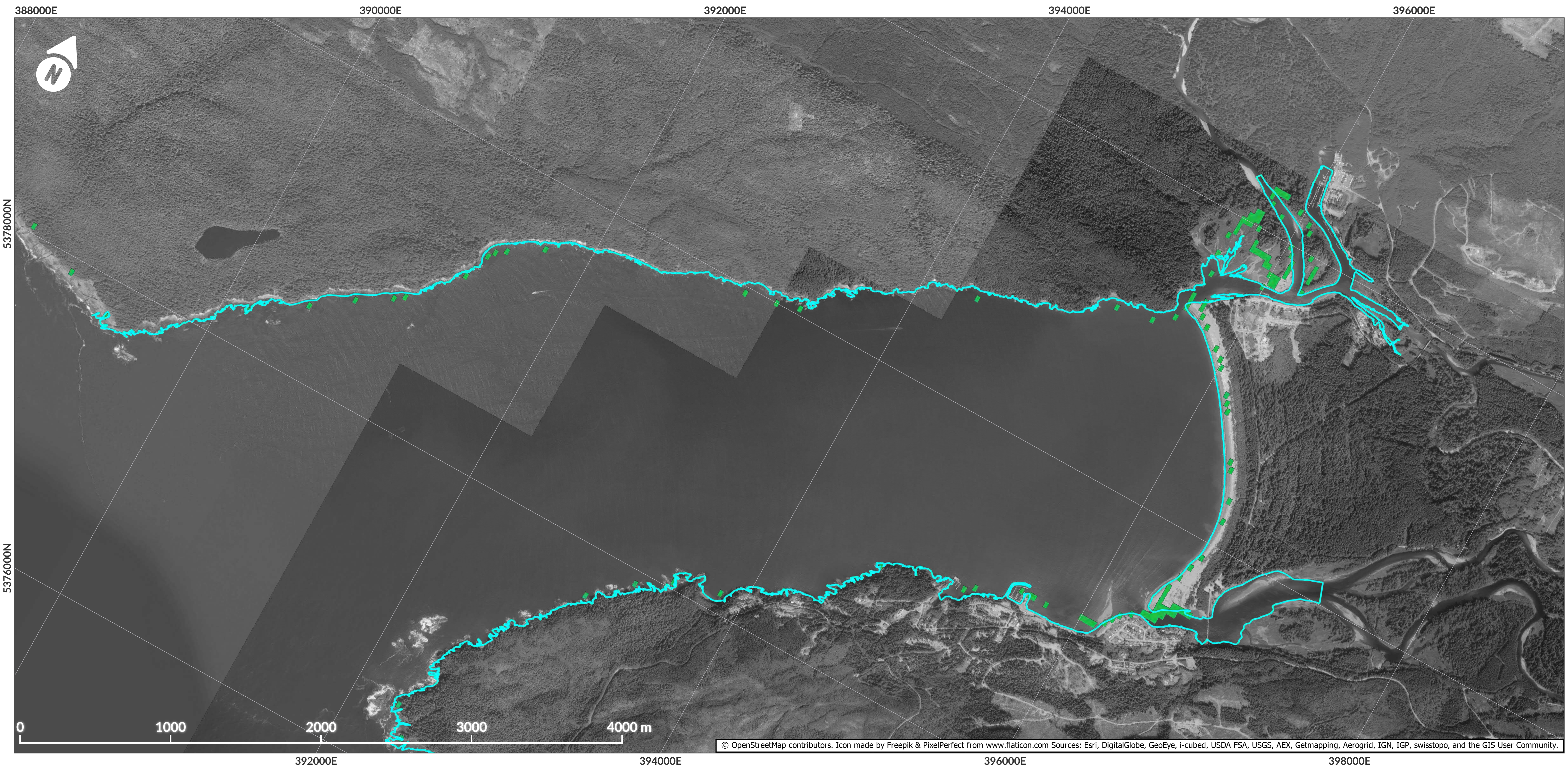


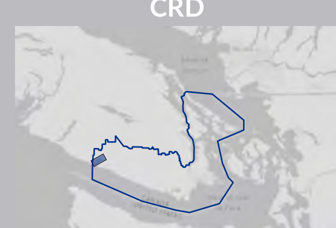
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

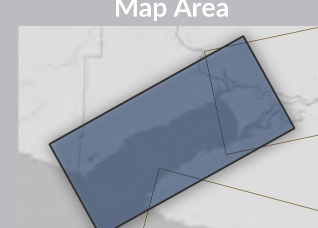
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Making a difference...together

DHI

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (ill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the C Fl d Hazard Area Land Use Management Guidelines.
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Appr ved by D. F rde, P.Eng.
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Map Sheet 1 f 41

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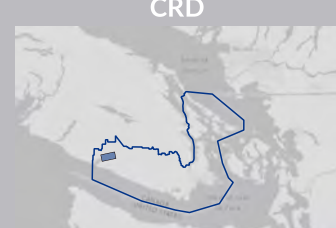
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 2 f 41

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pl t date: 2020.06.10
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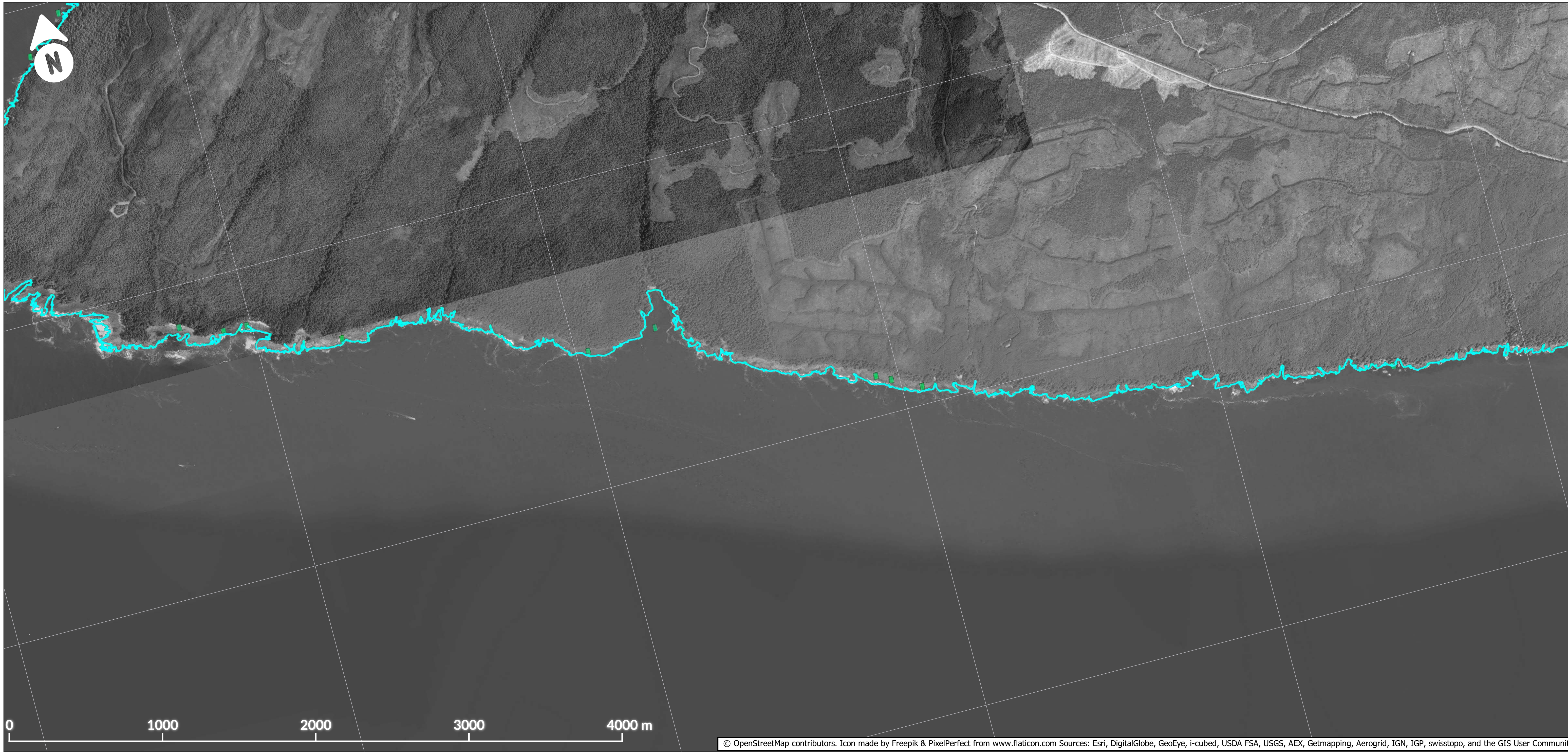


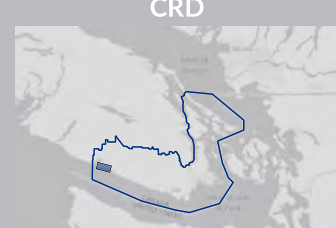
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

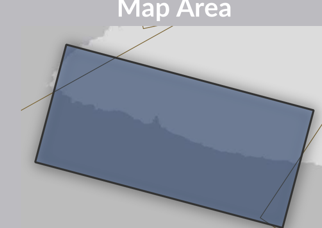
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Making a difference...together

DHI

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (ill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the C Fl d Hazard Area Land Use Management Guidelines.
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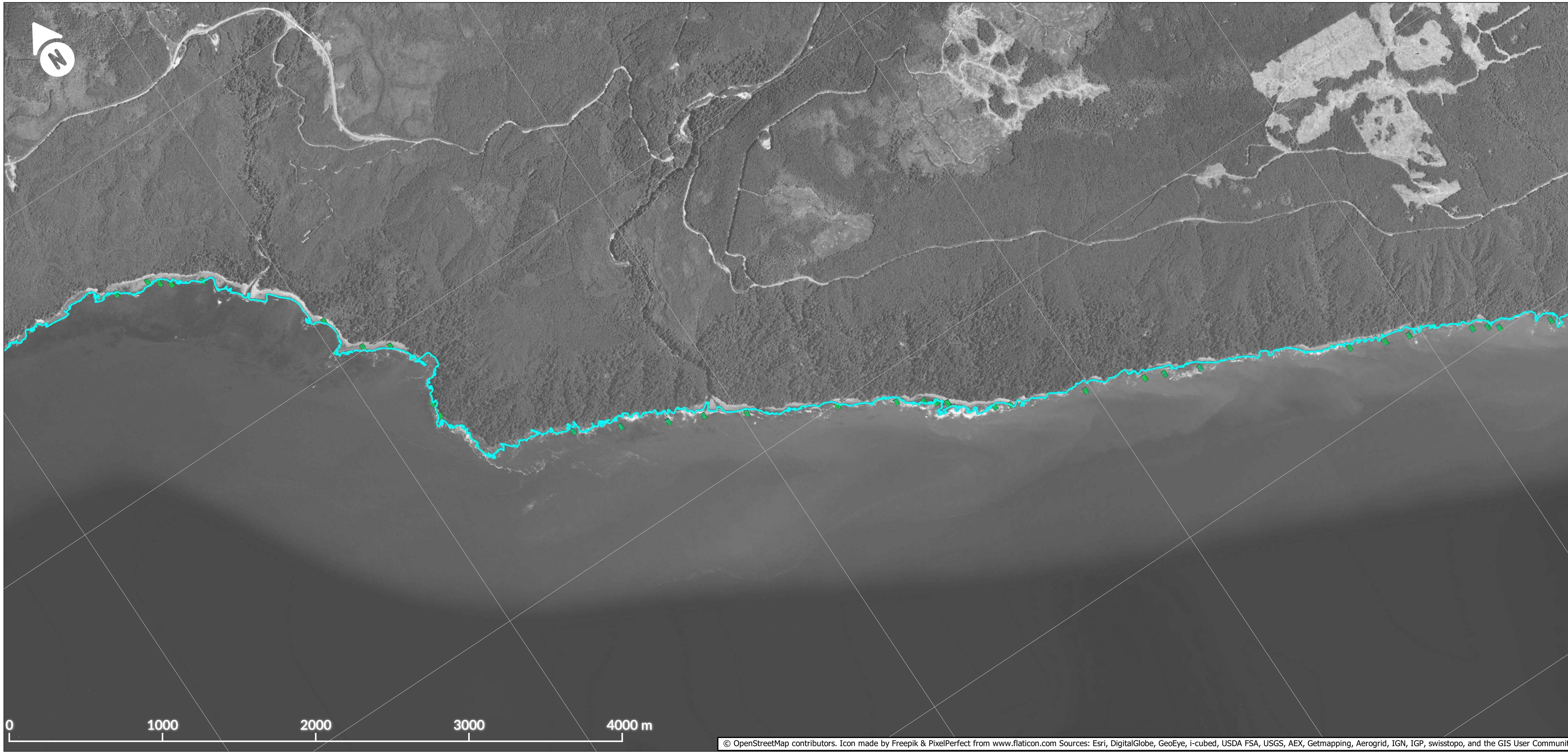
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 3 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



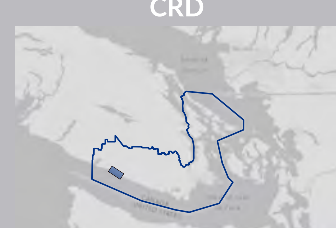
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
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Map Sheet 4 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

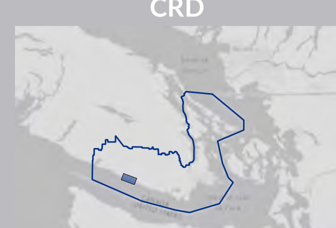
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
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Map Sheet 5 f 41

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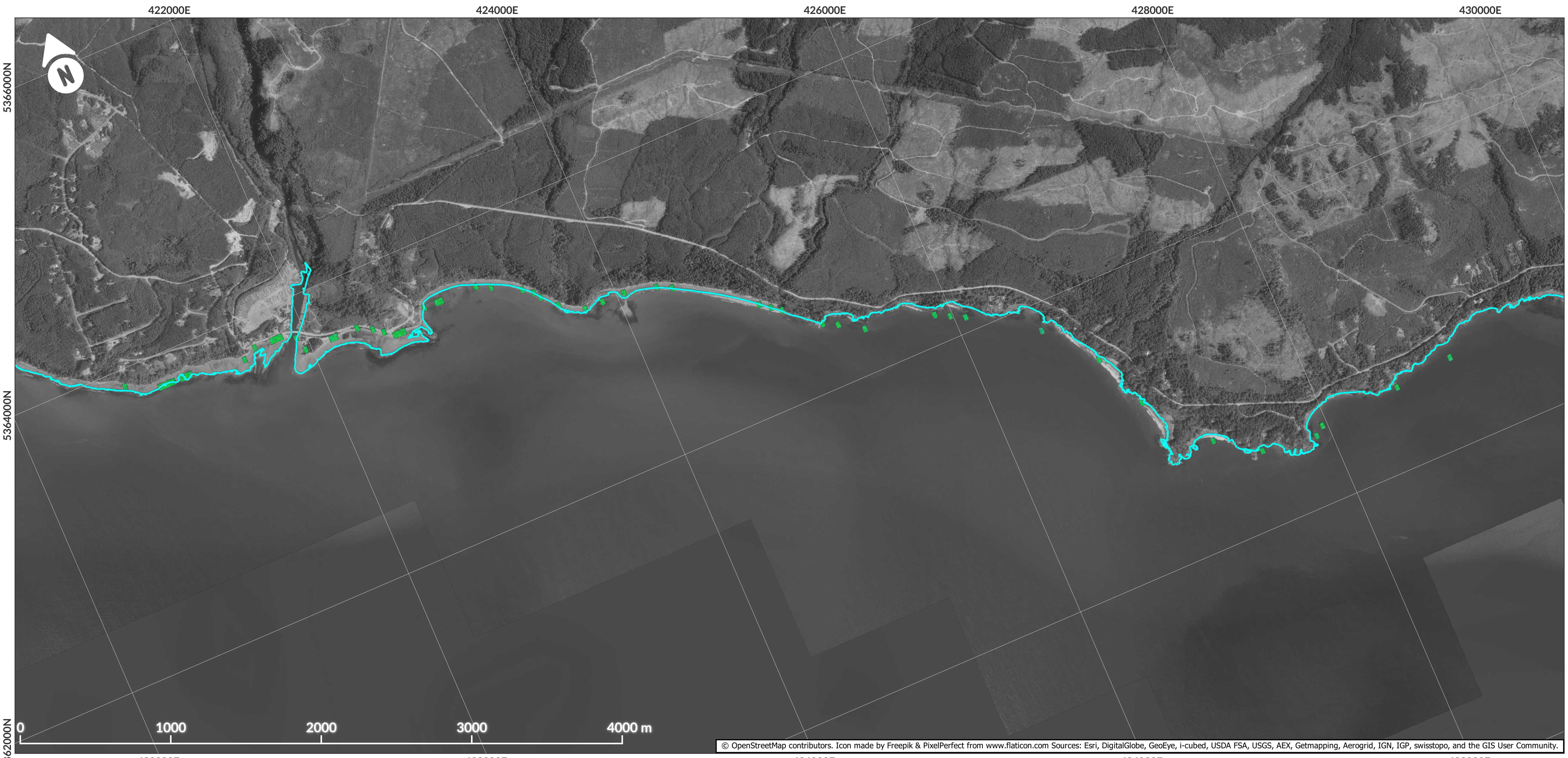
pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



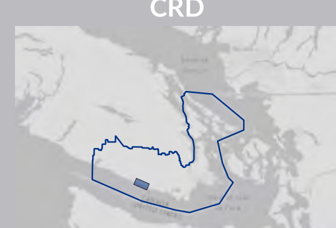
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Making a difference...together

DHI

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 6 f 41

pl t date: 2020.06.10
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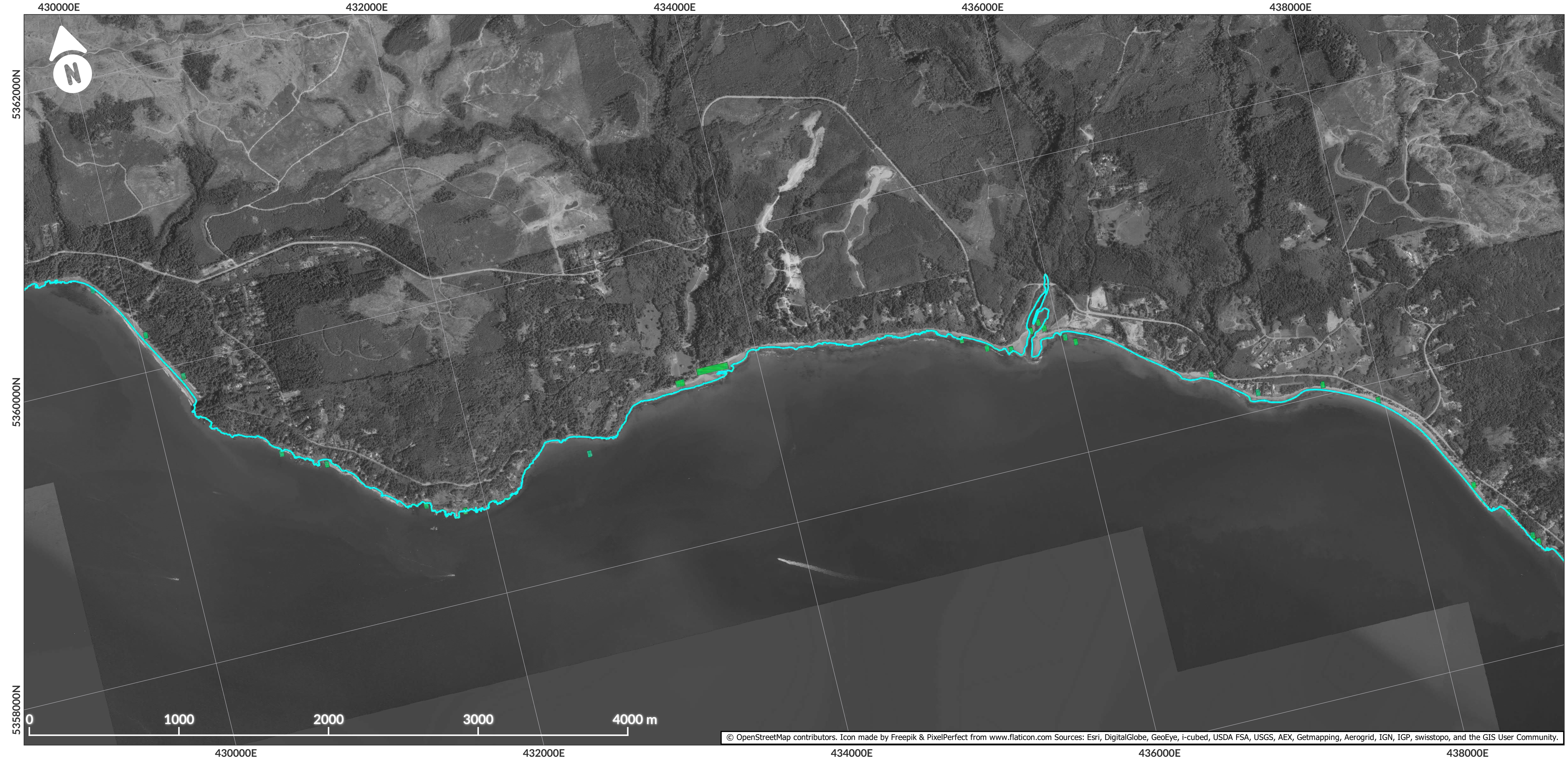


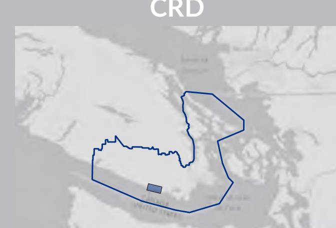
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 7 f 41

pl t date: 2020.06.10
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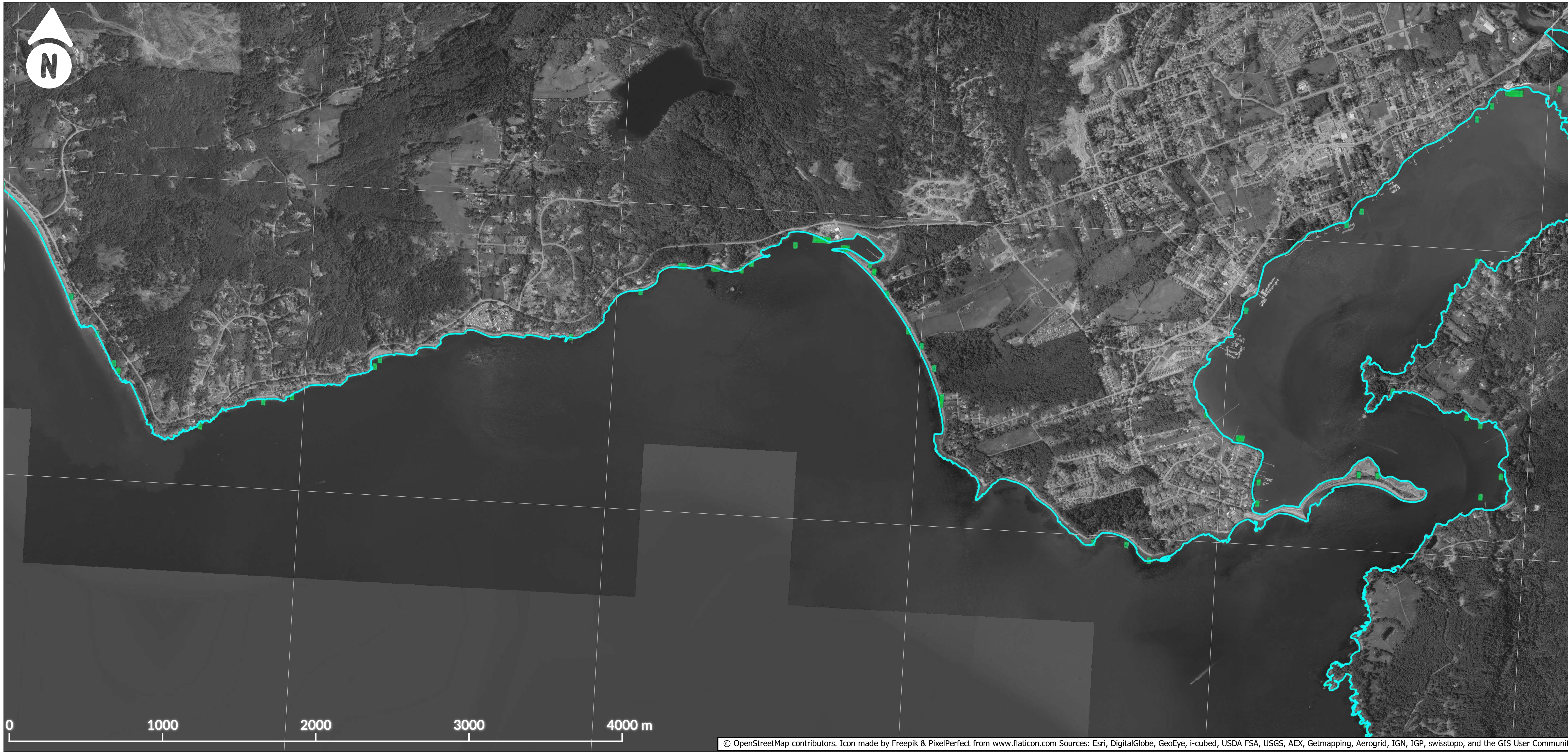


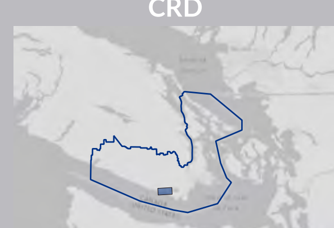
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 8 f 41

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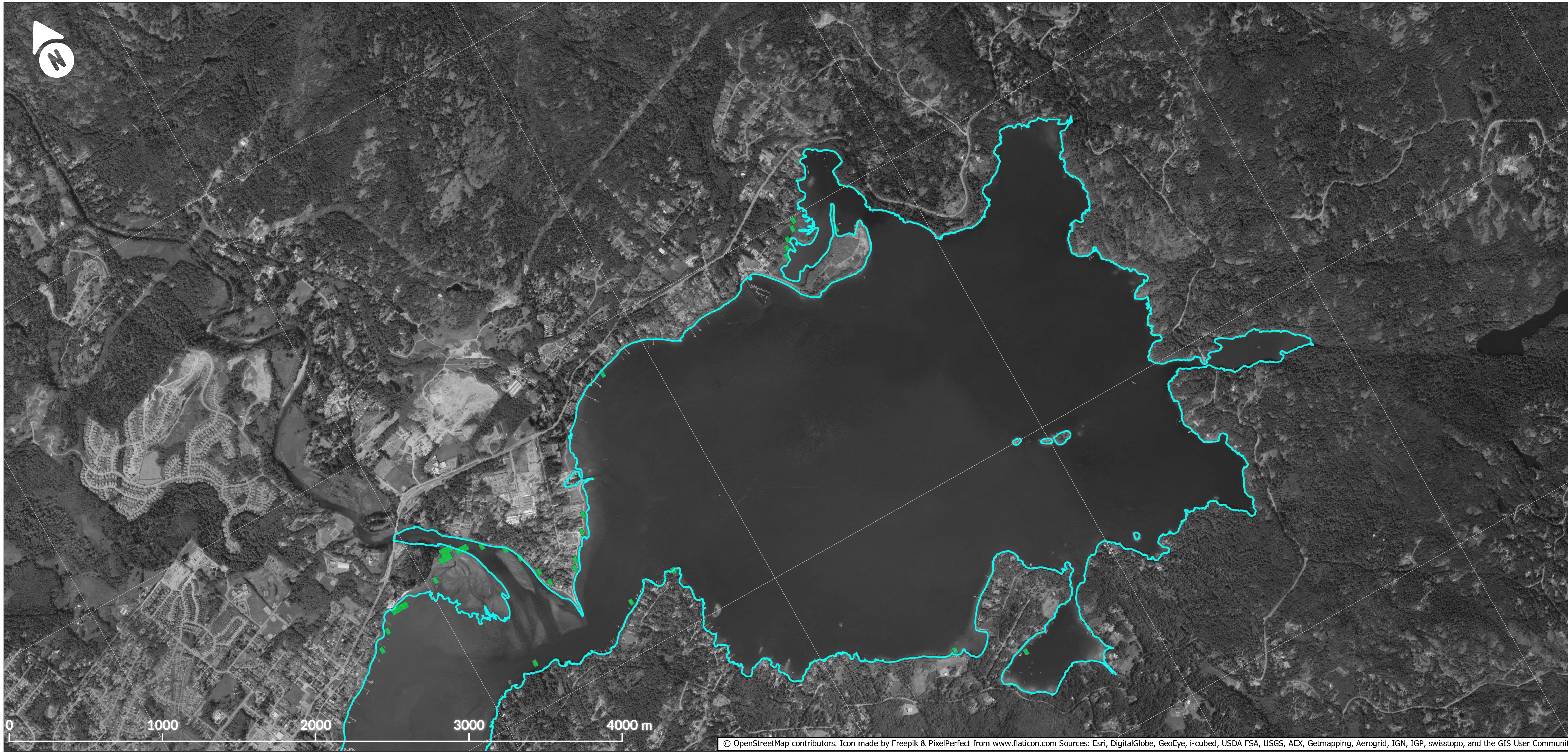
pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



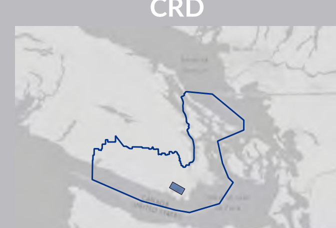
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

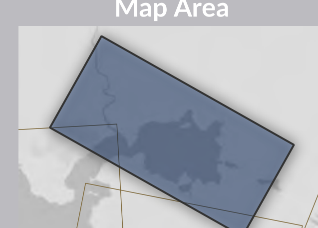
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Map Sheet 9 f 41

pl t date: 2020.06.10
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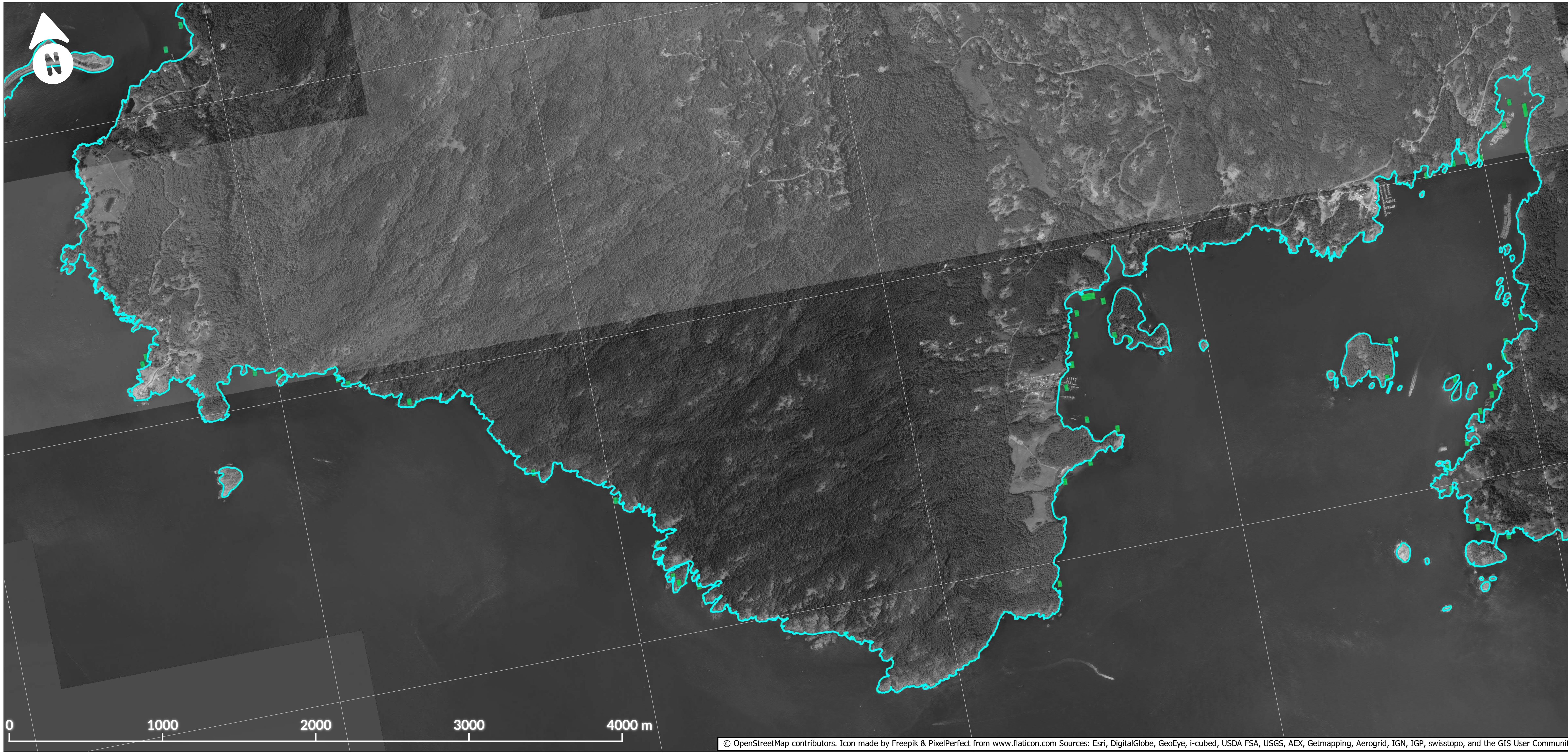


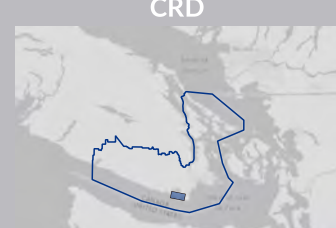
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

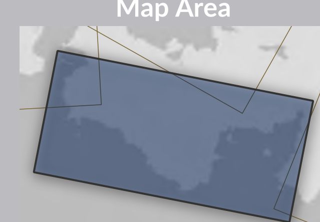
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Drawn by C. Duncan and S. Haley

Map Sheet 10 f 41

pl t date: 2020.06.10
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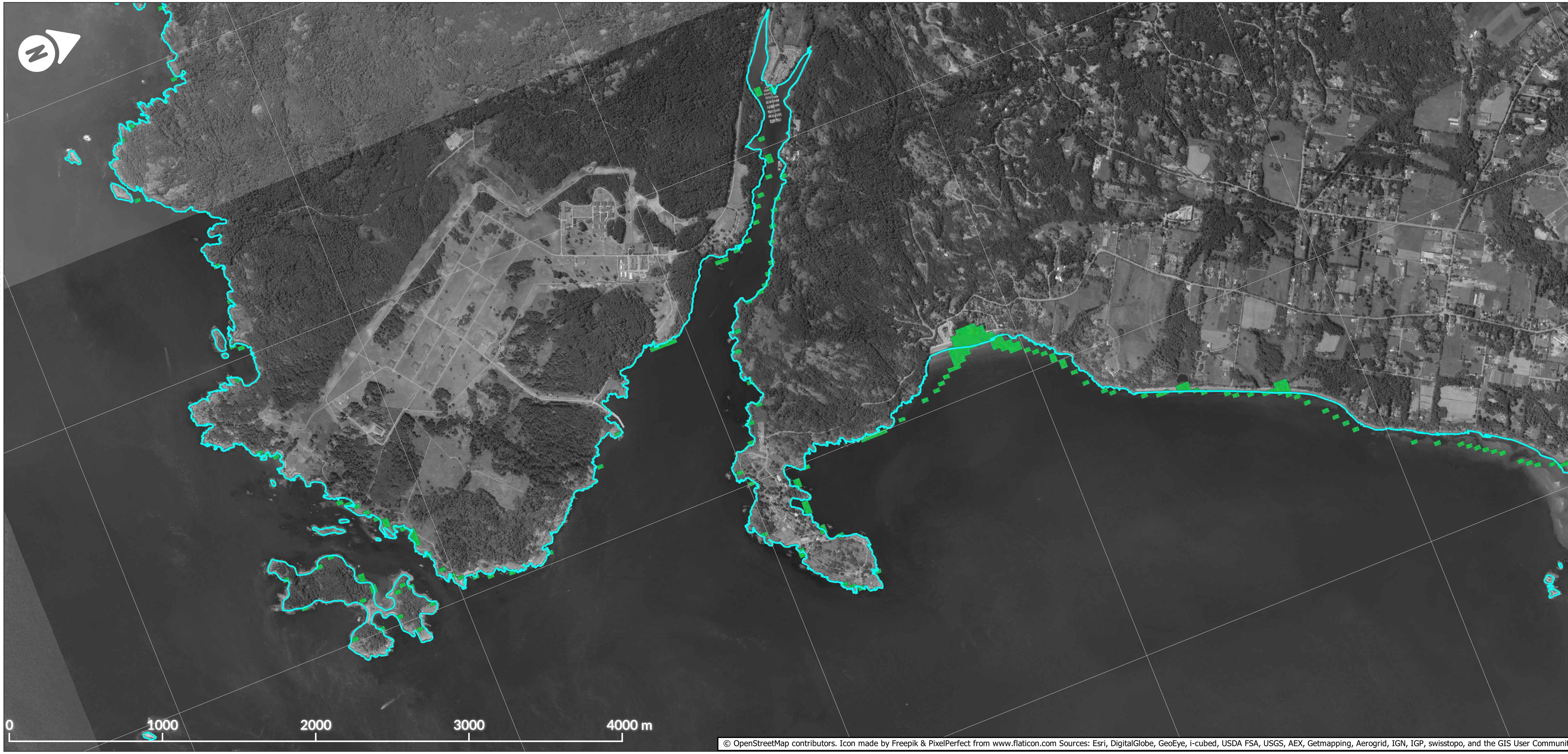


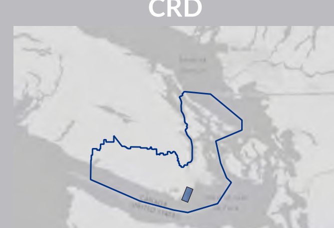
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 11 f 41

pl t date: 2020.06.10
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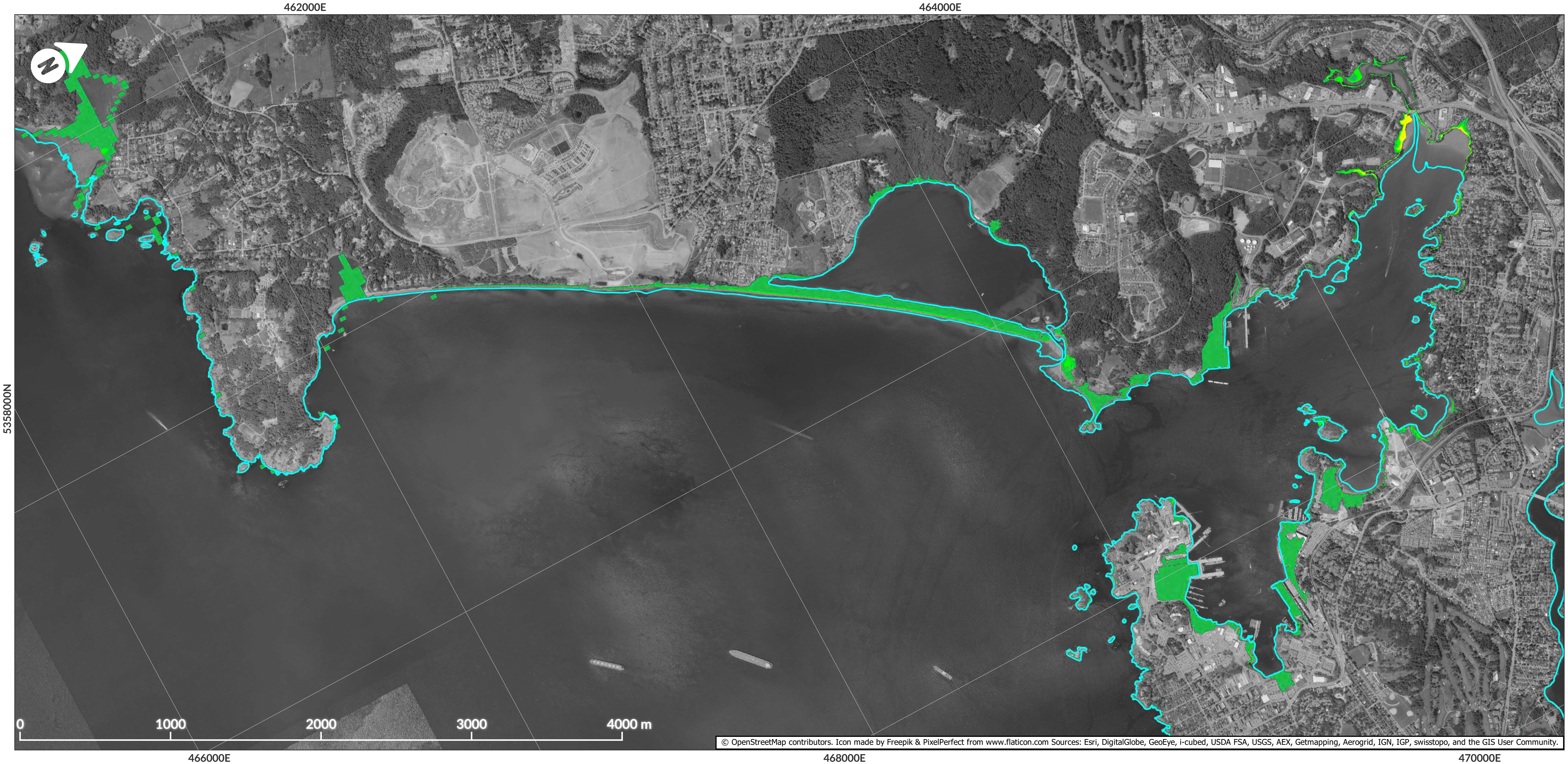


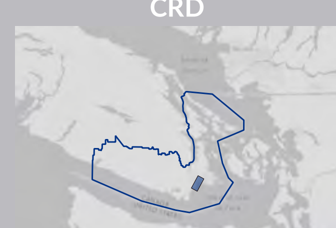
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

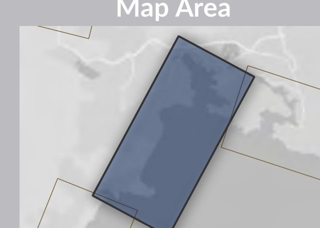
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
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Appr ved by D. F rde, P.Eng.
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Map Sheet 12 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

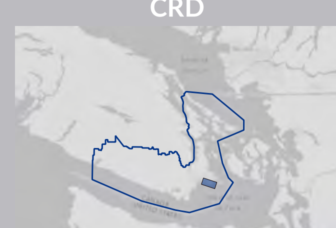
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Making a difference...together

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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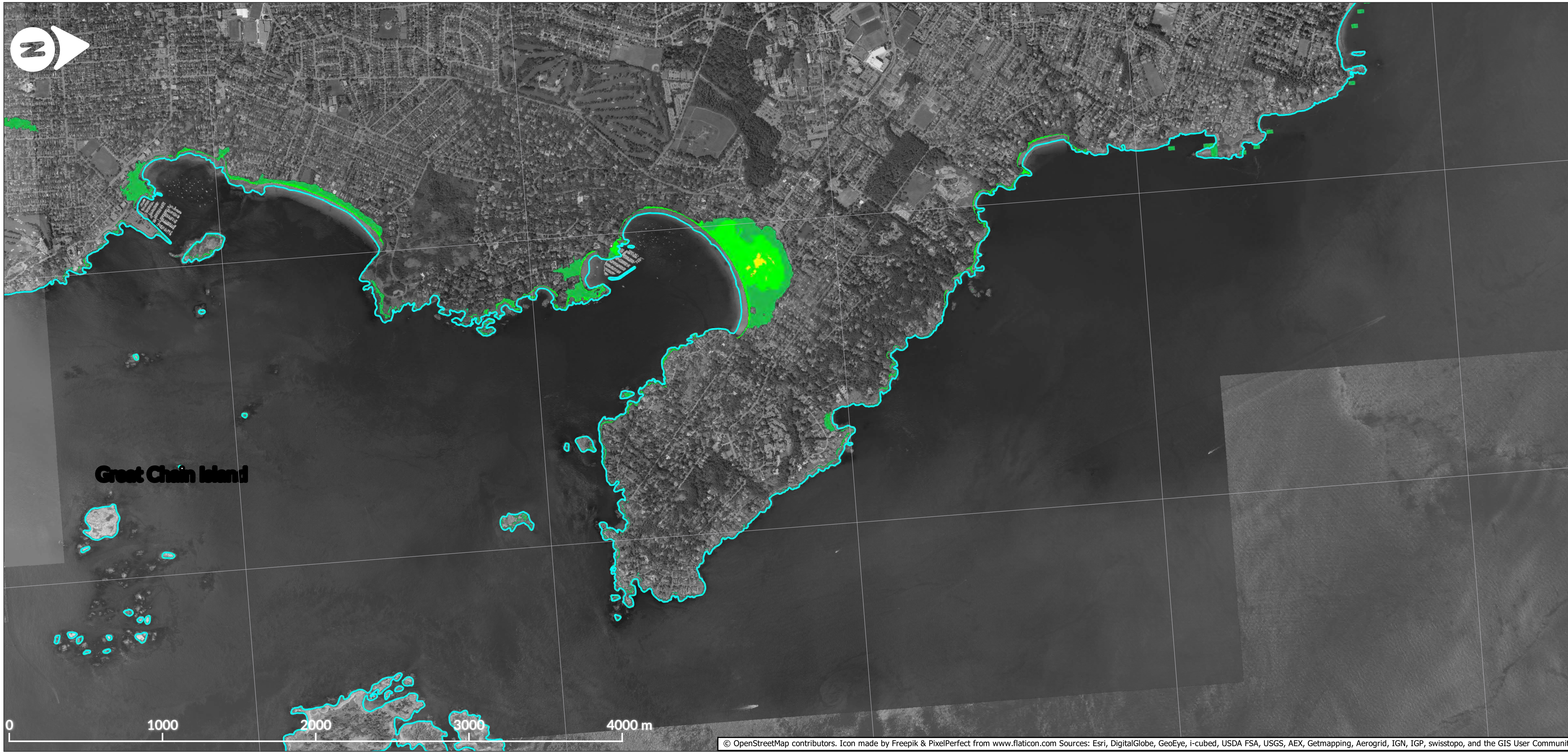
Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 13 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



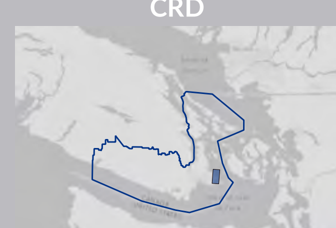
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

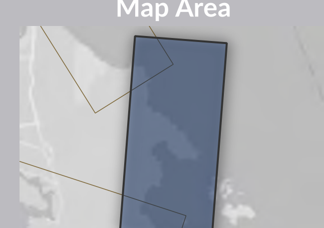
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (ill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the C Fl d Hazard Area Land Use Management Guidelines.
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file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS

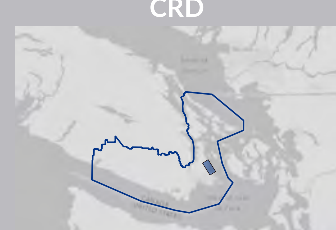
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

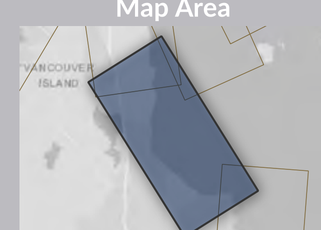
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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Map Sheet 15 f 41

pl t date: 2020.06.10
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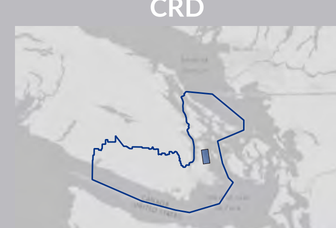
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

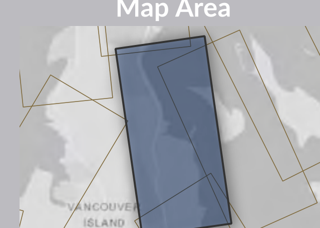
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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Map Sheet 16 f 41

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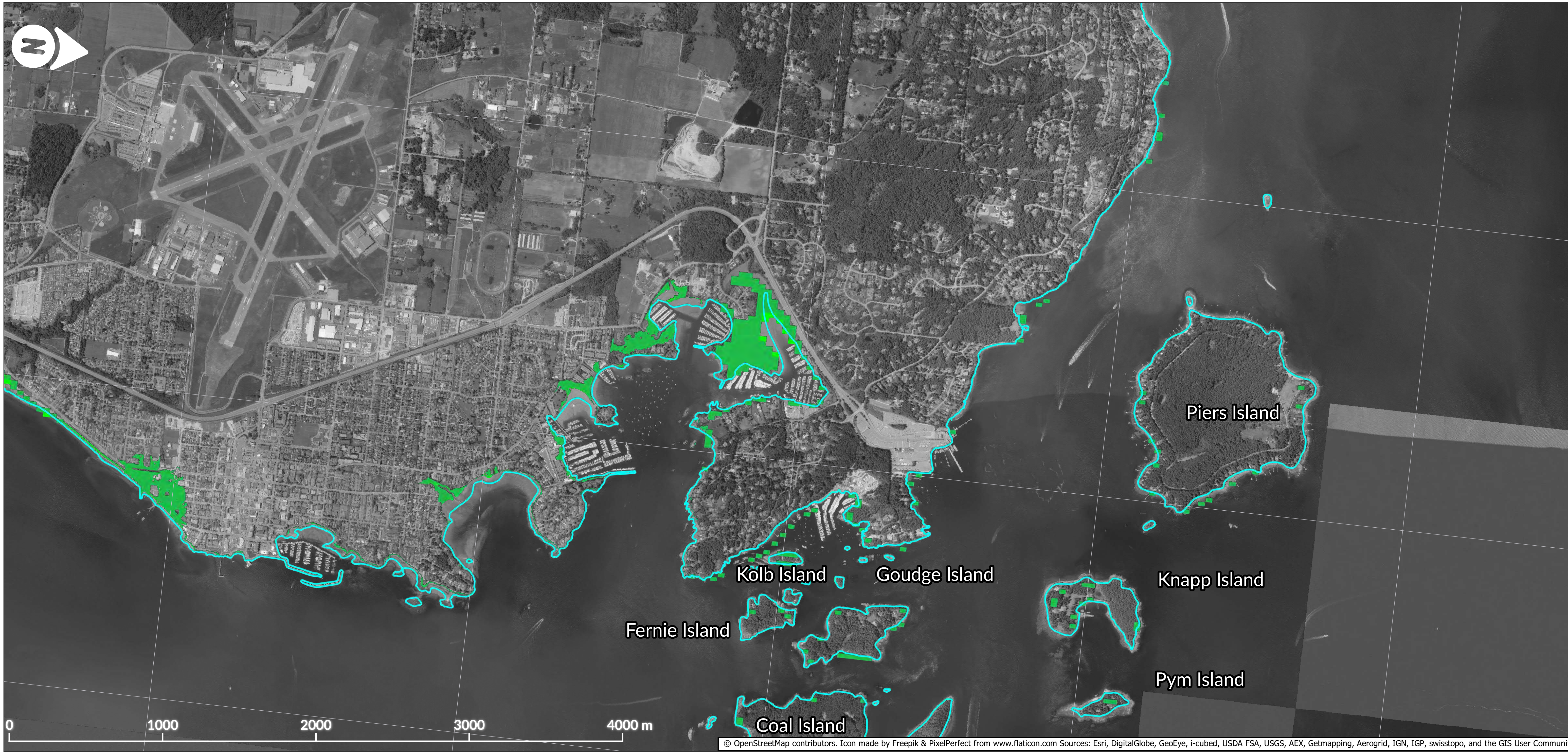
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



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C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

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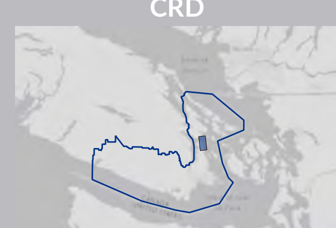
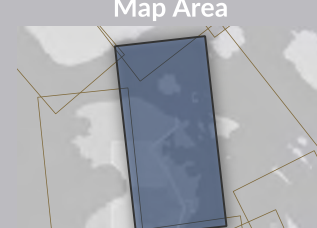
CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
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Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

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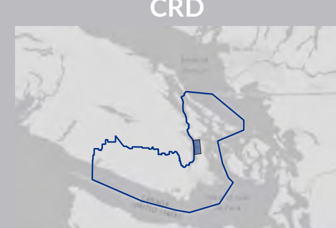
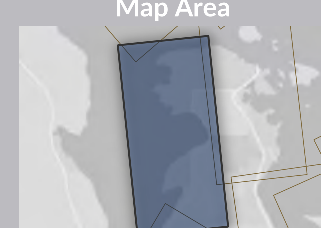
CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
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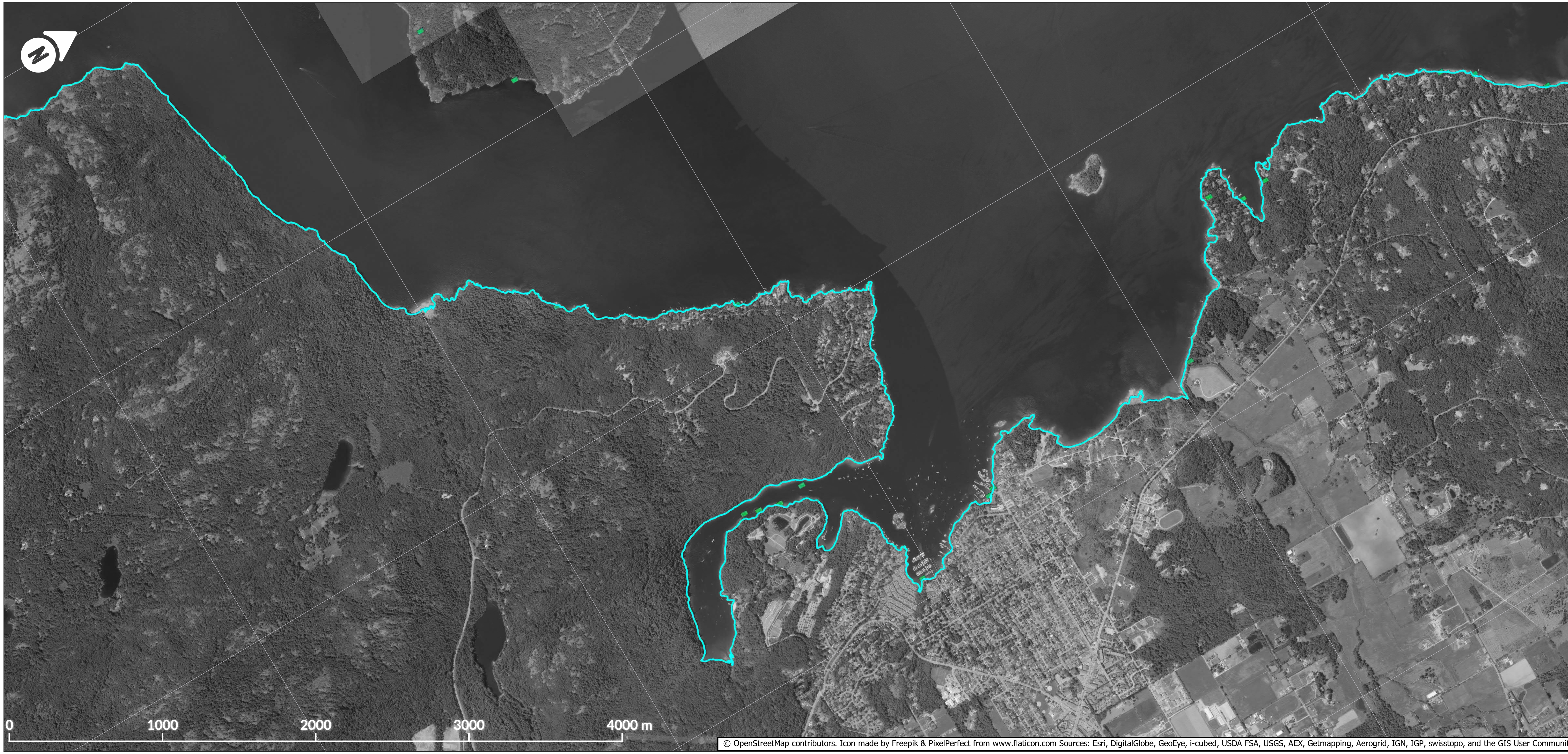
Map Sheet 18 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



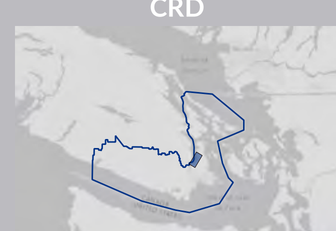
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



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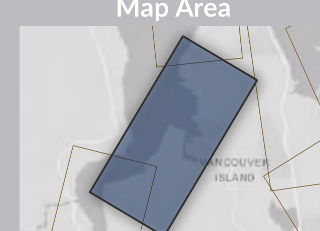

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Legend

Coastline

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Map Sheet 19 f 41

pl t date: 2020.06.10
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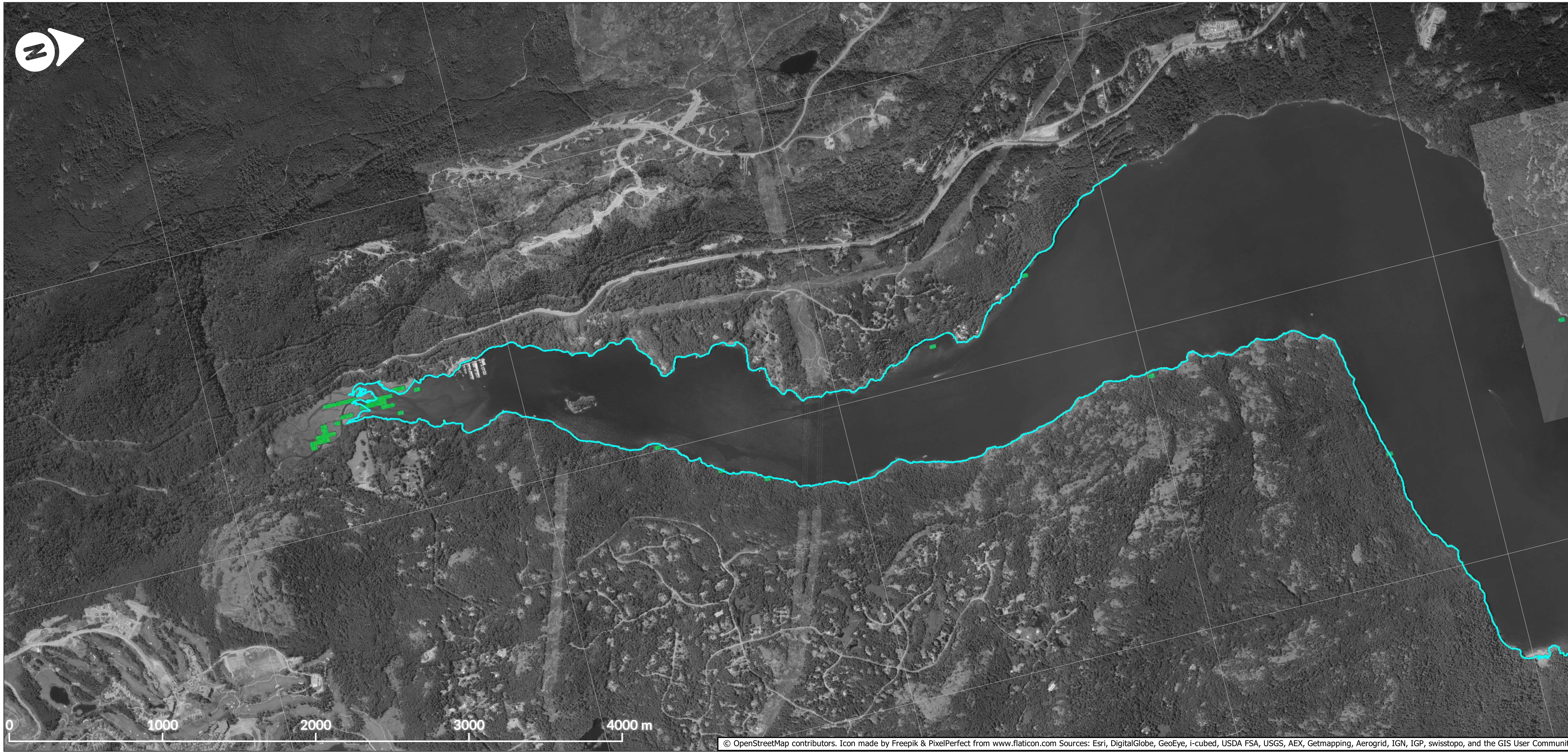


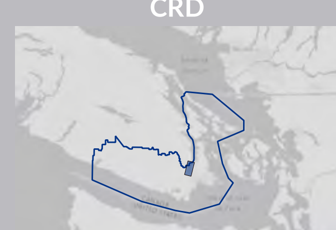
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



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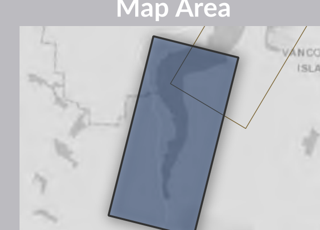

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Legend

Coastline

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Map Sheet 20 f 41

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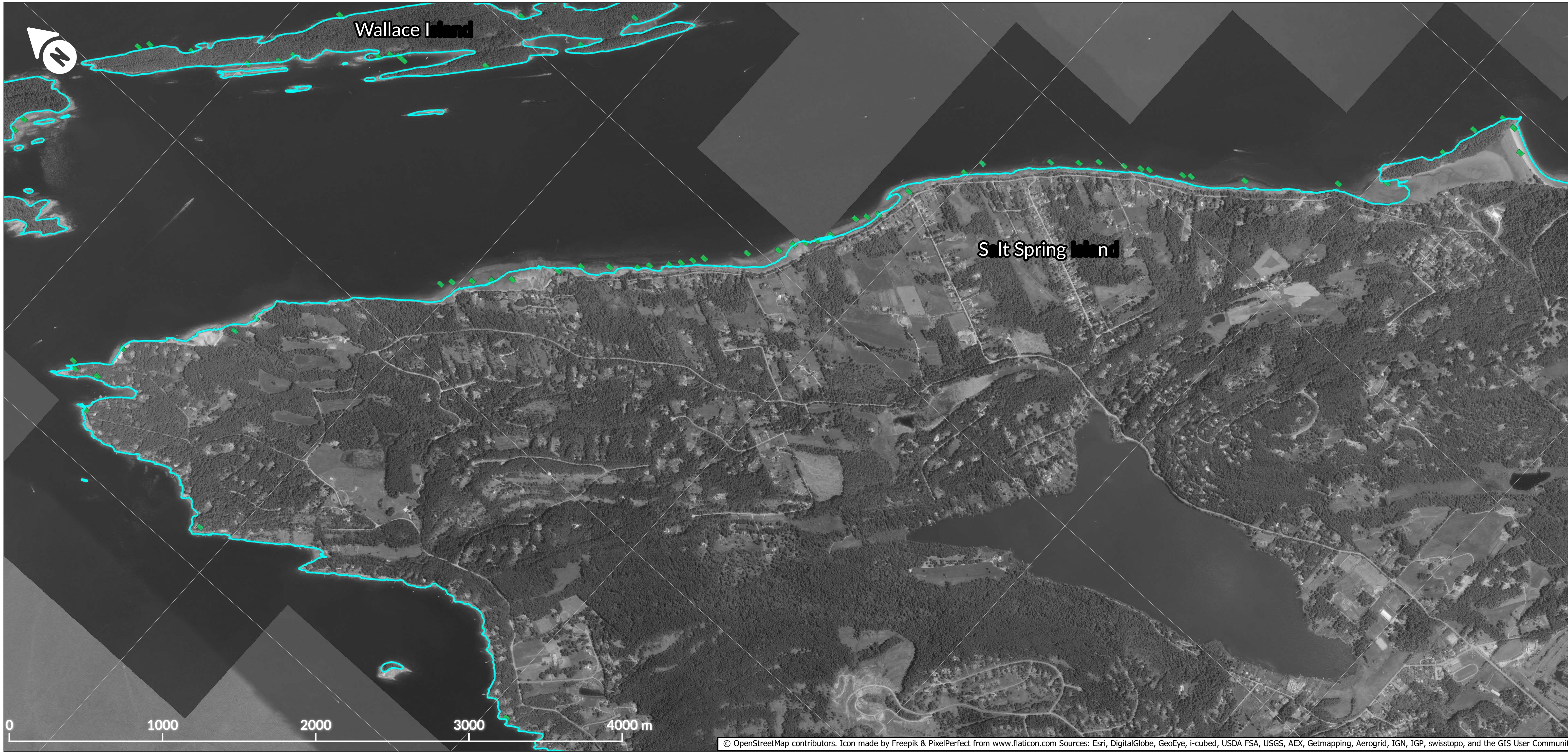


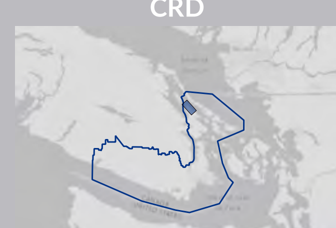
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

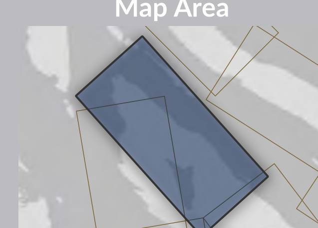
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

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Map Sheet 21 f 41

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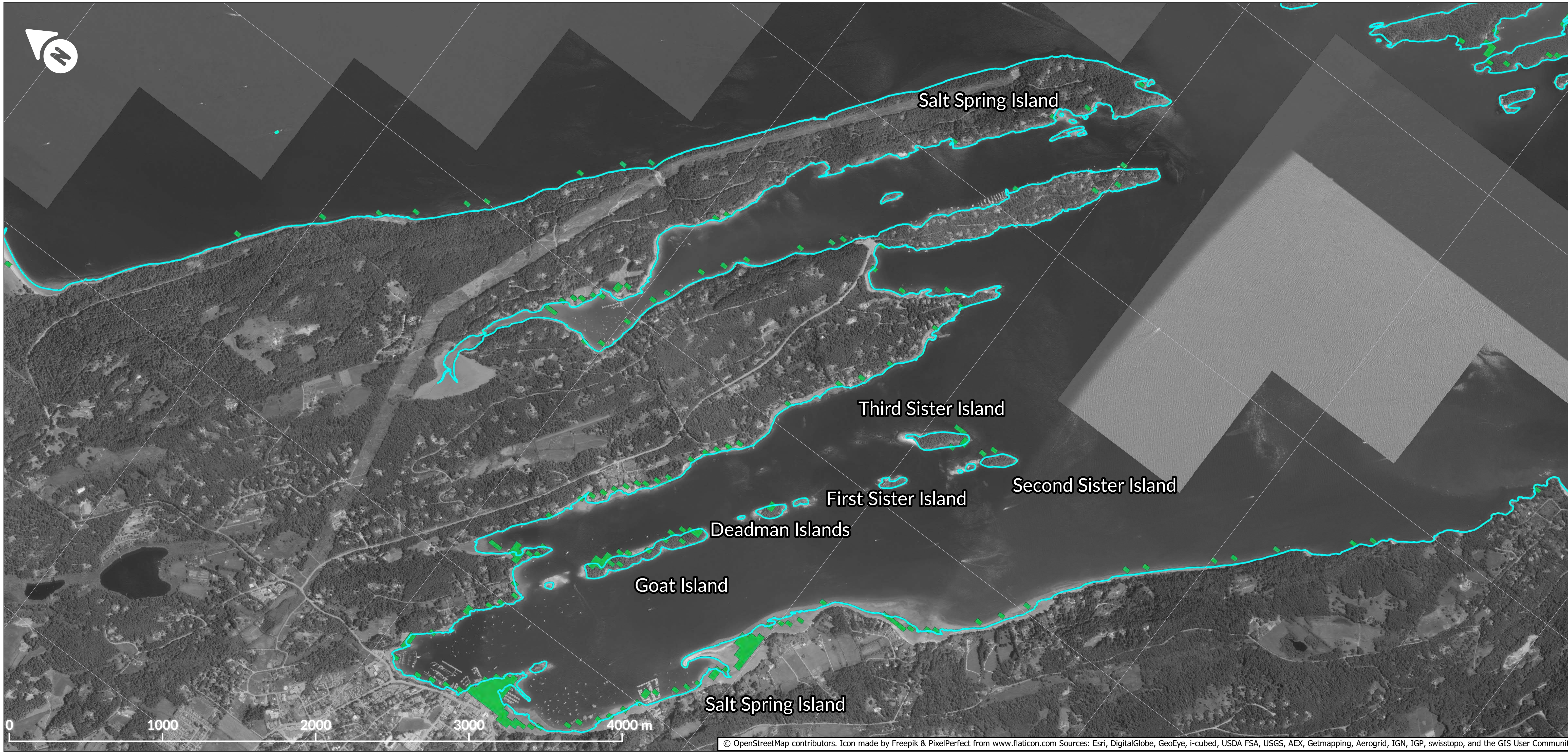

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Capital Regi nal District

March 2020

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Devil's M untain sland Fault Mw 7.5

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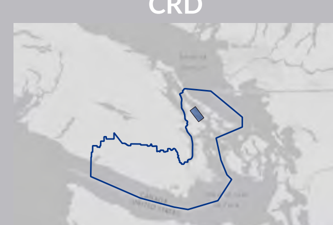
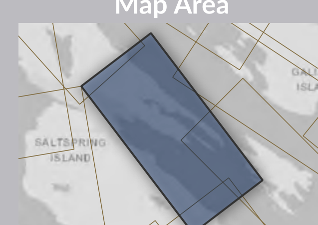


Map Area



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Legend

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Map Sheet 22 f 41

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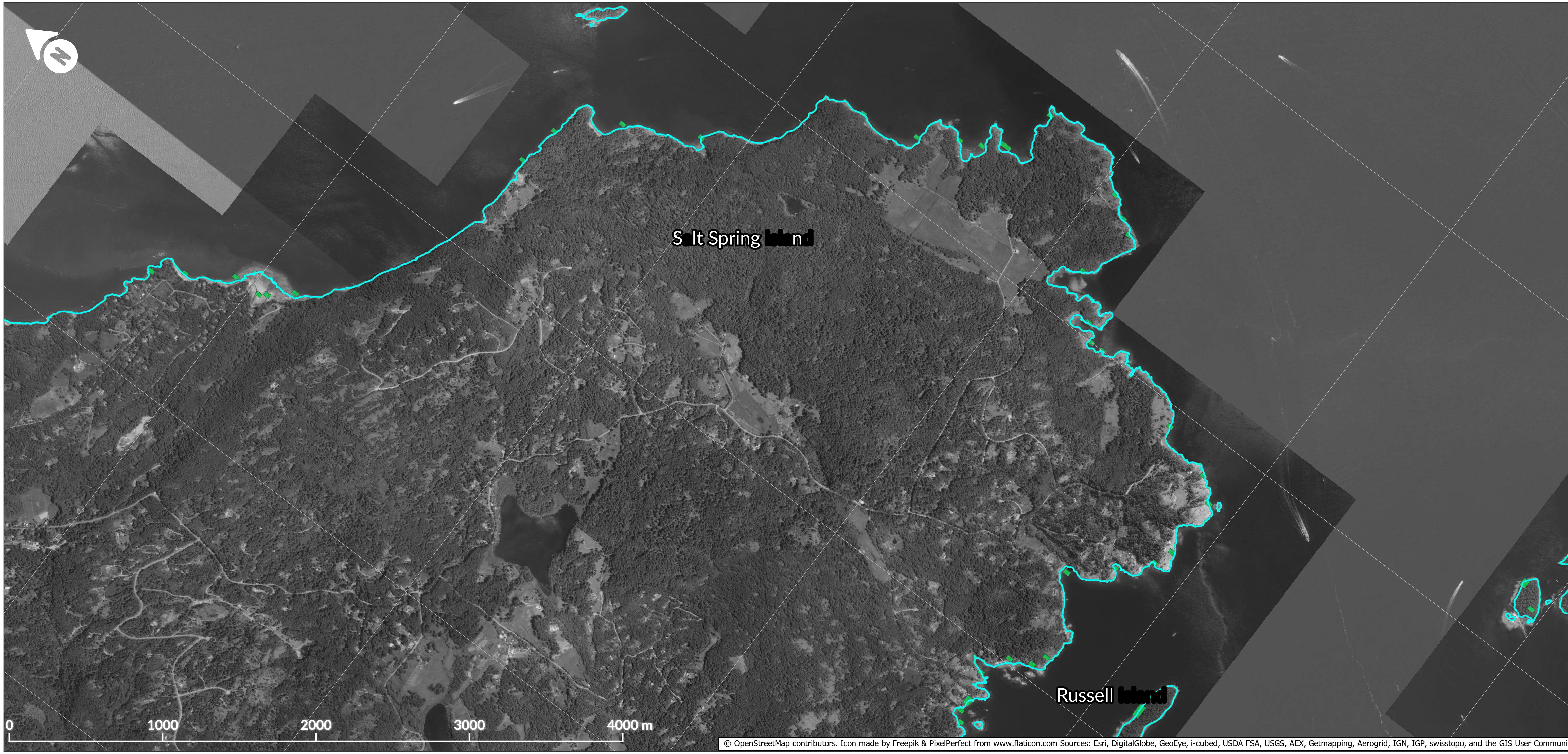

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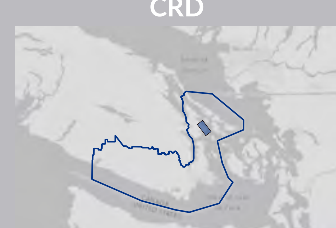
Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

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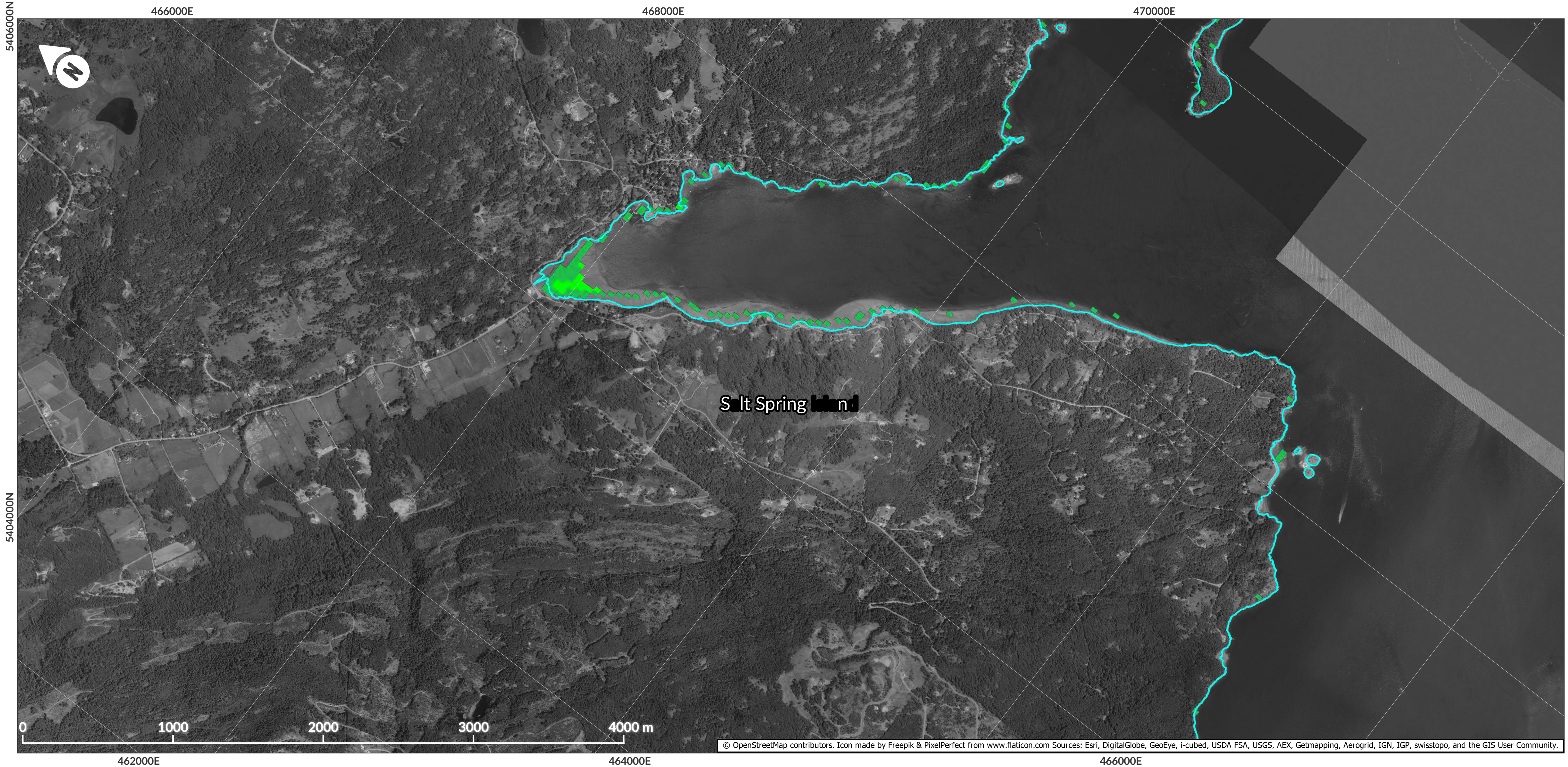


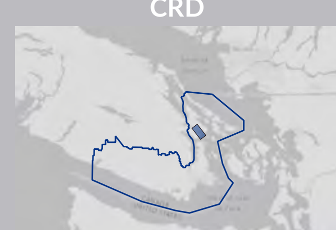
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

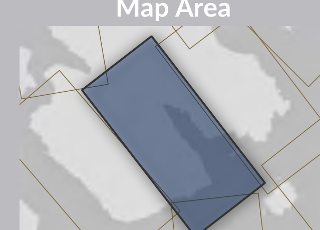
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (ill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the C Fl d Hazard Area Land Use Management Guidelines.
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5. F r further inf rmati n, please refer t Task 3 – Tsunami M delling and Mapping Rep rt. These maps c nstitute Appendix C f said rep rt.

Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 24 f 41

pl t date: 2020.06.10
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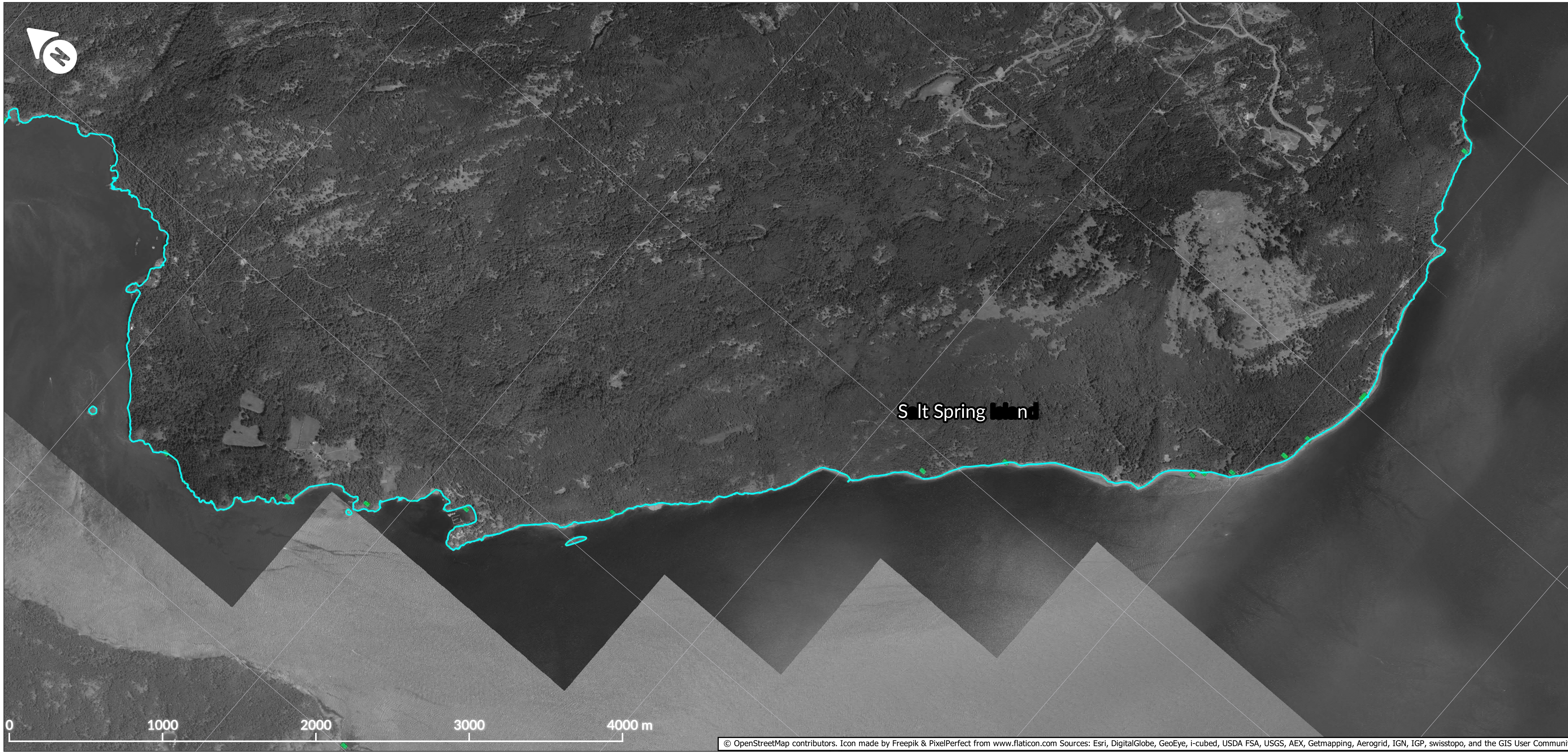

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Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

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CRD

Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 25 f 41

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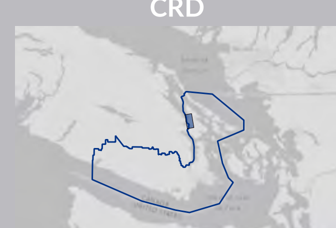
Capital Regi nal District

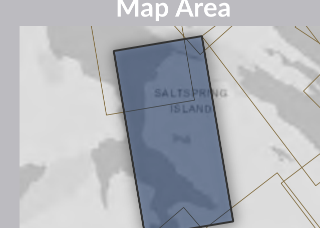
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
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- >8.0

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Map Sheet 26 f 41

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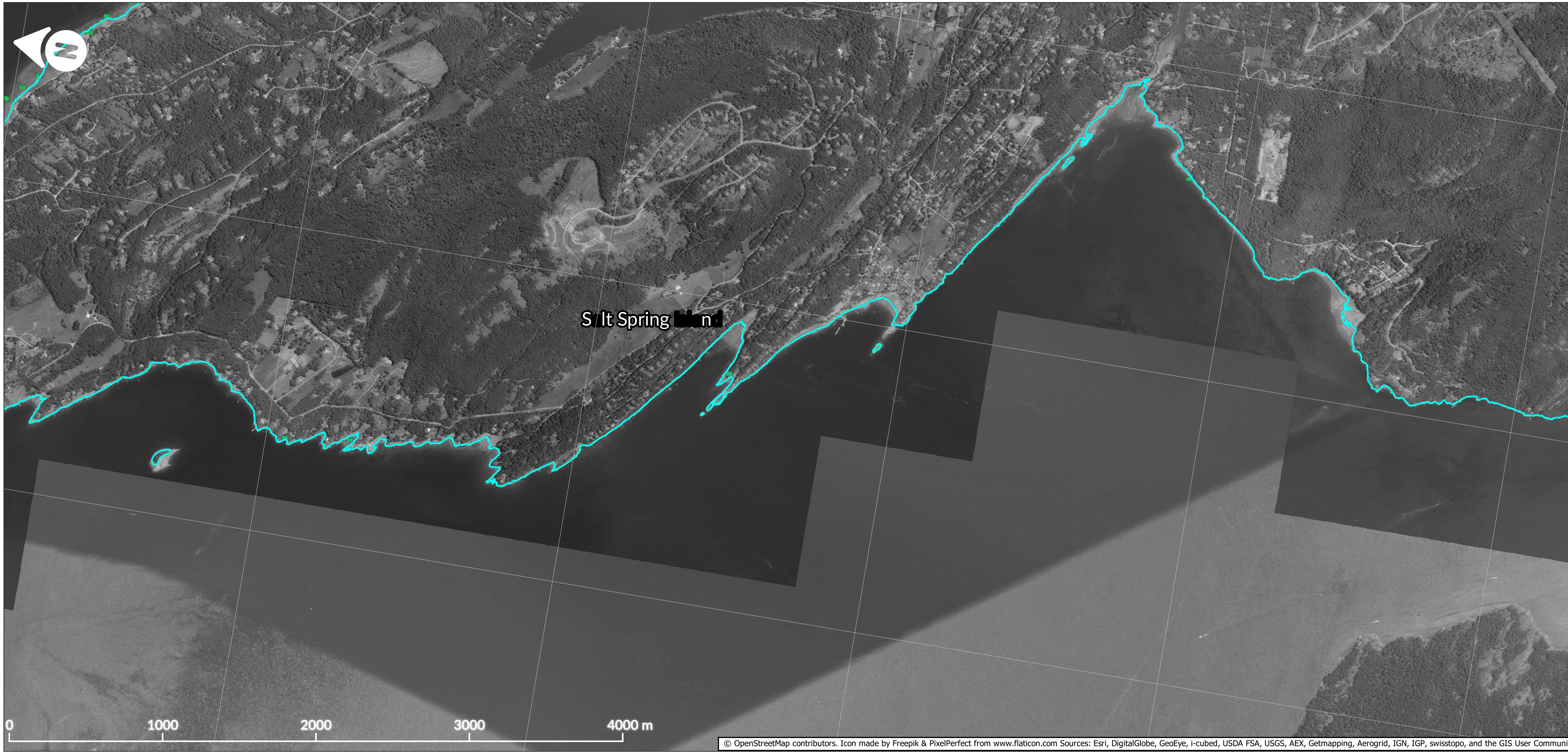

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Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

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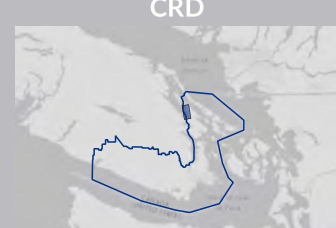
CRD



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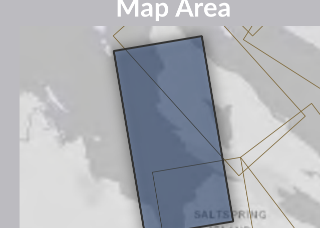

Legend

Coastline

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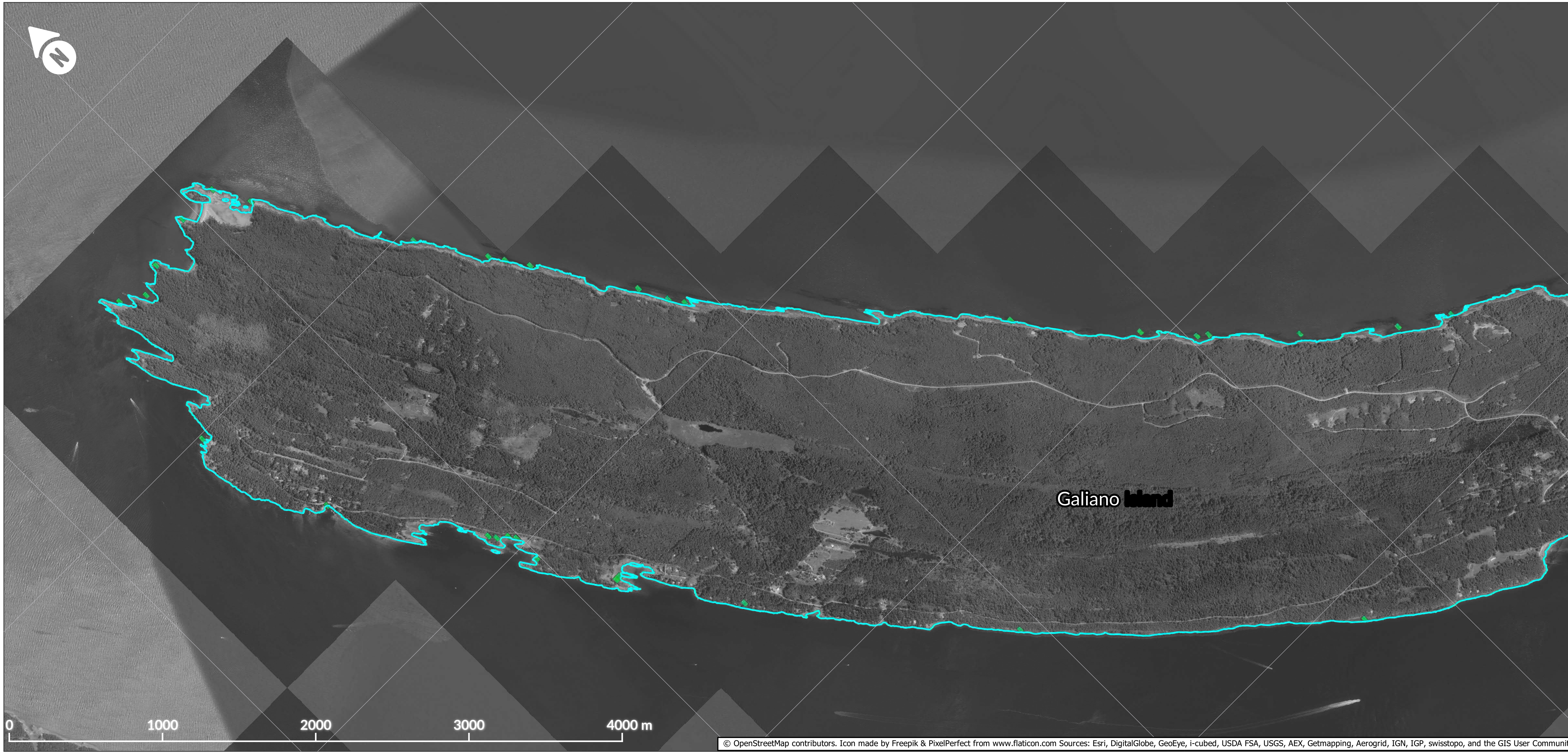
Map Sheet 27 f 41



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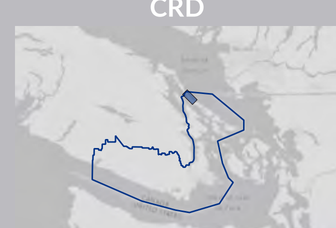
Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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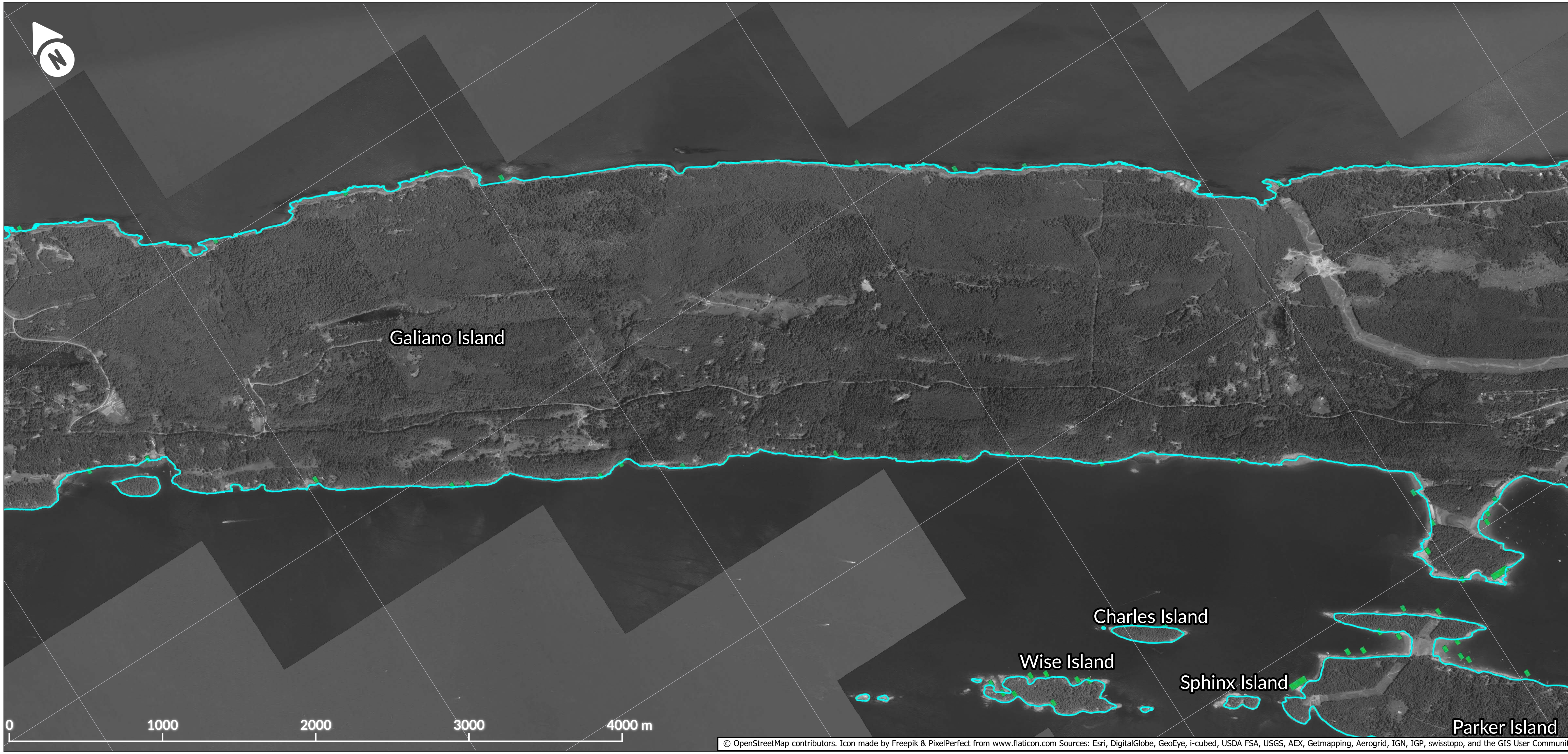


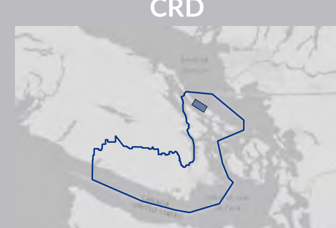
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



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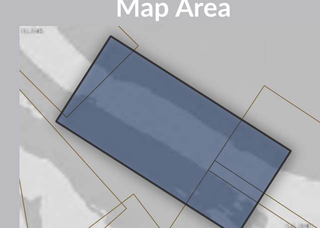

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
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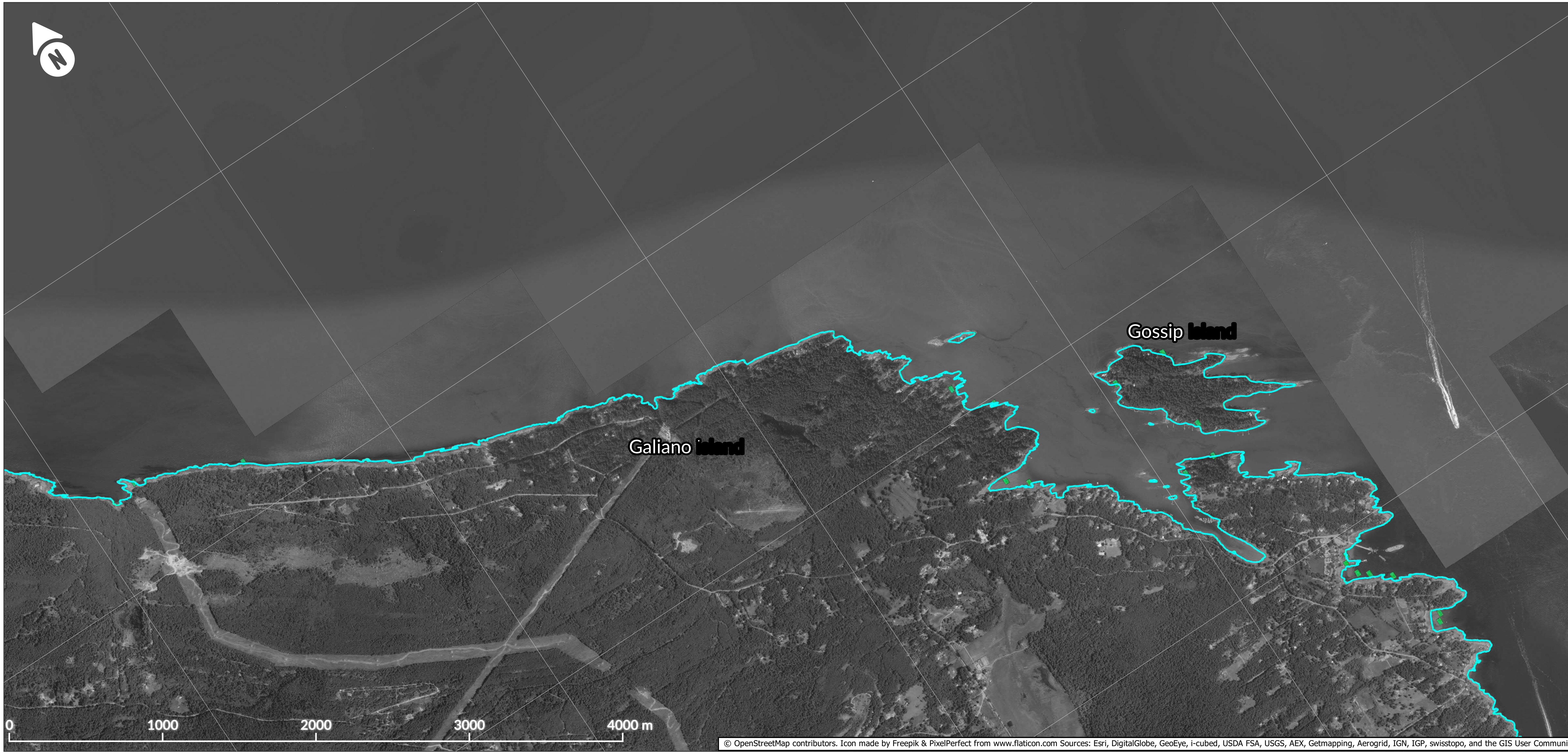

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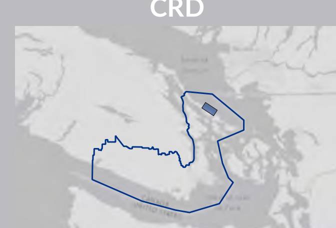
Capital Regi nal District

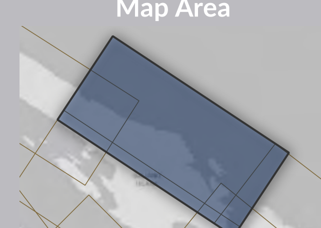
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

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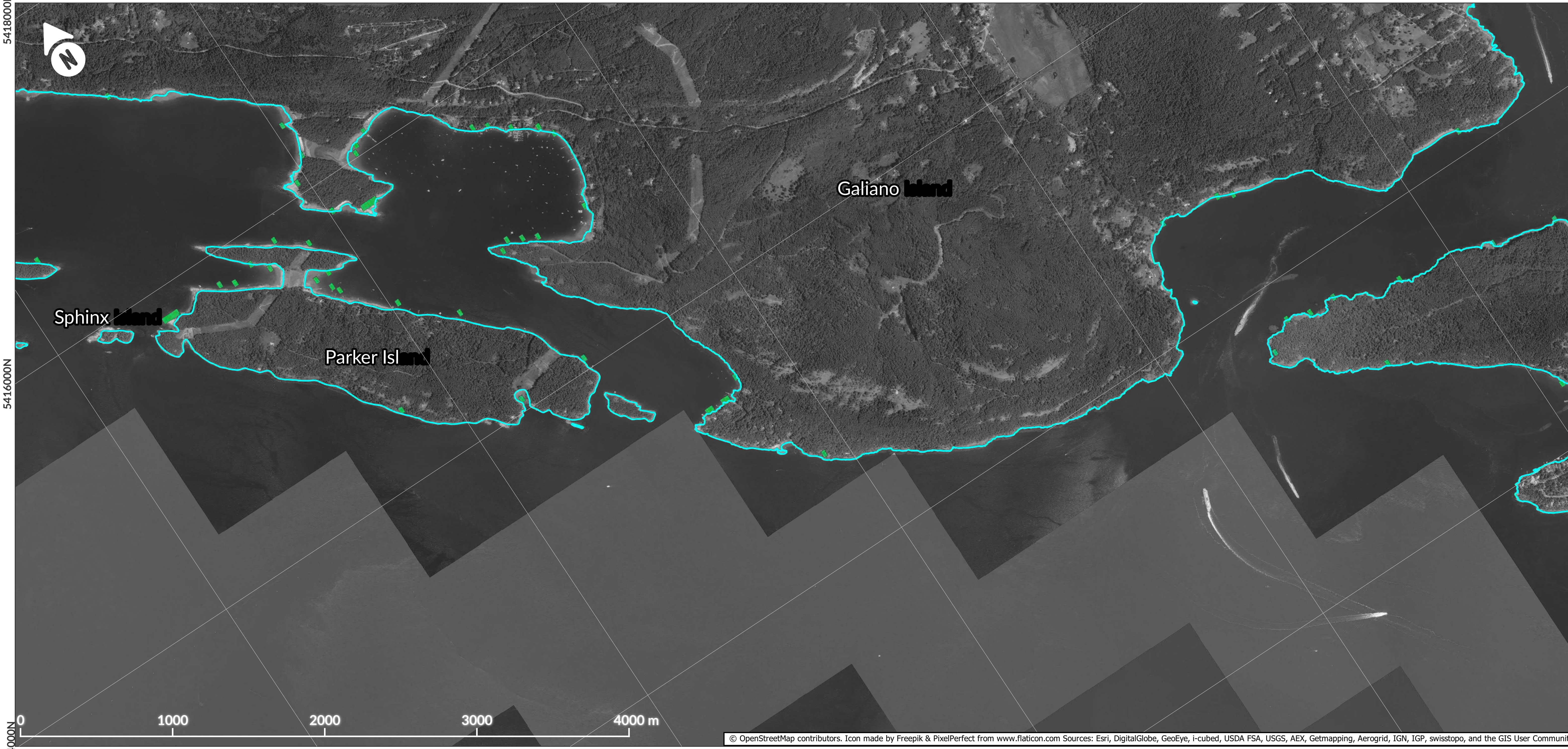

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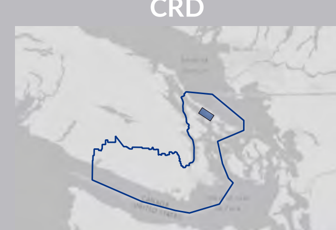
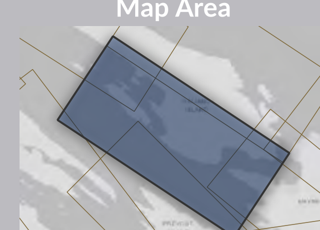


Map Area



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Legend

- Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
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Map Sheet 31 f 41

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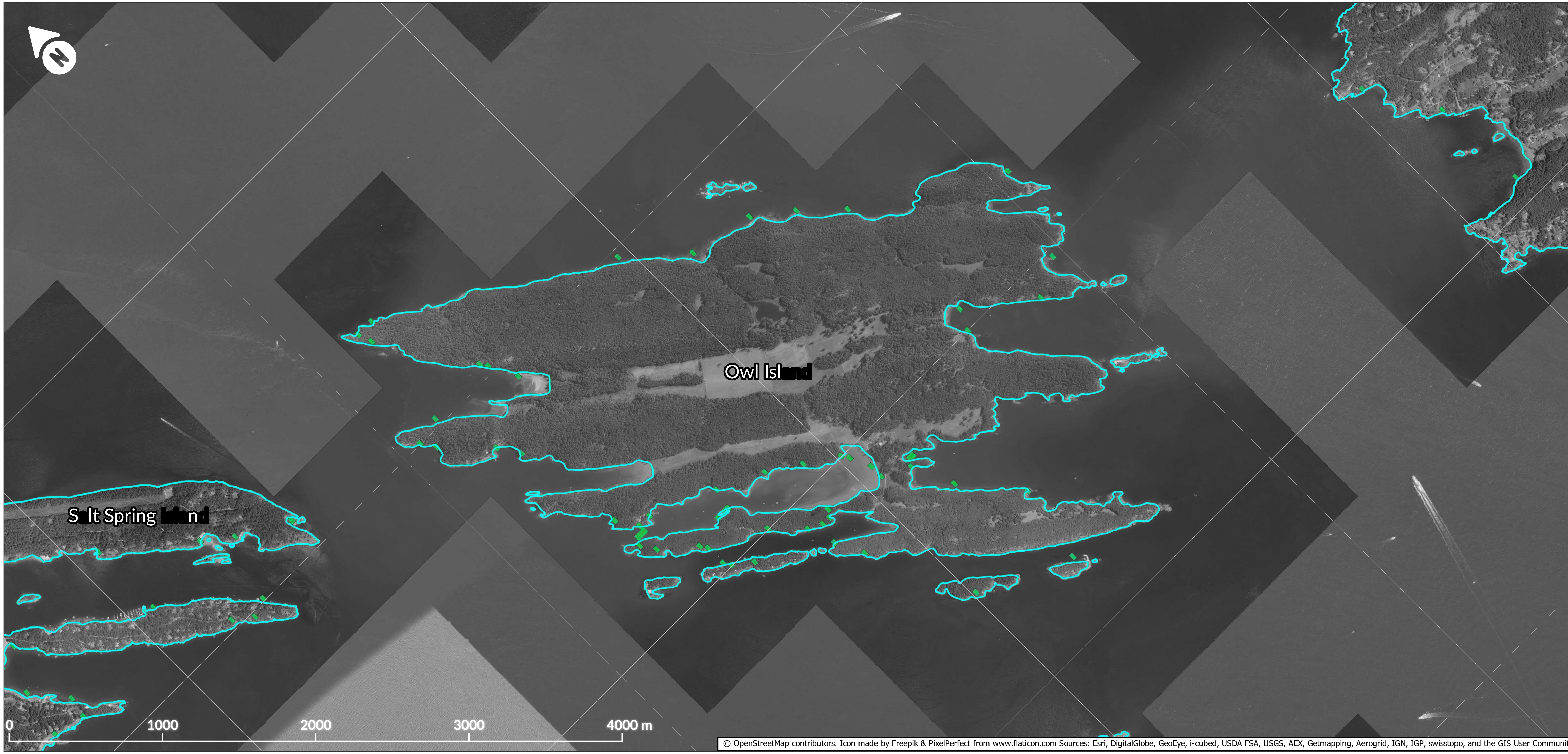

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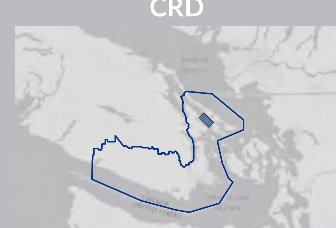
Capital Regi nal District

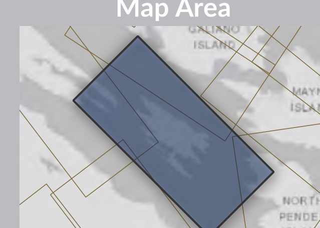
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

Inundation Depth (m)

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Map Sheet 32 f 41

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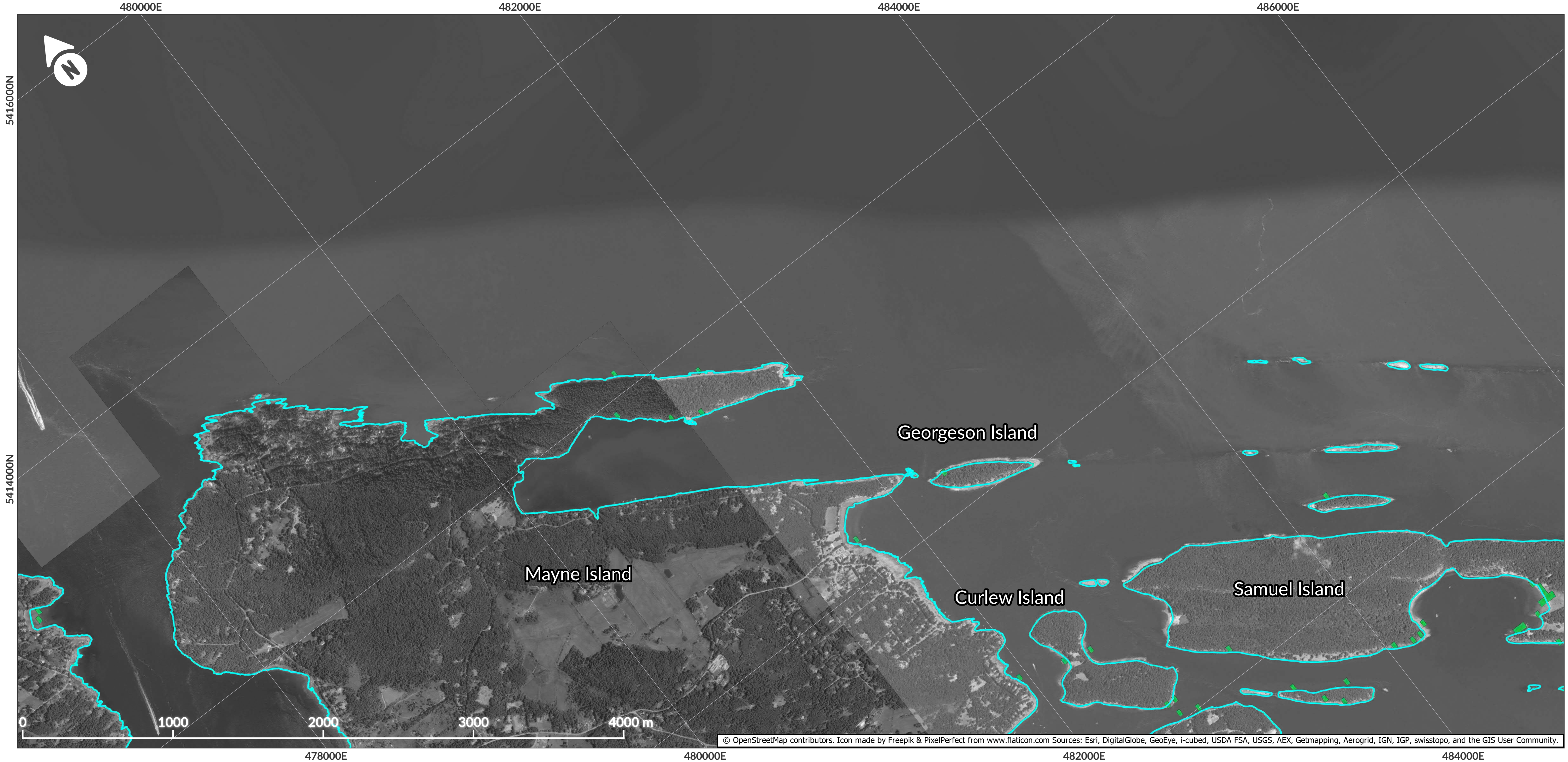

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March 2020

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Devil's M untain sland Fault Mw 7.5

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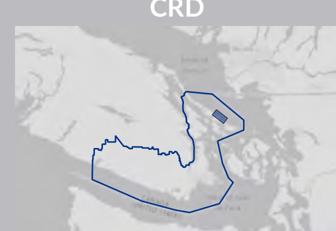
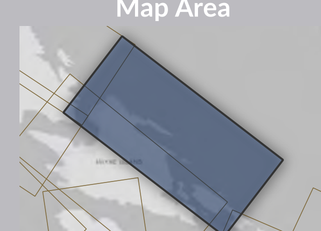


Map Area



Legend

Coastline

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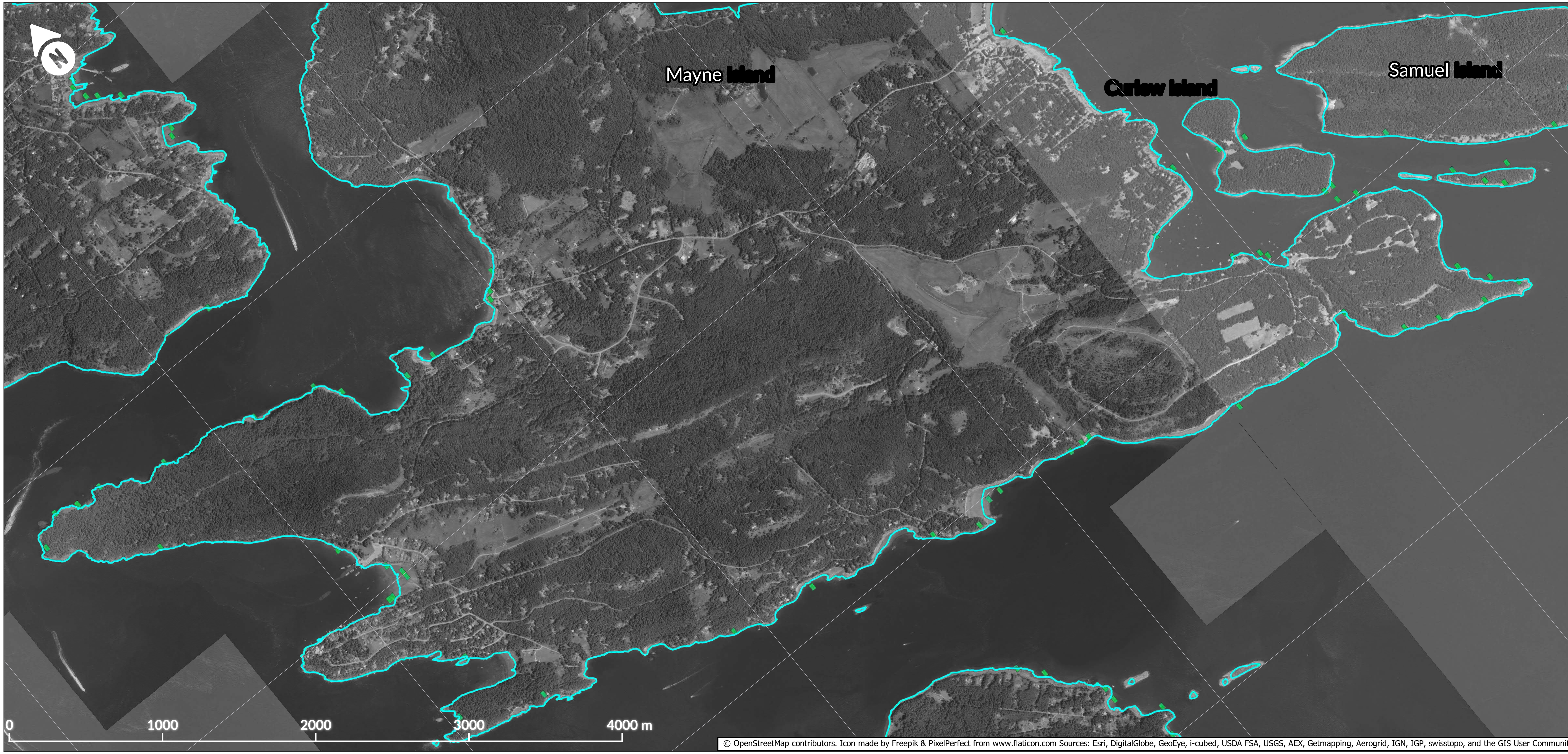

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Devil's M untain sland Fault Mw 7.5

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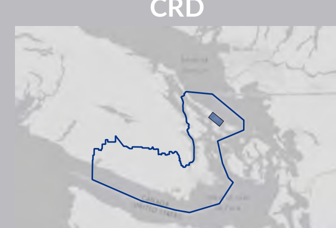
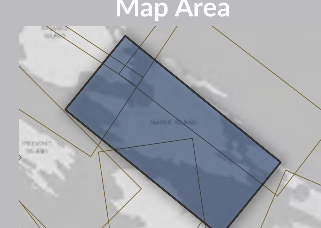
CRD



Map Area



Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

1. Under the pr visi ns f the Fl d Hazard Statutes Amendment Act, 2003 (ill 56), l cal g vernments have the r le and resp nsibility f r making decisi ns ab ut l cal fl dplain devel pment practices, including decisi ns ab ut fl dplain bylaws within their c mmunities. nf rmati n n fl dplain management guidelines can be f und in the C Fl d Hazard Area Land Use Management Guidelines.
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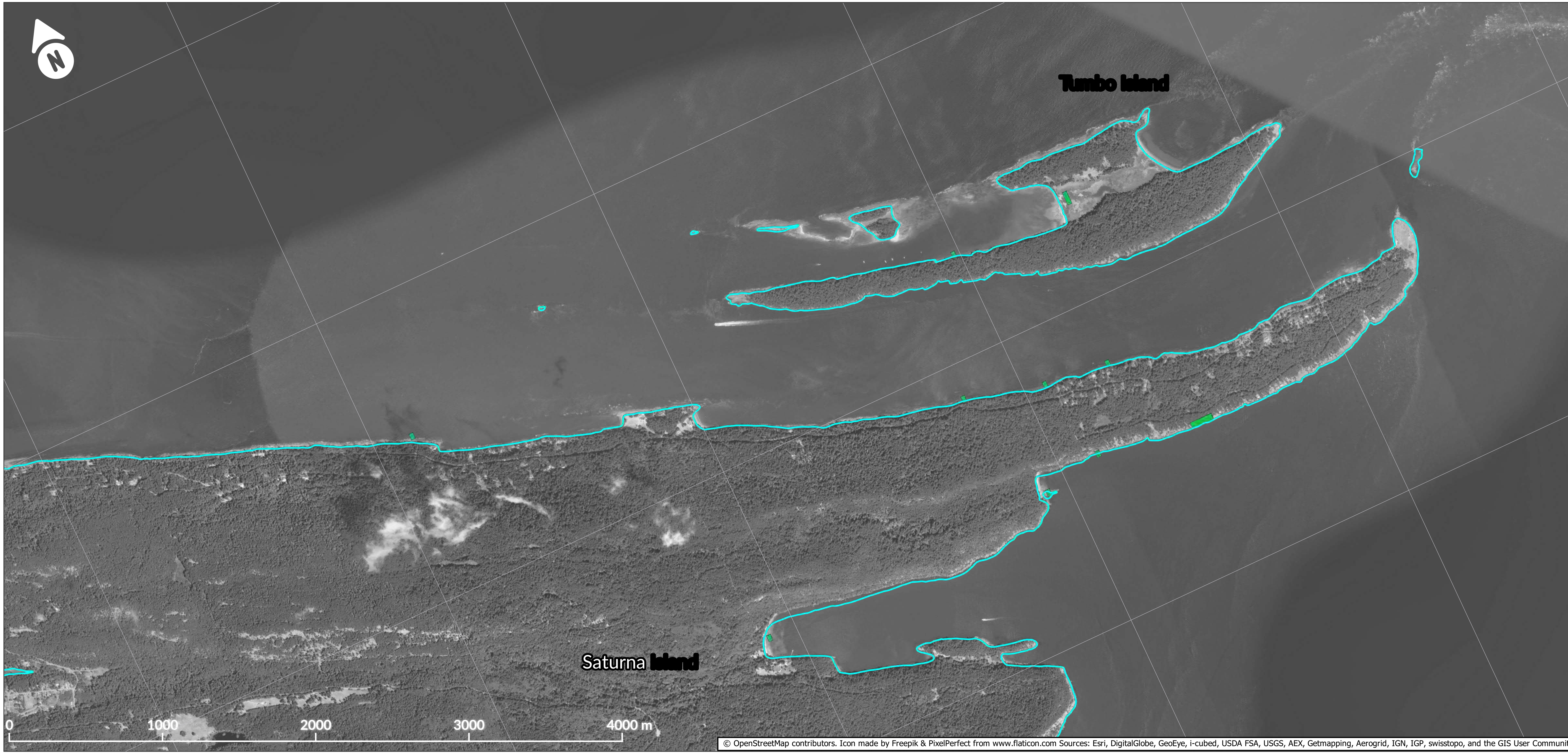
4. Data s urces: Orth imagery (CRD, 2017)
5. F r further inf rmati n, please refer t Task 3 – Tsunami M delling and Mapping Rep rt. These maps c nstitute Appendix C f said rep rt.

Pr ject N . 20192676
Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 34 f 41

pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



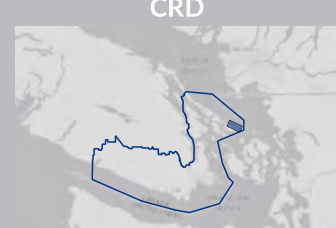
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 35 f 41

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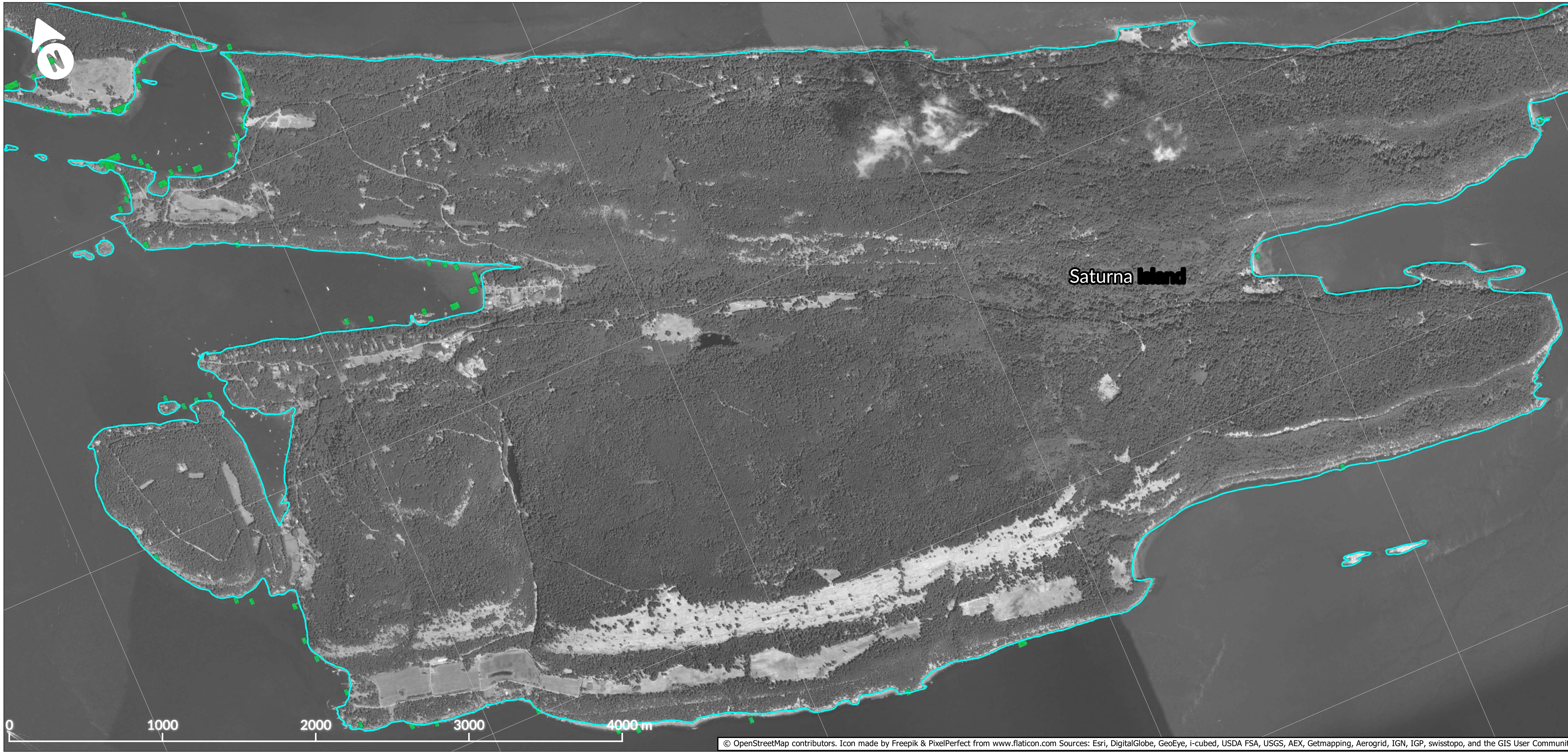
pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



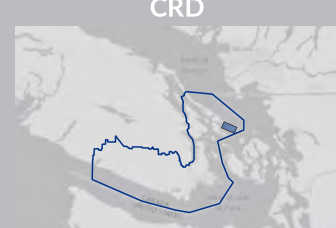
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 36 f 41

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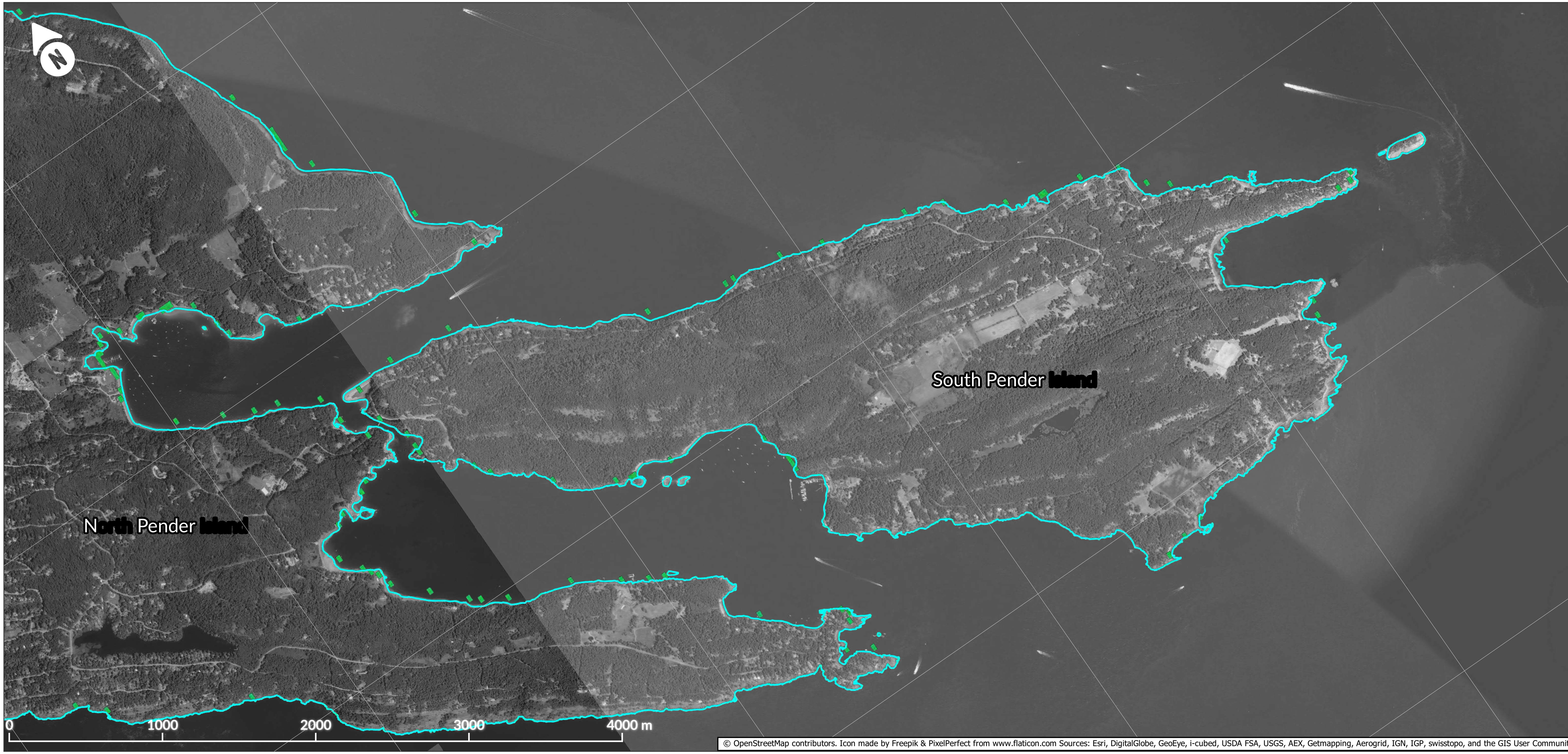
pl t date: 2020.06.10
file: P:\20192676\00_C astFl dTsunami\W rking_Dwgs\010_GIS



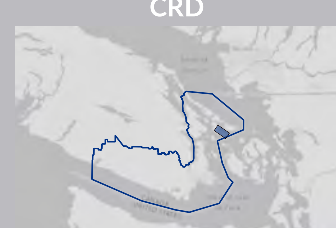
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

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Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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Appr ved by D. F rde, P.Eng.
Drawn by C. Duncan and S. Haley

Map Sheet 37 f 41

pl t date: 2020.06.10
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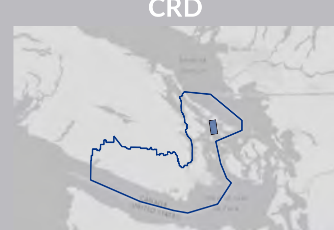
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

Inundation Depth (m)

- 0 2.0
- 2.0 4.0
- 4.0 6.0
- 6.0 8.0
- >8.0

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pl t date: 2020.06.10
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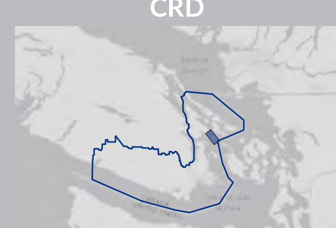
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area

Legend

Coastline

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- 0 2.0
- 2.0 4.0
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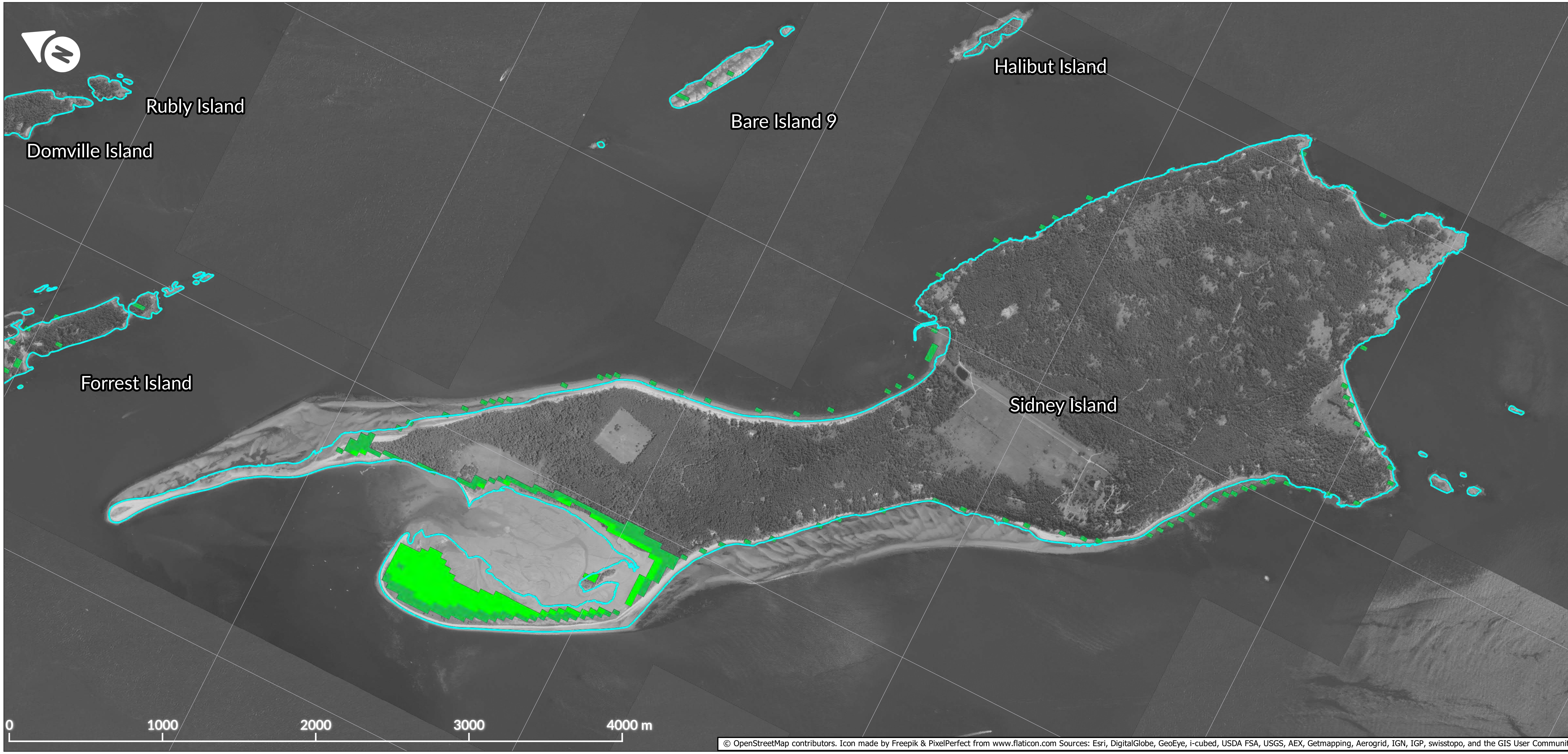
Map Sheet 39 f 41



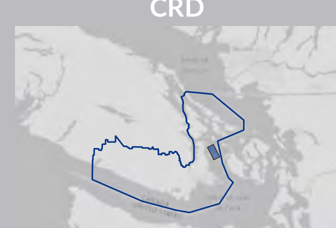
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

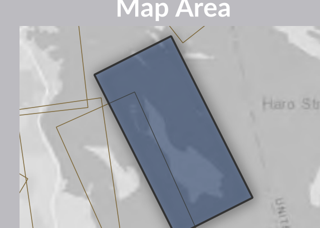
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



Legend

Coastline

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- 2.0 4.0
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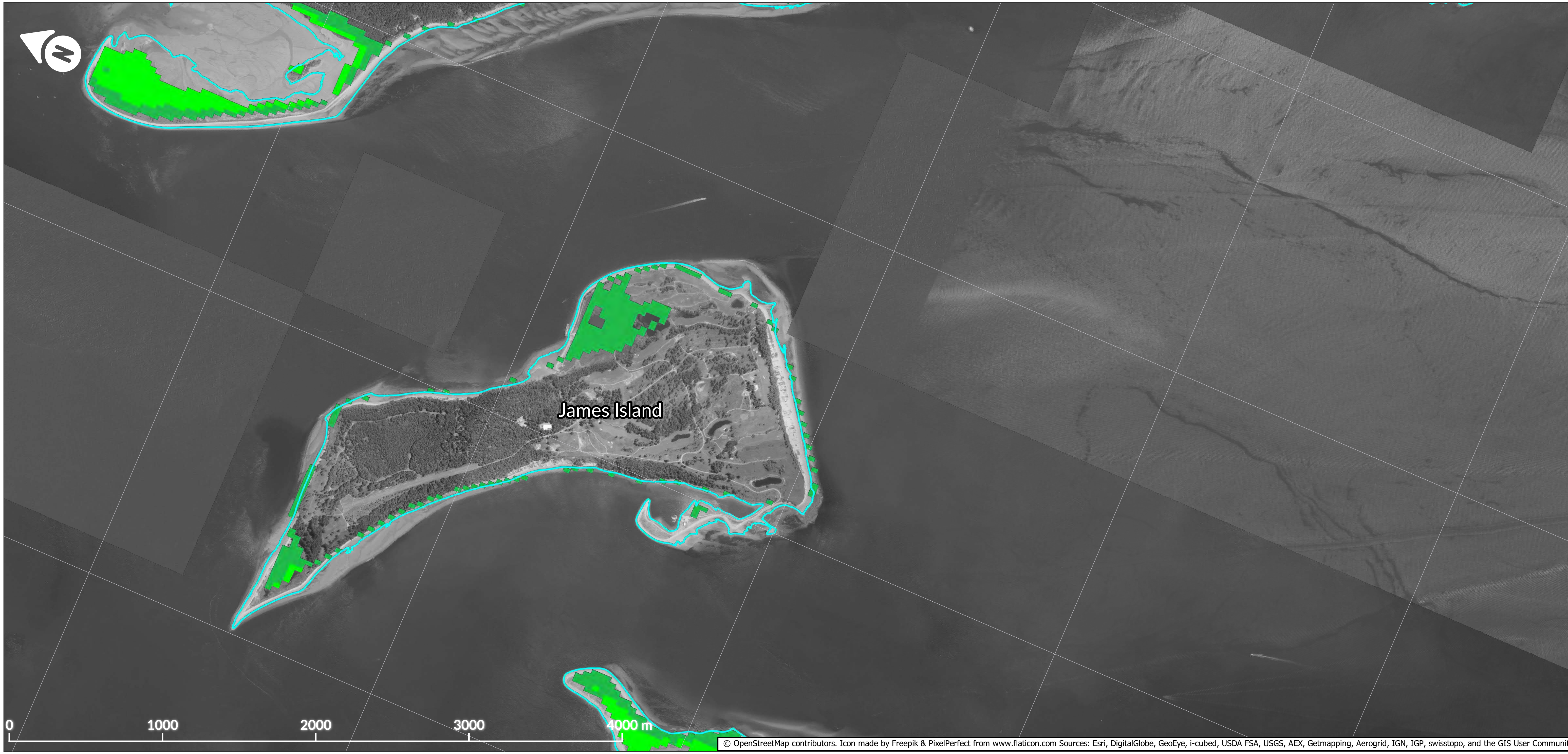


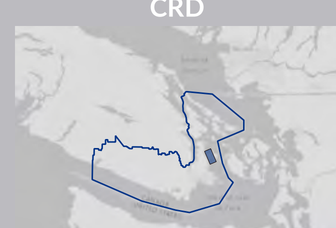
C astal Fl d Inundati n Mapping Pr ject

Capital Regi nal District

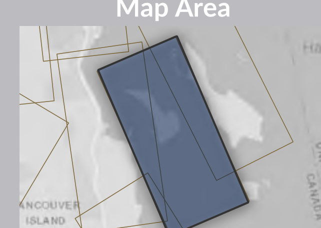
March 2020

Tsunami nundati n Map
Devil's M untain sland Fault Mw 7.5

CRD



Map Area



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Legend

Coastline

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Map Sheet 41 f 41

pl t date: 2020.06.10
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APPENDIX D - TSUNAMI MODEL RESULTS AT PROJECT TRANSECTS

This appendix presents the maximum water surface elevation results (mCGVD2013) that were extracted at each coastal transect (as defined in the Task 2 reporting; refer to that document for exact map location of each transect). The transects in the following table have been grouped together per respective local government and electoral area. Early in the project it was found that AL, UN, SW2 and DM2 events had minimal impact in the capital region, as such results for these events are only reported in the detailed model grids where the grid was fine enough to discern water surface changes in appropriate detail. With respect to the Haida Gwaii events (HG1 and HG2), note the following:

- HG1 - Event used for calibration purposes only. Effects in capital region minimal.
- HG2 - Effects in capital region minimal.
- Local Government / Electoral Area Key:

JDF – Juan de Fuca EA	*SOO* – District of Sooke	*MET* – District of Metchosin	*COL* – City of Colwood
VWR – Town of View Royal	*ESQ* – Township of Esquimalt	*COV* – City of Victoria	*DOS* – District of Saanich
OAK – District of Oak Bay	*DCS* – District of Central Saanich	*DNS* – District of North Saanich	*SID* – Town of Sidney
DOH – District of Highlands	*LAN* – City of Langford	*SSI* – Salt Spring Island EA	*SGI* – Southern Gulf Islands EA

Local Gov. or EA	Transect (TR)	CSZ L1	CSZ NS	CSZ CS	DM1	DM2	SW1	SW2	UN	AL
JDF	001	11.00	7.25	1.84	2.12	1.29	2.77	1.32	1.28	1.74
JDF	002	11.02	7.95	1.83	2.06	1.29	2.80	1.31	1.28	1.72
JDF	003	10.44	7.40	1.75	1.82	1.27	2.61	1.30	1.27	1.63
JDF	004	9.79	6.25	1.62	1.69	1.25	1.75	1.25	1.25	1.45
JDF	005	8.19	5.09	1.78	1.52	1.24	1.66	1.24	1.25	1.44
JDF	006	7.65	5.08	2.00	1.82	1.26	1.74	1.27	1.26	1.52
JDF	007	7.78	4.95	1.59	1.83	1.26	1.70	1.27	1.25	1.47
JDF	008	7.66	5.13	1.68	1.92	1.25	1.71	1.26	1.25	1.49
JDF	009	7.58	5.03	1.55	1.74	1.07	1.55	1.07	1.06	1.34
JDF	010	7.84	5.32	1.50	1.62	1.07	1.56	1.09	1.07	1.32
JDF	011	7.51	5.21	1.38	1.49	1.08	1.47	1.08	1.06	1.29
JDF	012	6.80	4.56	1.31	1.28	1.05	1.42	1.05	1.05	1.23
JDF	013	7.27	4.90	1.32	1.47	1.07	1.45	1.07	1.06	1.25
JDF	014	8.64	4.74	1.32	1.42	1.05	1.43	1.06	1.05	1.23

Local Gov. or EA	Transect (TR)	CSZ L1	CSZ NS	CSZ CS	DM1	DM2	SW1	SW2	UN	AL
JDF	015	7.05	4.83	1.31	1.38	1.05	1.43	1.06	1.05	1.23
SOO	017	8.09	5.28	1.33	1.71	1.08	1.58	1.10	1.06	1.26
SOO	019	7.19	4.87	1.32	1.54	1.07	1.43	1.07	1.07	1.25
SOO	020	7.59	3.62	1.30	1.39	1.06	1.49	1.08	1.06	1.24
SOO	021	3.28	2.23	1.22	1.18	1.04	1.22	1.05	1.05	1.19
SOO	023	7.80	4.92	1.32	1.44	1.06	1.43	1.06	1.05	1.23
SOO	025	6.61	4.41	1.31	1.63	1.07	1.59	1.08	1.06	1.24
SOO	027	7.15	4.55	1.33	1.83	1.10	1.91	1.10	1.06	1.25
SOO & MET	029	7.93	4.80	1.36	2.82	1.16	3.37	1.17	1.06	1.27
MET	030	7.24	4.69	1.32	2.00	1.13	2.60	1.13	1.06	1.26
MET	031	6.64	4.35	1.30	1.57	1.07	1.51	1.07	1.05	1.23
MET	033	5.21	3.54	1.00	1.33	0.80	1.27	0.81	0.79	0.94
MET	035	5.35	3.51	1.03	2.43	0.89	1.87	0.87	0.79	0.95
MET	037	5.22	3.53	1.03	2.89	0.88	2.55	0.89	0.79	0.95
MET	039	5.57	3.52	1.04	2.46	0.91	2.22	0.96	0.79	0.95
MET	040	5.26	3.44	1.04	2.18	0.86	1.76	0.85	0.79	0.95
MET	041	5.25	3.46	1.05	2.16	0.86	1.74	0.85	0.87	0.95
MET	042	5.16	3.61	1.07	1.84	0.83	1.59	0.84	0.79	0.96
MET & COL	043	5.63	3.78	1.09	2.22	0.85	1.94	0.87	0.79	0.97
COL	044	5.40	3.61	1.04	2.90	0.82	1.75	0.84	0.80	0.98
COL	045	5.55	3.86	1.04	4.20	0.85	2.01	0.85	0.80	0.98

Local Gov. or EA	Transect (TR)	CSZ L1	CSZ NS	CSZ CS	DM1	DM2	SW1	SW2	UN	AL
	046									
COL	047	6.05	4.45	1.08	3.35	0.88	2.75	0.85	0.82	1.01
COL	049	8.25	4.65	1.13	3.08	0.90	2.50	0.93	0.87	1.07
COL	050	7.65	6.01	1.17	3.84	0.94	2.98	0.97	0.89	1.11
COL & VWR	051	9.01	6.27	1.20	4.55	0.96	3.39	1.01	0.91	1.14
VWR	053	8.06	6.19	1.19	4.61	1.02	3.75	0.99	0.93	1.18
ESQ	055	8.22	5.12	1.14	4.32	0.91	2.94	0.91	0.90	1.30
ESQ	057	8.54	5.09	1.14	3.57	0.92	2.99	0.92	0.88	1.09
ESQ	059	7.32	4.79	1.11	2.98	0.86	2.20	0.87	0.86	1.06
ESQ	060	6.00	3.92	1.06	3.07	0.84	1.96	0.84	0.82	1.00
ESQ	061	5.67	3.83	1.05	3.01	0.83	1.89	0.83	0.80	0.98
ESQ	063	5.64	3.80	1.05	2.82	0.82	1.90	0.86	0.80	0.99
ESQ	065	5.78	4.04	1.04	2.52	0.81	1.91	0.83	0.84	0.98
COV	067	6.95	5.11	1.06	3.39	0.84	2.24	0.88	0.80	1.00
COV	069	7.20	4.59	1.09	4.25	0.86	2.36	0.89	0.81	1.03
COV	070	7.11	3.91	1.03	2.67	0.82	1.95	0.83	0.80	0.99
COV	071	5.60	4.29	1.04	2.96	0.85	2.54	0.93	0.79	0.97
COV	072	5.44	4.45	1.04	3.26	0.85	2.47	0.91	0.79	0.97
COV	073	5.47	4.21	1.02	2.89	0.84	2.22	0.89	0.79	0.96
COV	074	5.29	4.80	1.03	2.82	0.85	2.40	0.92	0.79	0.96
COV	075	5.17	3.44	1.01	2.52	0.84	1.93	0.84	0.79	0.96

Local Gov. or EA	Transect (TR)	CSZ L1	CSZ NS	CSZ CS	DM1	DM2	SW1	SW2	UN	AL
COV	077	4.88	3.20	1.01	2.37	0.83	1.95	0.82	0.79	0.95
COV	079	4.55	3.15	0.96	3.10	0.87	2.08	0.88	0.79	0.95
COV & OAK	080	4.66	3.22	0.97	3.48	0.91	2.68	0.92	0.79	0.95
OAK	081	4.53	3.25	0.97	3.28	0.86	2.25	0.86	0.79	0.94
OAK	083	4.77	3.30	0.95	4.18	0.96	3.08	0.99	0.78	0.93
OAK	085	3.69	2.48	0.93	2.93	0.84	1.90	0.88	0.78	0.91
OAK	087	3.58	2.31	0.93	2.55	0.84	1.50	0.88	0.78	0.91
OAK	089	3.52	2.94	0.94	3.53	0.97	1.79	0.93	0.78	0.91
OAK	090	3.51	2.69	0.94	3.66	0.97	1.81	0.92	0.78	0.91
OAK	091	3.42	2.62	0.94	4.08	0.89	1.73	0.90	0.78	0.91
OAK	093	3.71	2.41	0.95	4.40	0.91	2.31	0.88	0.78	0.92
								0.92	0.78	0.92
DOS	095	4.77	2.83	0.95	5.86	0.95	2.76	0.91	0.78	0.92
DOS	096	3.63	2.53	0.95	4.33	0.91	2.51	0.88	0.78	0.91
DOS	097	3.32	2.30	0.93	2.74	0.86	1.54	0.84	0.78	0.88
DOS	099	3.02	2.23	0.95	2.07	0.84	1.25	0.80	0.78	0.88
DOS	100	3.25	2.50	0.96	2.33	0.85	1.46	0.81	0.78	0.88
DOS	101	3.27	2.55	0.97	2.63	0.85	1.56	0.81	0.78	0.89
DOS	102	3.40	2.62	0.98	3.34	0.90	1.75	0.82	0.78	0.89
DOS	103	3.44	2.76	0.98	4.33	1.03	2.11	0.86	0.78	0.90
DOS	104	3.06	2.17	0.93	3.10	0.91	1.49	0.82	0.78	0.89
DOS	105	3.11	2.28	0.94	2.48	0.88	1.42	0.81	0.78	0.90
DOS	106	3.24	2.30	0.94	2.37	0.87	1.43	0.82	0.78	0.90
DOS	107	3.40	2.39	0.95	2.75	0.89	1.51	0.84	0.79	0.91

Local Gov. or EA	Transect (TR)	CSZ L1	CSZ NS	CSZ CS	DM1	DM2	SW1	SW2	UN	AL
	108									
DOS	109	3.72	2.80	0.96	2.92	0.92	1.81	0.84	0.79	0.92
DOS	110	3.88	2.99	0.97	3.92	0.97	2.40	0.85	0.80	0.93
DOS	111	4.11	3.22	0.99	5.03	1.09	2.70	0.87	0.80	0.93
DOS & DCS	113	4.07	3.29	1.42	3.95	1.34	2.68	1.29	1.23	1.37
DCS	115	4.77	3.58	1.42	4.66	1.34	2.59	1.28	1.23	1.37
DCS	117	4.85	4.34	1.44	4.30	1.35	3.03	1.28	1.23	1.39
DCS	119	4.79	3.39	1.50	4.00	1.34	2.81	1.30	1.24	1.40
DCS	120	4.90	3.36	1.50	4.09	1.34	2.77	1.29	1.24	1.40
DCS & DNS	121	4.90	3.32	1.50	4.00	1.33	2.73	1.29	1.24	1.40
DNS	123	4.92	3.34	1.51	4.31	1.35	2.78	1.29	1.24	1.40
SID	125	5.28	3.03	1.41	3.84	1.32	2.35	1.27	1.24	1.39
SID	127	4.38	2.94	1.41	3.39	1.31	2.12	1.26	1.24	1.38
SID	129	4.39	2.91	1.41	2.86	1.29	2.09	1.26	1.24	1.38
SID	130	4.54	2.93	1.41	2.98	1.29	2.13	1.26	1.23	1.37
SID	131	4.87	3.05	1.42	3.50	1.32	2.41	1.28	1.24	1.37
SID	132	4.58	3.00	1.41	3.16	1.30	2.23	1.26	1.23	1.37
SID & DNS	133	5.83	3.48	1.45	3.62	1.48	2.95	1.34	1.24	1.39
DNS	134	5.14	3.25	1.43	3.36	1.30	2.29	1.28	1.24	1.38
DNS	135	4.44	2.78	1.47	2.98	1.30	2.22	1.30	1.26	1.36
DNS	136	4.10	2.54	1.43	2.49	1.36	1.96	1.30	1.23	1.33
DNS	137	3.76	2.43	1.41	2.29	1.27	1.86	1.25	1.23	1.32
DNS	138	3.60	2.38	1.40	2.19	1.26	1.90	1.25	1.23	1.32

Local Gov. or EA	Transect (TR)	CSZ L1	CSZ NS	CSZ CS	DM1	DM2	SW1	SW2	UN	AL
DNS	139	3.60	2.37	1.45	2.14	1.27	1.91	1.25	1.23	1.31
DNS	140	3.64	2.39	1.39	2.10	1.27	1.93	1.25	1.24	1.31
DNS	141	3.33	2.34	1.32	2.35	1.27	1.86	1.25	1.25	1.29
DNS	143	3.07	2.54	1.33	1.65	1.24	1.48	1.23	1.22	1.31
DNS	145	3.19	2.65	1.34	1.62	1.23	1.49	1.23	1.22	1.32
DNS	147	3.42	2.79	1.36	1.94	1.25	1.56	1.24	1.22	1.34
DNS	149	3.33	2.77	1.36	1.80	1.25	1.59	1.23	1.22	1.34
DNS & DCS	150	3.38	2.84	1.38	1.79	1.24	1.58	1.23	1.23	1.35
DCS	151	3.39	2.84	1.37	1.81	1.24	1.65	1.24	1.23	1.34
DCS	153	3.51	2.96	1.38	1.88	1.24	1.67	1.24	1.23	1.34
JDF	155	3.43	2.87	1.38	1.82	1.24	1.68	1.24	1.23	1.35
DOH	157	3.54	2.94	1.41	1.97	1.25	1.72	1.24	1.28	1.37
SSI	159	3.12	2.42	1.29	1.73	1.24	1.61	1.24	1.22	1.28
SSI	160	3.51	2.67	1.33	1.90	1.25	1.66	1.24	1.23	1.29
SSI	161	3.30	2.71	1.41	1.96	1.25	1.71	1.24	1.23	1.31
SSI	162	3.18	2.68	1.37	1.94	1.25	1.66	1.24	1.22	1.31
SSI	163	3.47	2.59	1.39	2.15	1.25	1.87	1.24	1.23	1.33
SSI	164	3.23	2.53	1.36	2.09	1.25	1.79	1.25	1.22	1.32
SSI	165	4.21	4.03	1.55	3.03	1.33	2.69	1.31	1.24	1.35
SSI	166	4.36	4.16	1.57	3.04	1.34	2.70	1.32	1.24	1.36
SSI	167	3.47	2.34	1.35	1.88	1.25	1.69	1.24	1.22	1.31
SSI	168	2.75	2.17	1.32	1.94	1.25	1.69	1.24	1.23	1.31

Local Gov. or EA	Transect (TR)	CSZ L1	CSZ NS	CSZ CS	DM1	DM2	SW1	SW2	UN	AL
SSI	169	3.70	3.01	1.36	4.66	1.39	3.45	1.35	1.24	1.31
SSI	170	3.28	2.30	1.35	2.61	1.31	1.94	1.26	1.24	1.30
SSI	171	3.22	2.24	1.34	2.31	1.27	1.70	1.24	1.23	1.30
SSI	173	3.13	2.06	1.29	1.65	1.24	1.49	1.23	1.22	1.28
SSI	175	2.92	2.16	1.30	1.39	1.22	1.33	1.22	1.22	1.29
SGI	177	2.58	2.04	1.27	1.41	1.22	1.40	1.22	1.23	1.27
SGI	179	2.10	1.72	1.27	1.51	1.23	1.46	1.23	1.22	1.26
SGI	180	2.75	2.26	1.33	1.78	1.23	1.58	1.23	1.22	1.31
SGI	181	3.59	2.89	1.31	1.97	1.25	1.72	1.24	1.22	1.28
		2.67	2.24	1.33	1.79	1.24	1.55	1.23	1.22	1.31
SGI	183	2.90	2.36	1.33	2.07	1.25	1.69	1.24	1.22	1.31
SGI	185	2.17	1.74	1.27	1.51	1.23	1.44	1.23	1.22	1.27
SGI	187	2.49	1.82	1.30	1.73	1.25	1.55	1.24	1.23	1.29
SGI	189	3.46	2.95	1.36	2.07	1.26	1.83	1.25	1.22	1.33
SGI	190	2.91	2.32	1.34	2.06	1.25	1.79	1.24	1.22	1.32
SGI	191	2.41	1.87	1.29	1.81	1.24	1.58	1.24	1.22	1.29
SGI	192	2.18	1.78	1.28	1.50	1.23	1.45	1.23	1.22	1.27
SGI	193	2.36	1.75	1.29	1.52	1.23	1.46	1.23	1.23	1.28
SGI	194	2.69	2.56	1.39	1.52	1.23	1.48	1.23	1.41	1.43
SGI	195	3.31	2.25	1.33	1.72	1.24	1.60	1.23	1.23	1.31
SGI	196	2.43	1.99	1.31	1.67	1.23	1.68	1.24	1.22	1.29
SGI	197	3.73	2.50	1.34	1.99	1.25	1.77	1.25	1.25	1.32
SGI	198	3.63	3.09	1.36	2.25	1.27	1.83	1.26	1.22	1.33
SGI	198a	4.62	3.07	1.45	2.09	1.22	1.86	1.22	1.23	1.36
SGI	199	4.86	3.54	1.43	2.95	1.30	2.18	1.30	1.23	1.38
SGI	200	3.53	2.65	1.37	2.15	1.27	1.82	1.25	1.22	1.34
SGI	201	3.47	2.48	1.40	2.69	1.29	2.45	1.29	1.22	1.36

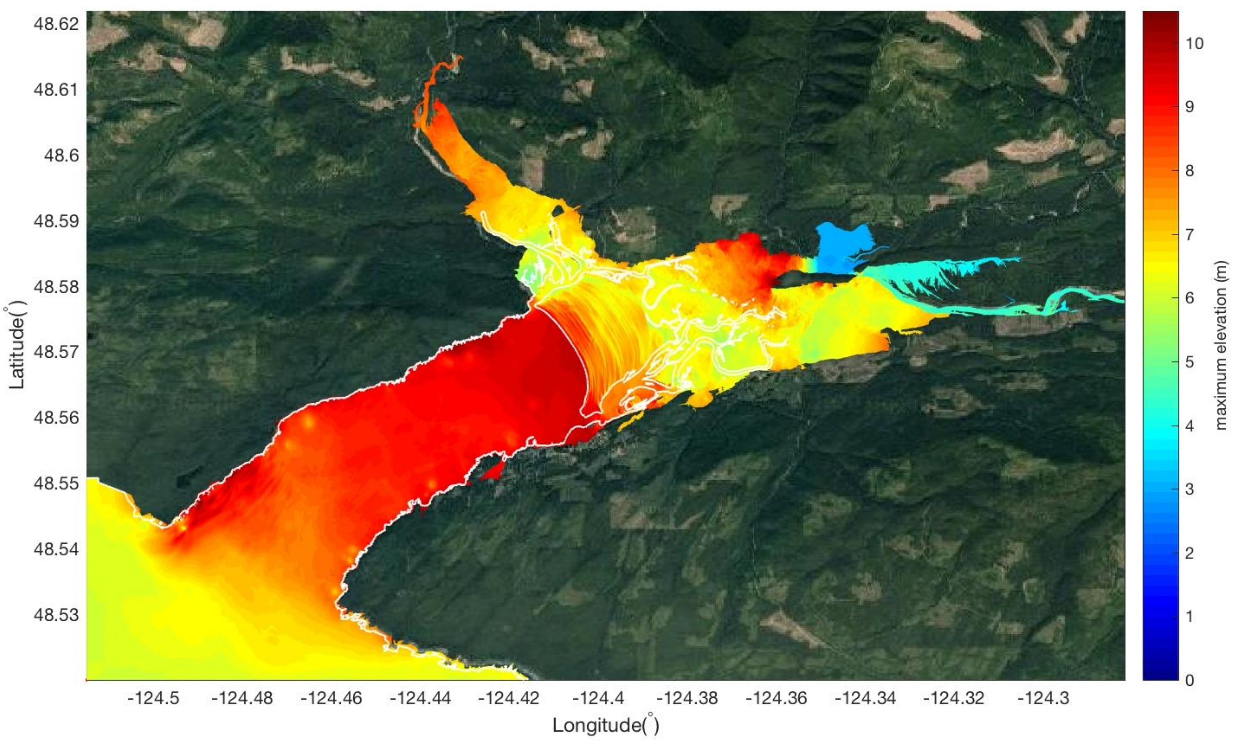
Local Gov. or EA	Transect (TR)	CSZ L1	CSZ NS	CSZ CS	DM1	DM2	SW1	SW2	UN	AL
SGI	201a	2.94	2.13	1.32	2.38	1.29	2.20	1.30	1.23	1.30
SGI	202	4.76	3.89	1.55	1.79	1.24	1.68	1.24	1.28	1.53
SGI	203	2.77	2.12	1.32	1.93	1.25	1.69	1.24	1.22	1.30
SGI	204	2.67	2.22	1.33	1.95	1.25	1.64	1.24	1.22	1.31
SGI	205	2.87	2.32	1.33	1.95	1.25	1.84	1.25	1.22	1.31
SGI	206	2.46	1.99	1.31	1.69	1.24	1.69	1.24	1.22	1.30
SGI	207	2.65	2.02	1.32	1.78	1.24	1.68	1.24	1.23	1.30
SGI	208	3.18	2.18	1.34	2.39	1.27	1.79	1.25	1.23	1.32
SGI	209	2.70	2.06	1.32	1.86	1.24	1.68	1.24	1.23	1.30
SGI	210	3.38	2.27	1.36	2.14	1.26	1.79	1.25	1.23	1.31
SGI	211	3.59	2.35	1.39	2.13	1.27	1.91	1.25	1.23	1.37
SGI	212	3.49	2.40	1.34	2.40	1.27	1.88	1.25	1.23	1.30
SGI	213	3.73	2.46	1.41	2.21	1.27	1.87	1.25	1.23	1.33
SGI	214	3.82	2.59	1.42	2.68	1.28	2.05	1.26	1.23	1.35
SGI	215	3.49	2.27	1.38	2.29	1.28	1.83	1.25	1.23	1.33
SGI	216	2.95	2.12	1.33	2.54	1.29	1.91	1.27	1.23	1.31
SGI	217	3.39	3.28	1.78	2.34	1.29	1.78	1.26	1.23	1.35
SGI	218	3.85	2.93	1.40	2.40	1.28	1.88	1.27	1.23	1.36
SGI	219	4.08	2.97	1.43	3.09	1.32	2.46	1.29	1.23	1.37
SGI	220	3.98	3.01	1.41	3.41	1.34	2.22	1.28	1.23	1.37

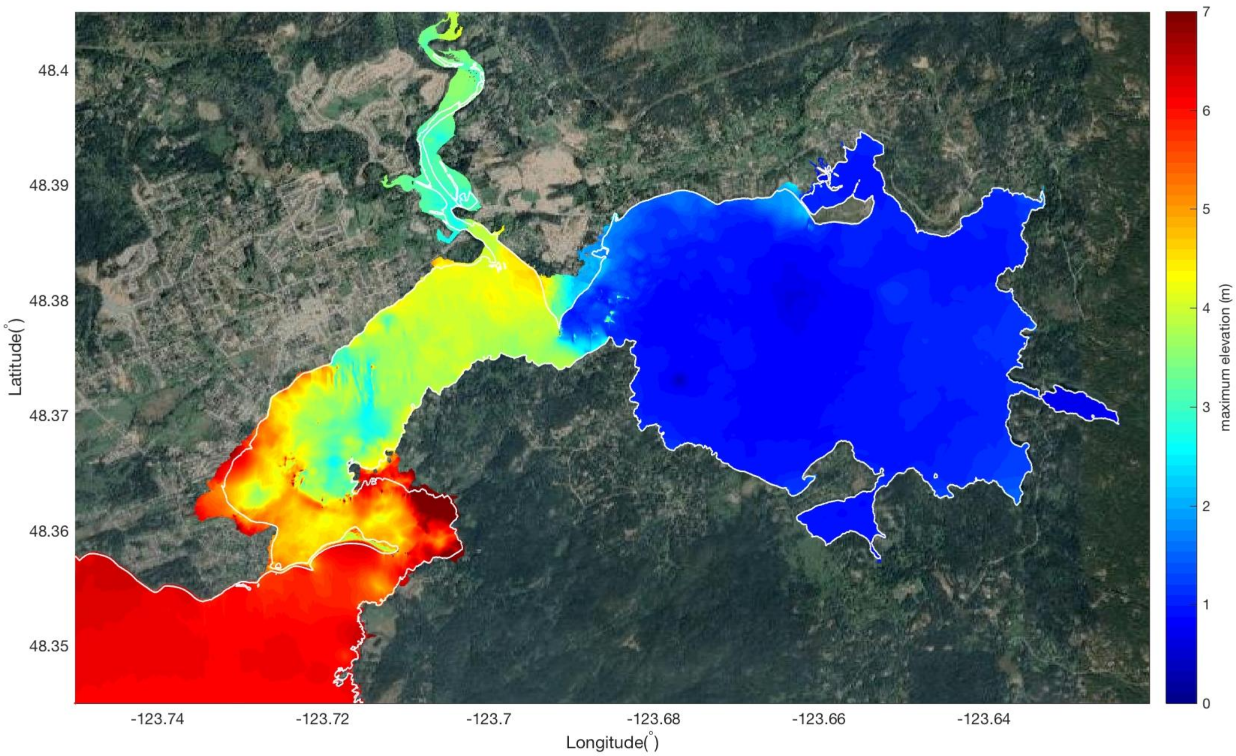
APPENDIX E - DETAILED INUNDATION GRID RESULTS: CSZ-L1 EVENT

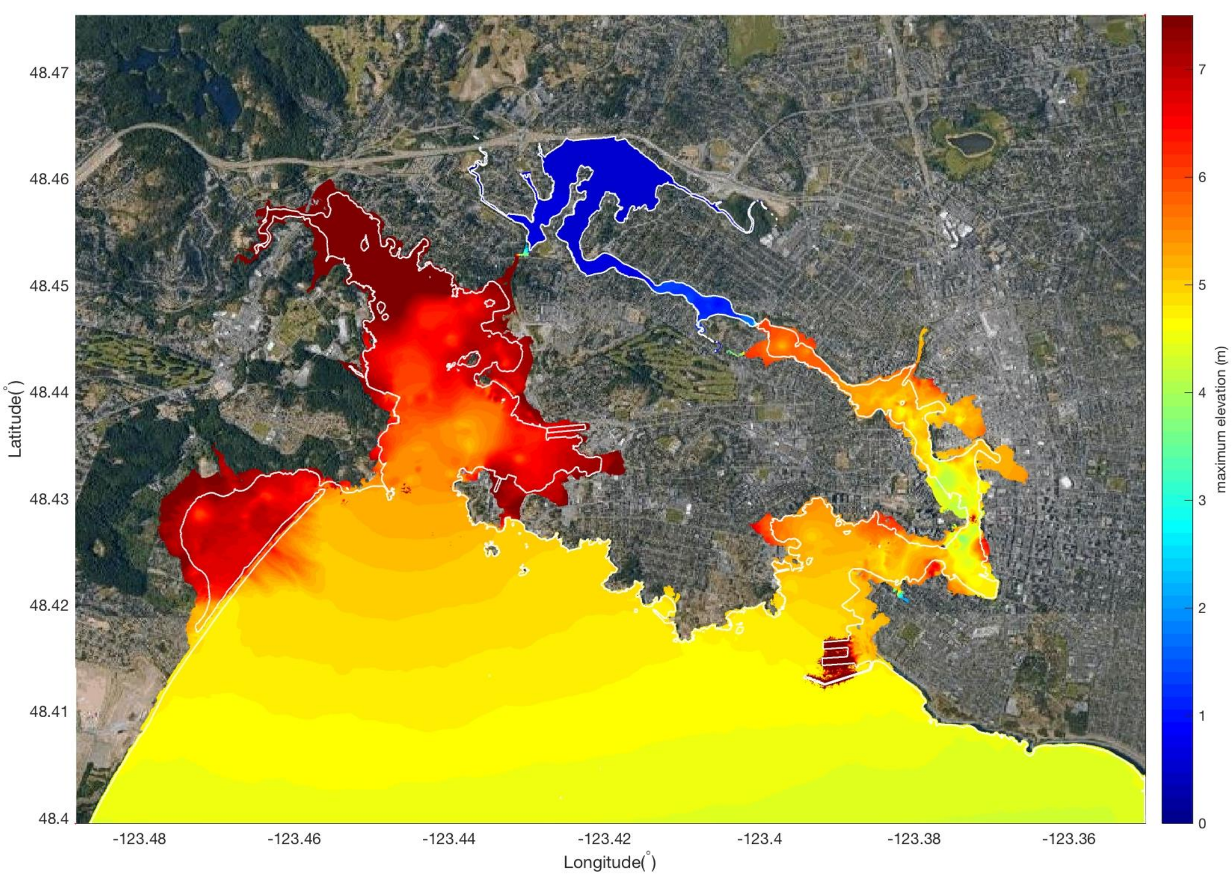
This appendix presents results for the CSZ-L1 event, for each detailed modelling domain. For each result parameter, the results are presented in the following order: Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

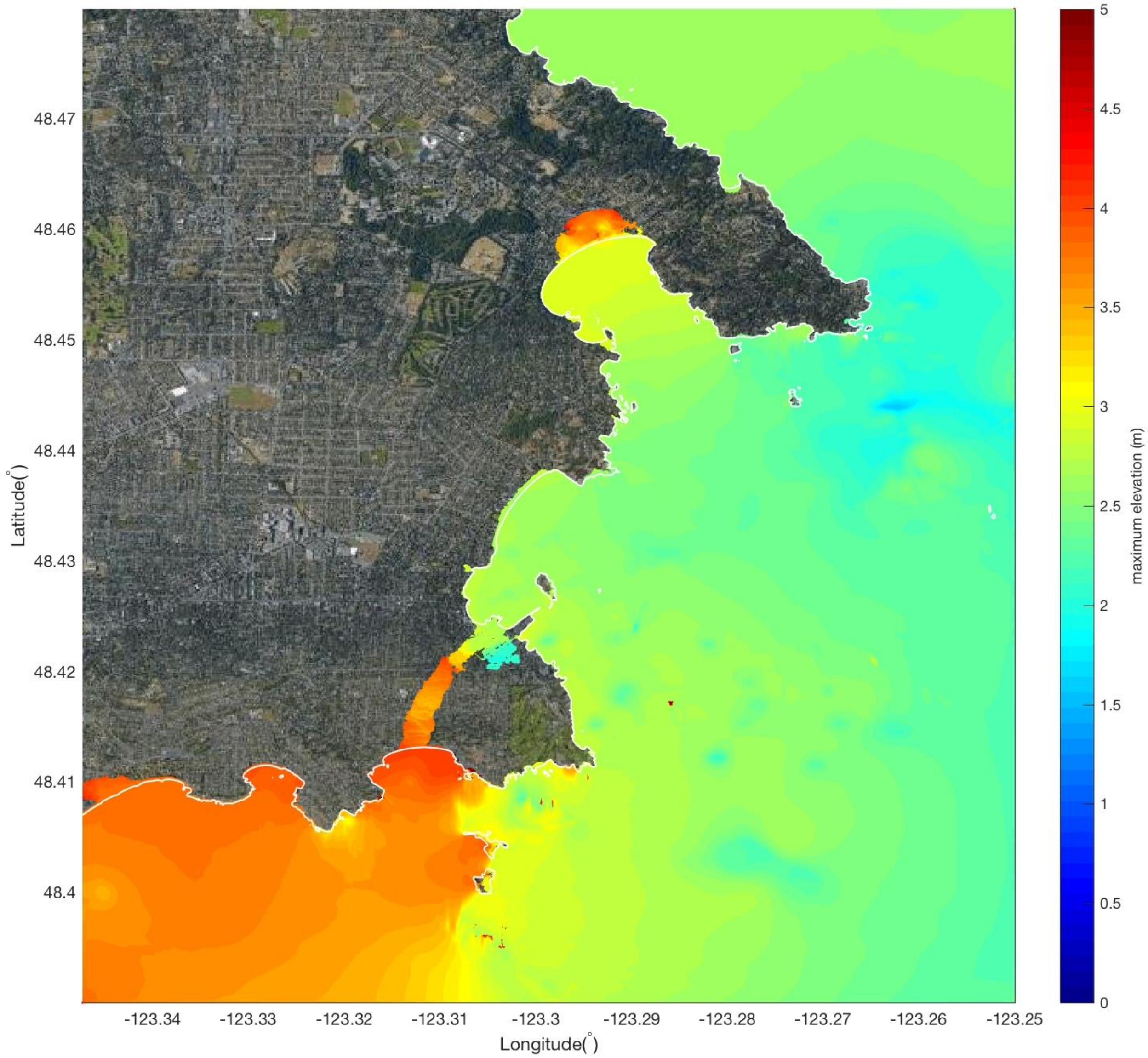
Maximum Water Surface Elevations: CSZ-L1

(Elevations are reported to m above HHWMT datum)

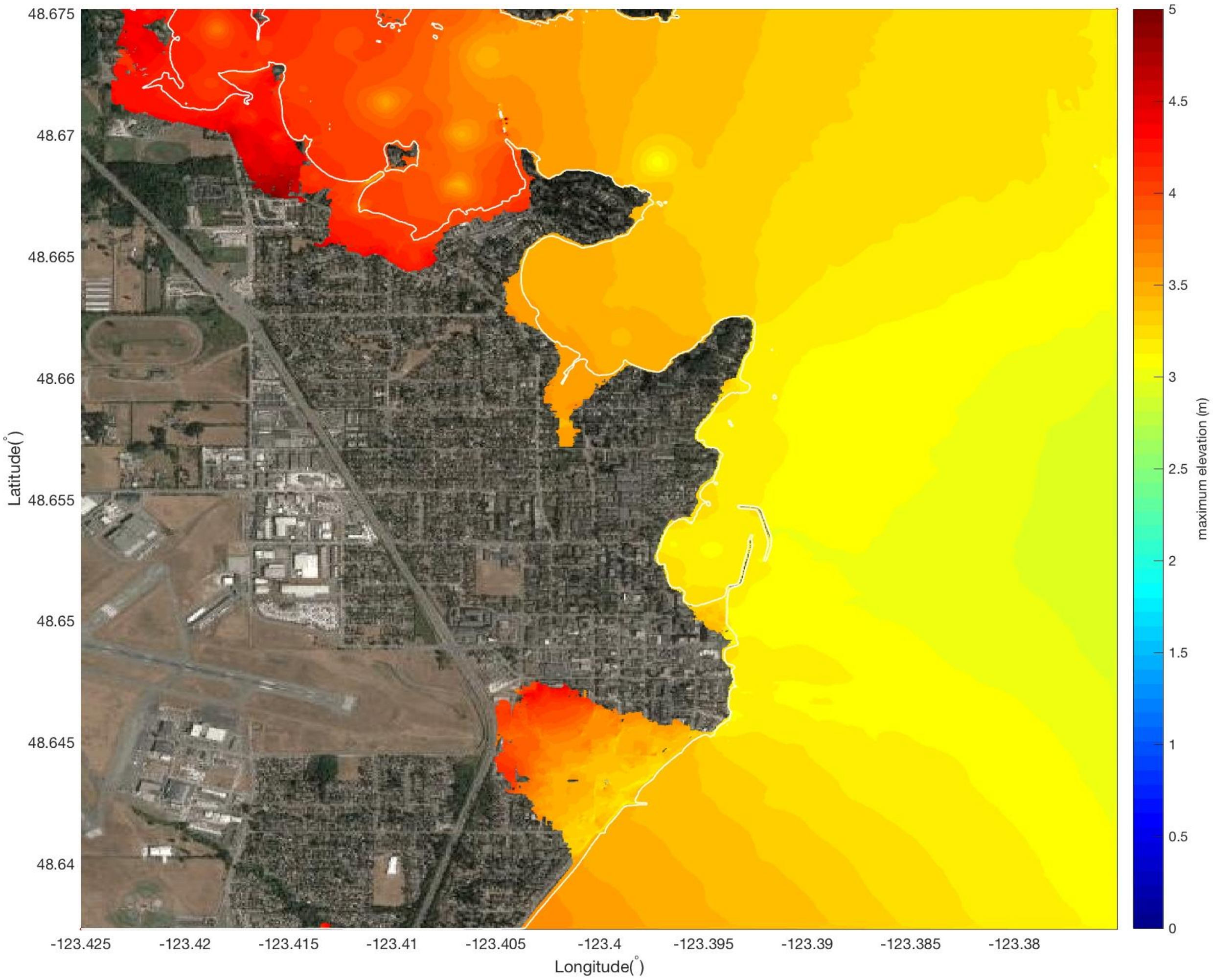



48.4
48.39
48.38
48.37
48.36
48.35
Latitude(°)
-123.74
-123.72
-123.7
-123.68
-123.66
-123.64
Longitude(°)
7
6
5
4
3
2
1
0
maximum elevation (m)

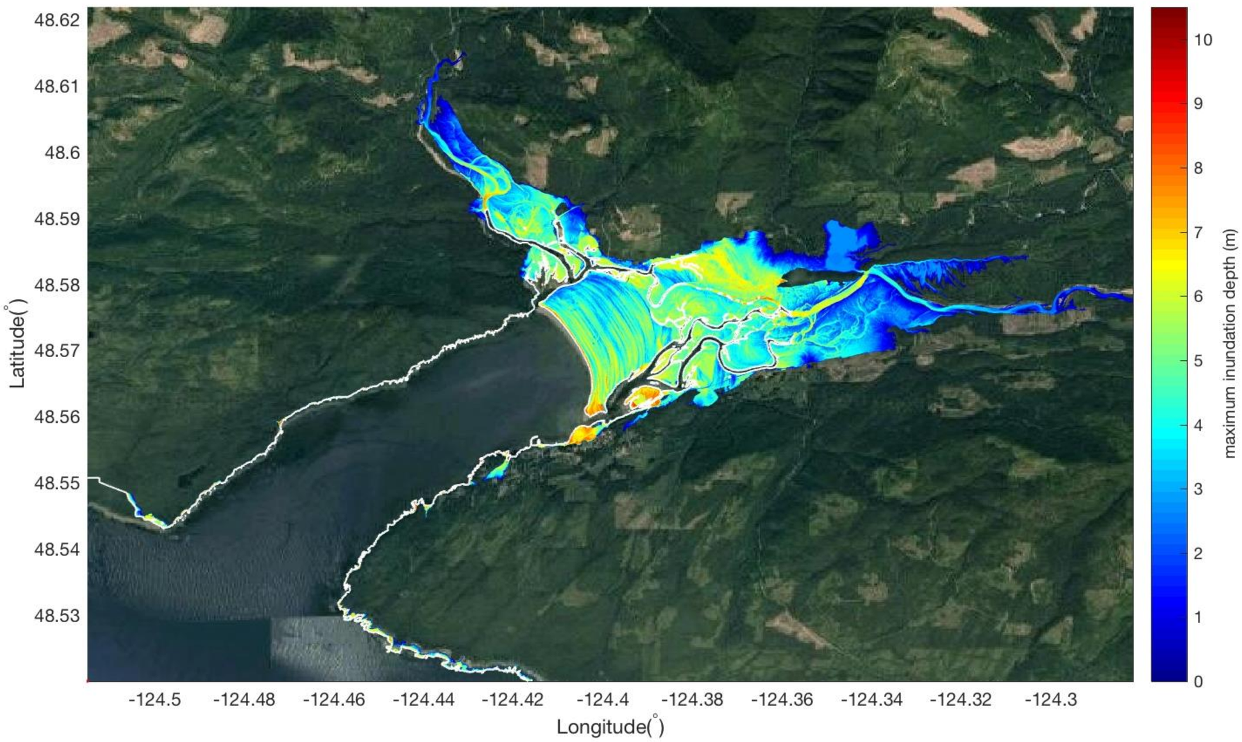

48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
7
6
5
4
3
2
1
0
maximum elevation (m)

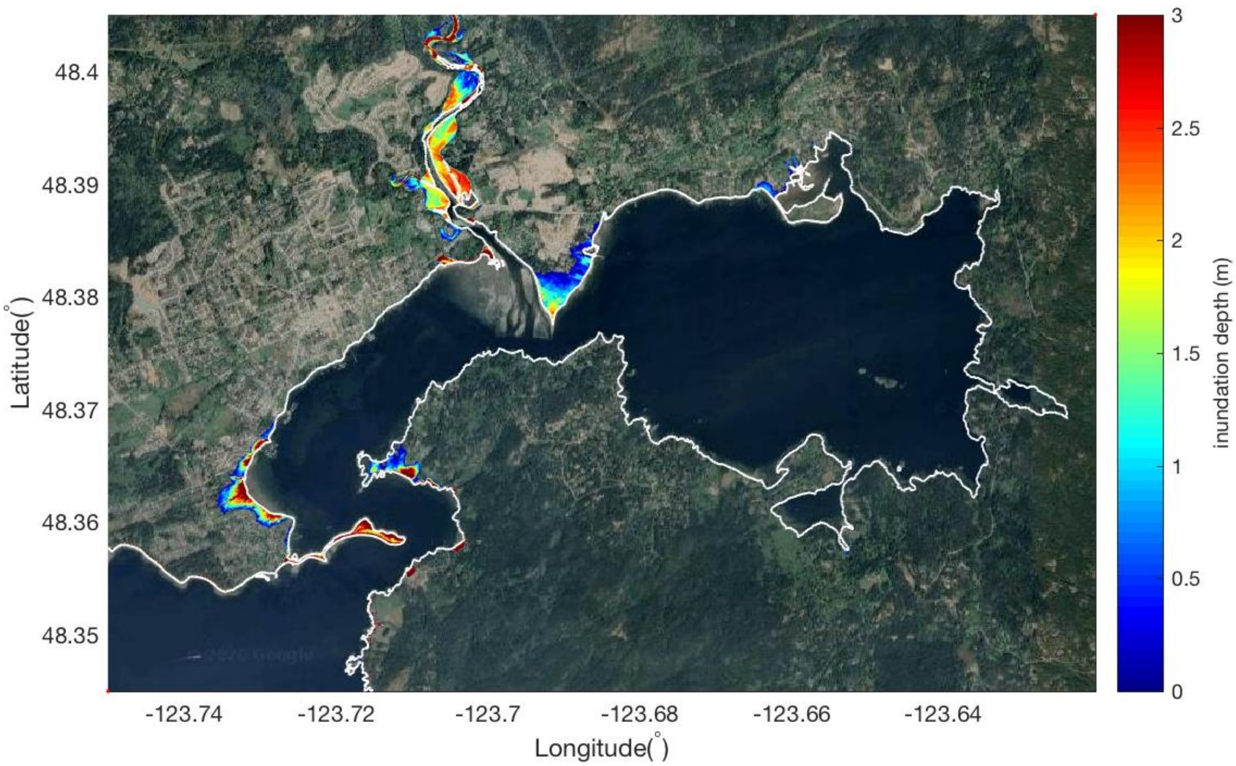


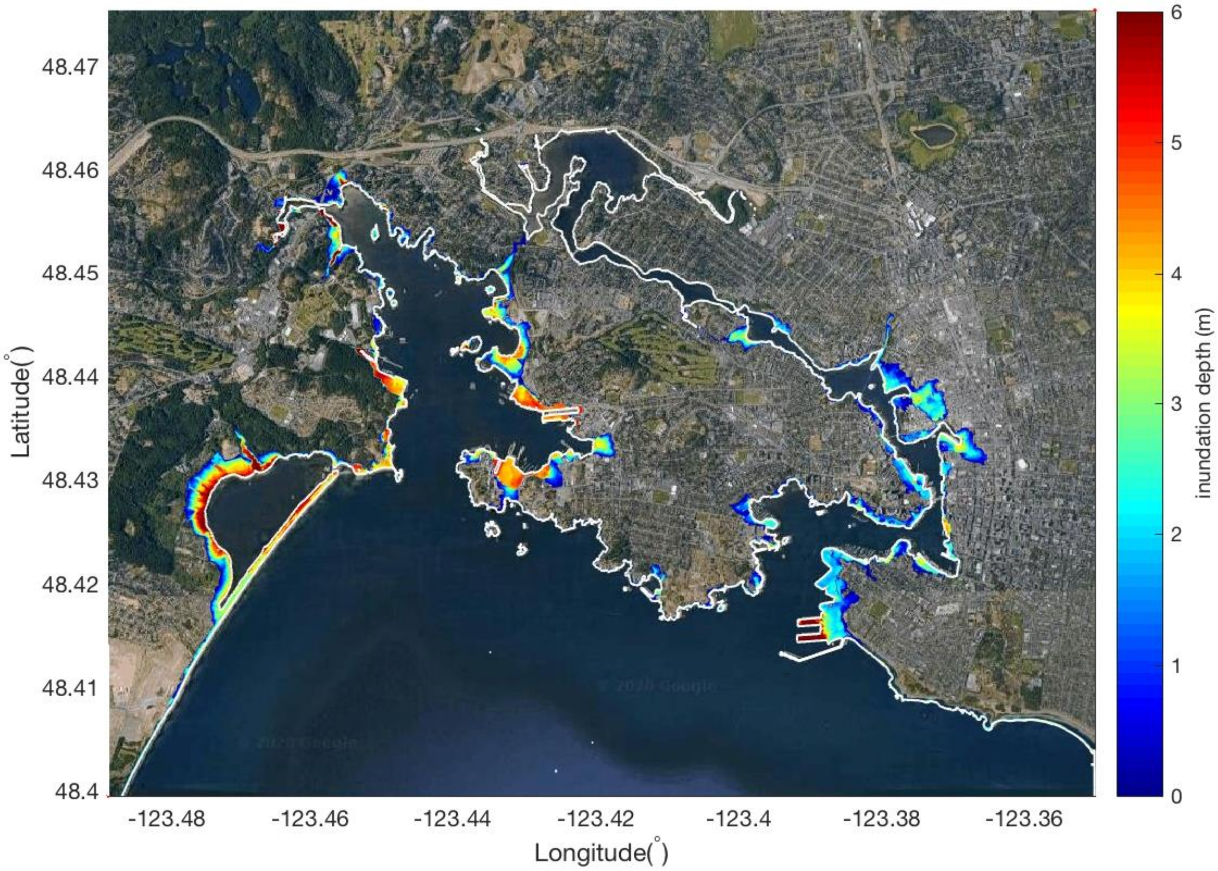
48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum elevation (m)

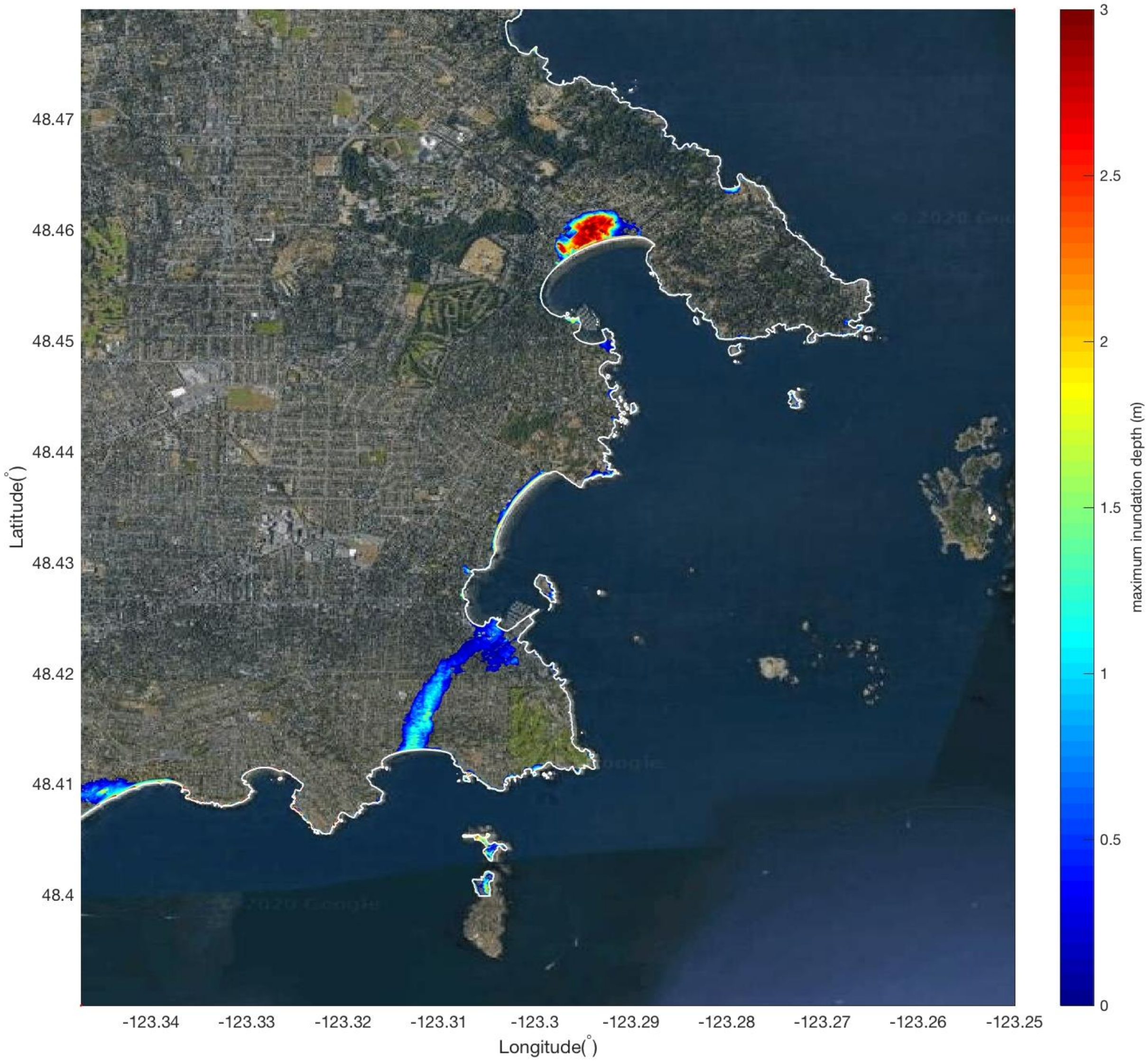

48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425
-123.42
-123.415
-123.41
-123.405
-123.4
-123.395
-123.39
-123.385
-123.38
Longitude(°)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum elevation (m)

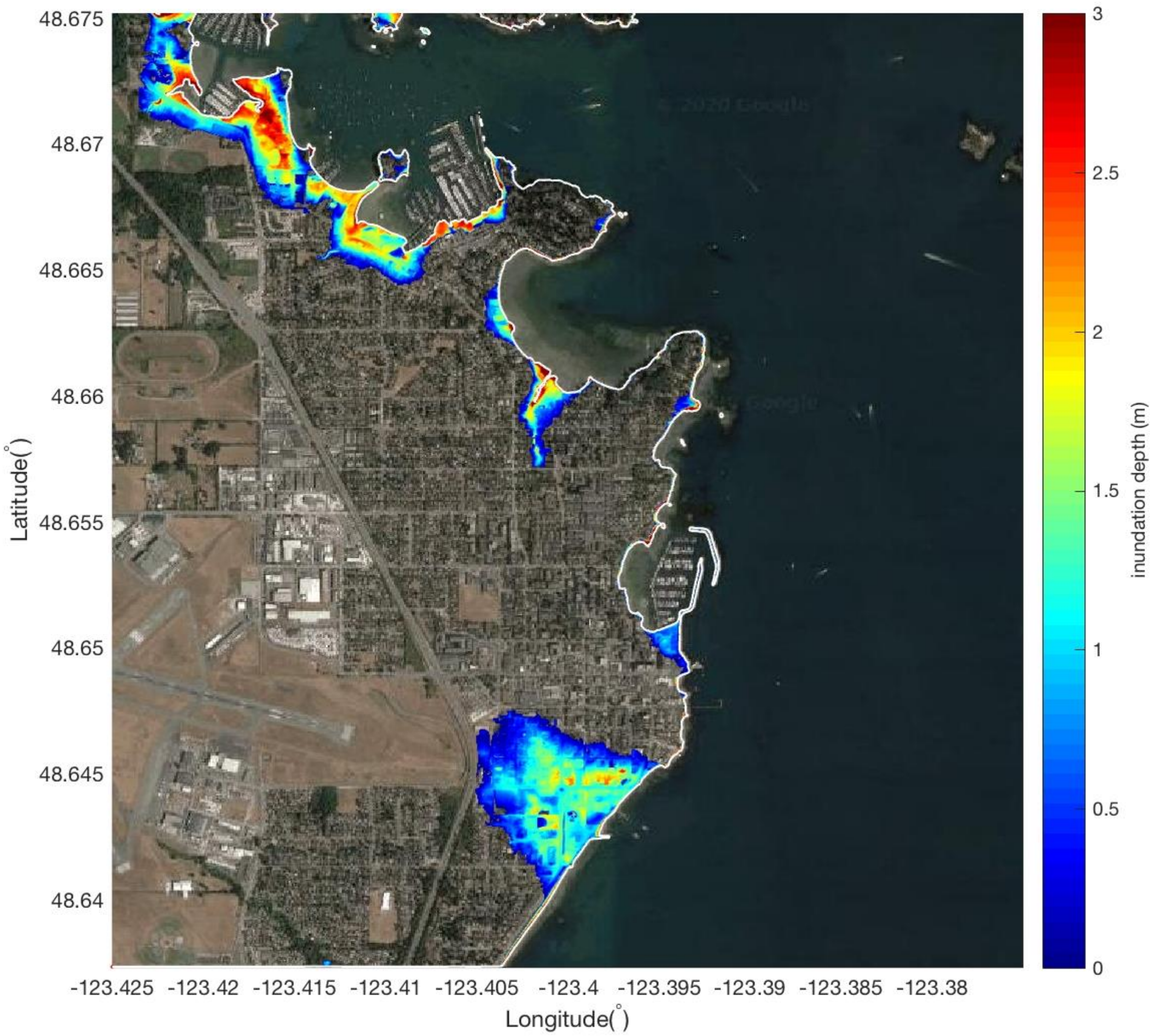
Maximum Inundation Depths: CSZ-L1



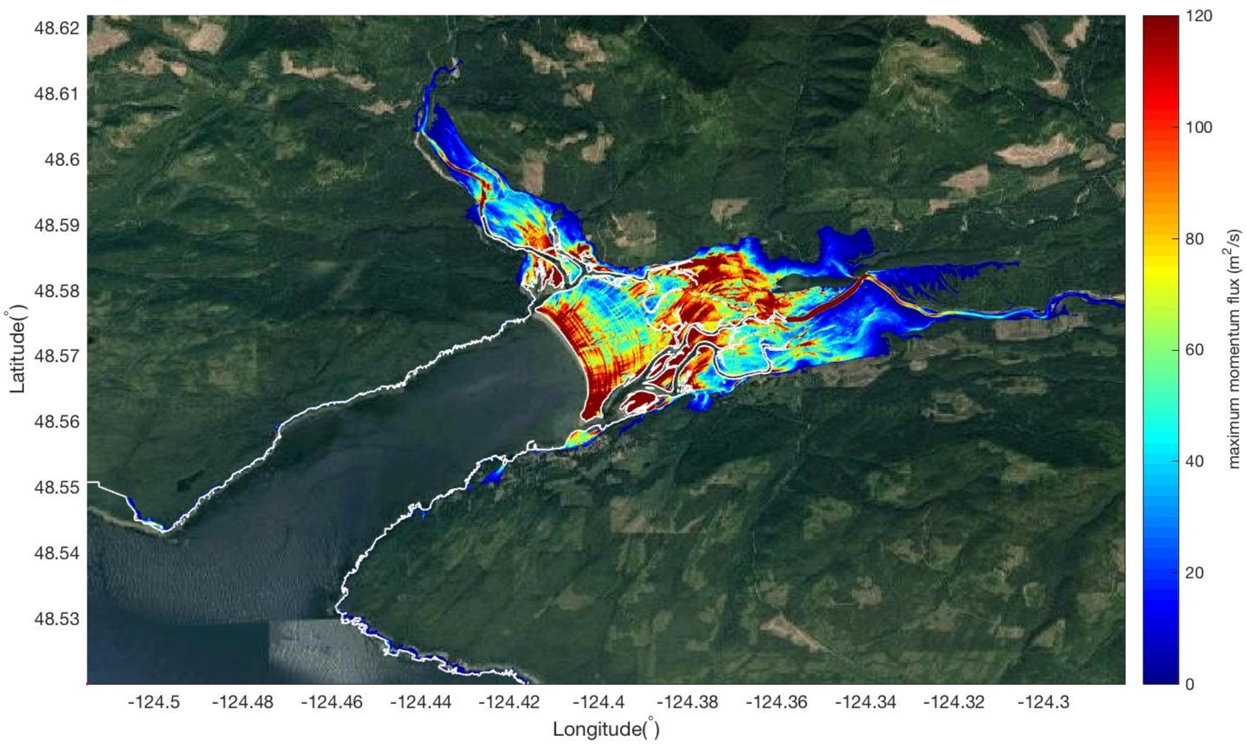


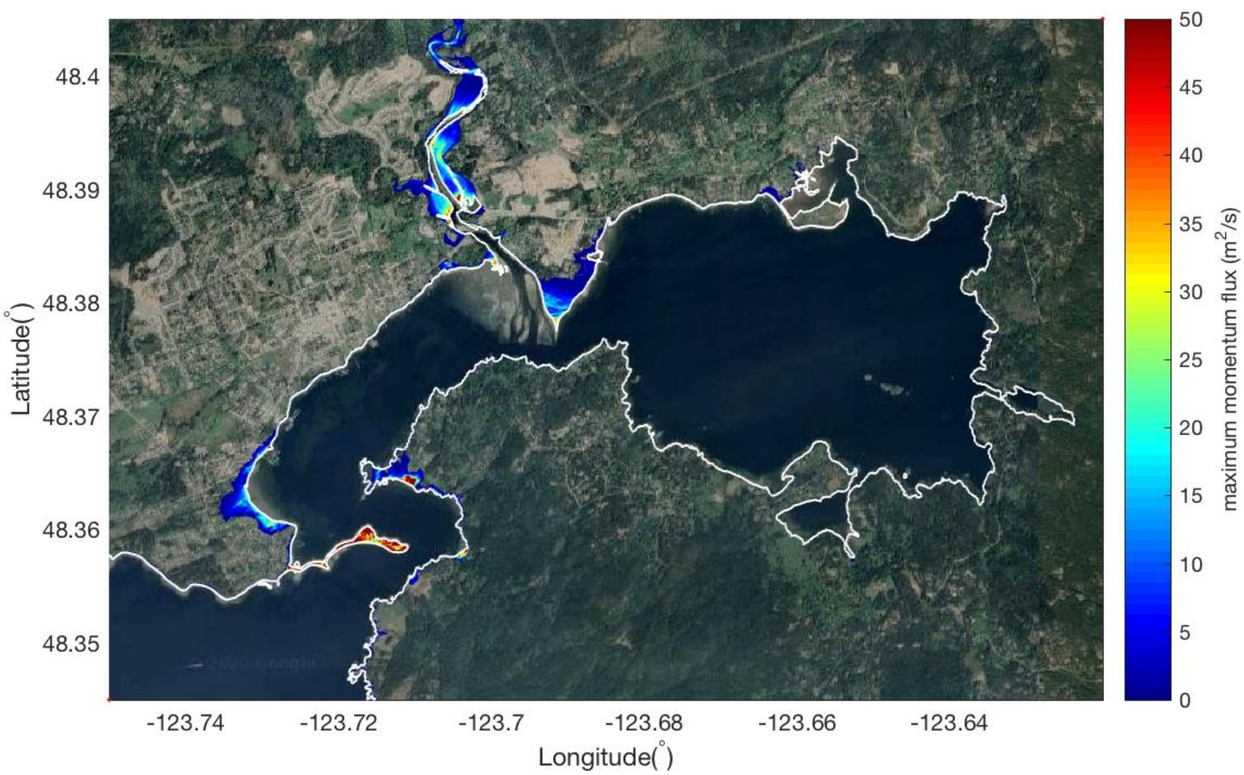

48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
6
5
4
3
2
1
0
inundation depth (m)

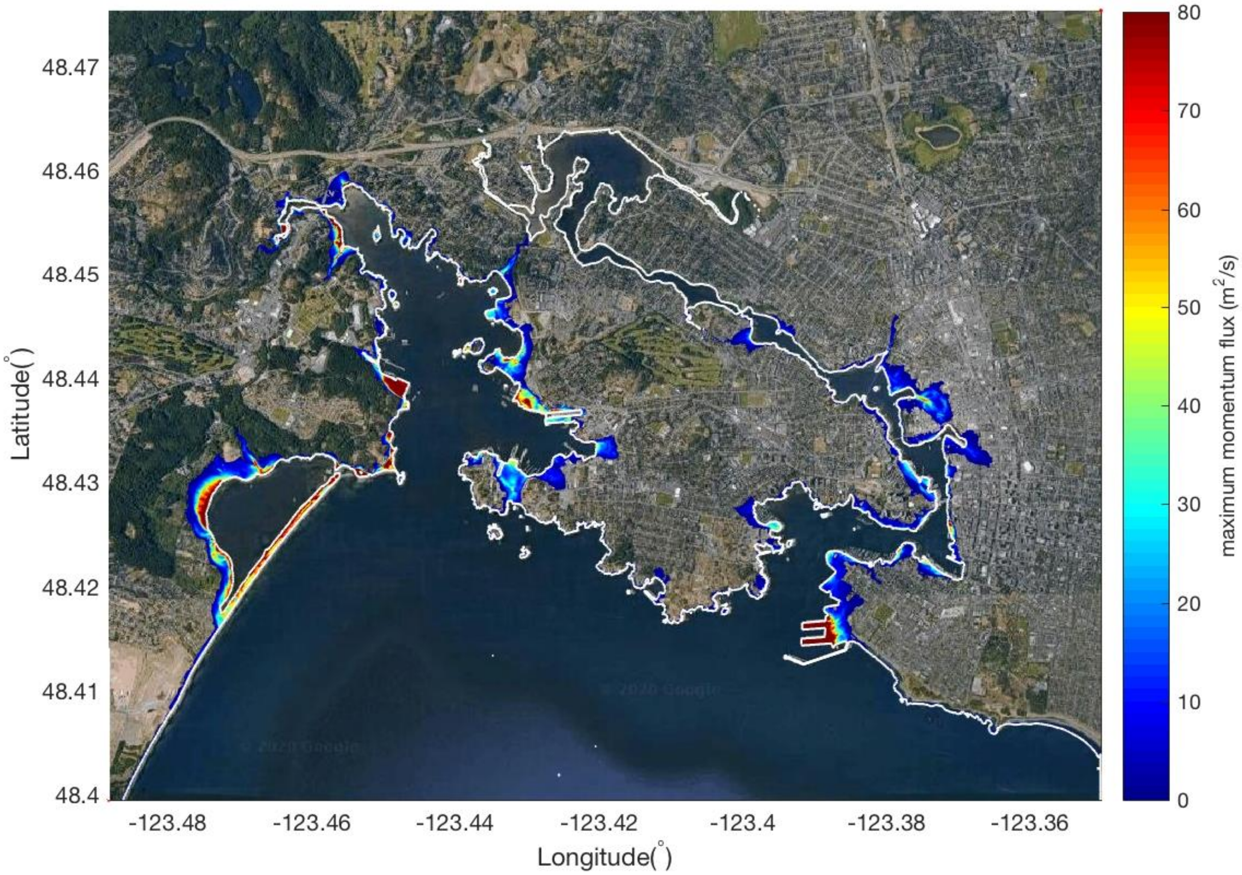

48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
3
2.5
2
1.5
1
0.5
0
maximum inundation depth (m)

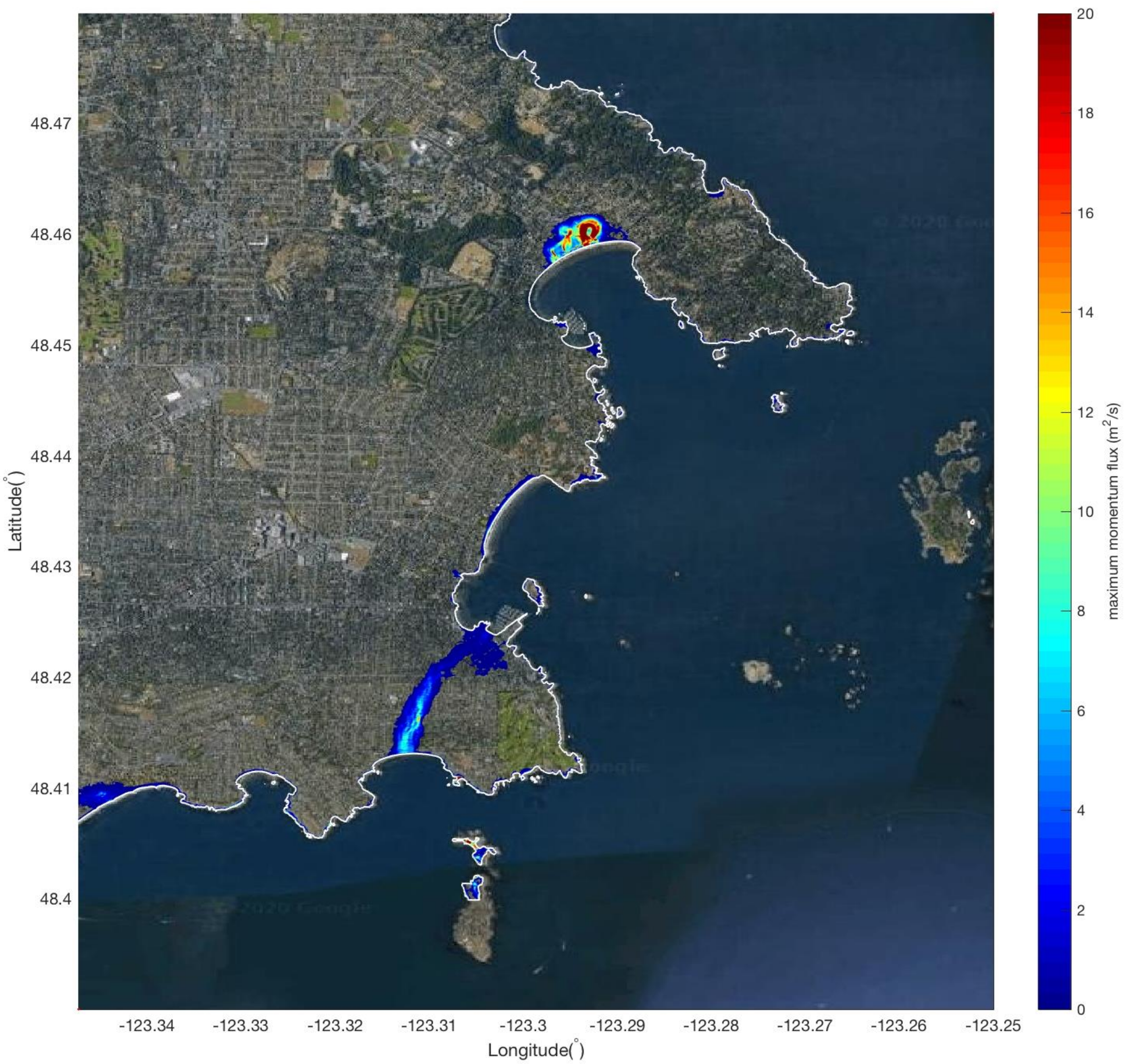

48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
3
2.5
2
1.5
1
0.5
0
inundation depth (m)

Maximum Momentum Flux: CSZ-L1






48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
80
70
60
50
40
30
20
10
0
maximum momentum flux (m²/s)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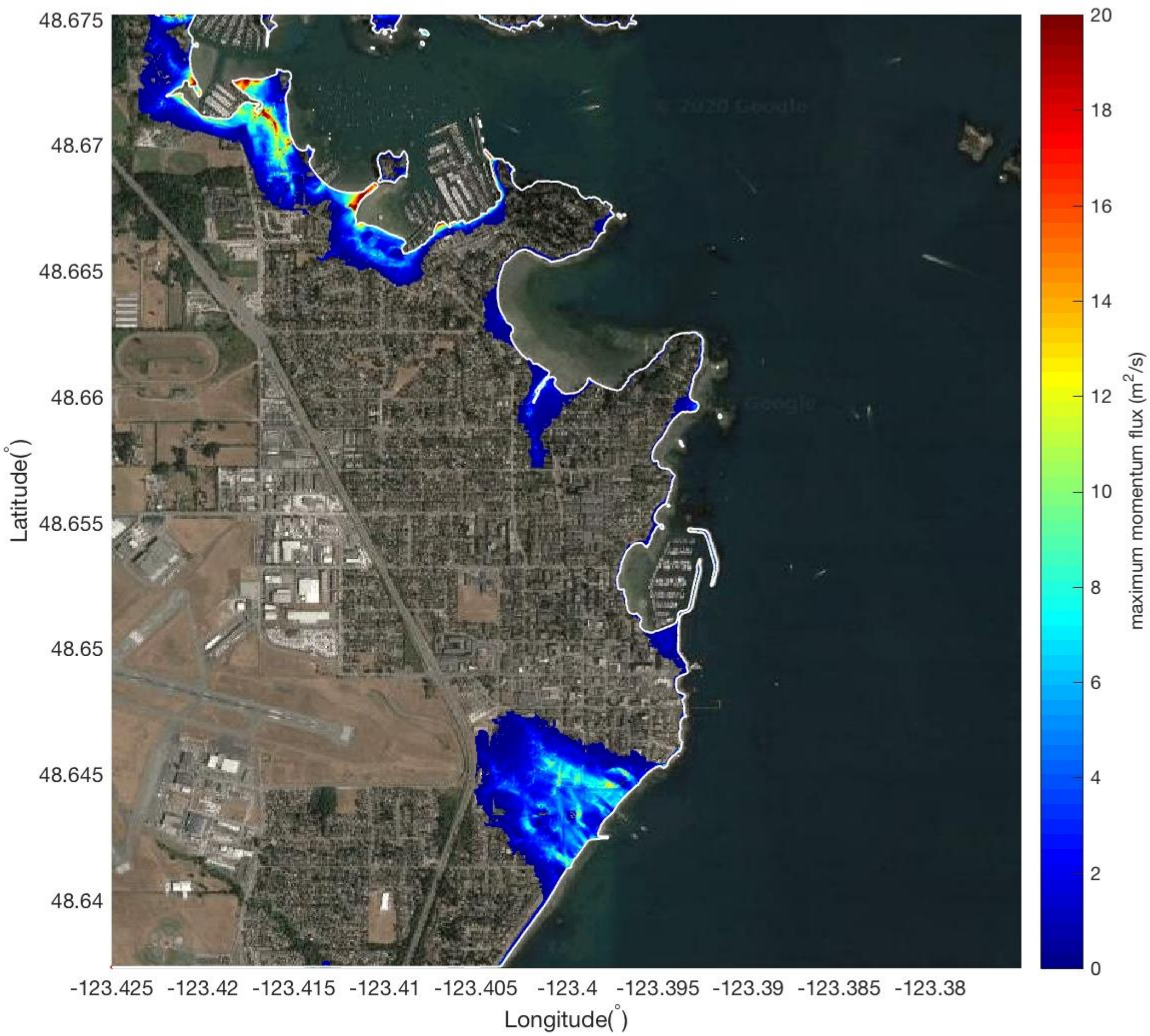
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
20
18
16
14
12
10
8
6
4
2
0
maximum momentum flux (m²/s)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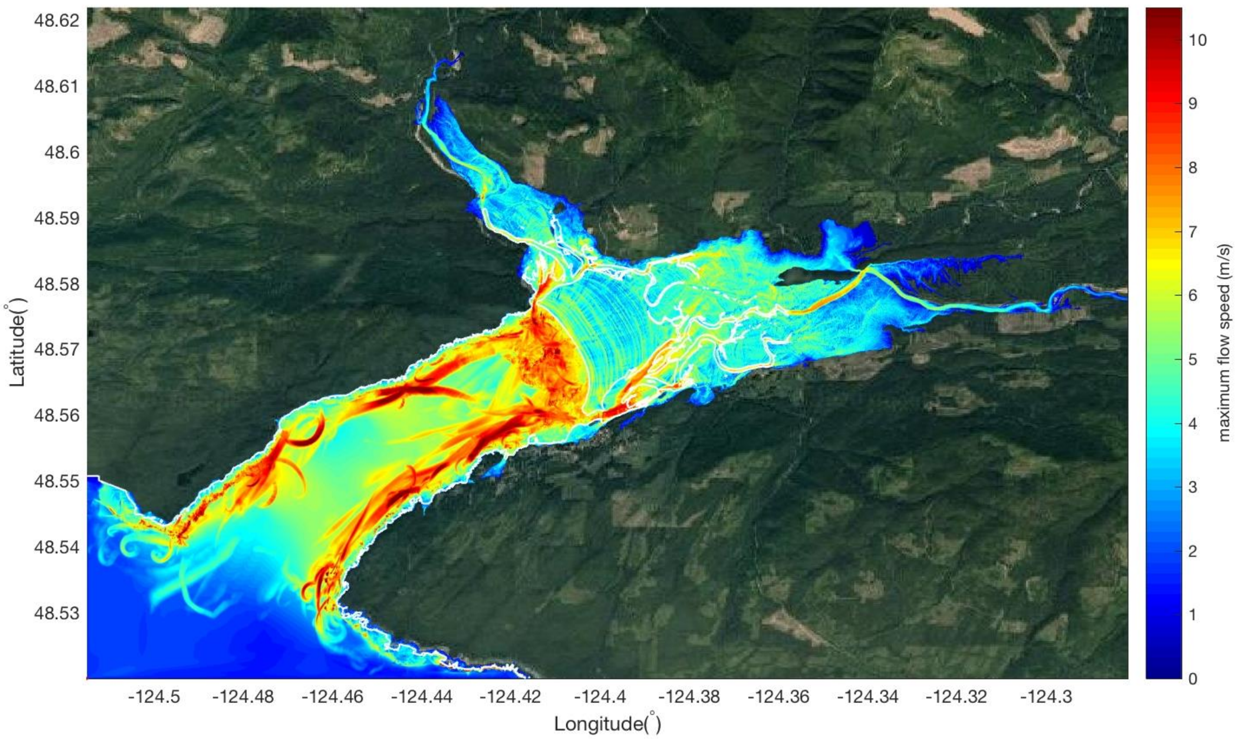
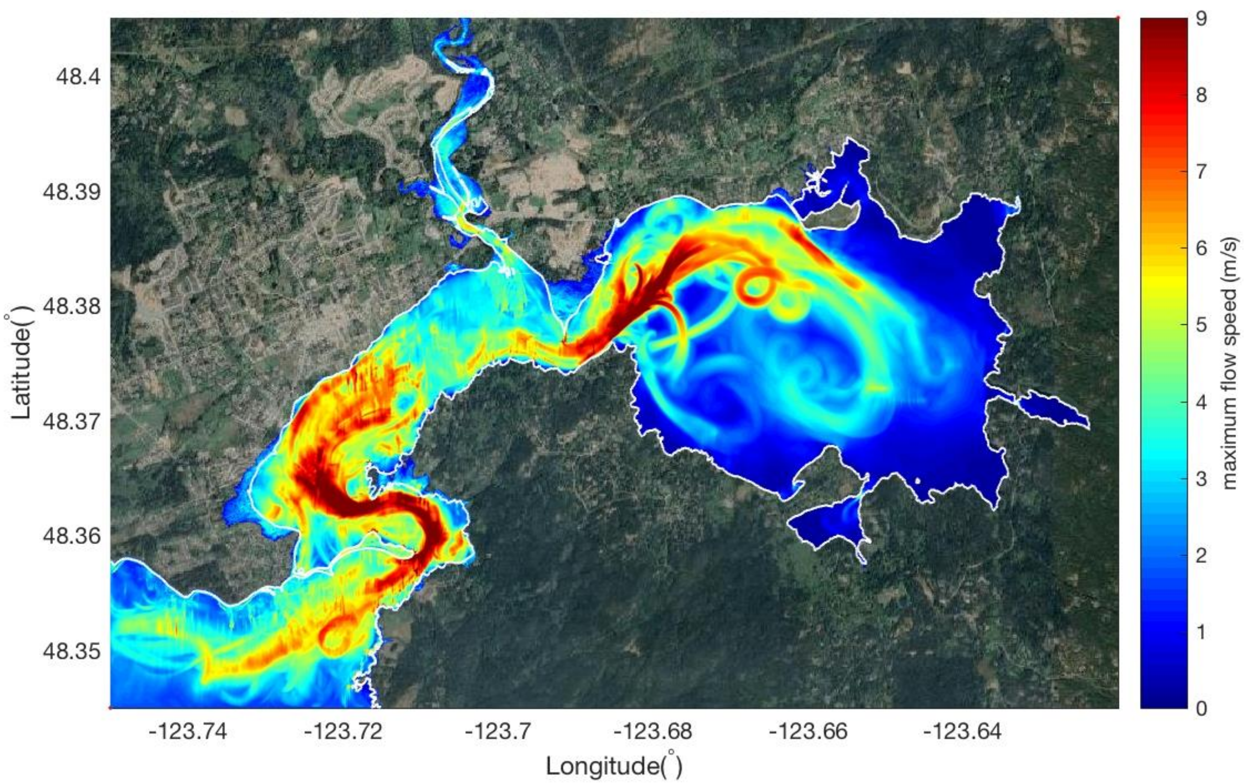
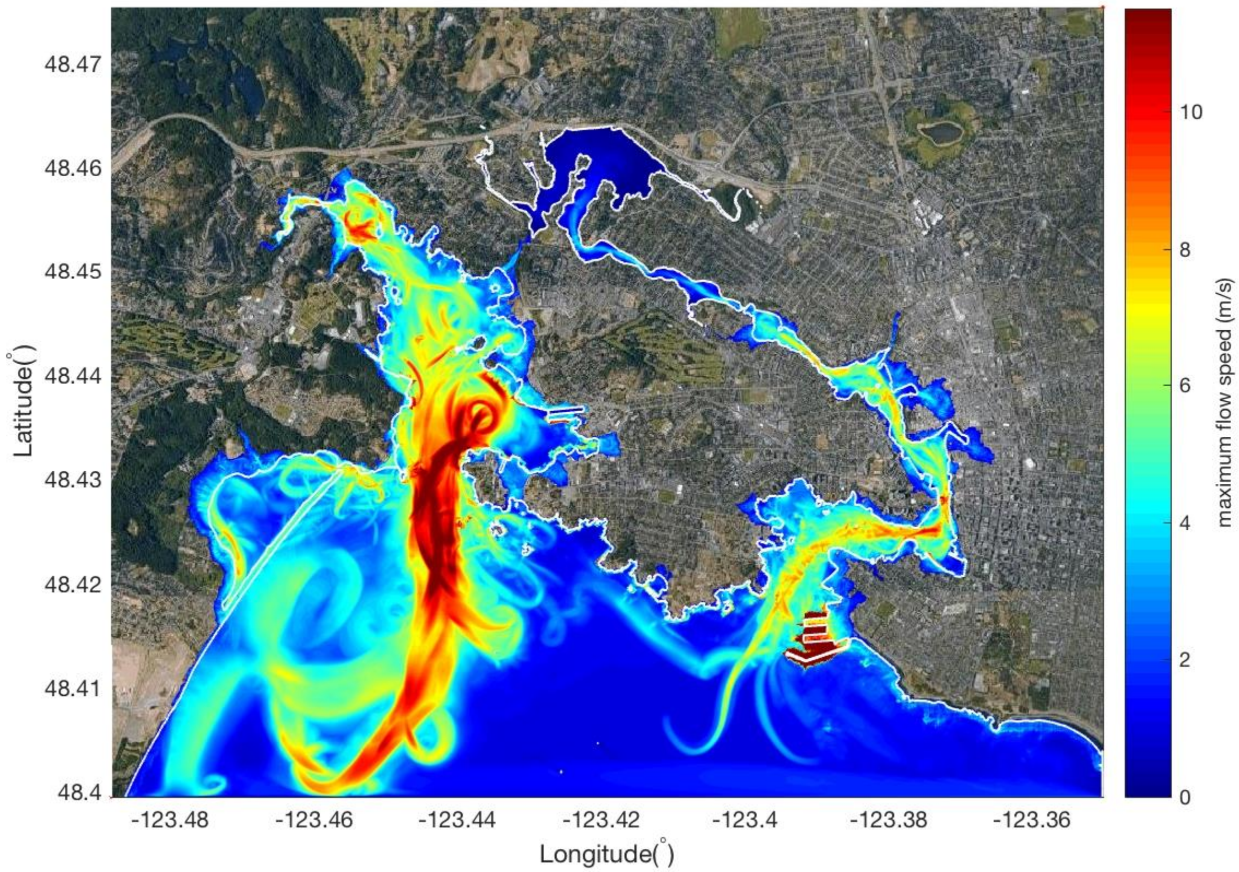
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
© 2020 Google
20
18
16
14
12
10
8
6
4
2
0
maximum momentum flux (m²/s)

Maximum Flow Speed: CSZ-L1



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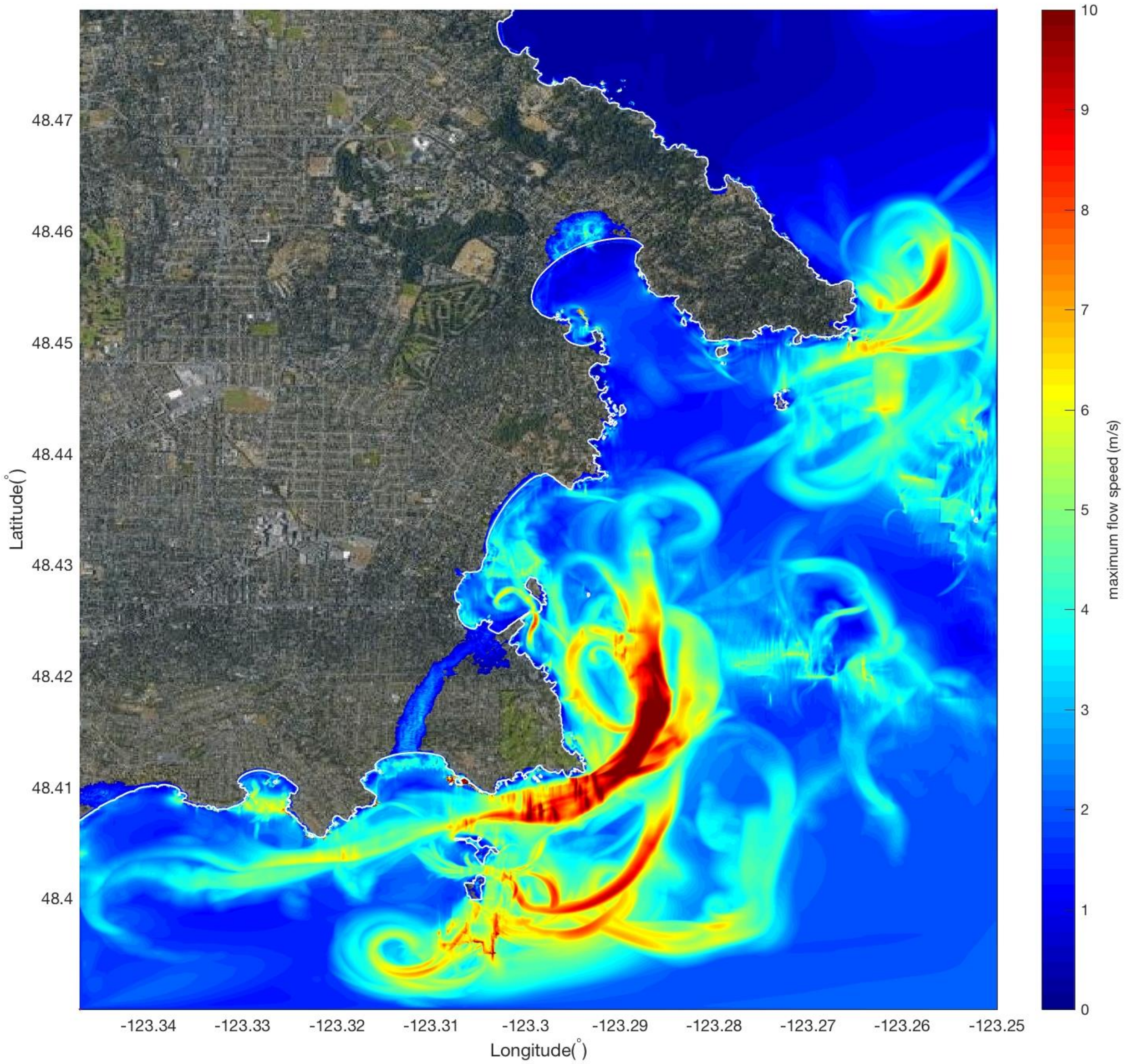
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
10
8
6
4
2
0
maximum flow speed (m/s)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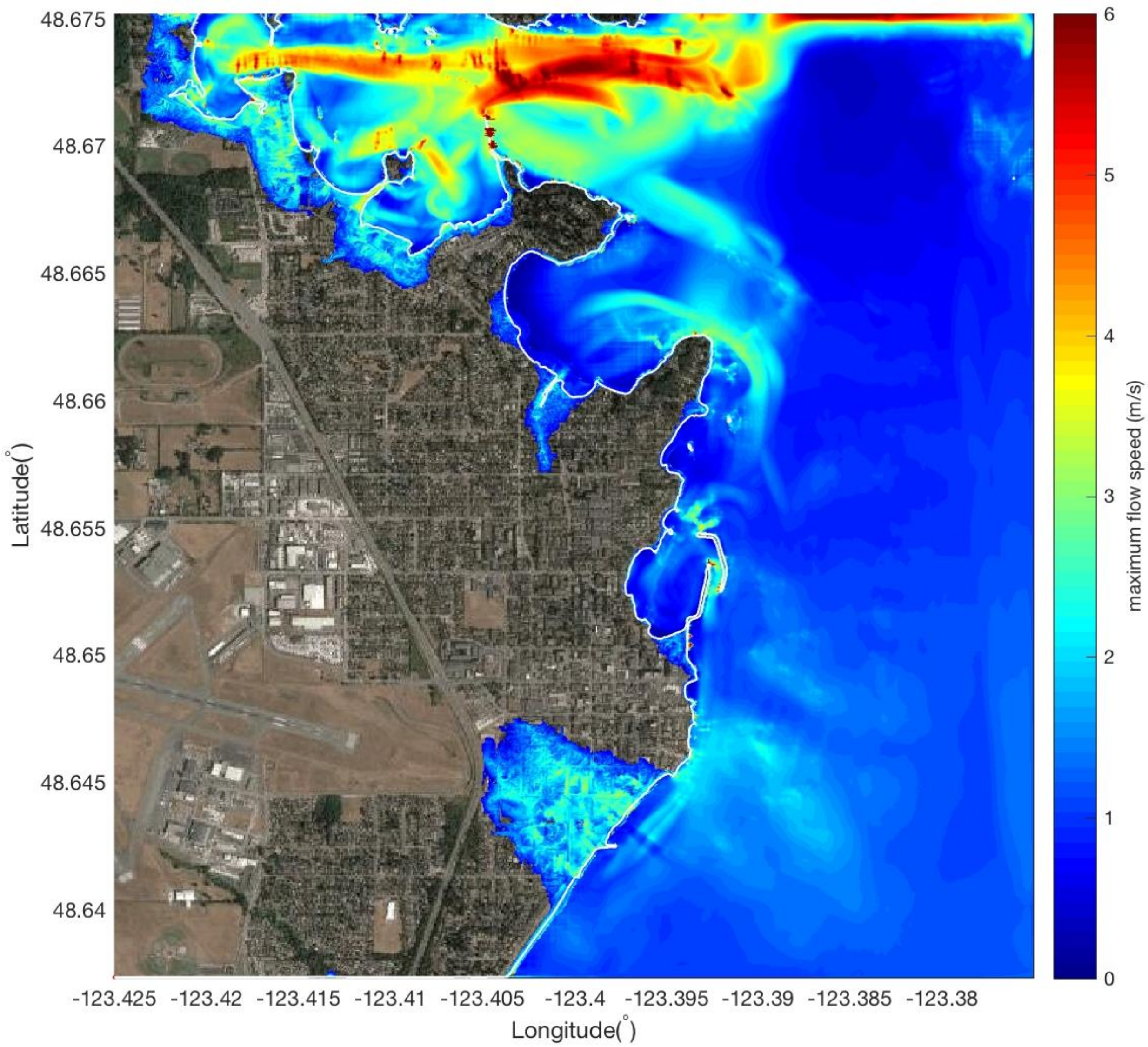
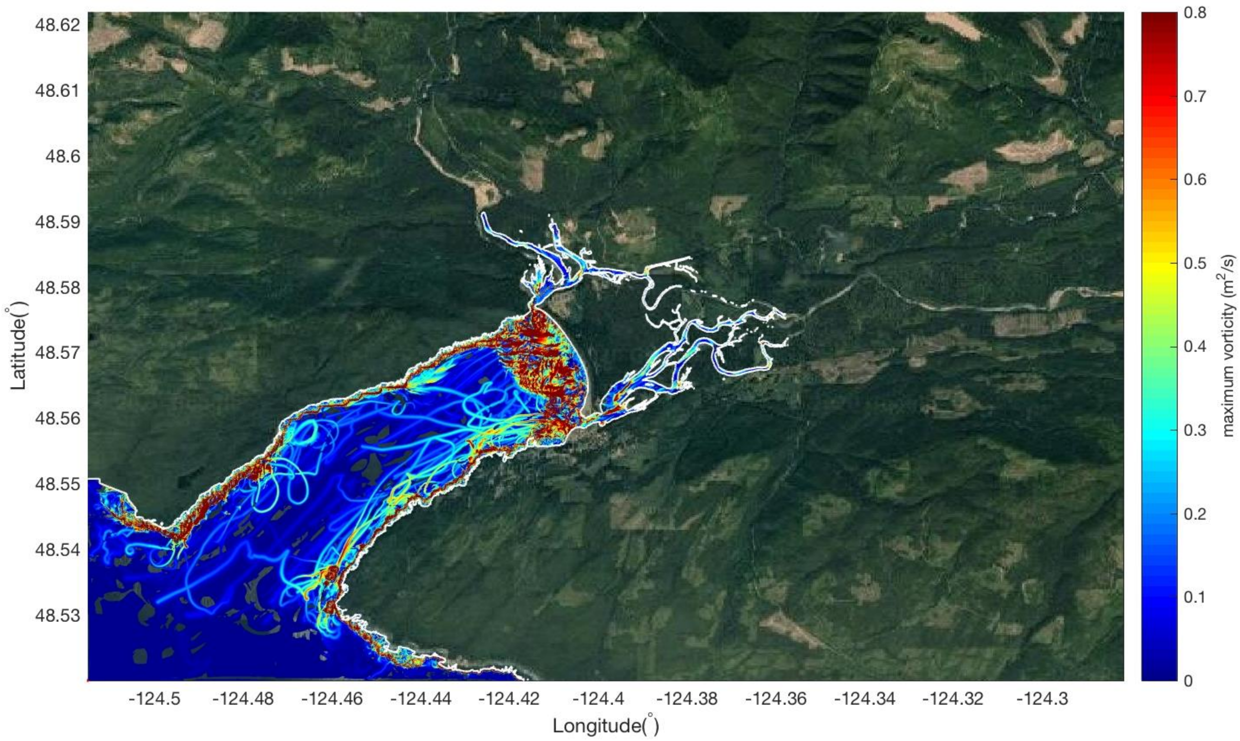
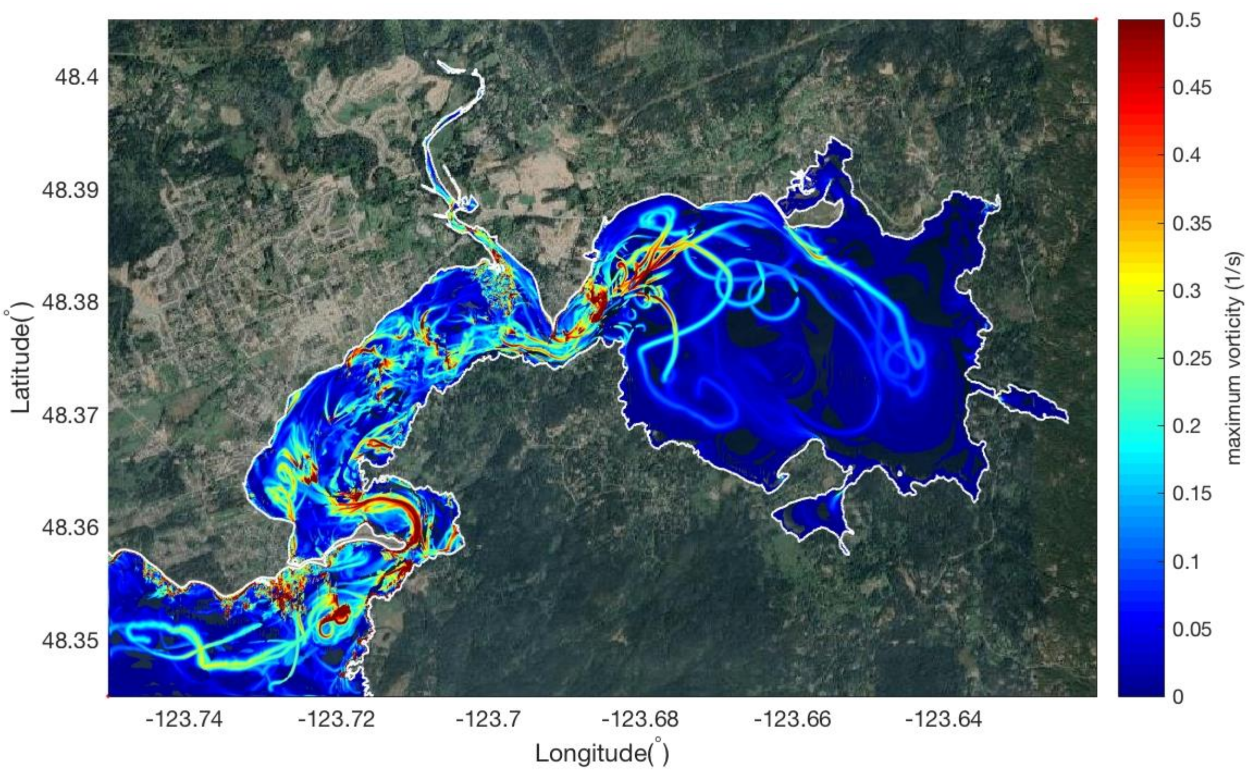
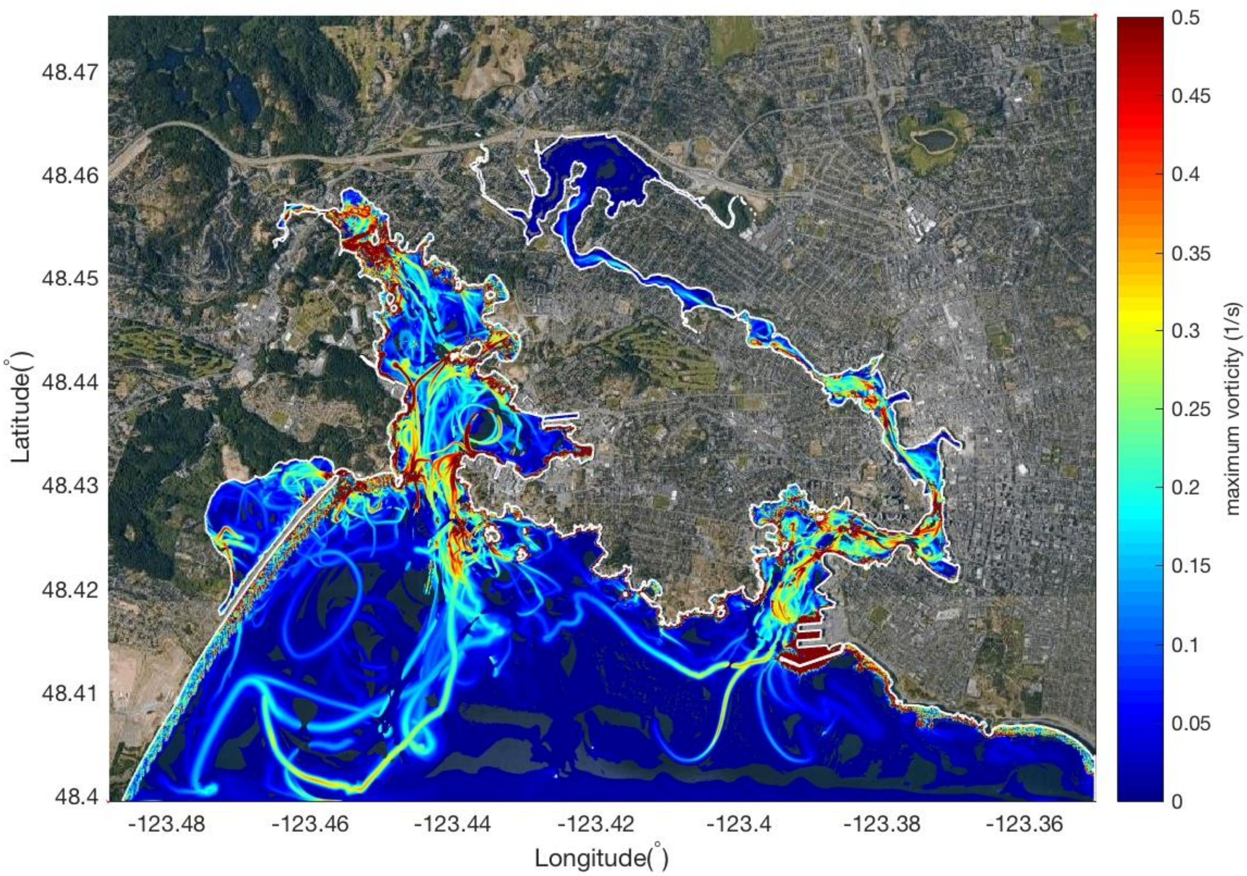
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
10
9
8
7
6
5
4
3
2
1
0
maximum flow speed (m/s)

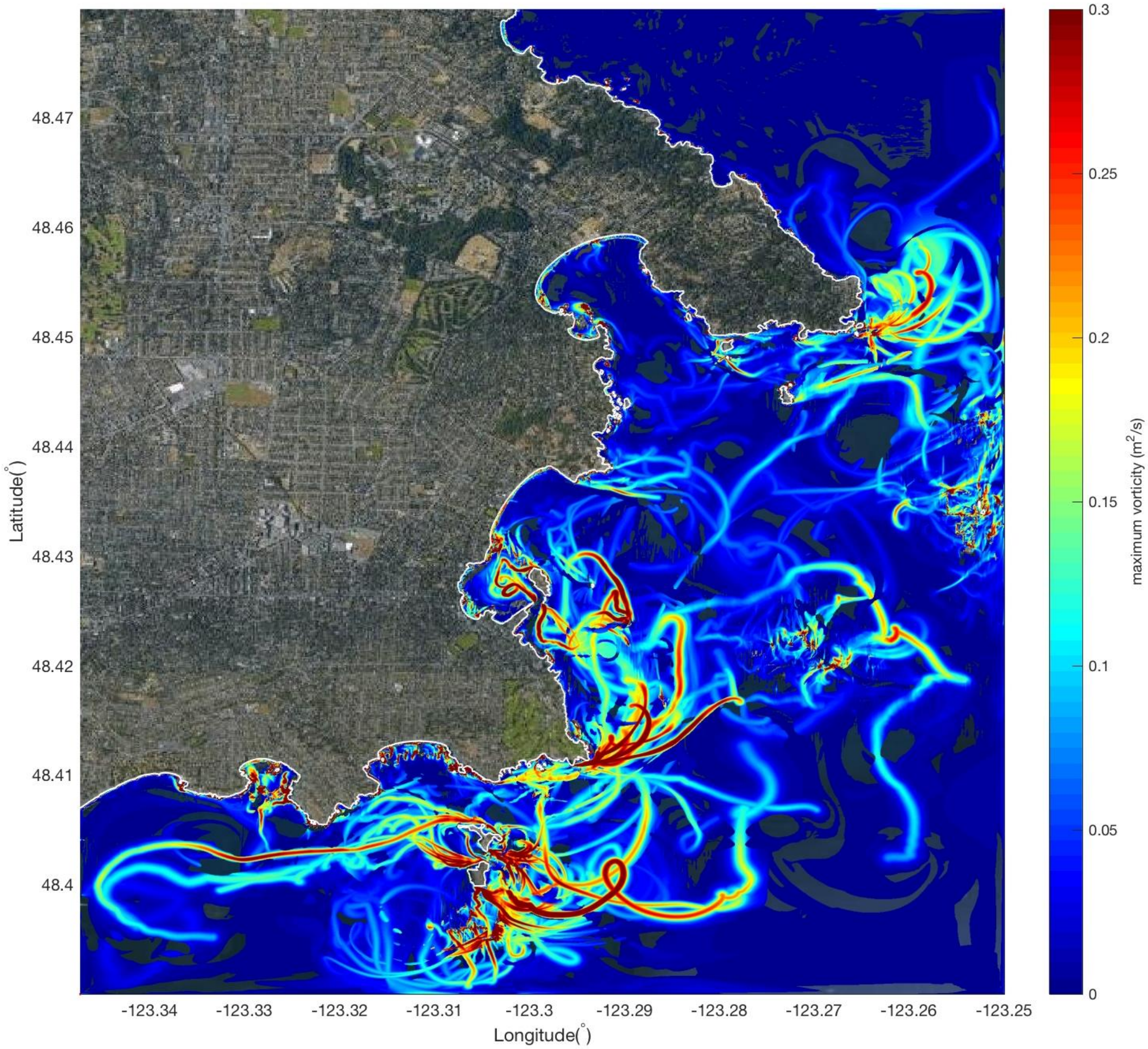

48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
6
5
4
3
2
1
0
maximum flow speed (m/s)

Maximum Vorticity: CSZ-L1






48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum vorticity (1/s)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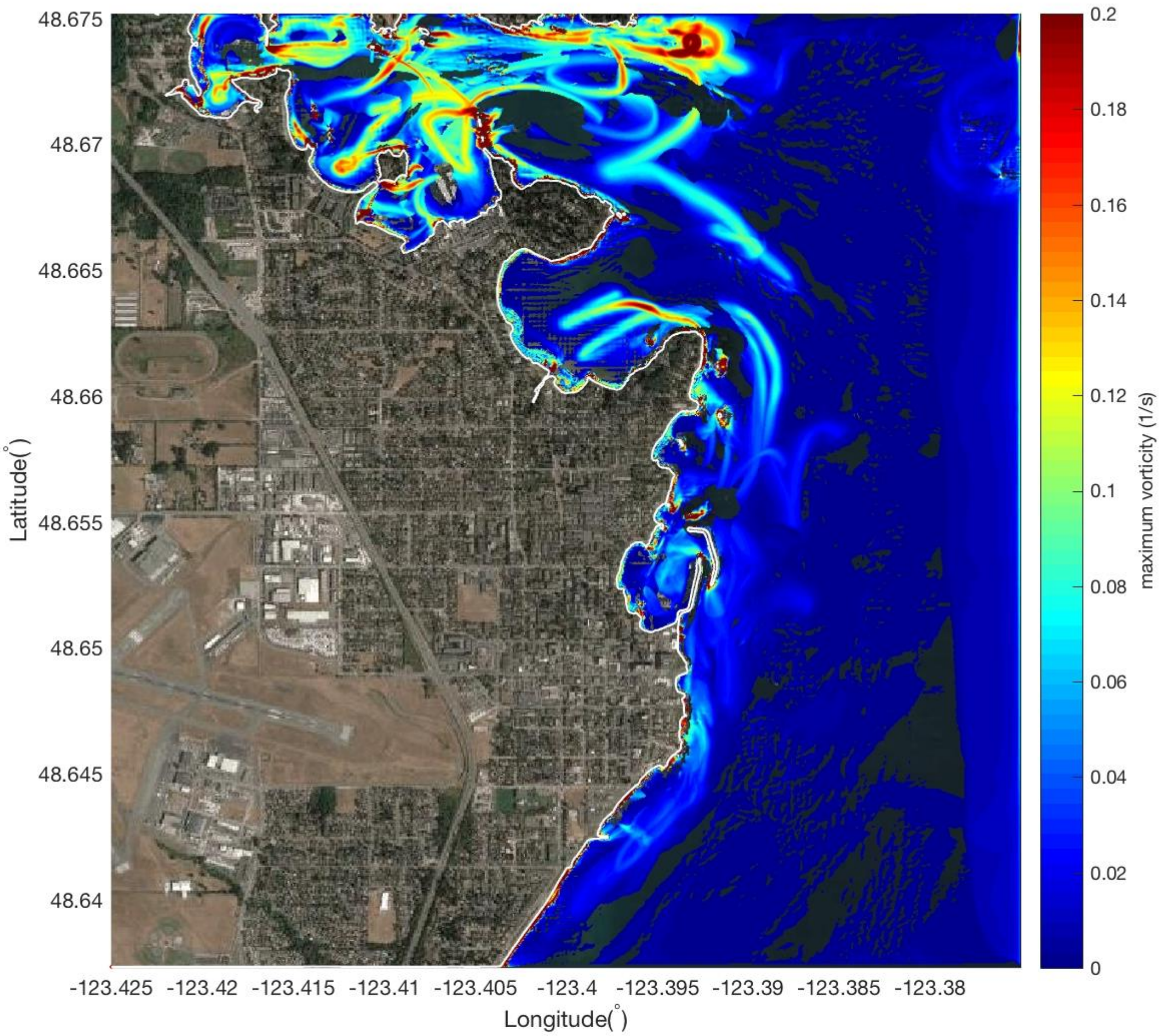
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum vorticity (m²/s)

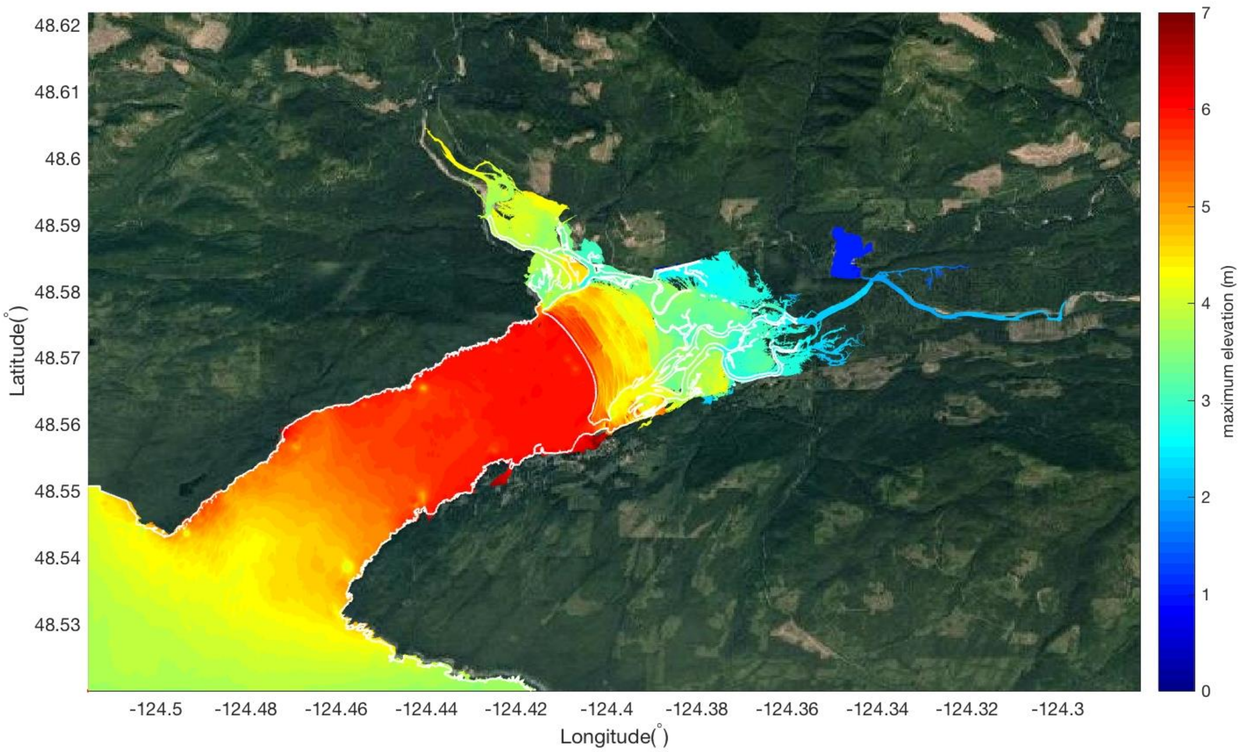

48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
maximum vorticity (1/s)

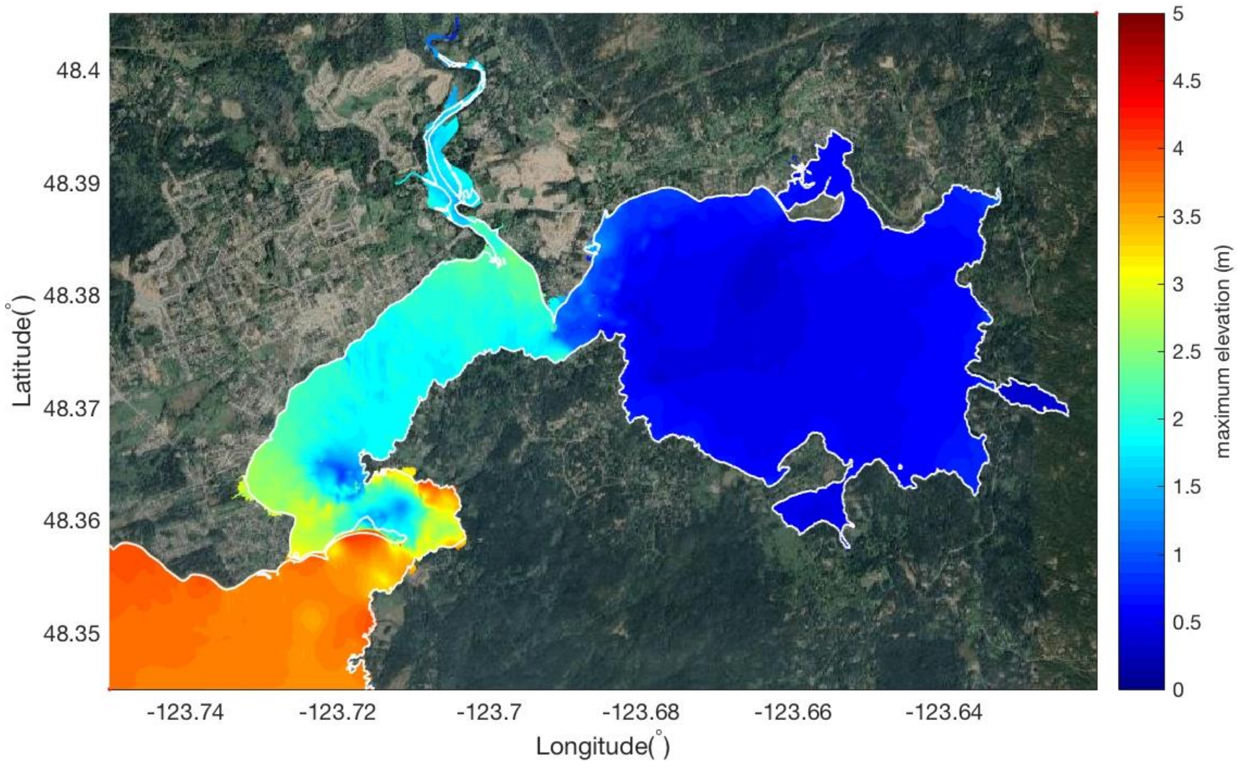
APPENDIX F - DETAILED INUNDATION GRID RESULTS: CSZ-NS

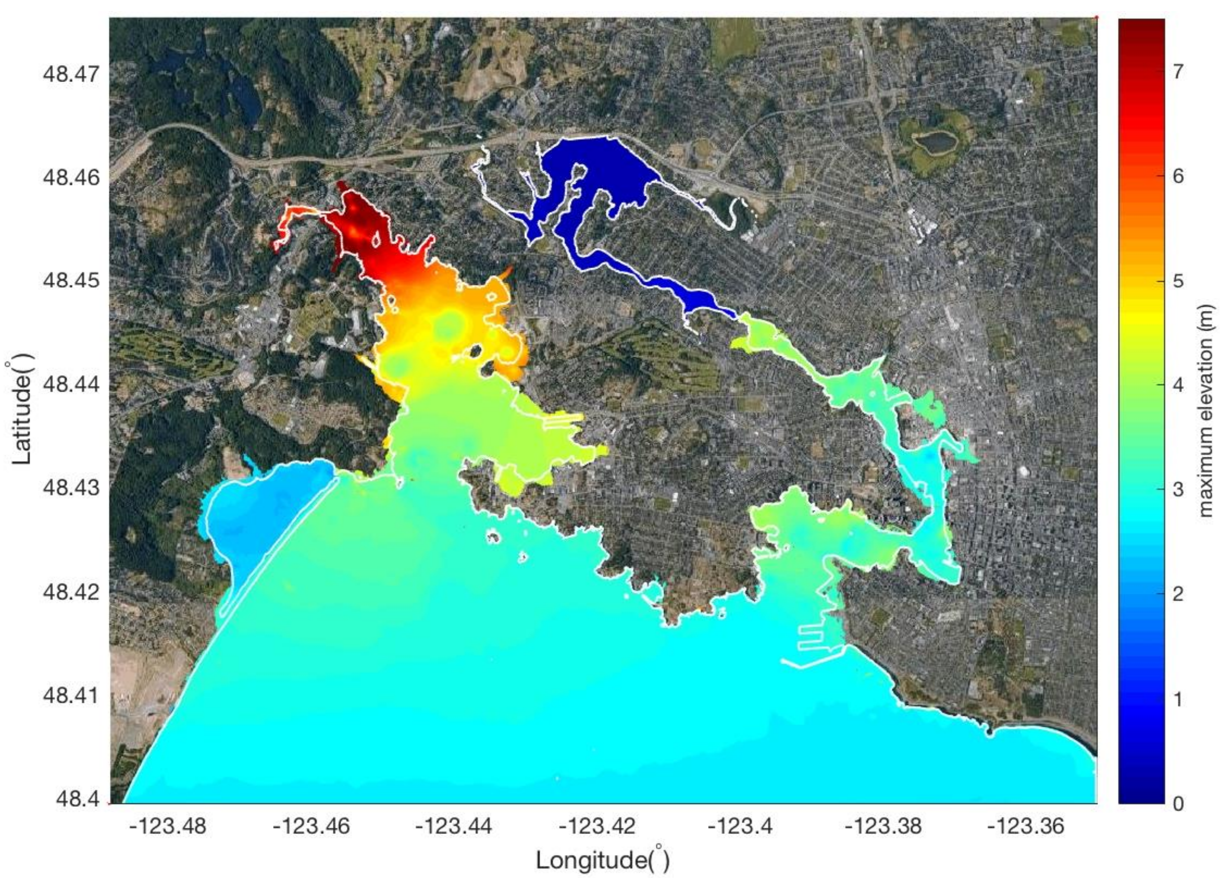
This appendix presents results for the CSZ-NS event, for each detailed modelling domain. For each result parameter, the results are presented in the following order: Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

Maximum Water Surface Elevations: CSZ-NS

(Elevations are reported to m above HHWMT datum)




48.4
48.39
48.38
48.37
48.36
48.35
Latitude(°)
-123.74
-123.72
-123.7
-123.68
-123.66
-123.64
Longitude(°)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum elevation (m)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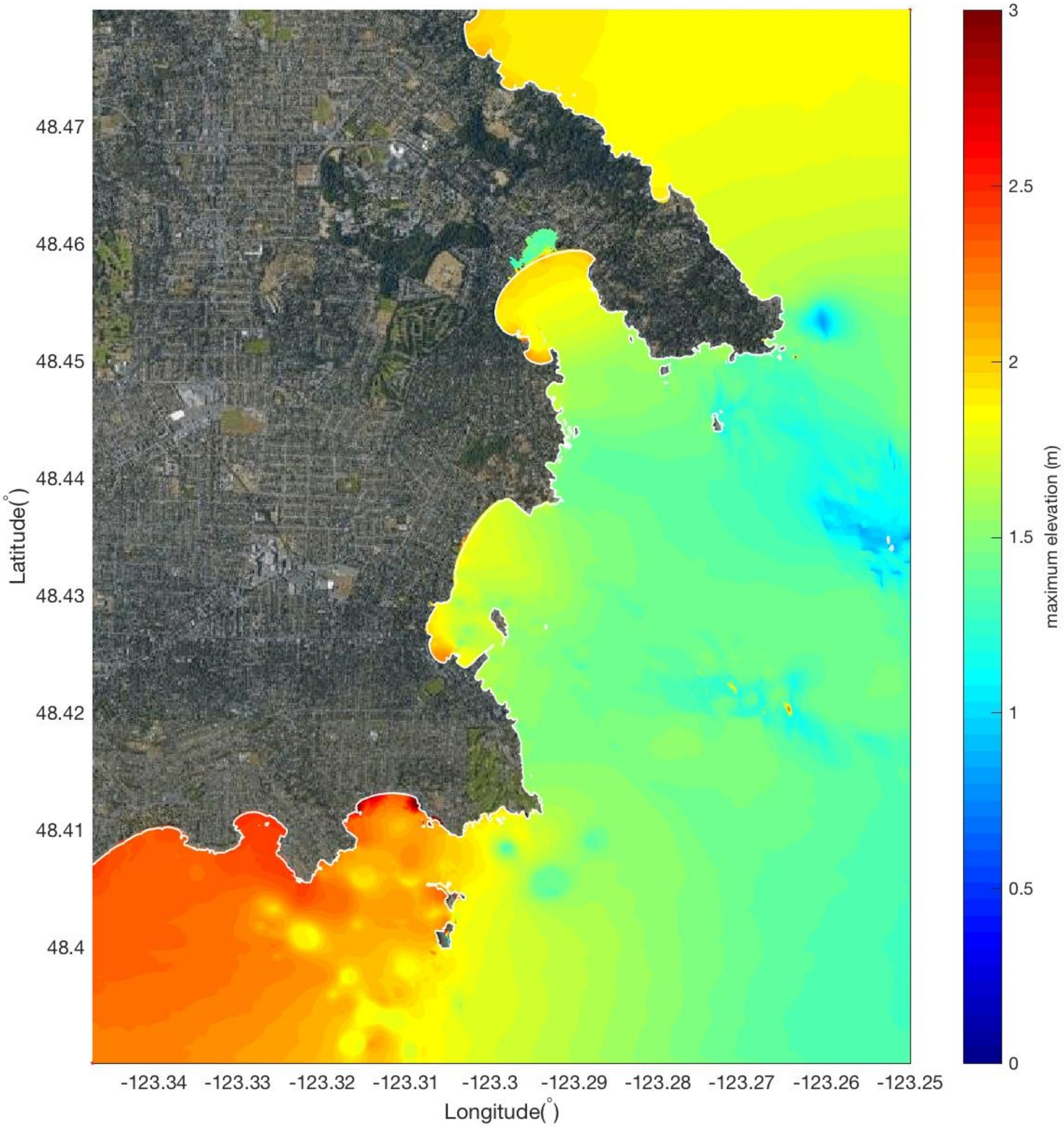
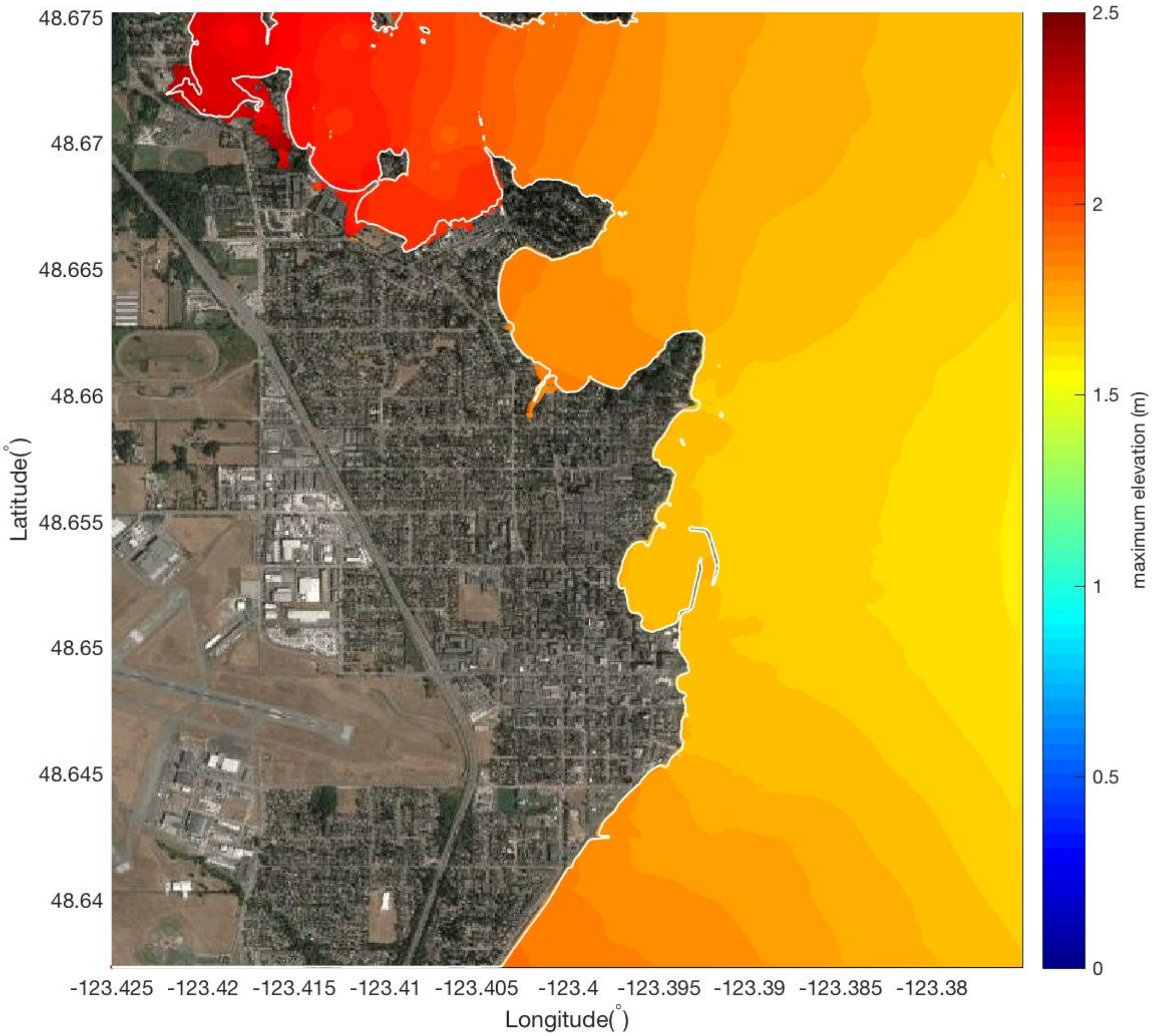
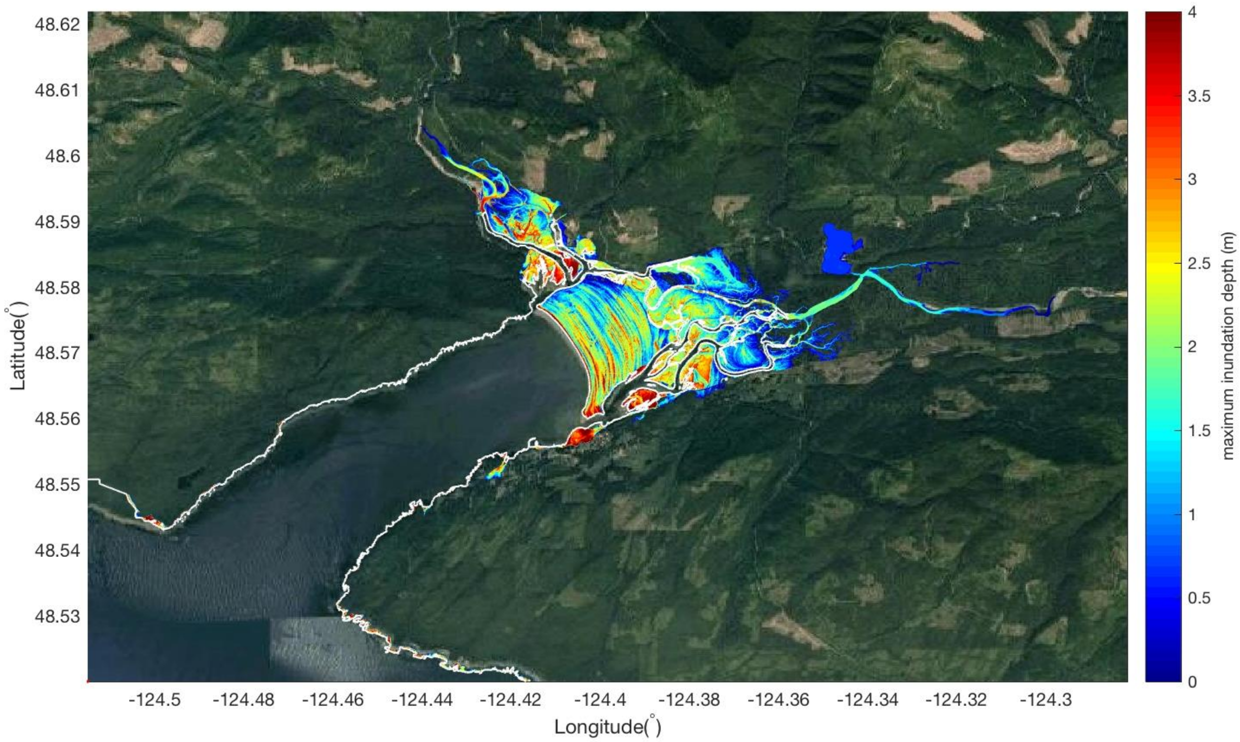
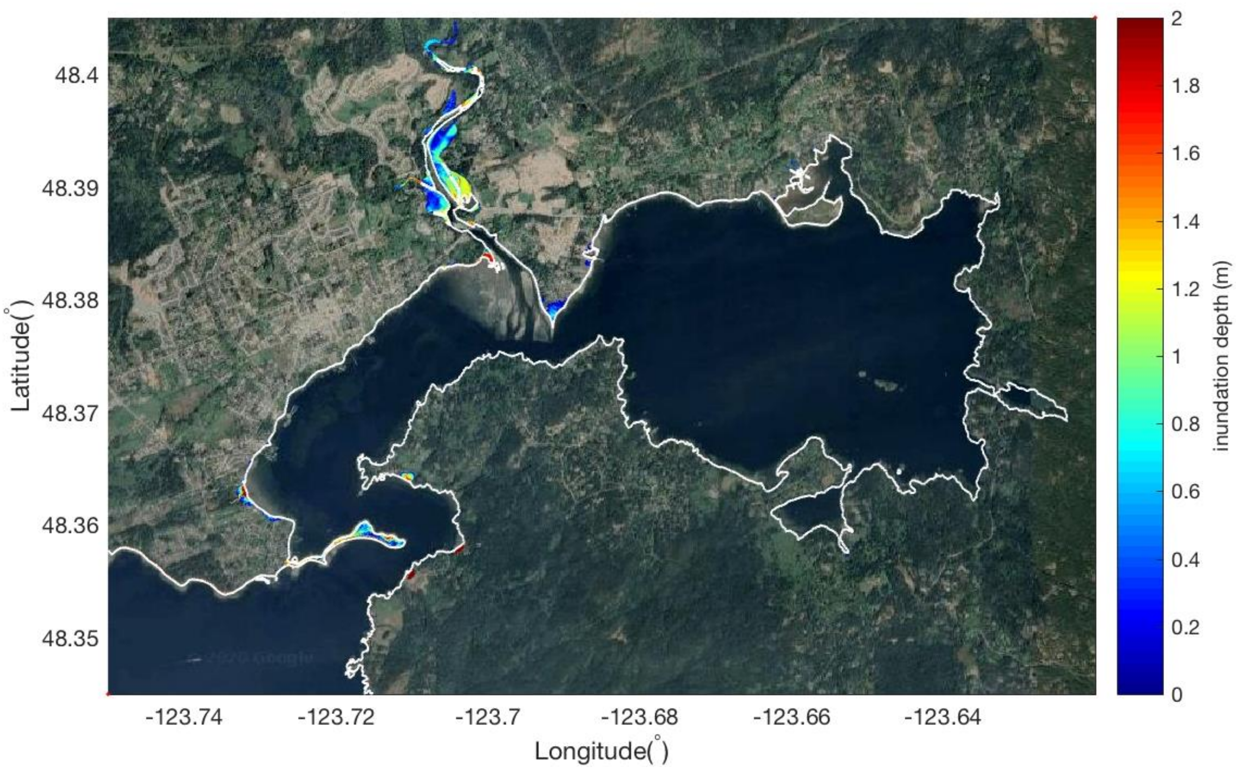
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
7
6
5
4
3
2
1
0
maximum elevation (m)

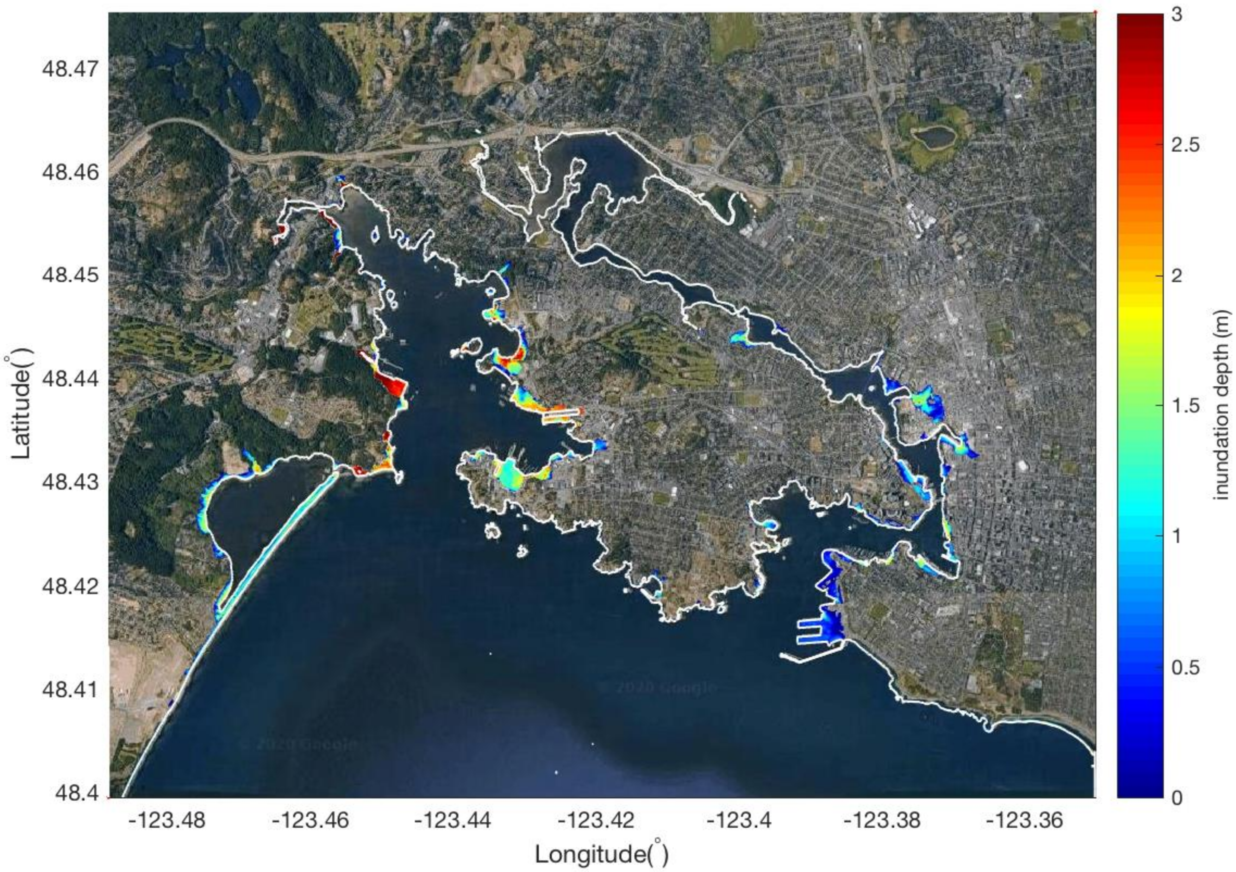

48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34 -123.33 -123.32 -123.31 -123.3 -123.29 -123.28 -123.27 -123.26 -123.25
Longitude(°)
3
2.5
2
1.5
1
0.5
0
maximum elevation (m)


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
2.5
2
1.5
1
0.5
0
maximum elevation (m)

Maximum Inundation Depths: CSZ-NS



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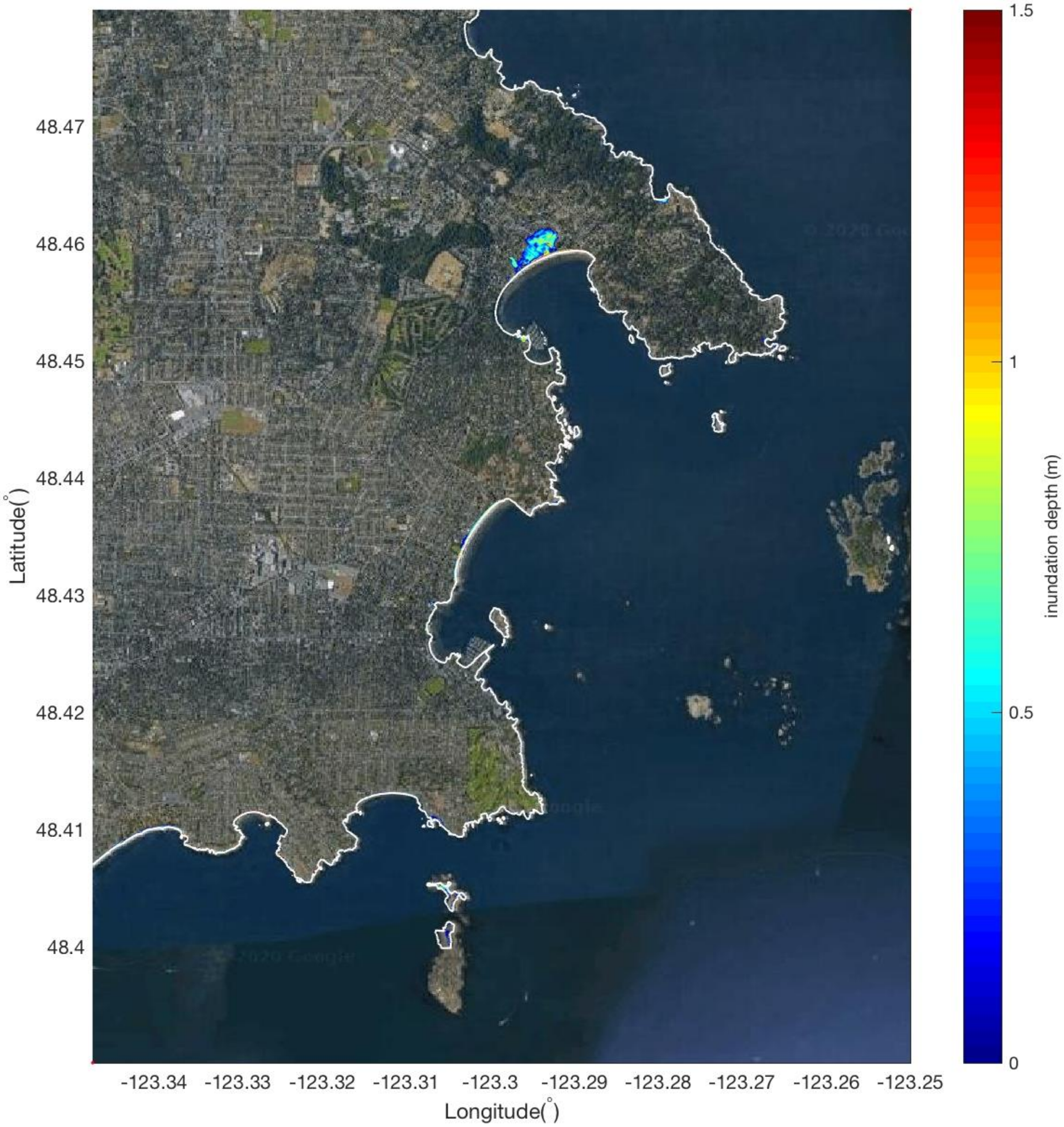
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
3
2.5
2
1.5
1
0.5
0
inundation depth (m)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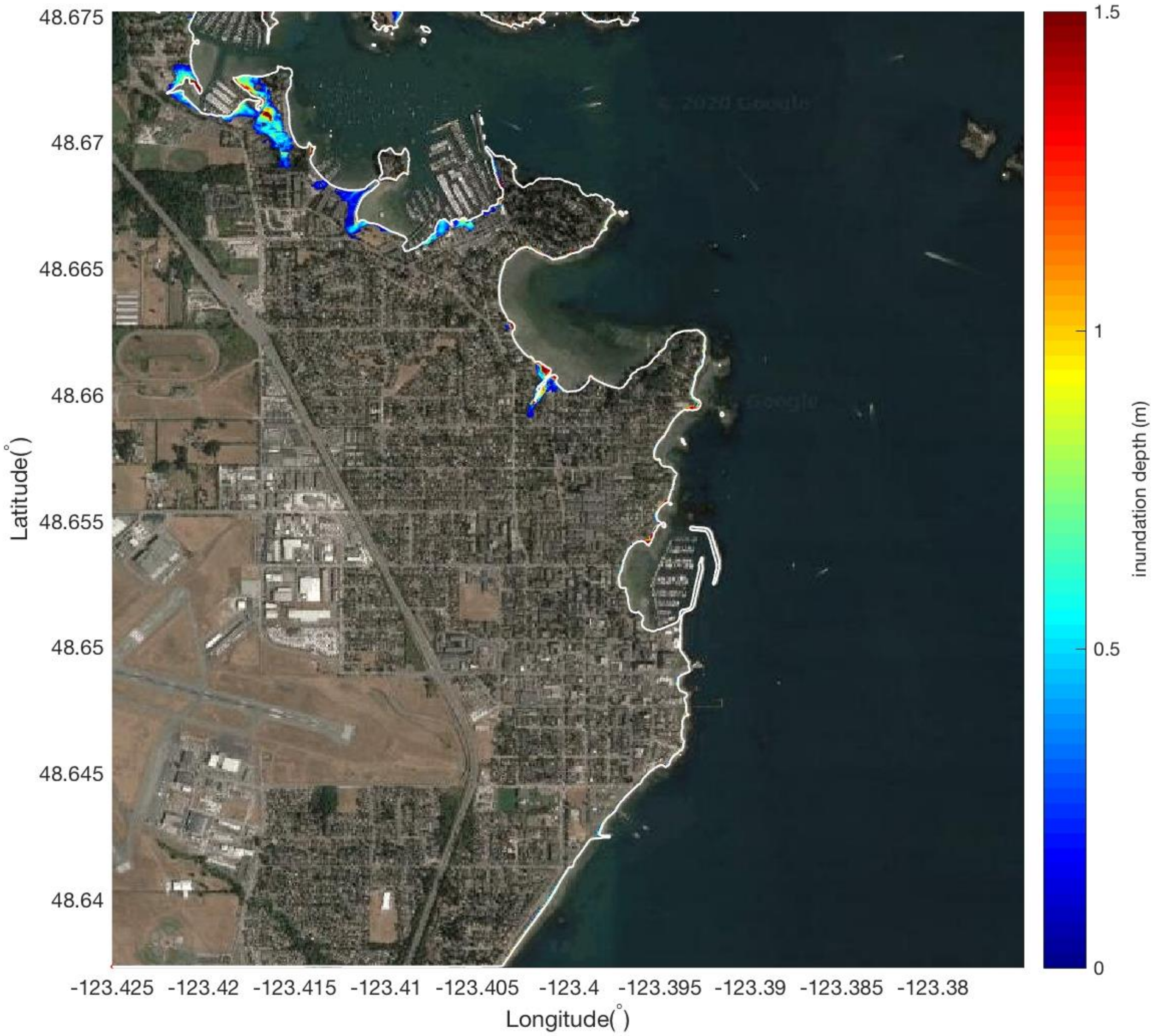
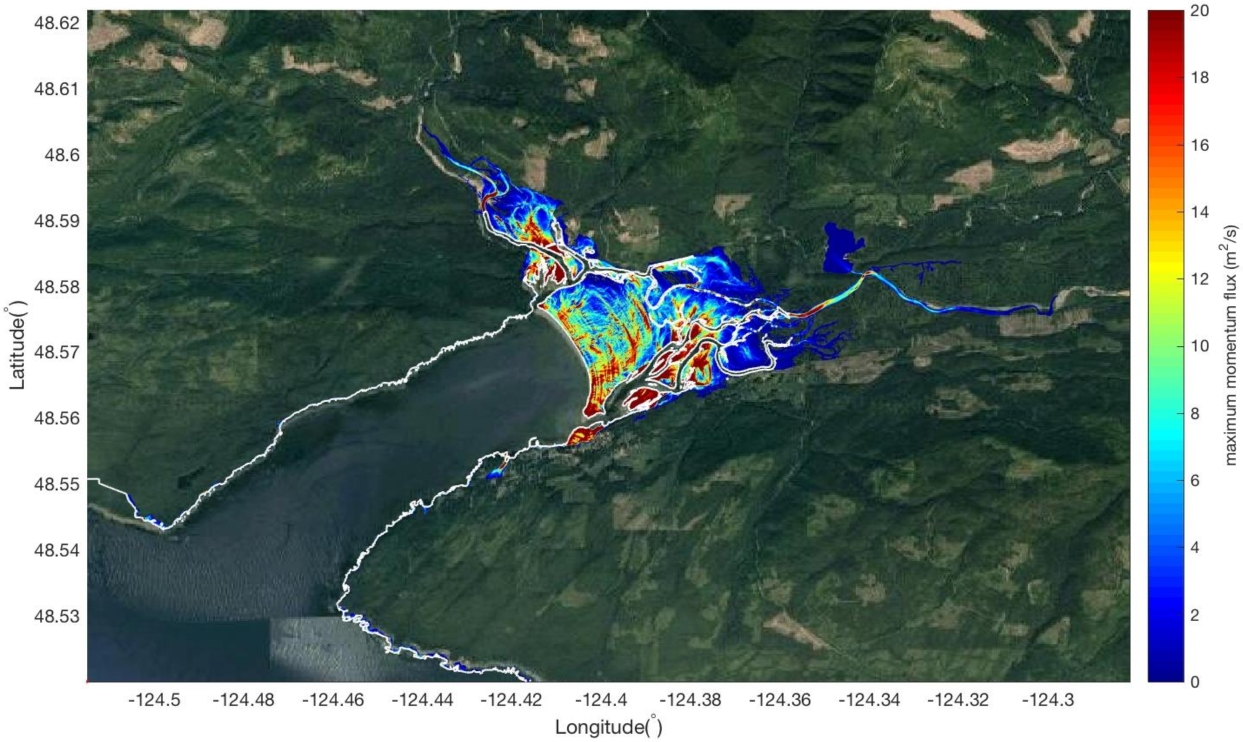
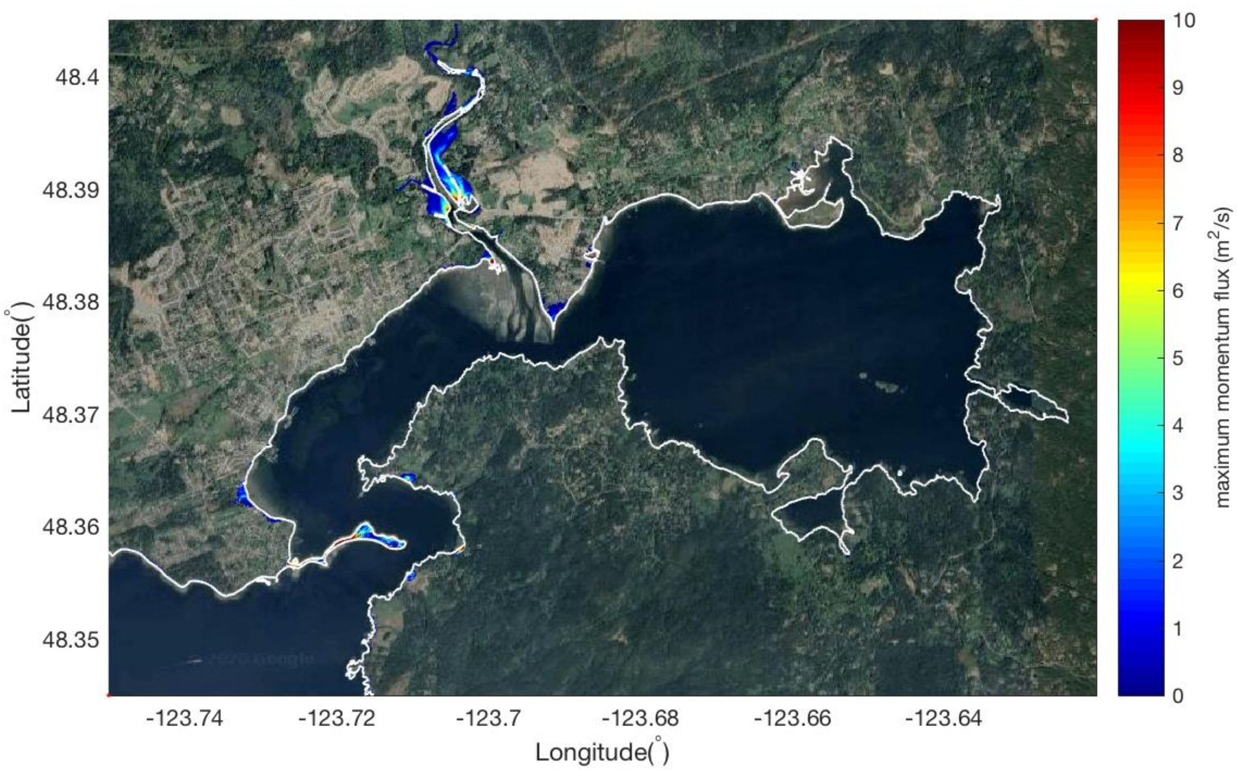
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34 -123.33 -123.32 -123.31 -123.3 -123.29 -123.28 -123.27 -123.26 -123.25
Longitude(°)
1.5
1
0.5
0
inundation depth (m)

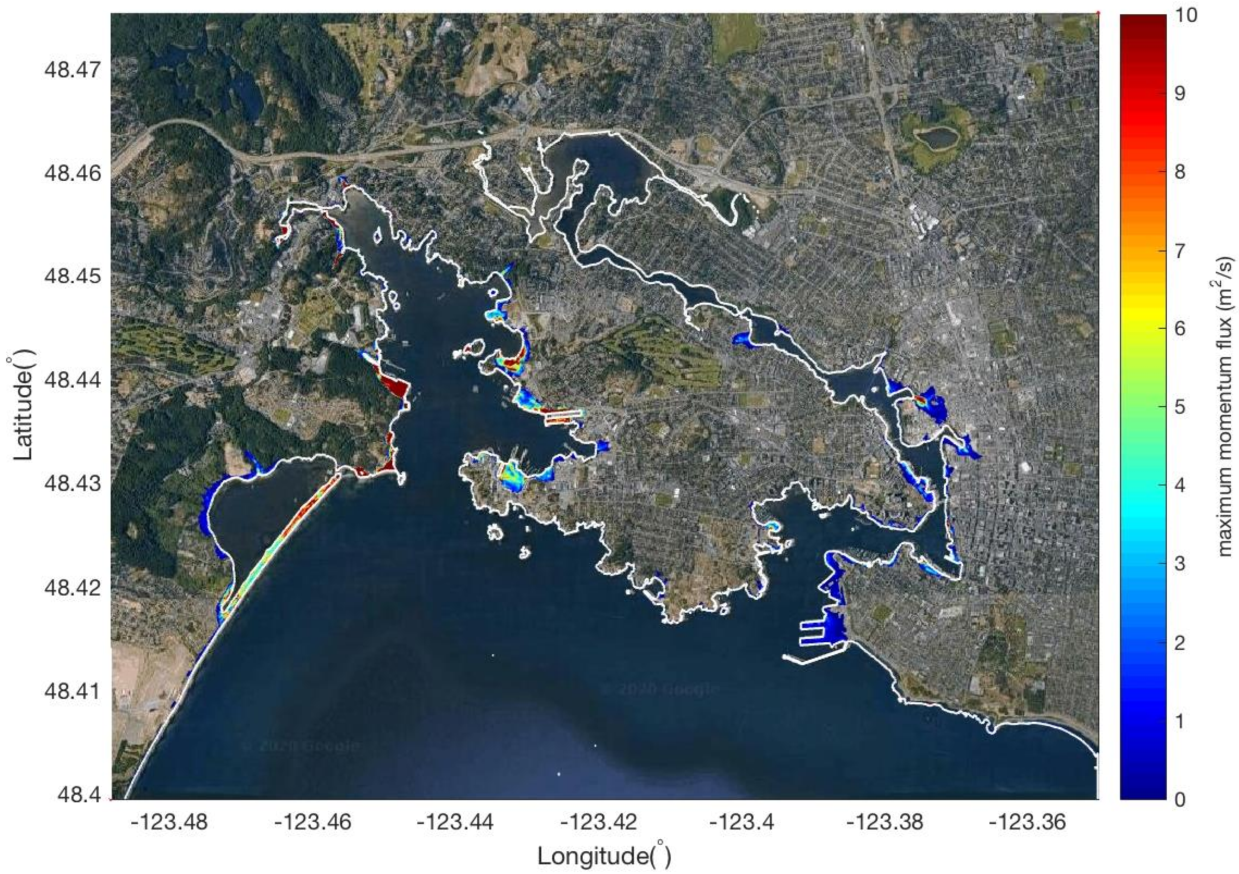


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425
-123.42
-123.415
-123.41
-123.405
-123.4
-123.395
-123.39
-123.385
-123.38
Longitude(°)
1.5
1
0.5
0
inundation depth (m)

Maximum Momentum Flux: CSZ-NS



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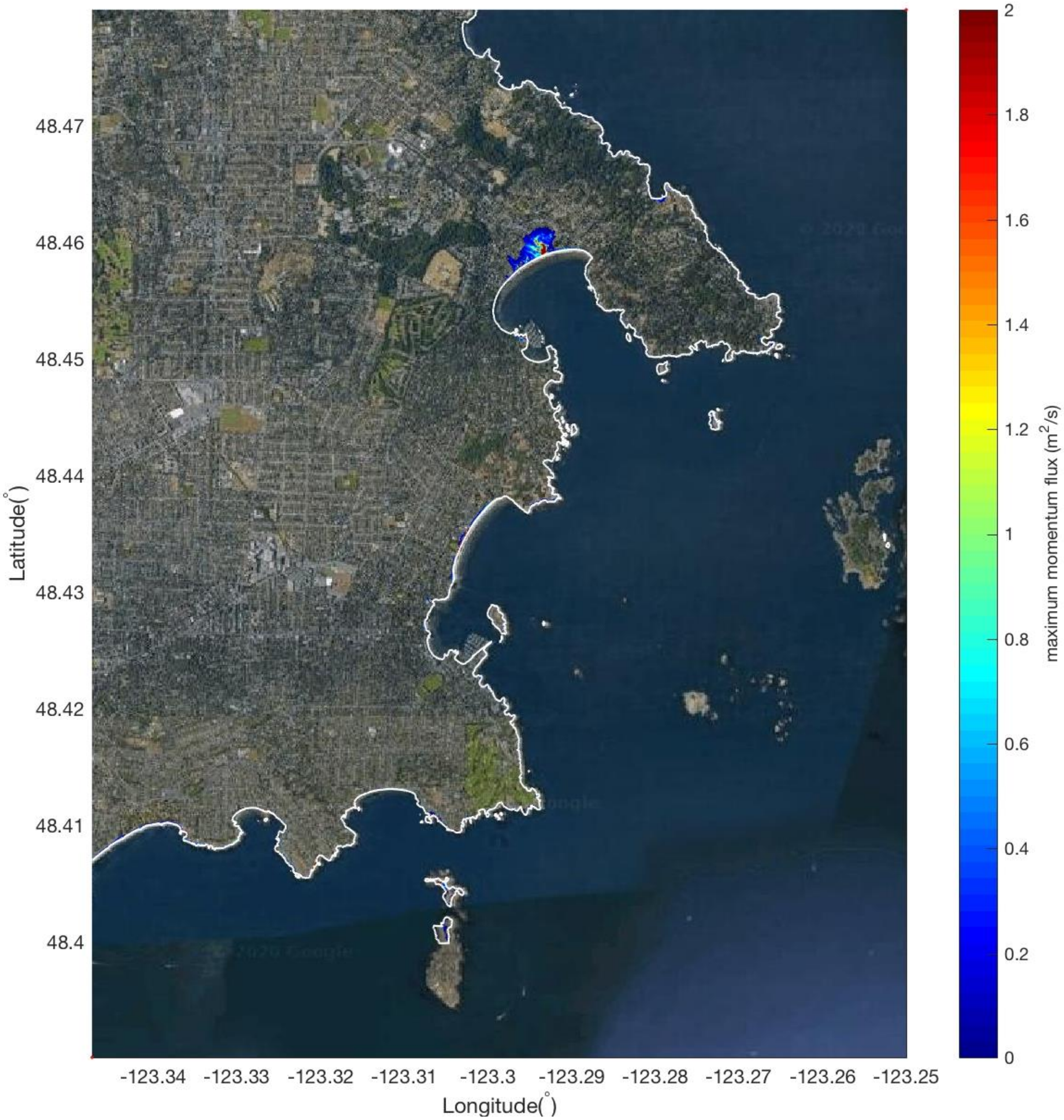
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
10
9
8
7
6
5
4
3
2
1
0
maximum momentum flux (m²/s)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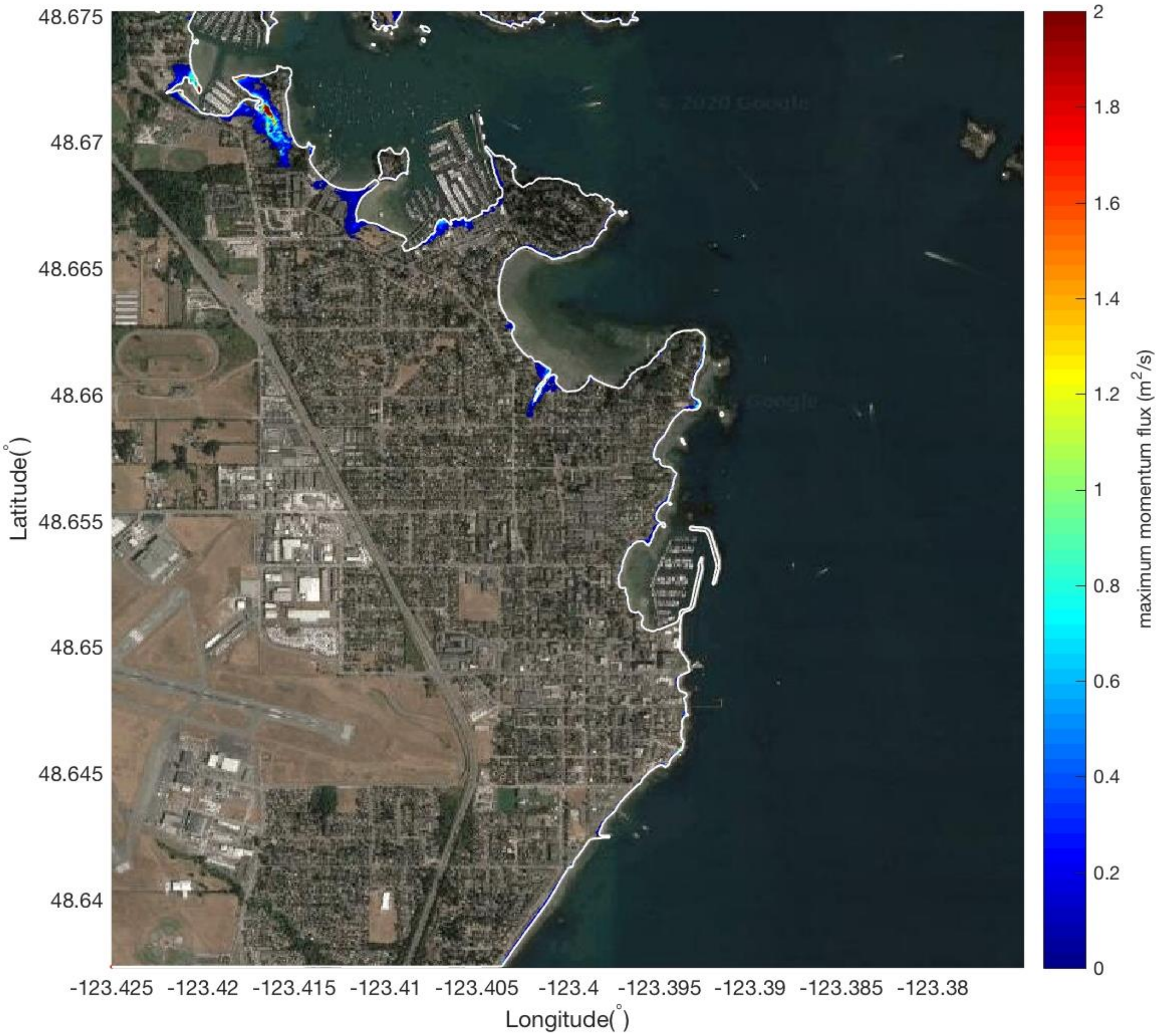
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34 -123.33 -123.32 -123.31 -123.3 -123.29 -123.28 -123.27 -123.26 -123.25
Longitude(°)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
maximum momentum flux (m²/s)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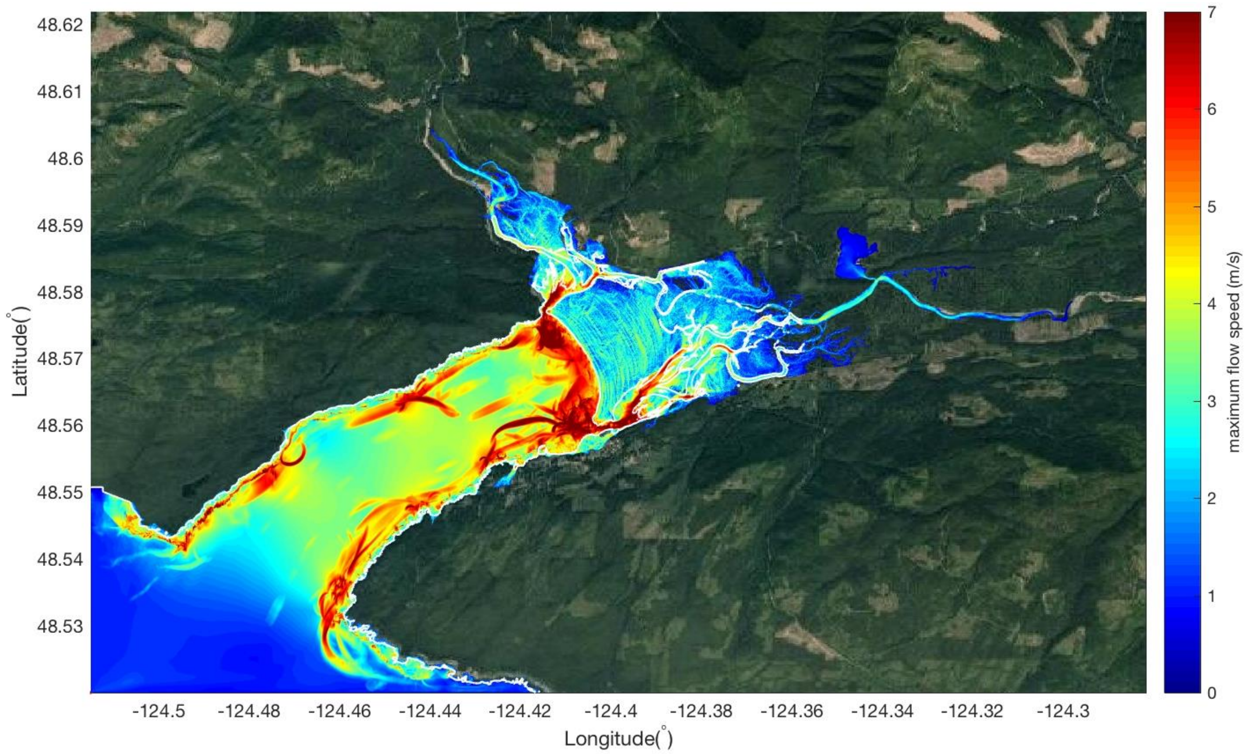
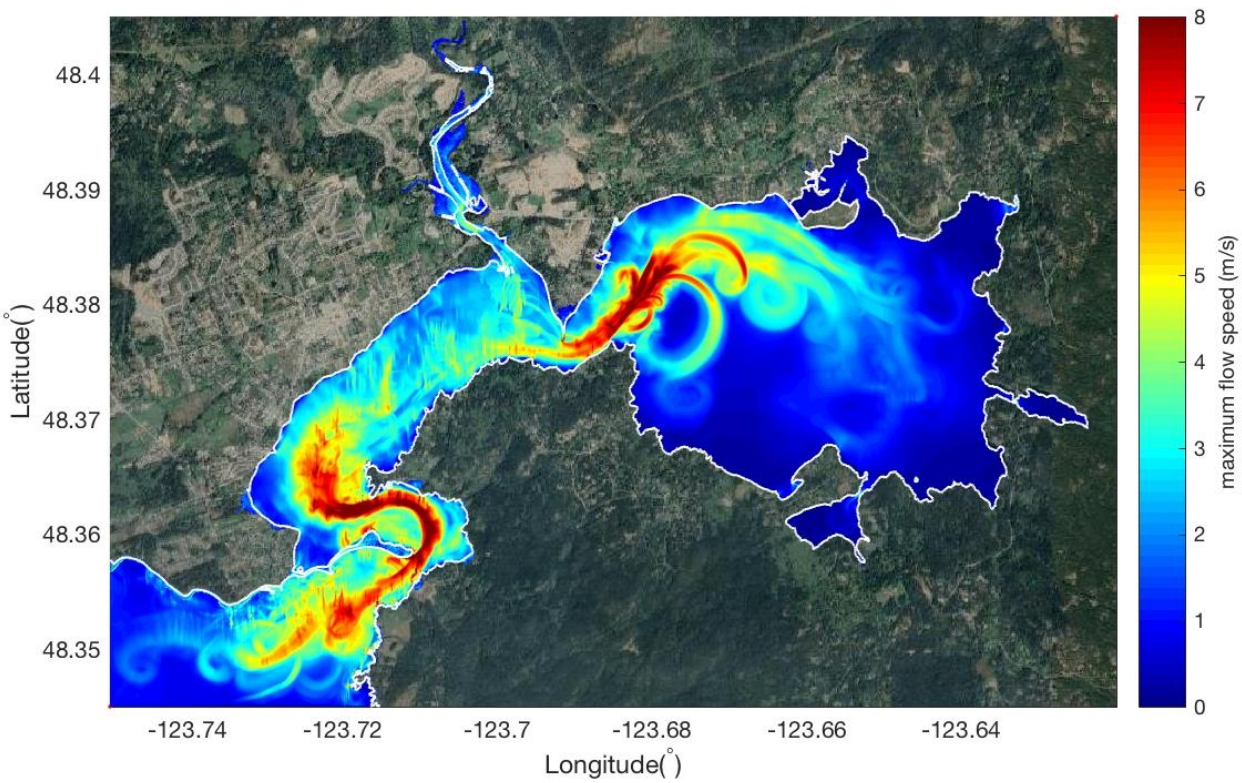
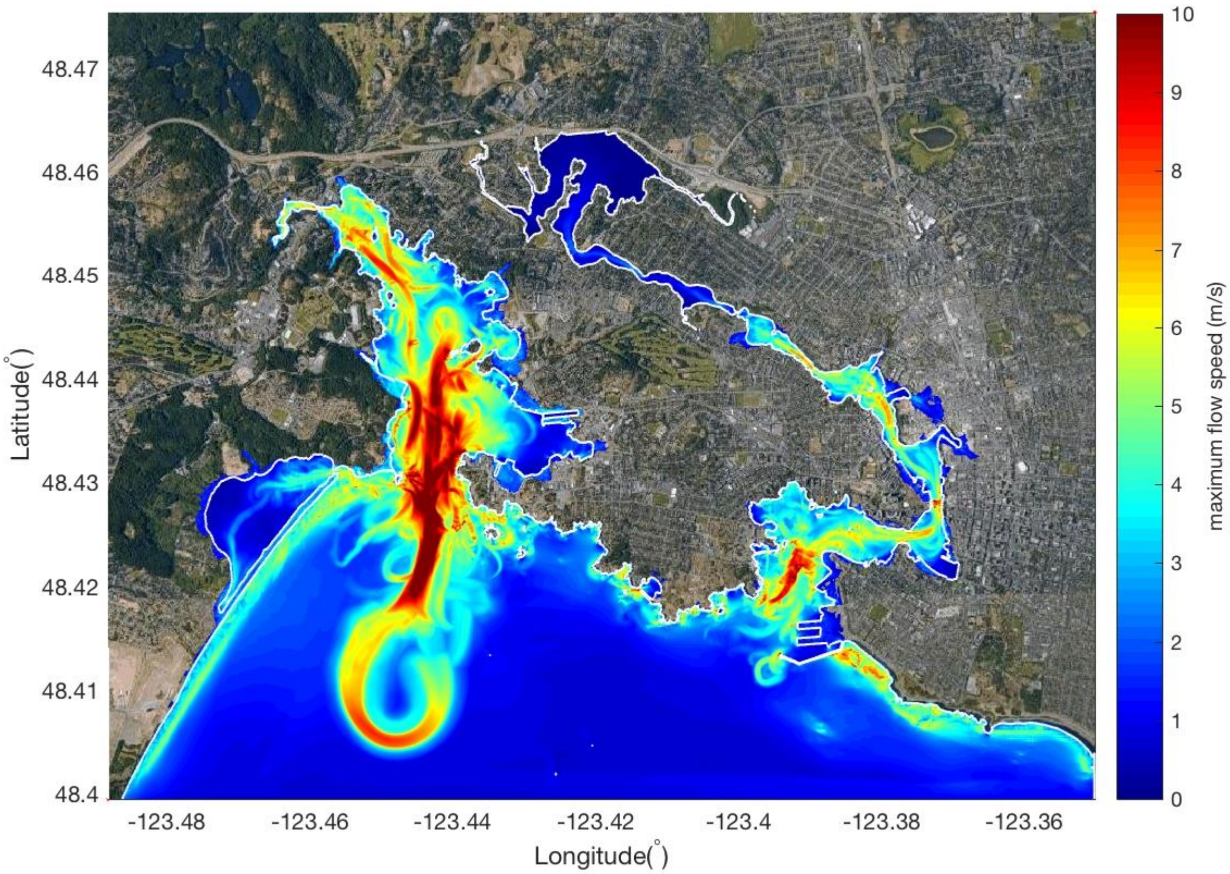
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425
-123.42
-123.415
-123.41
-123.405
-123.4
-123.395
-123.39
-123.385
-123.38
Longitude(°)
© 2020 Google
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
maximum momentum flux (m²/s)

Maximum Flow Speed: CSZ-NS



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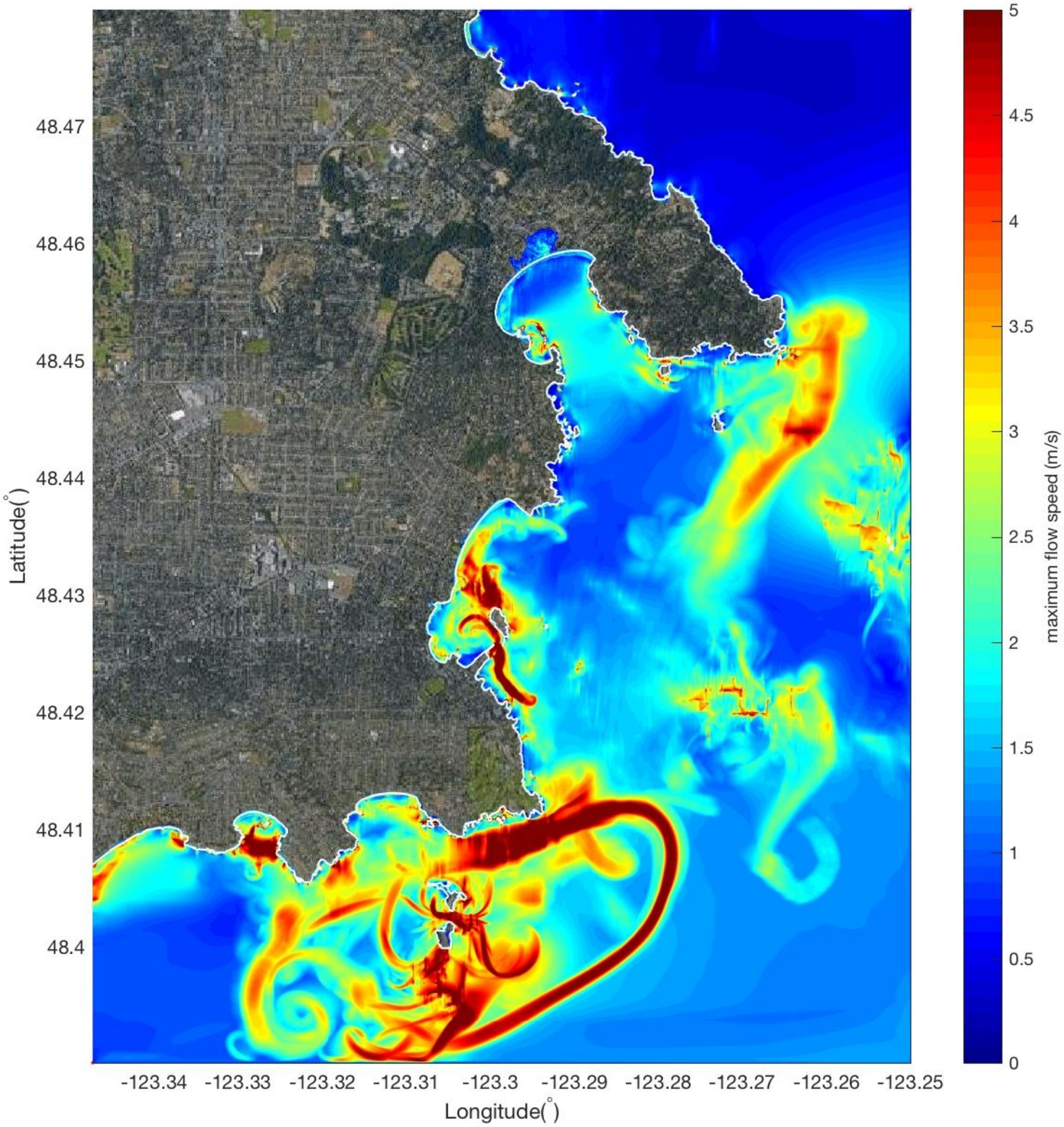
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
10
9
8
7
6
5
4
3
2
1
0
maximum flow speed (m/s)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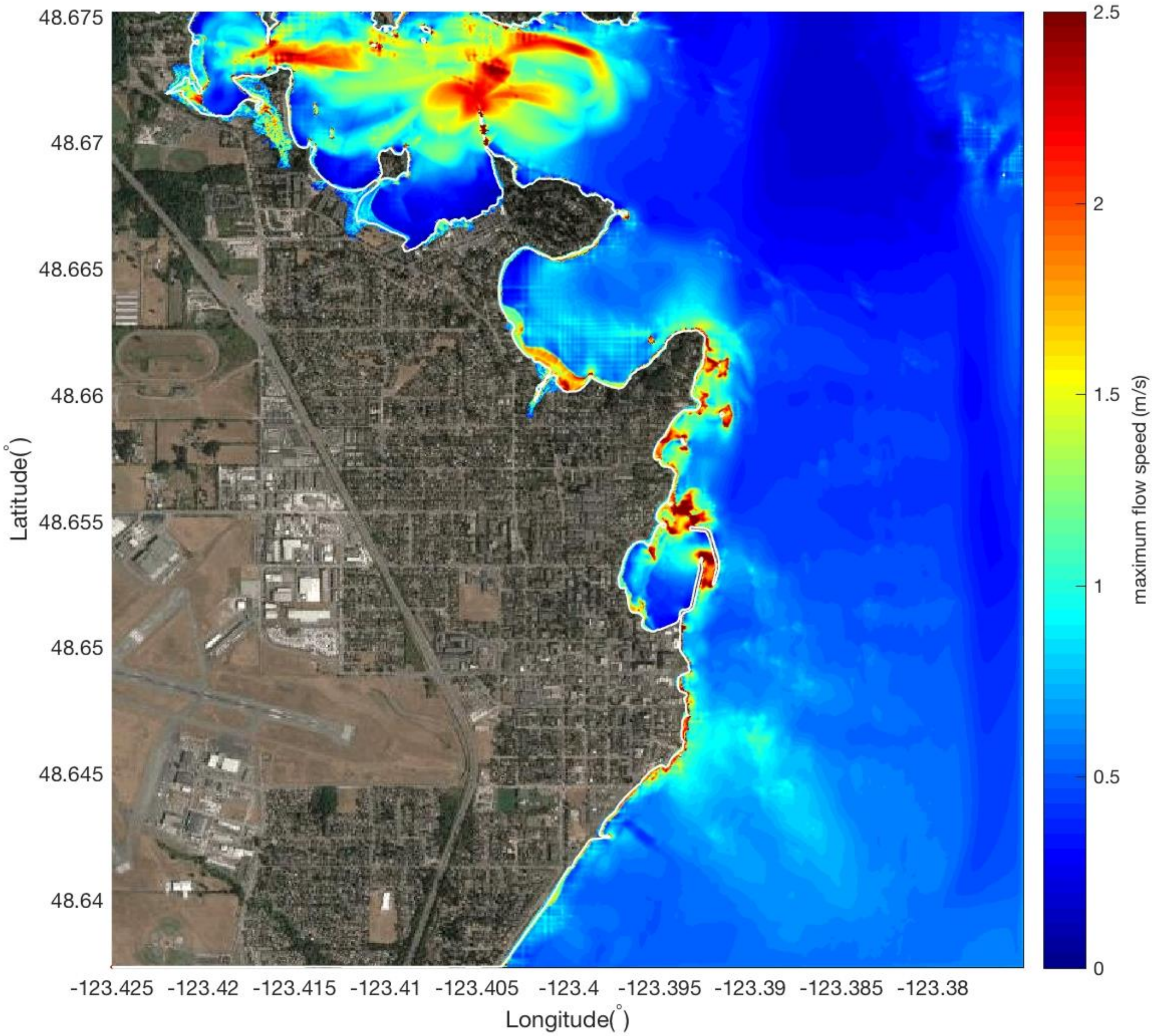
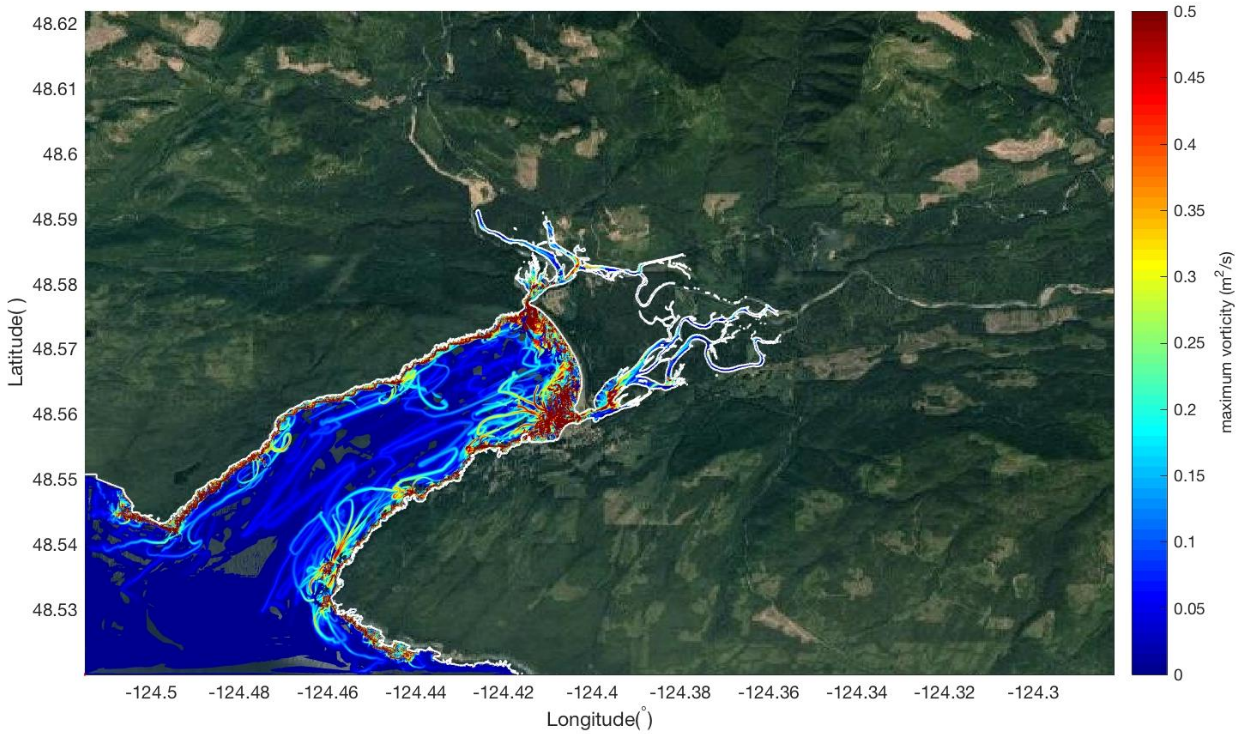
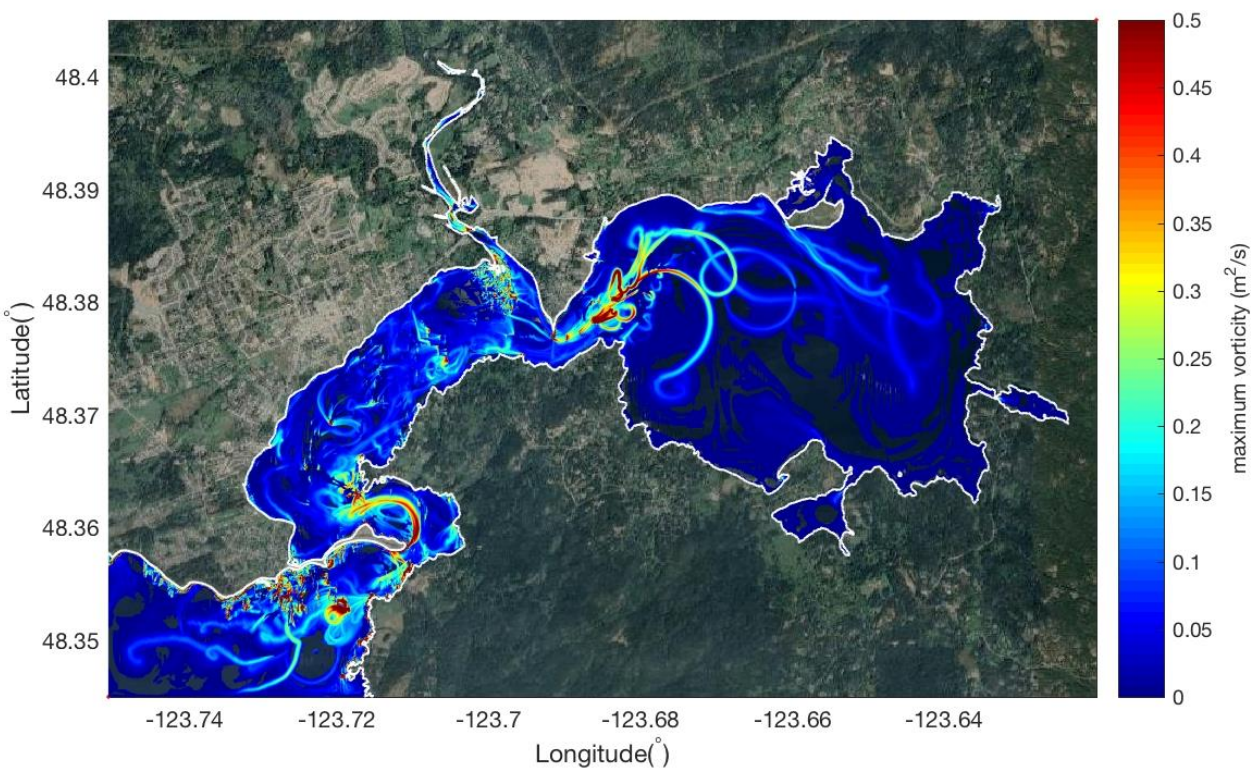
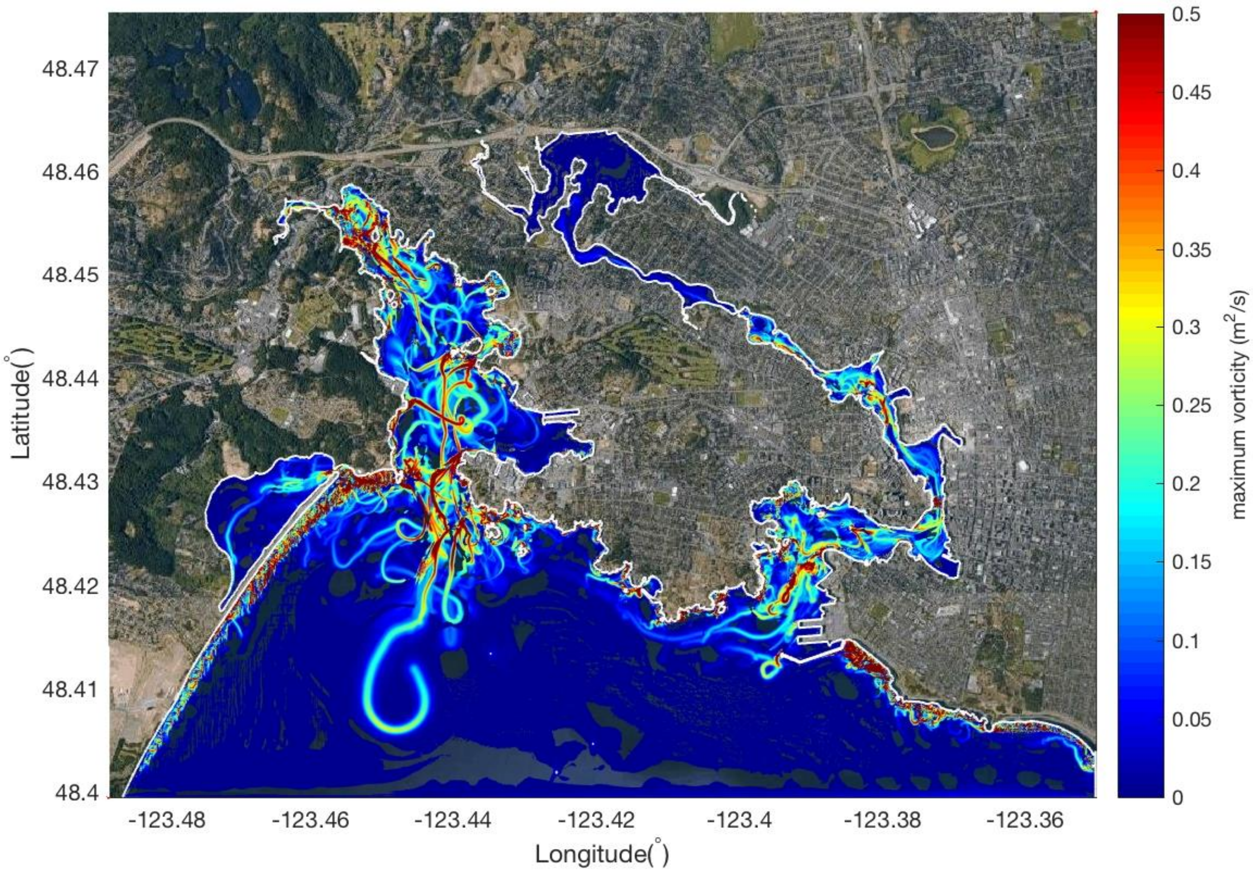
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum flow speed (m/s)


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
2.5
2
1.5
1
0.5
0
maximum flow speed (m/s)

Maximum Vorticity: CSZ-NS



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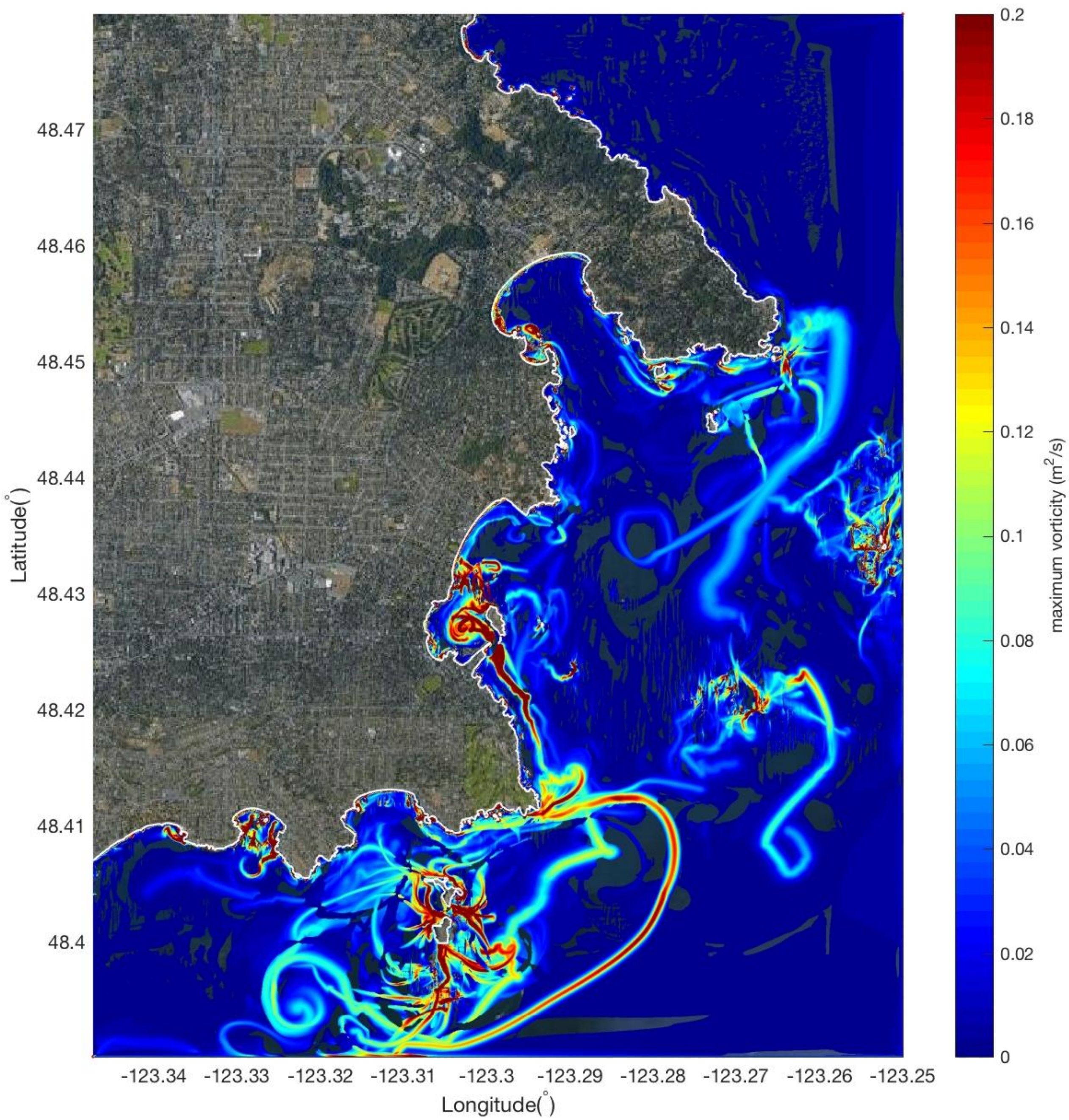
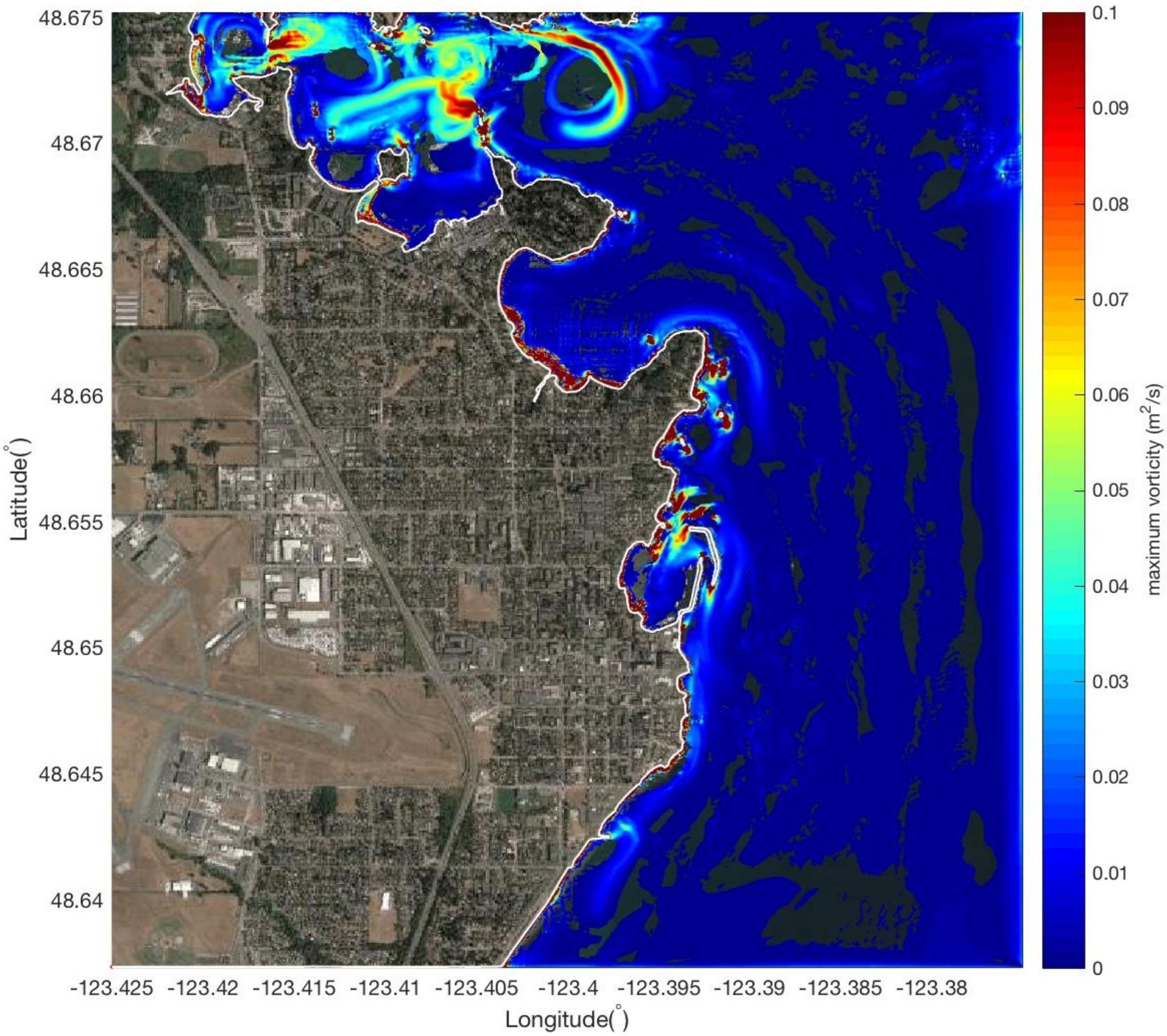
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum vorticity (m²/s)



48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
maximum vorticity (m²/s)

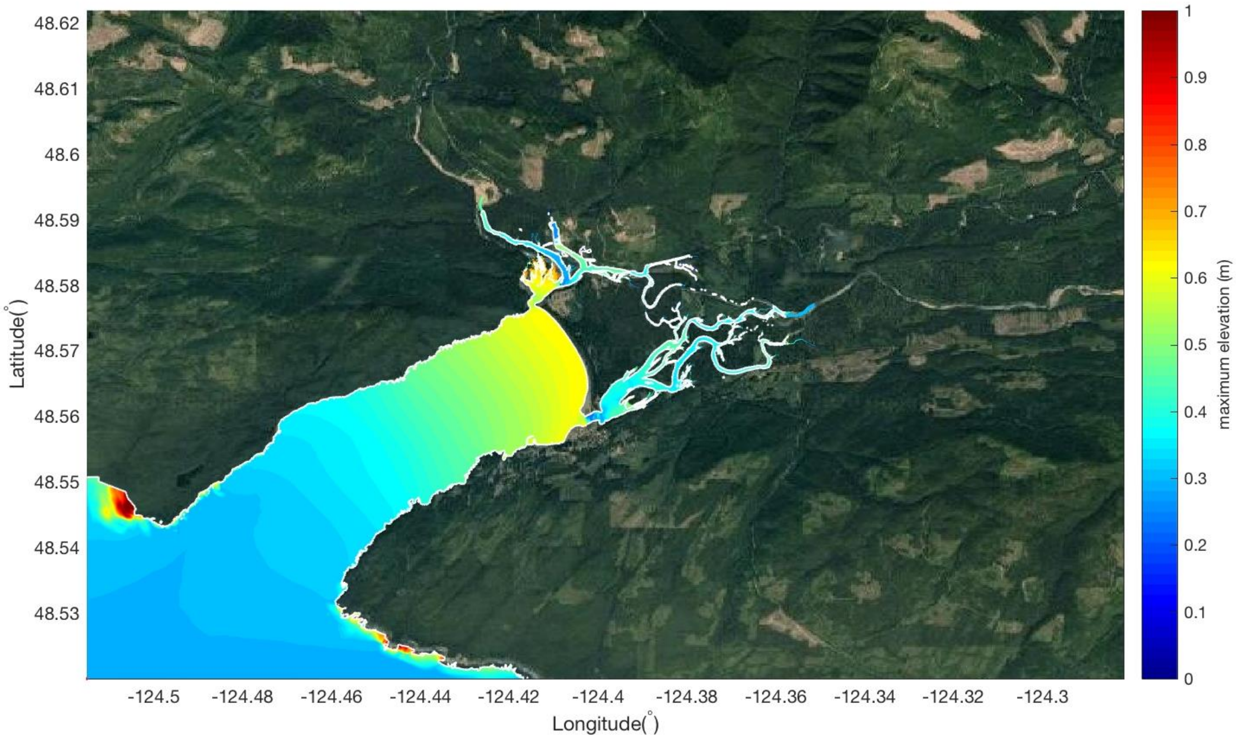

48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425
-123.42
-123.415
-123.41
-123.405
-123.4
-123.395
-123.39
-123.385
-123.38
Longitude(°)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
maximum vorticity (m2/s)

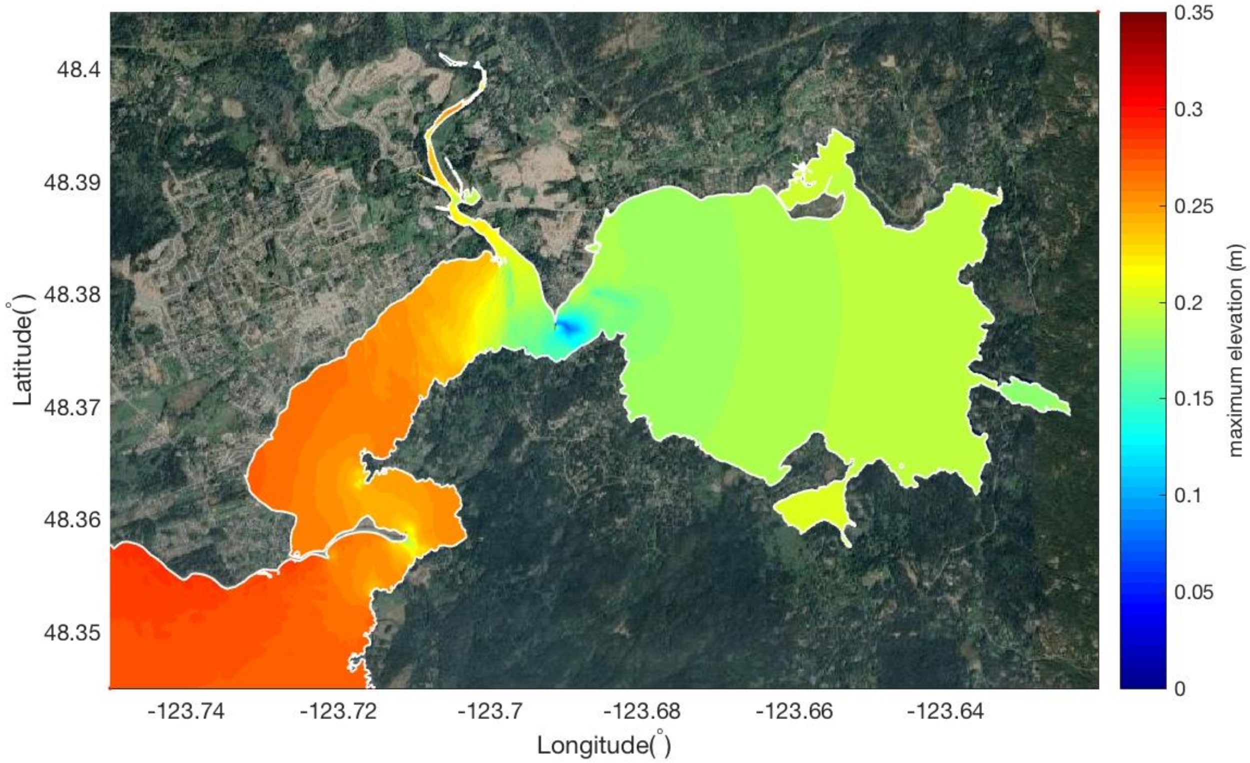
APPENDIX G - DETAILED INUNDATION GRID RESULTS: CSZ-CS

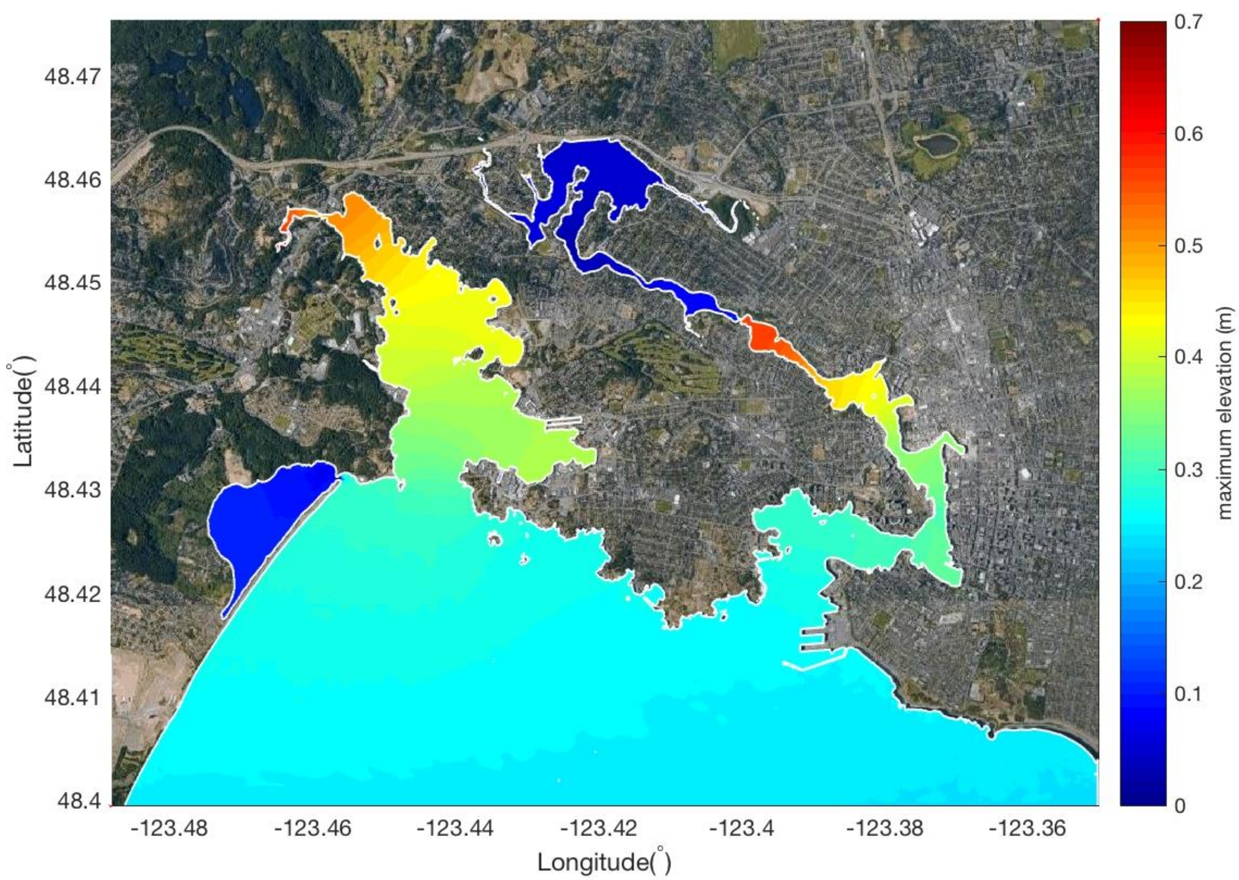
This appendix presents results for the CSZ-CS event, for each detailed modelling domain. For each result parameter, the results are presented in the following order: Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

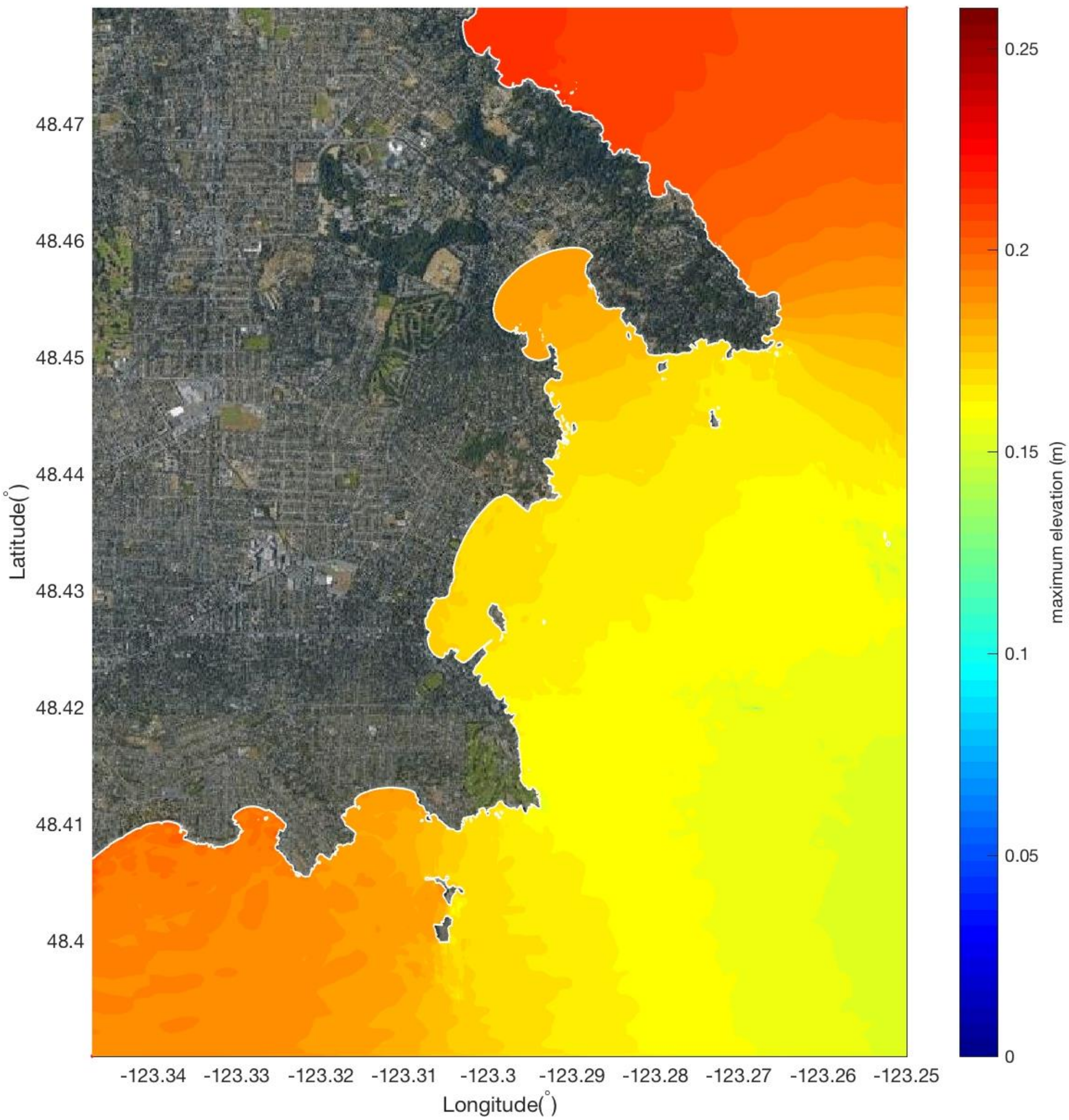
Maximum Water Surface Elevations: CSZ-CS

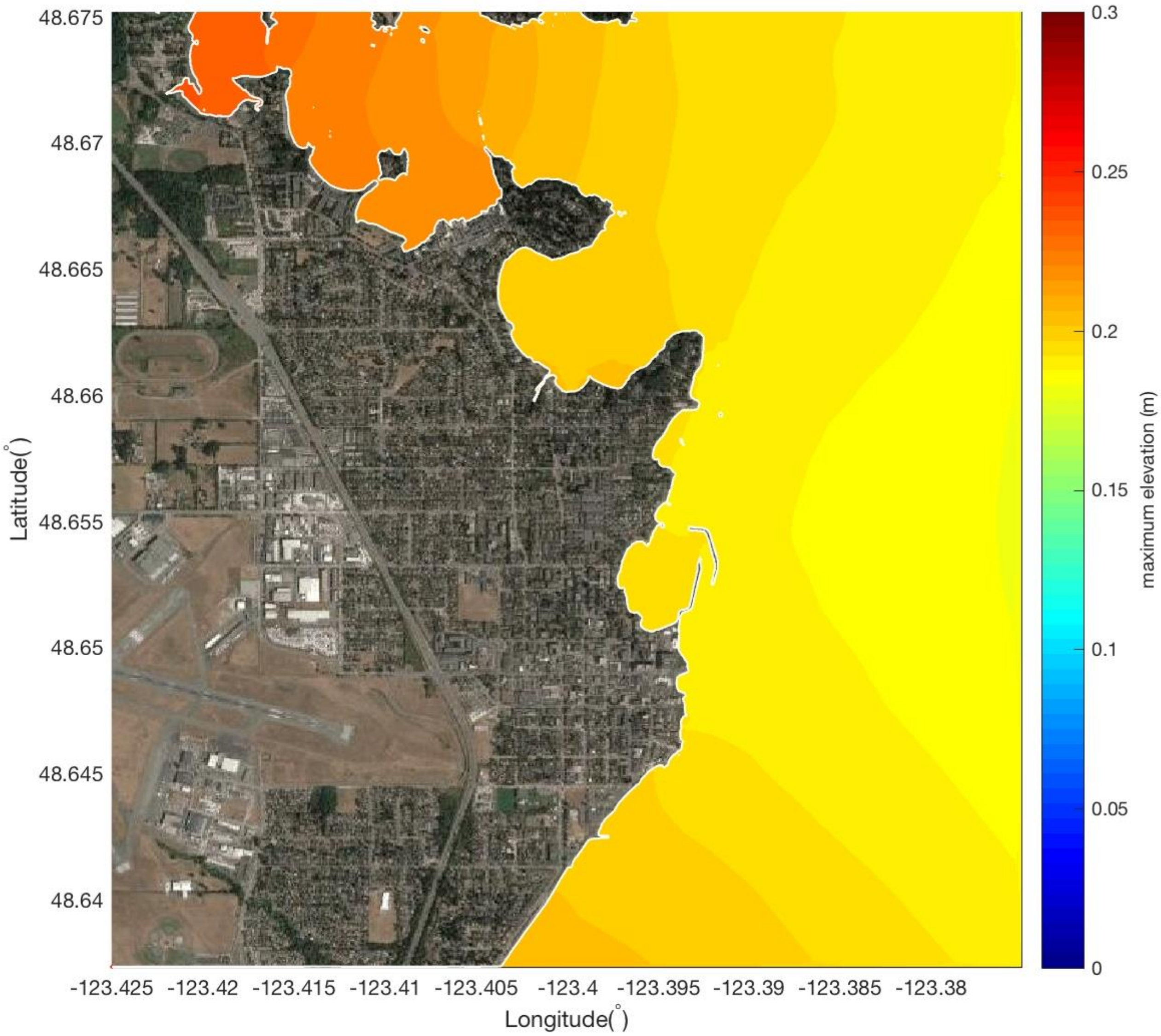
(Elevations are reported to m above HHWMT datum)




48.4
48.39
48.38
48.37
48.36
48.35
Latitude(°)
-123.74
-123.72
-123.7
-123.68
-123.66
-123.64
Longitude(°)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum elevation (m)


48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(°)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
maximum elevation (m)


48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
0.25
0.2
0.15
0.1
0.05
0
maximum elevation (m)


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum elevation (m)

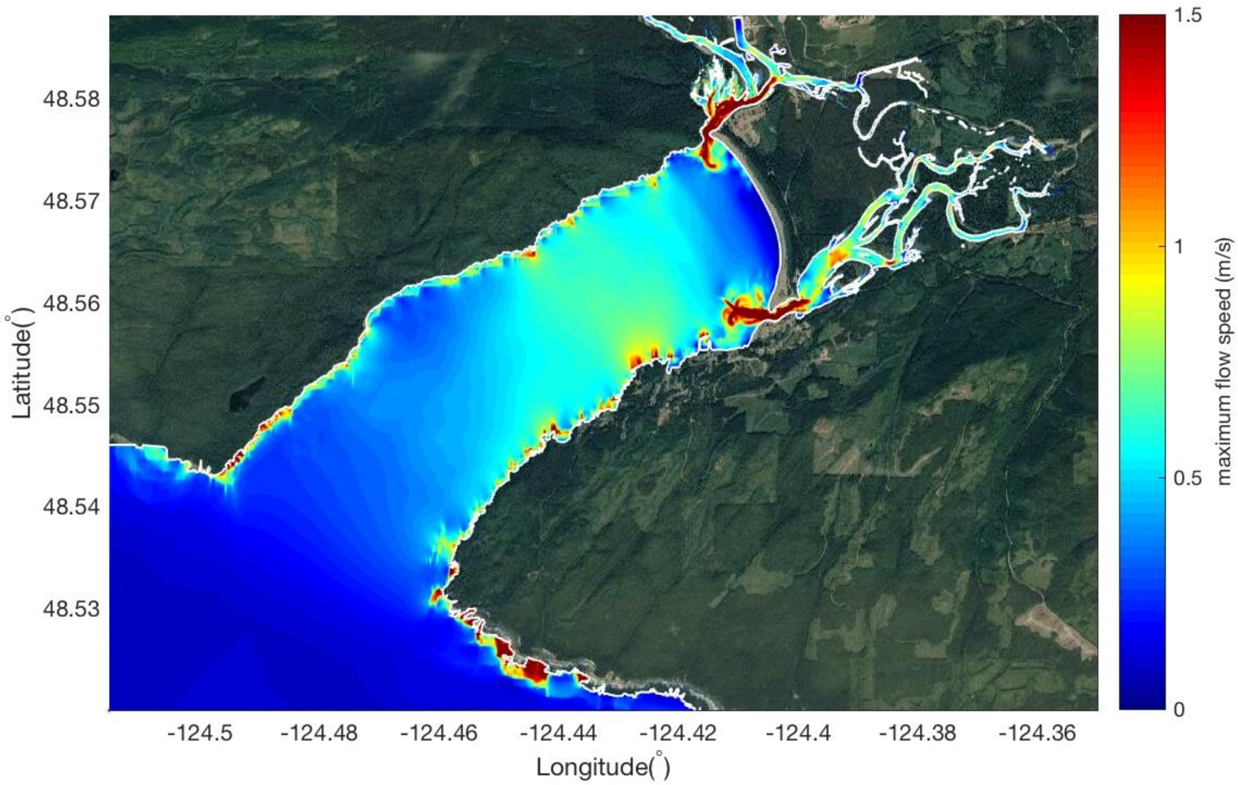
Maximum Inundation Depths: CSZ-CS

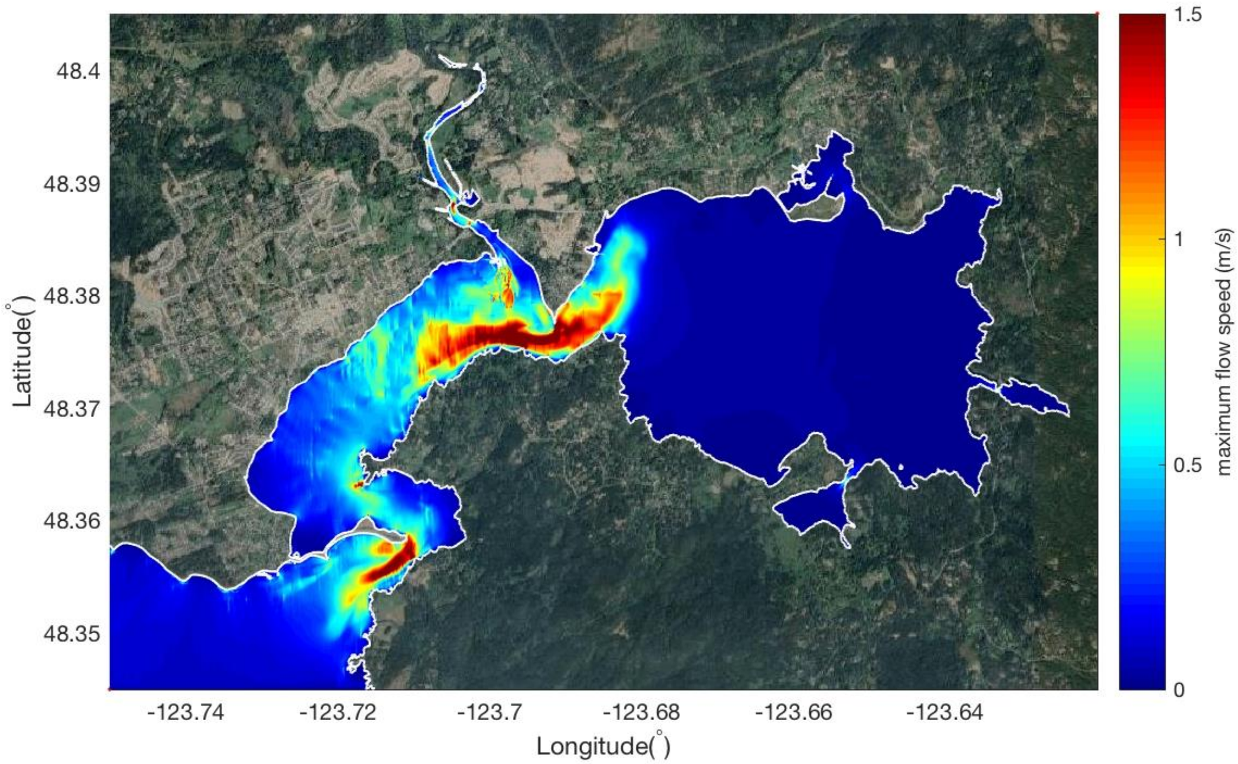
There was no inundation associated with CSZ-CS in the detailed model domains.

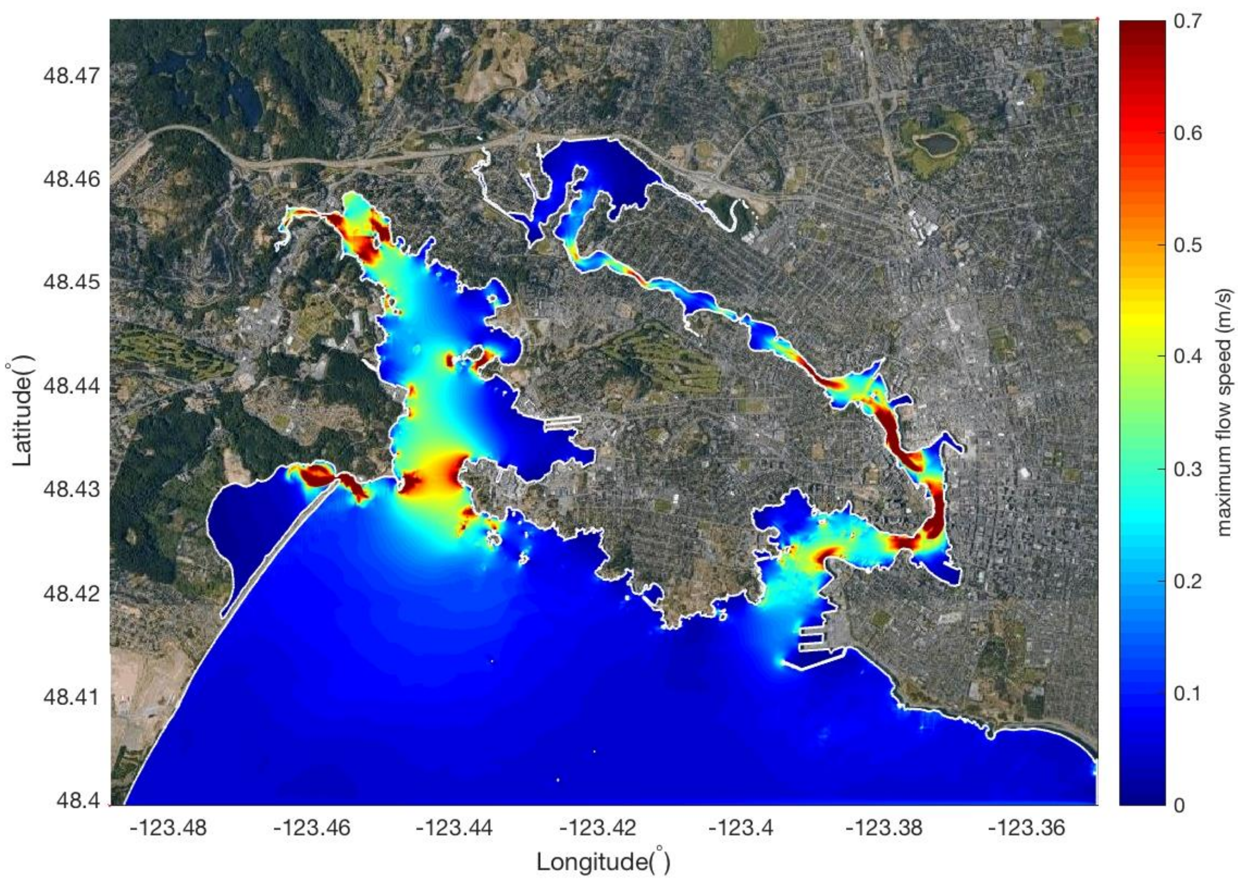
Maximum Momentum Flux: CSZ-CS

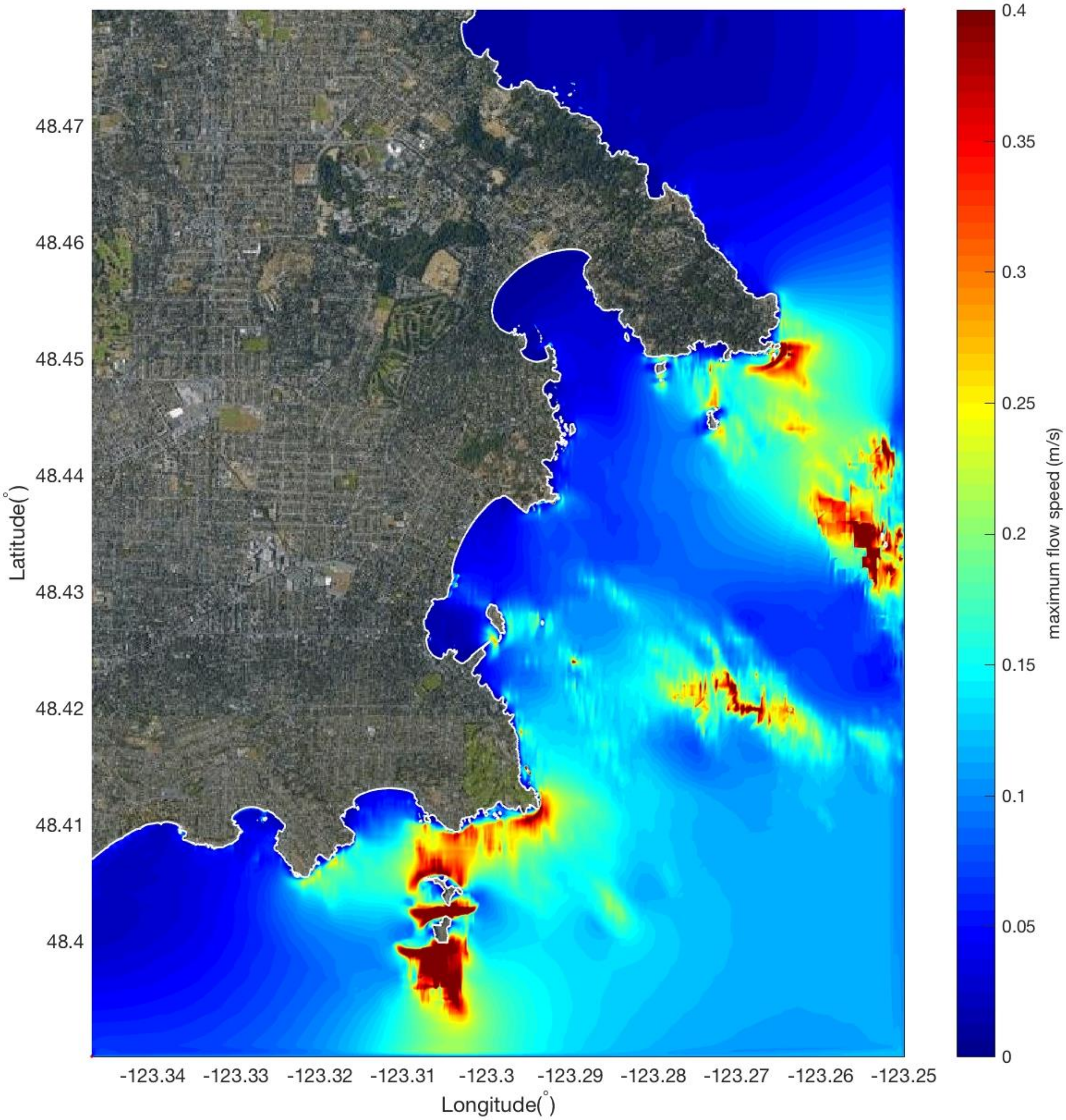
There were no momentum flux plots produced for CSZ-CS in the detailed model domains.

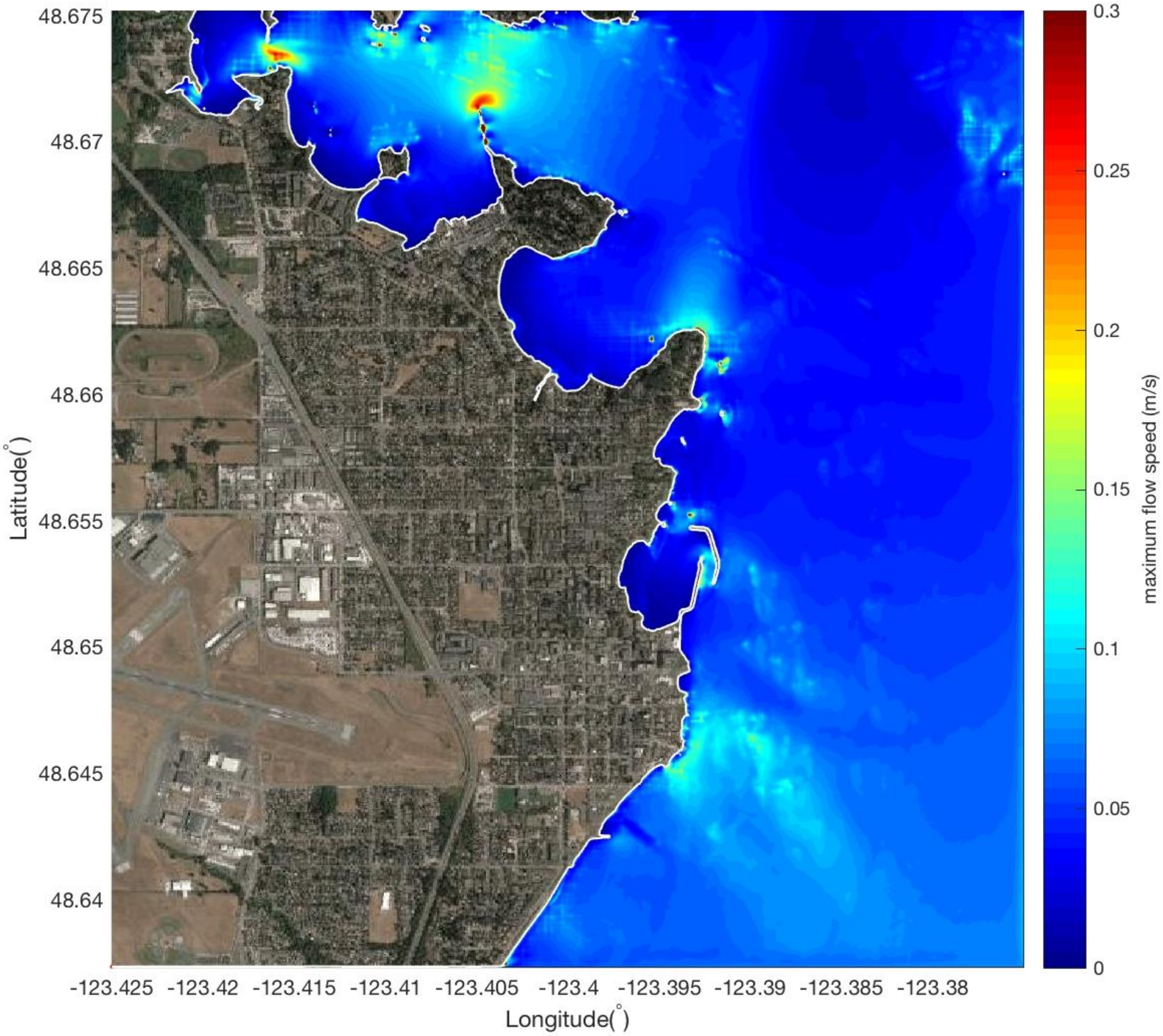
Maximum Flow Speed: CSZ-CS




48.4
48.39
48.38
48.37
48.36
48.35
Latitude(˚)
-123.74
-123.72
-123.7
-123.68
-123.66
-123.64
Longitude(˚)
1.5
1
0.5
0
maximum flow speed (m/s)


48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(˚)
-123.48
-123.46
-123.44
-123.42
-123.4
-123.38
-123.36
Longitude(˚)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
maximum flow speed (m/s)


48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34 -123.33 -123.32 -123.31 -123.3 -123.29 -123.28 -123.27 -123.26 -123.25
Longitude(°)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum flow speed (m/s)



Maximum Vorticity: CSZ-CS

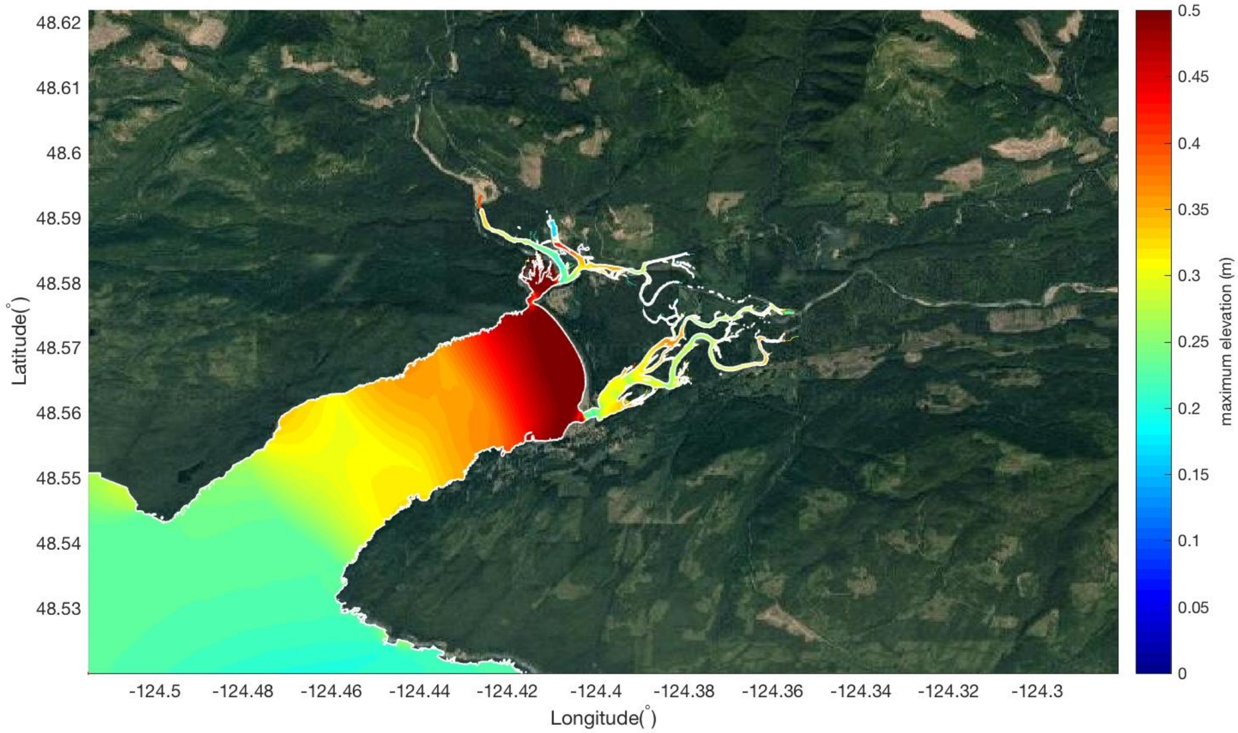
There were no vorticity plots produced for CSZ-CS for the detailed model domains.

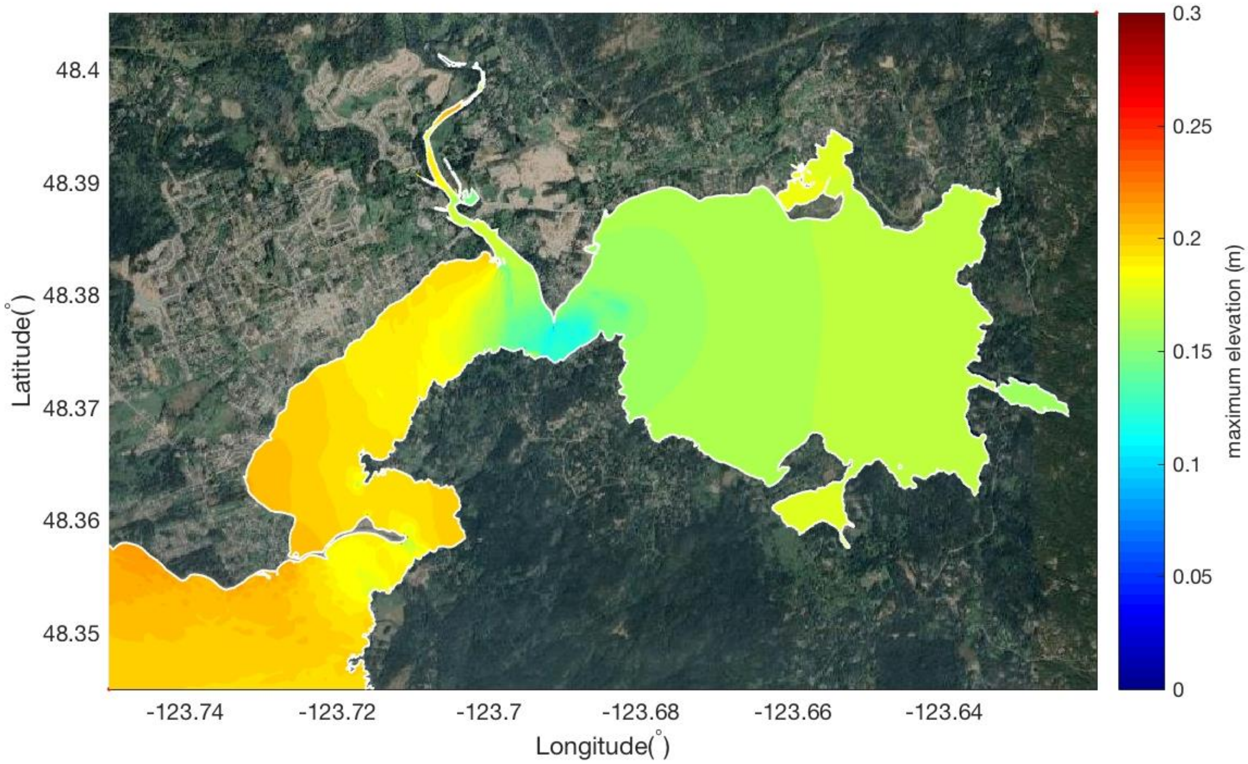
APPENDIX H - DETAILED INUNDATION GRID RESULTS: ALASKA 1964 (AL)

This appendix presents results for the AL event, for each detailed modelling domain. For each result parameter, the results are presented in the following order: Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

Maximum Water Surface Elevations: AL

(Elevations are reported to m above HHWMT datum)





AL results not produced for other detailed model areas as effects dissipate east of Sooke.

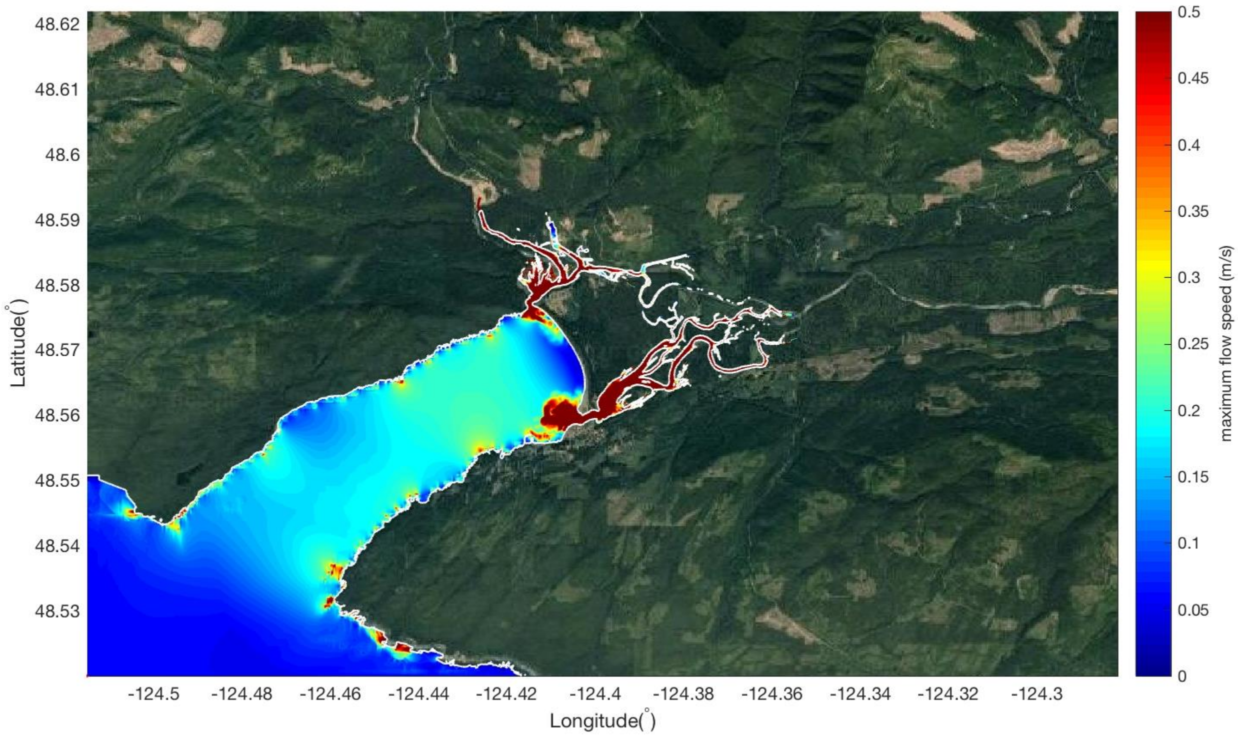
Maximum Inundation Depths: AL

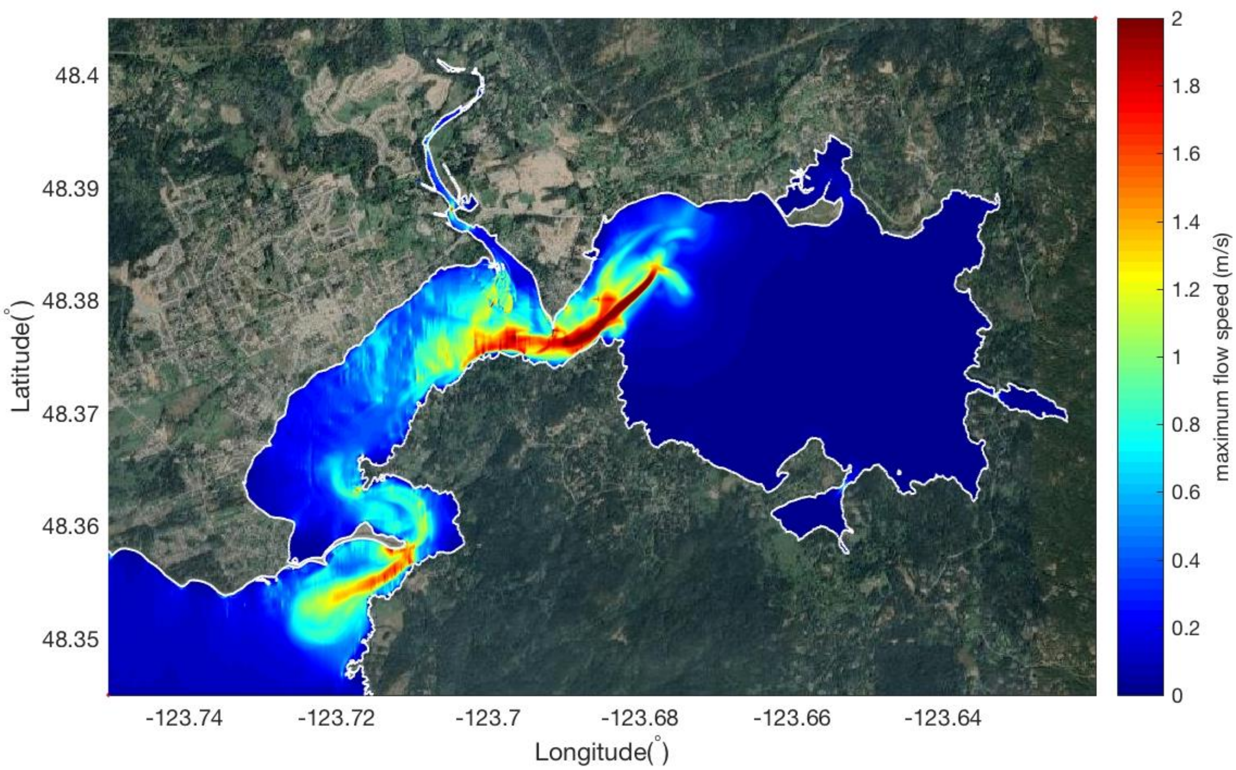
There was no inundation associated with AL event.

Maximum Momentum Flux: CSZ-CS

There were no momentum flux plots produced for AL in the detailed model domains.

Maximum Flow Speed: AL





Maximum Vorticity: AL

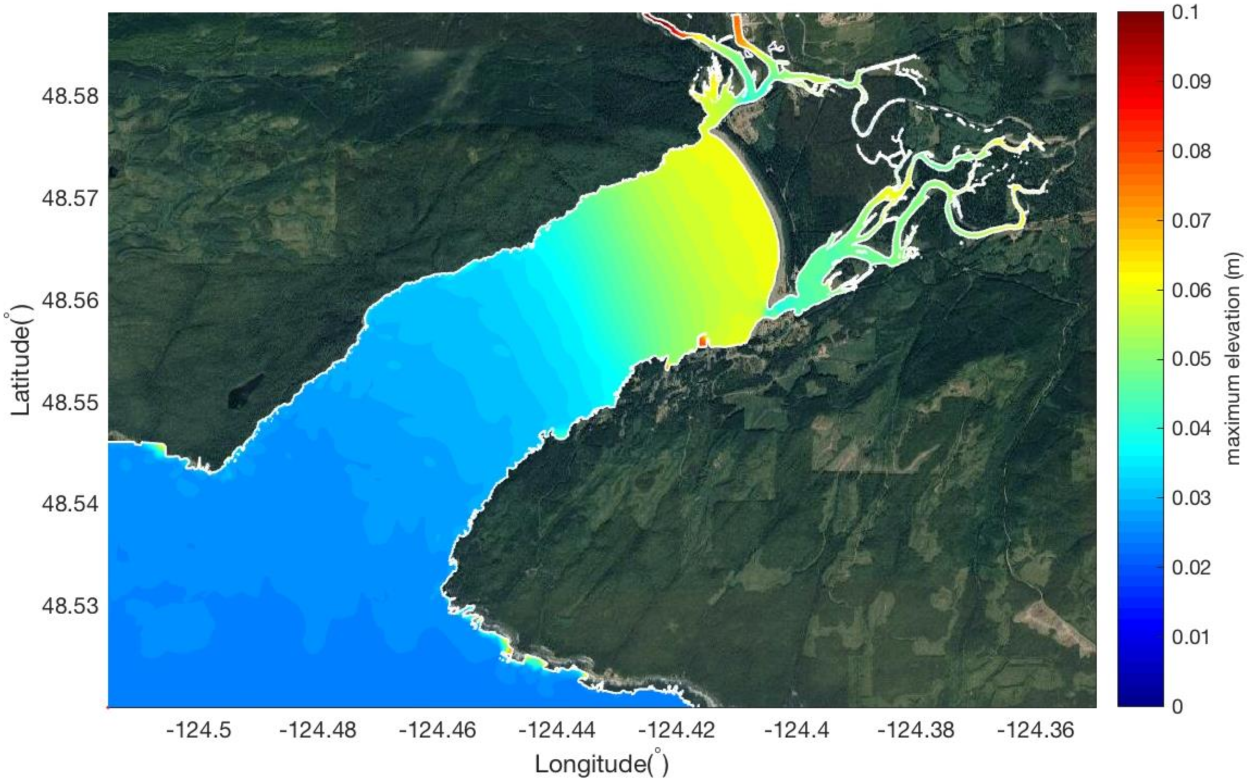
There were no vorticity plots produced for AL in the detailed model domains.

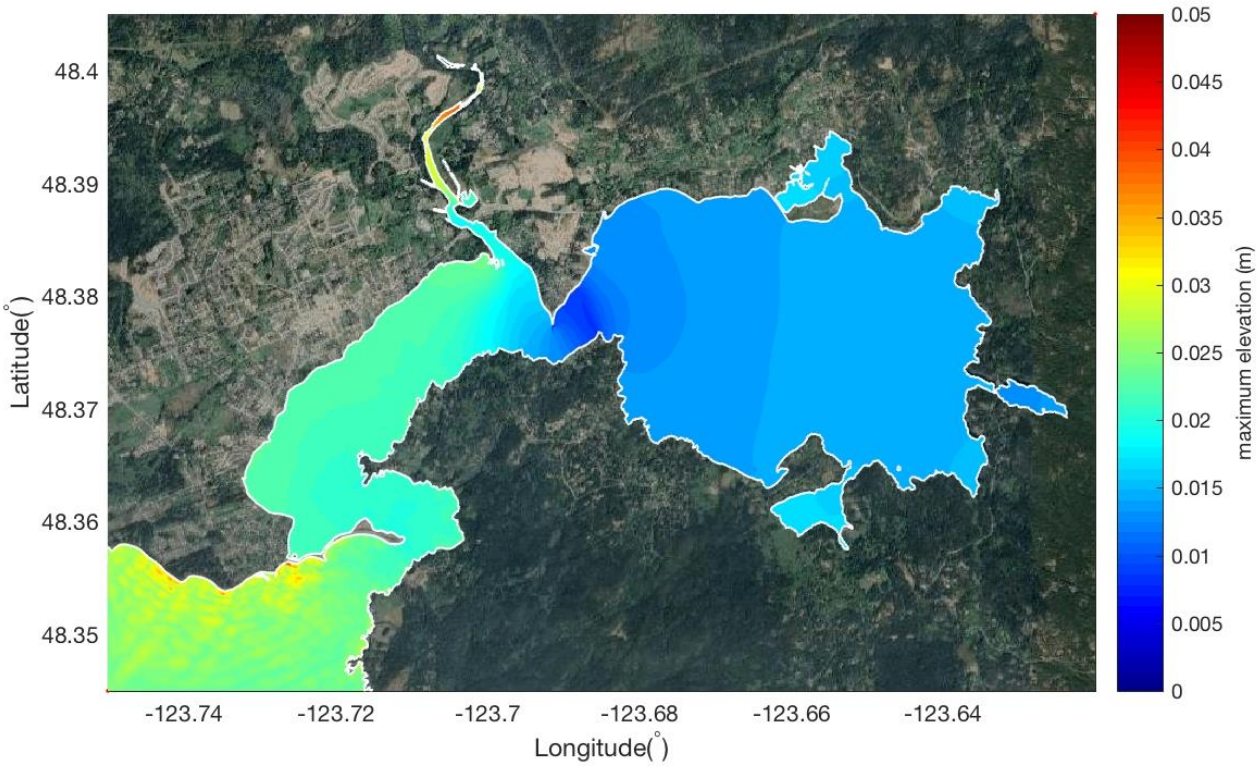
APPENDIX I - DETAILED INUNDATION GRID RESULTS: ALASKA UNIMAK 1947 (UN)

This appendix presents results for the UN event, for each detailed modelling domain. For each result parameter, the results are presented in the following order: Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

Maximum Water Surface Elevations: UN

(Elevations are reported to m above HHWMT datum)





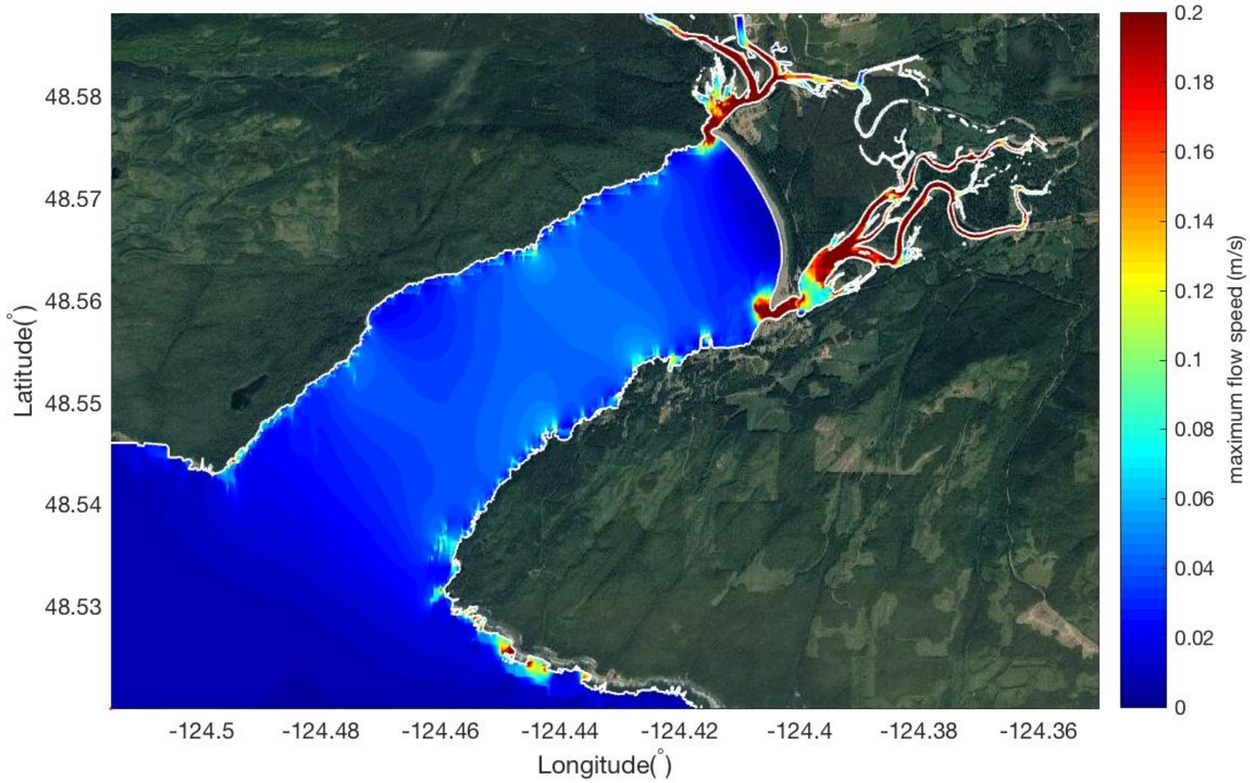
Maximum Inundation Depths: UN

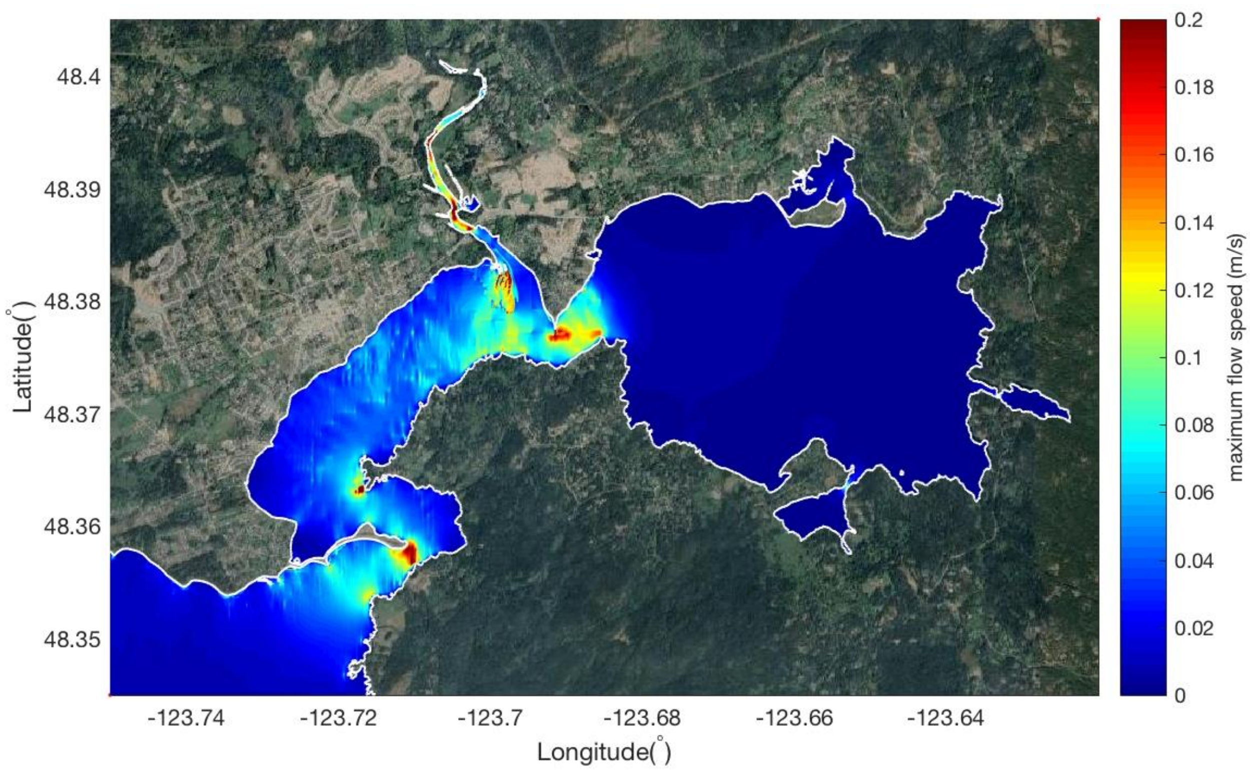
There was no inundation associated with UN event.

Maximum Momentum Flux: UN

There were no momentum flux plots produced for UN in the detailed model domains.

Maximum Flow Speed: UN





Maximum Vorticity: UN

There were no vorticity plots produced for UN in the detailed model domains.

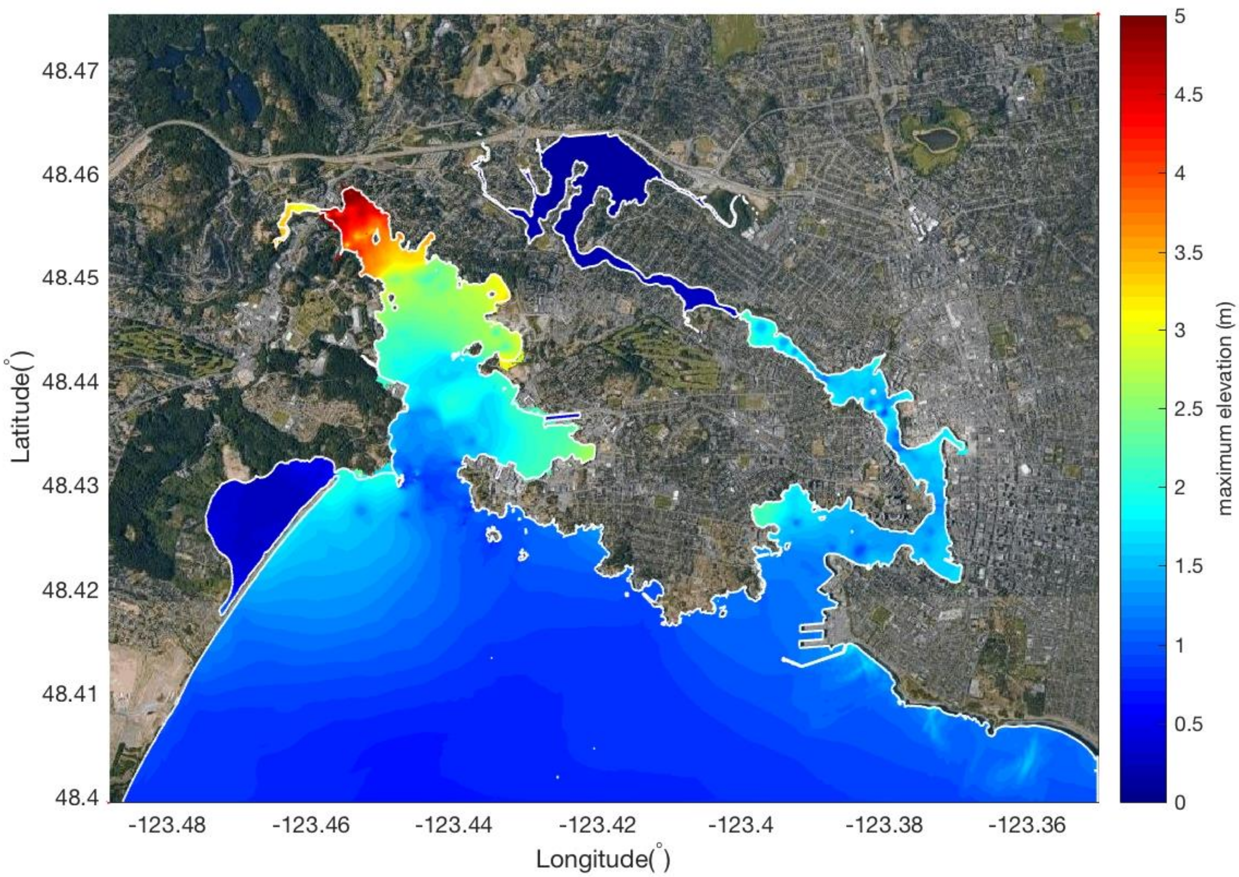
APPENDIX J - DETAILED INUNDATION GRID RESULTS: SOUTHERN WHIDBEY ISLAND, MW 7.5 (SW1)

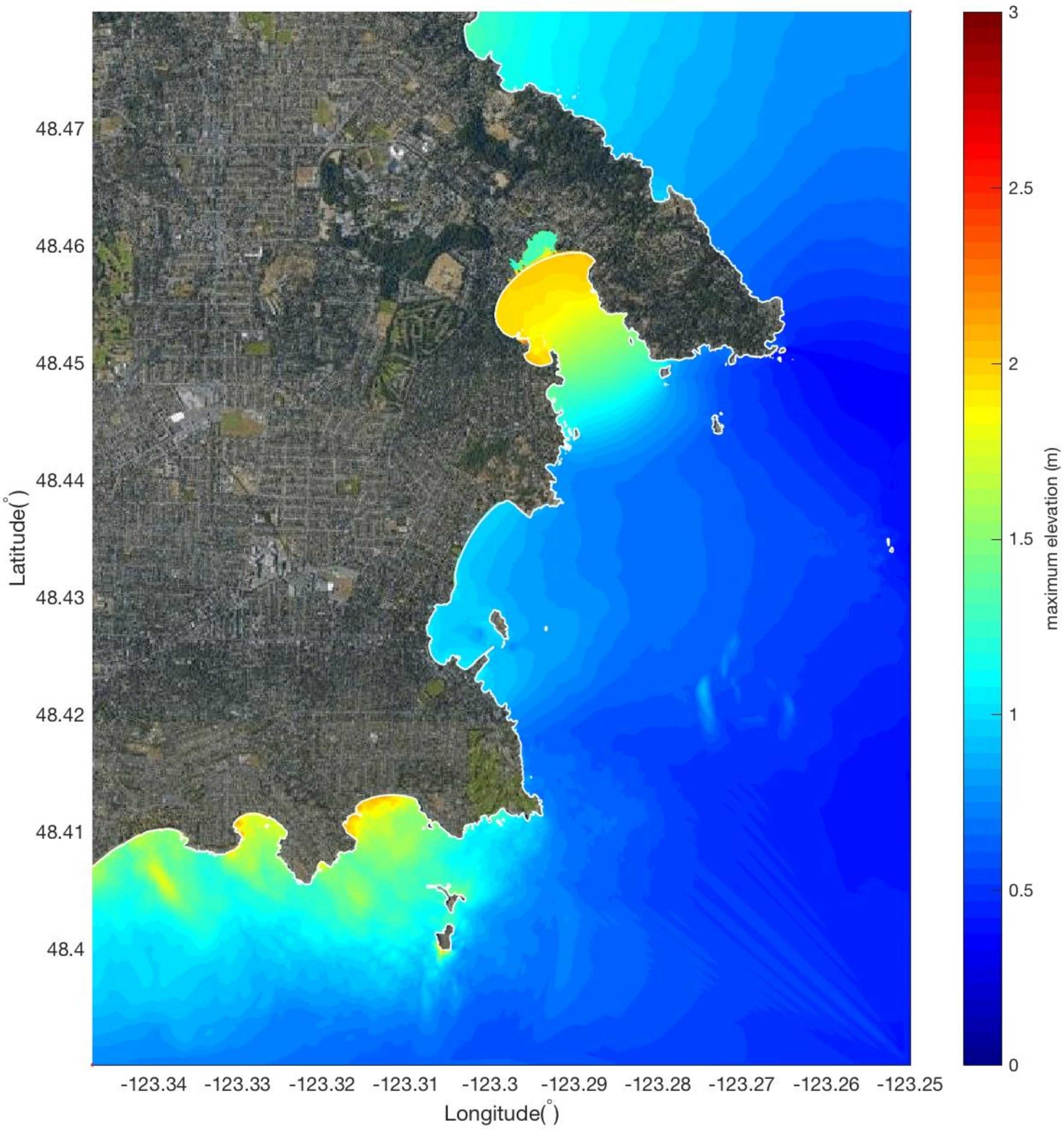
This appendix presents results for the SW1 event, for each detailed modelling domain. For each result parameter, the results are presented in the following order: Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

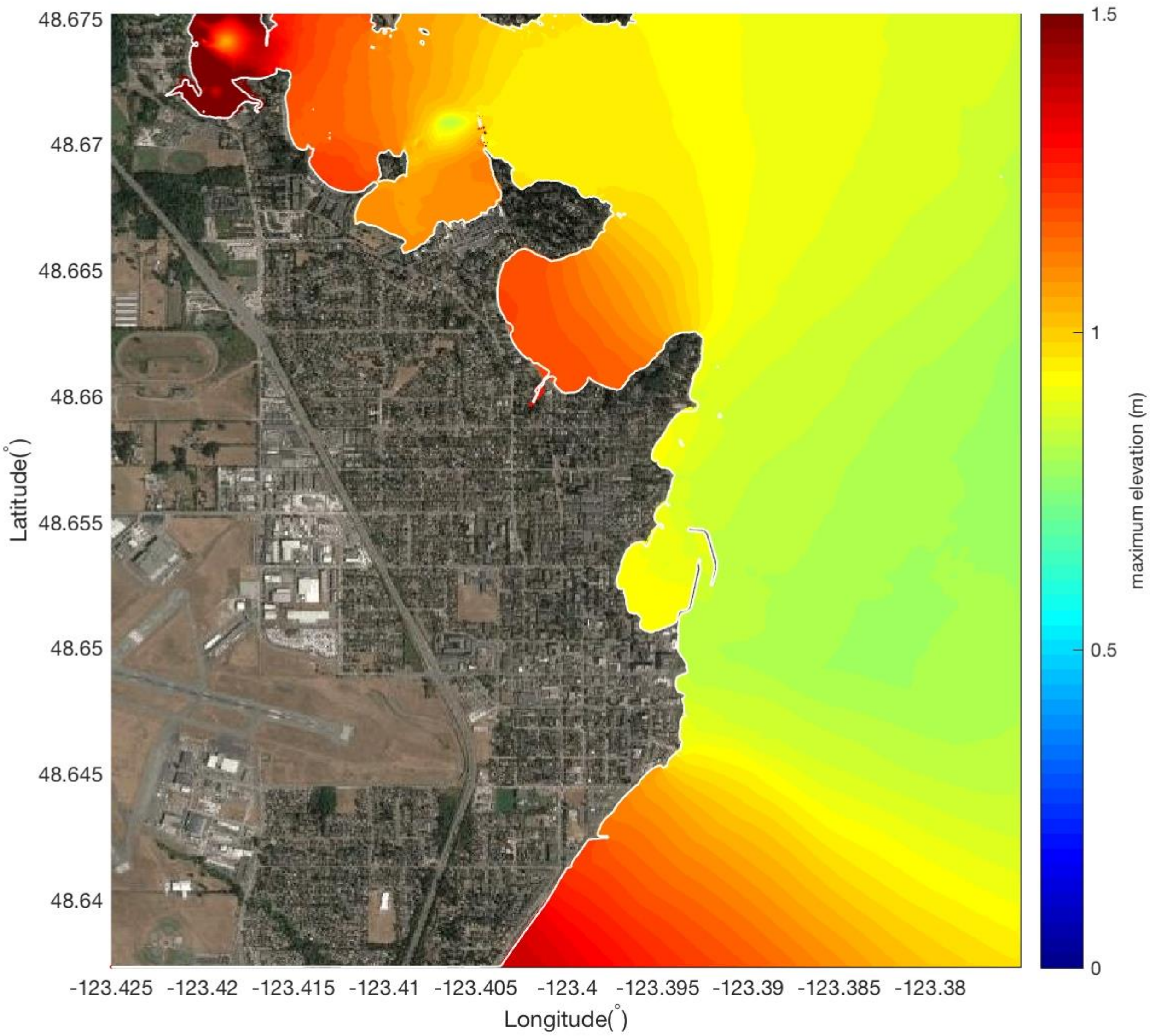
Maximum Water Surface Elevations: SW1

(Elevations are reported to m above HHWMT datum)

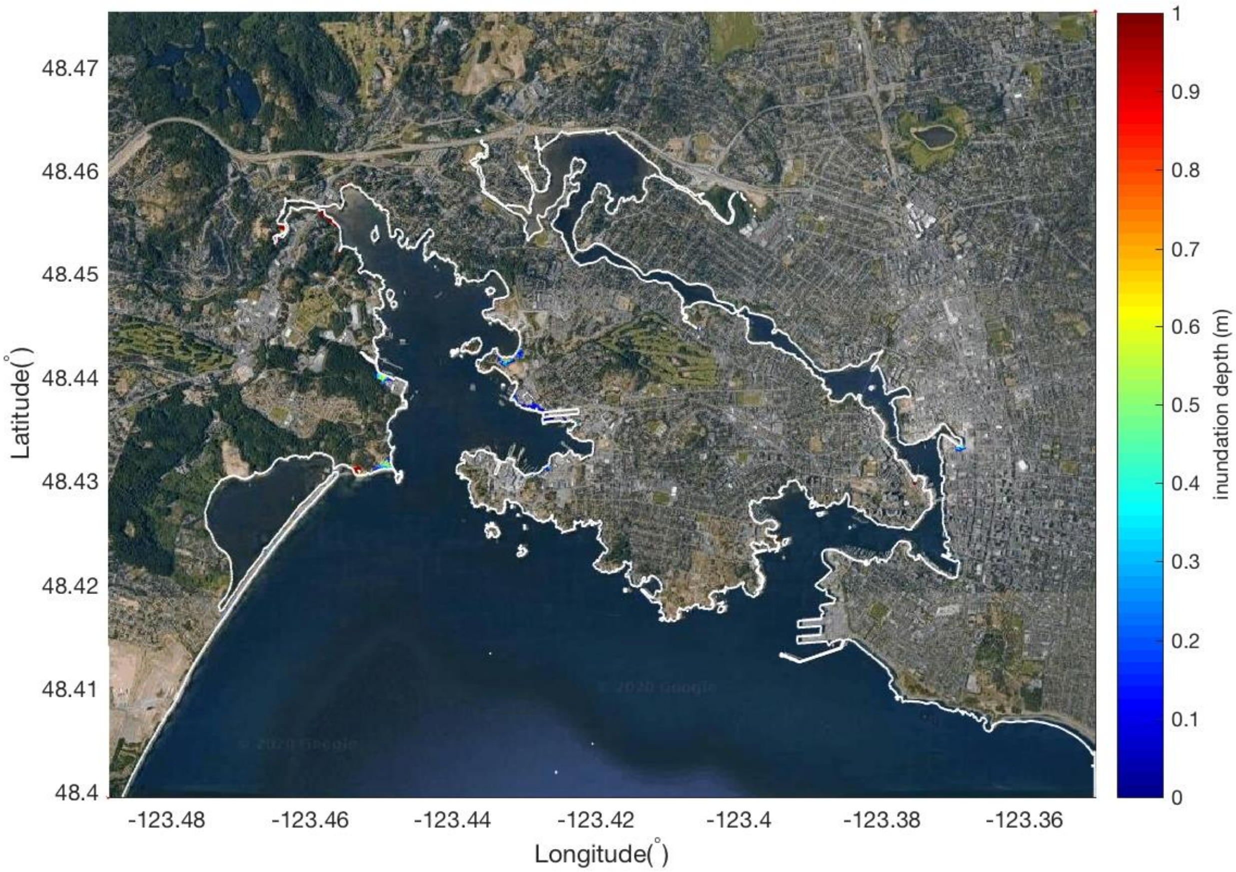
SW1 does not have noticeable effect on Sooke and Port Renfrew domains.

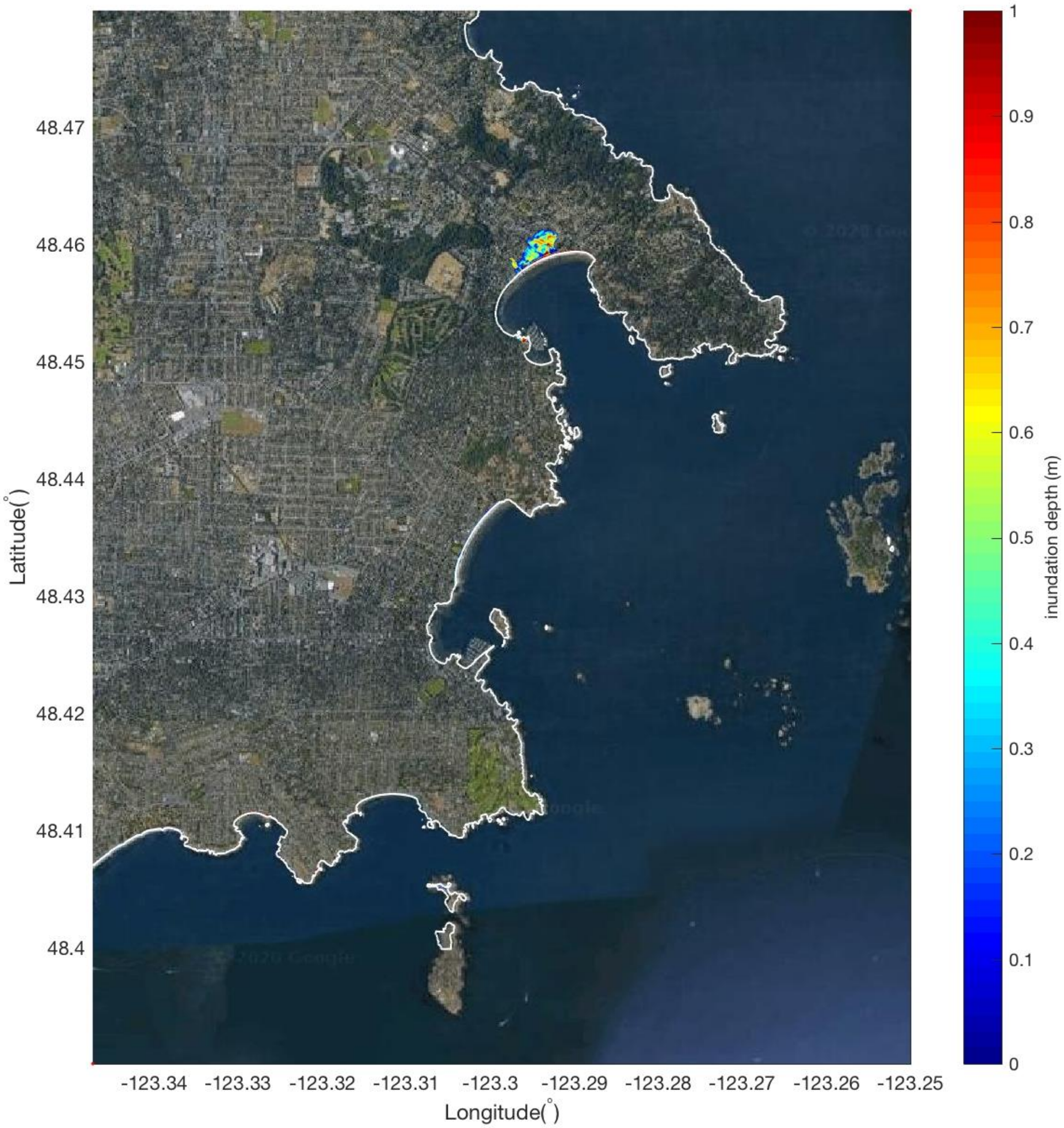


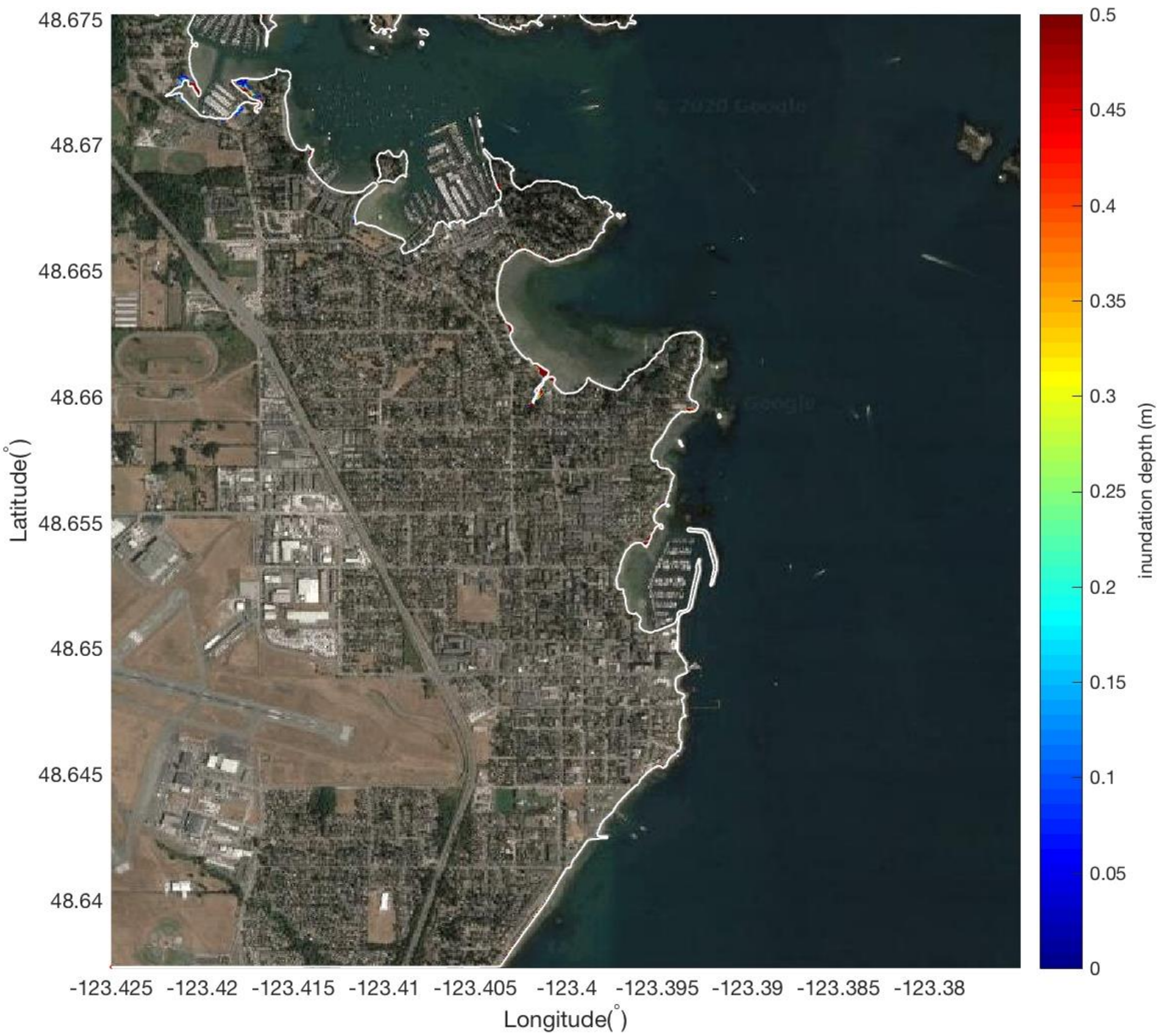

48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
3
2.5
2
1.5
1
0.5
0
maximum elevation (m)


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
1.5
1
0.5
0
maximum elevation (m)

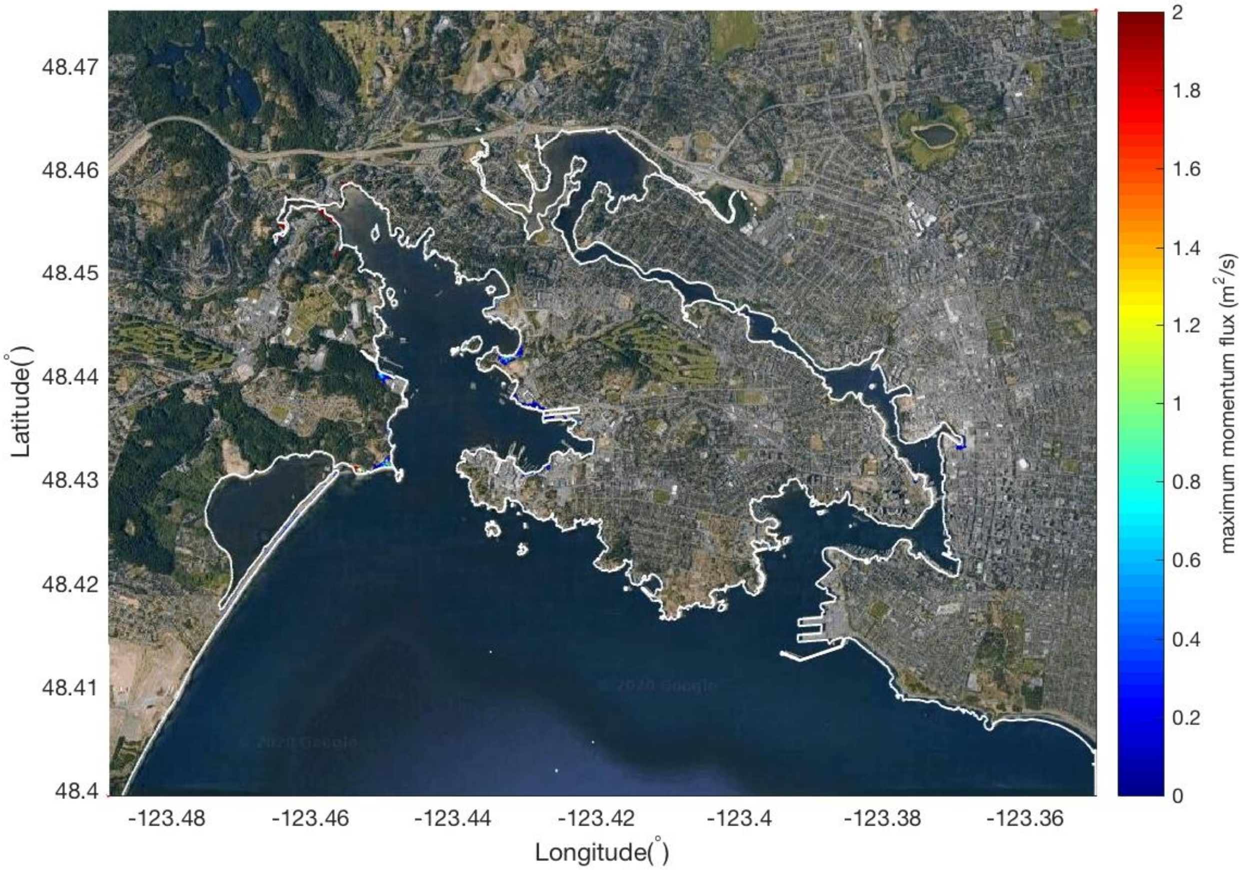
Maximum Inundation Depths: SW1

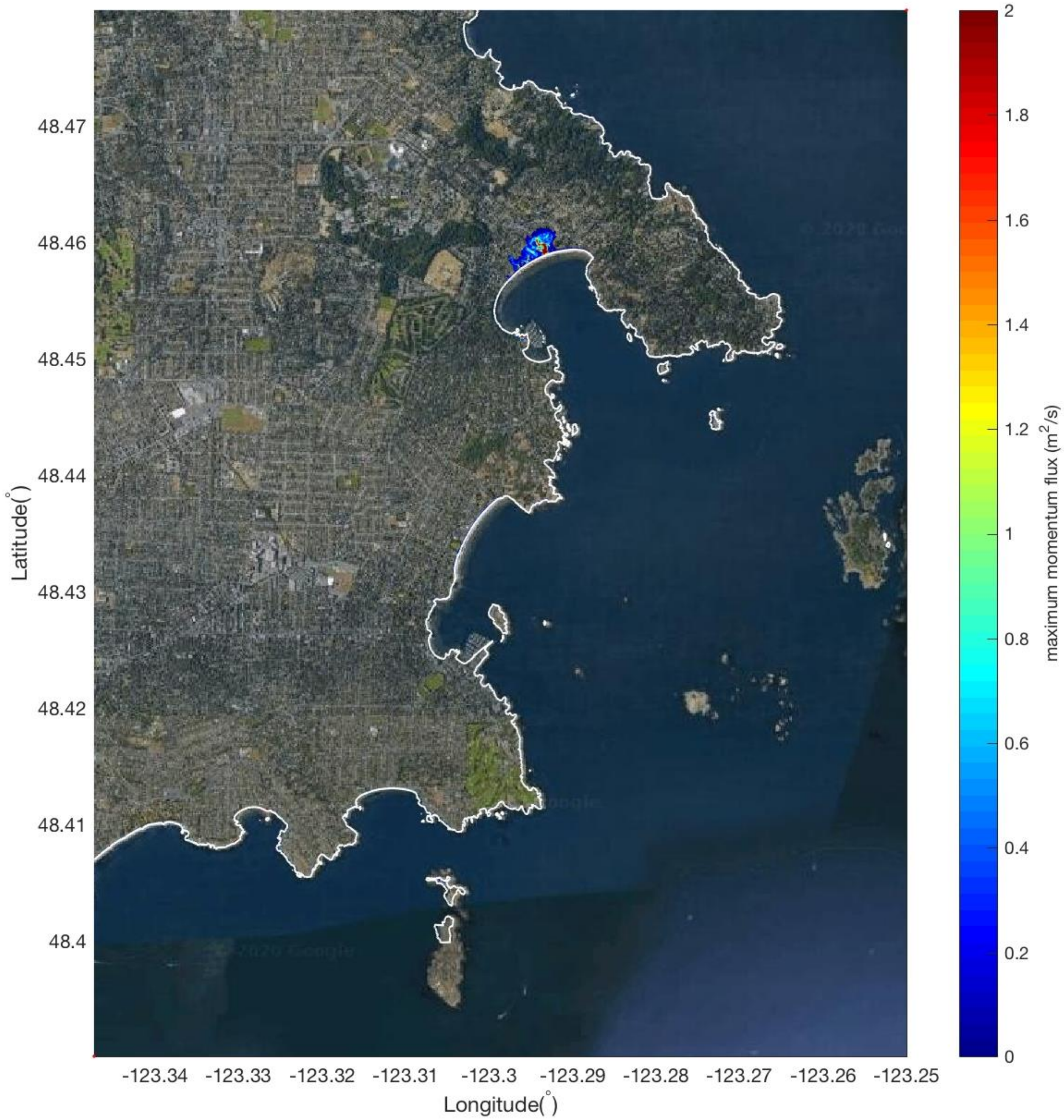


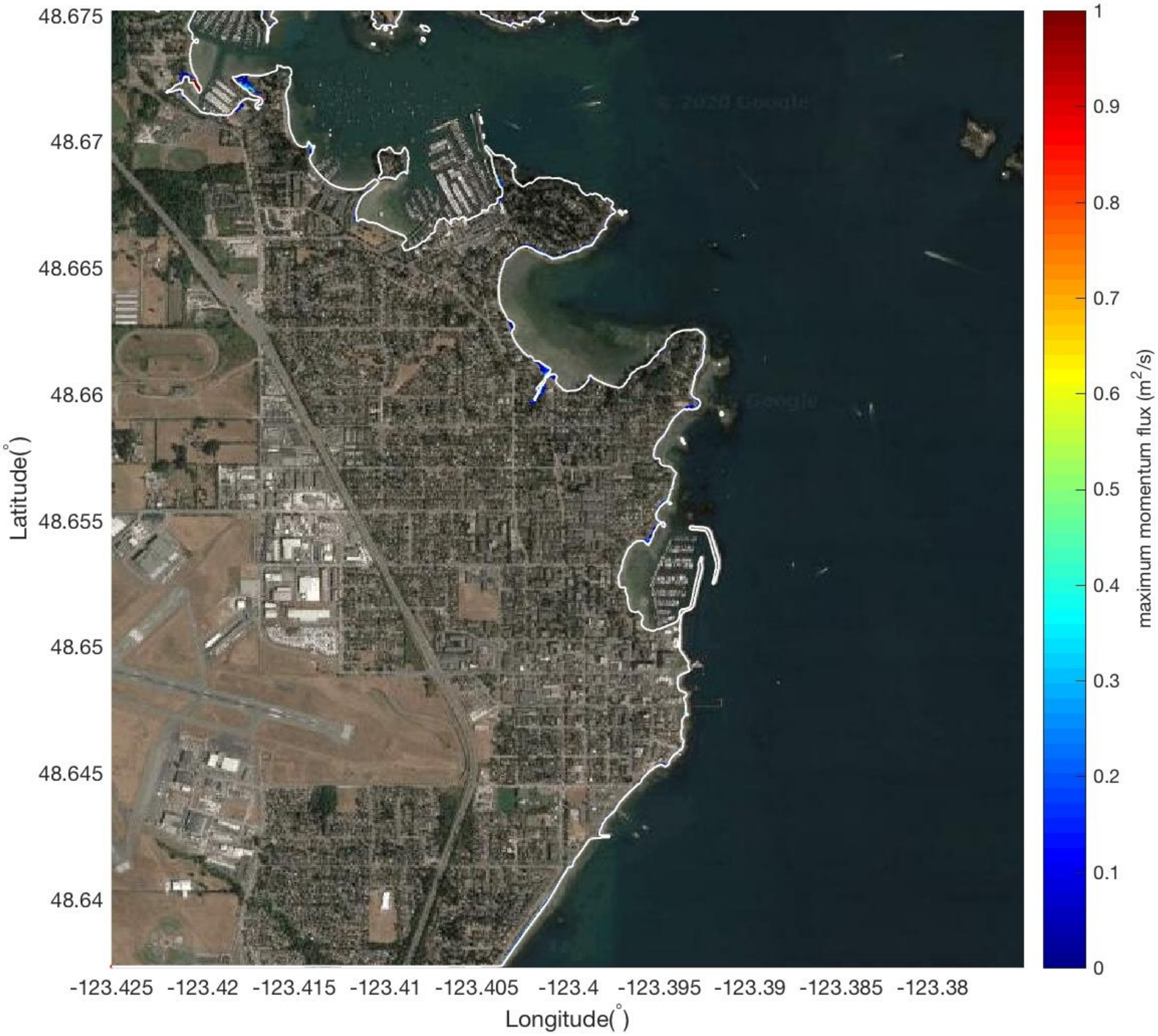

48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
inundation depth (m)


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
inundation depth (m)

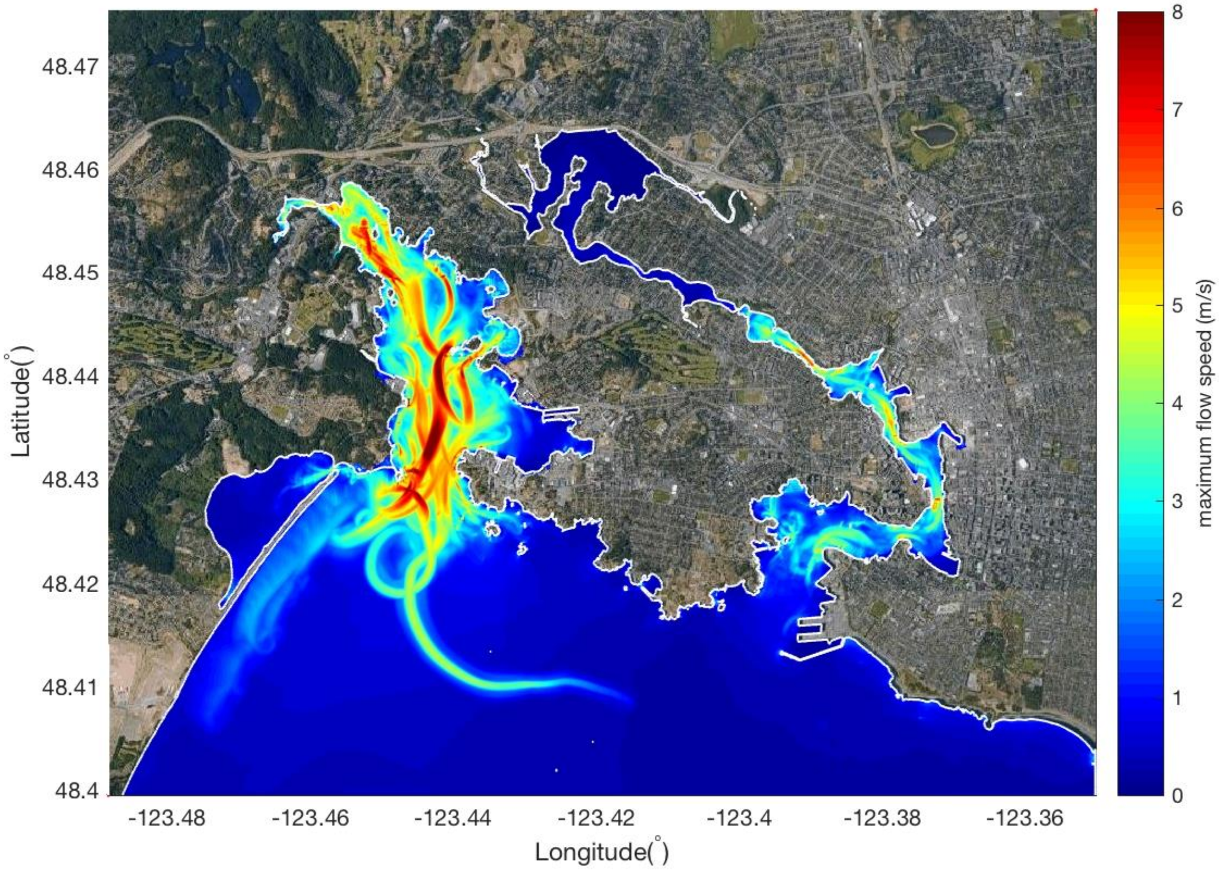
Maximum Momentum Flux: SW1

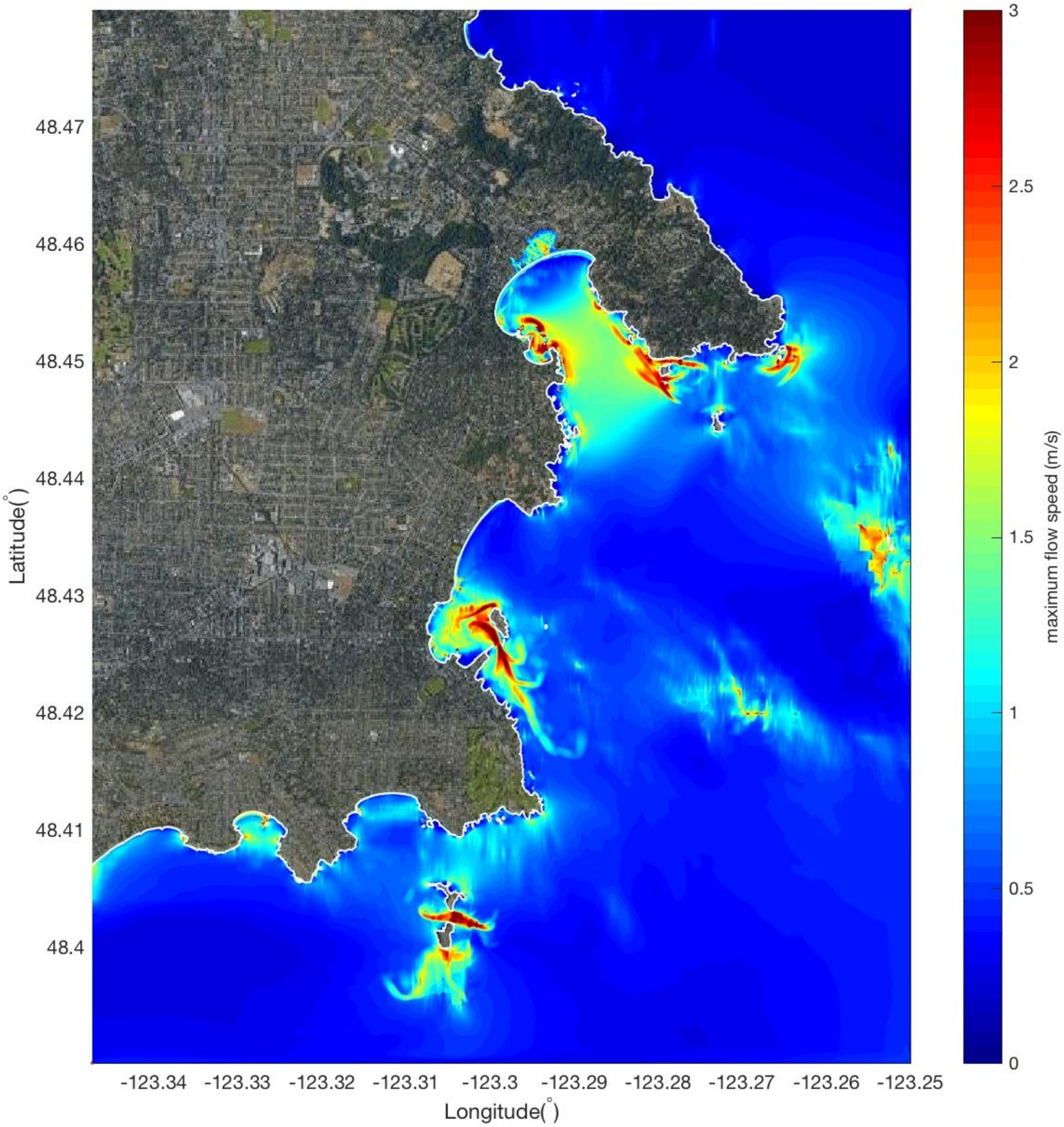


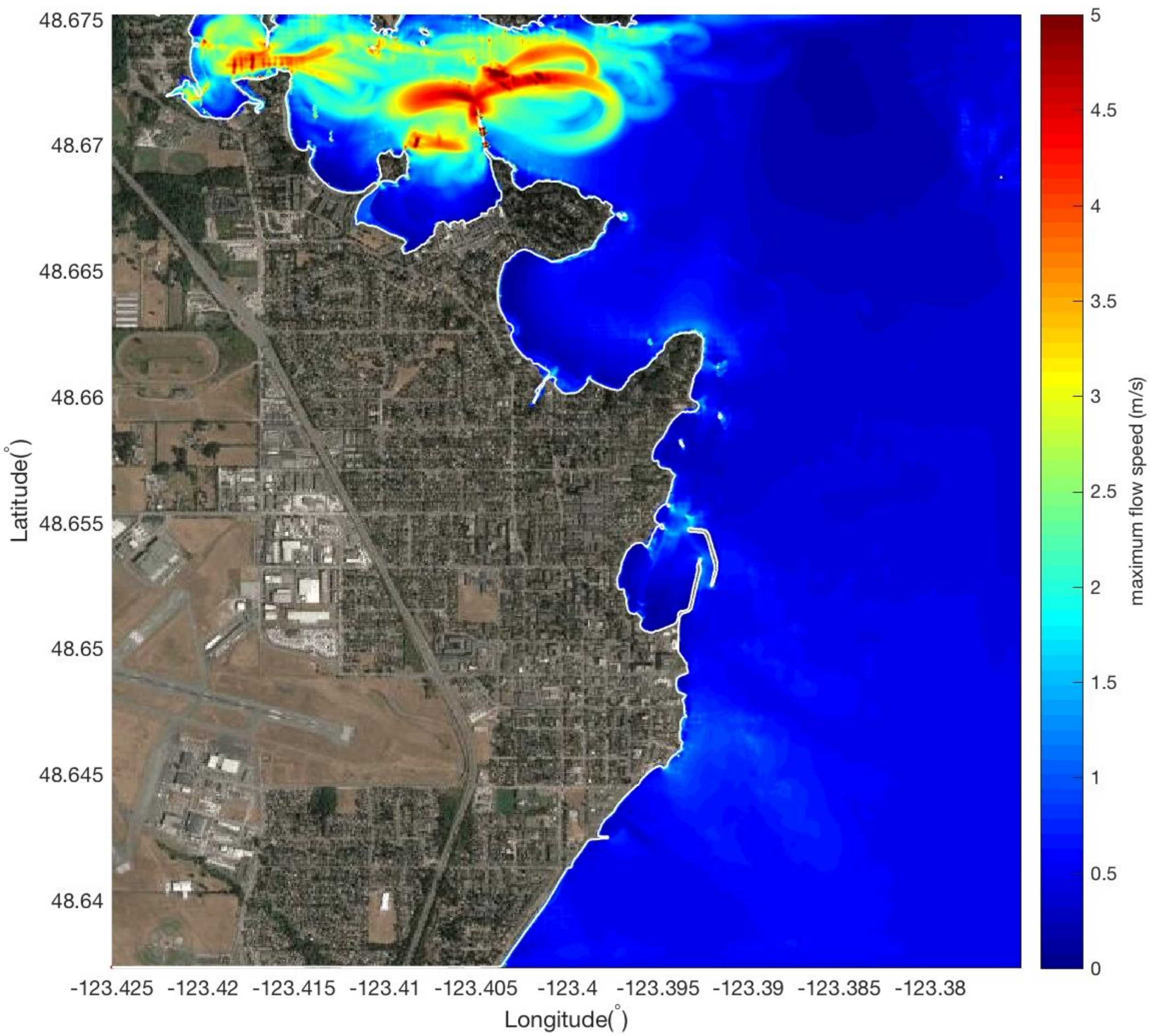

48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34 -123.33 -123.32 -123.31 -123.3 -123.29 -123.28 -123.27 -123.26 -123.25
Longitude(°)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
maximum momentum flux (m²/s)


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
maximum momentum flux (m²/s)

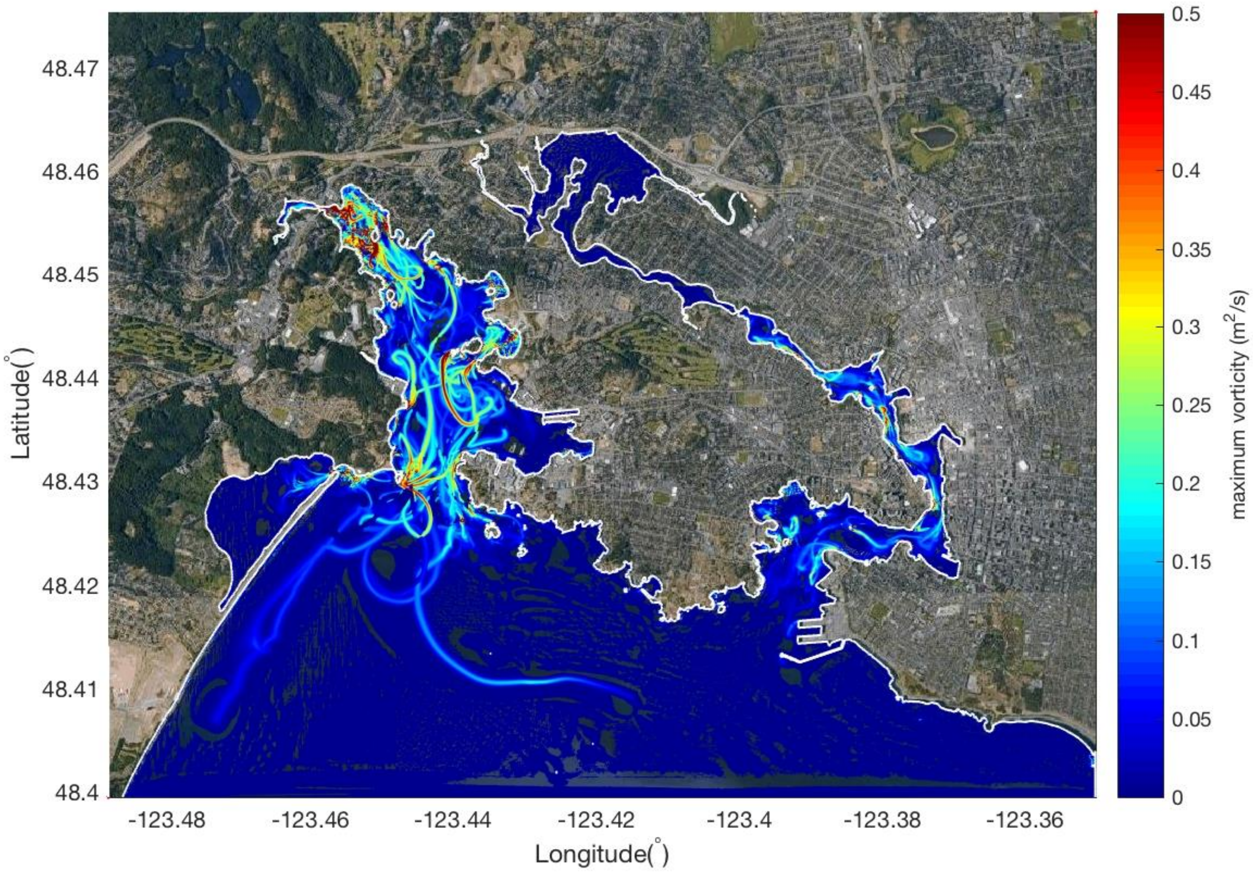
Maximum Flow Speed: SW1

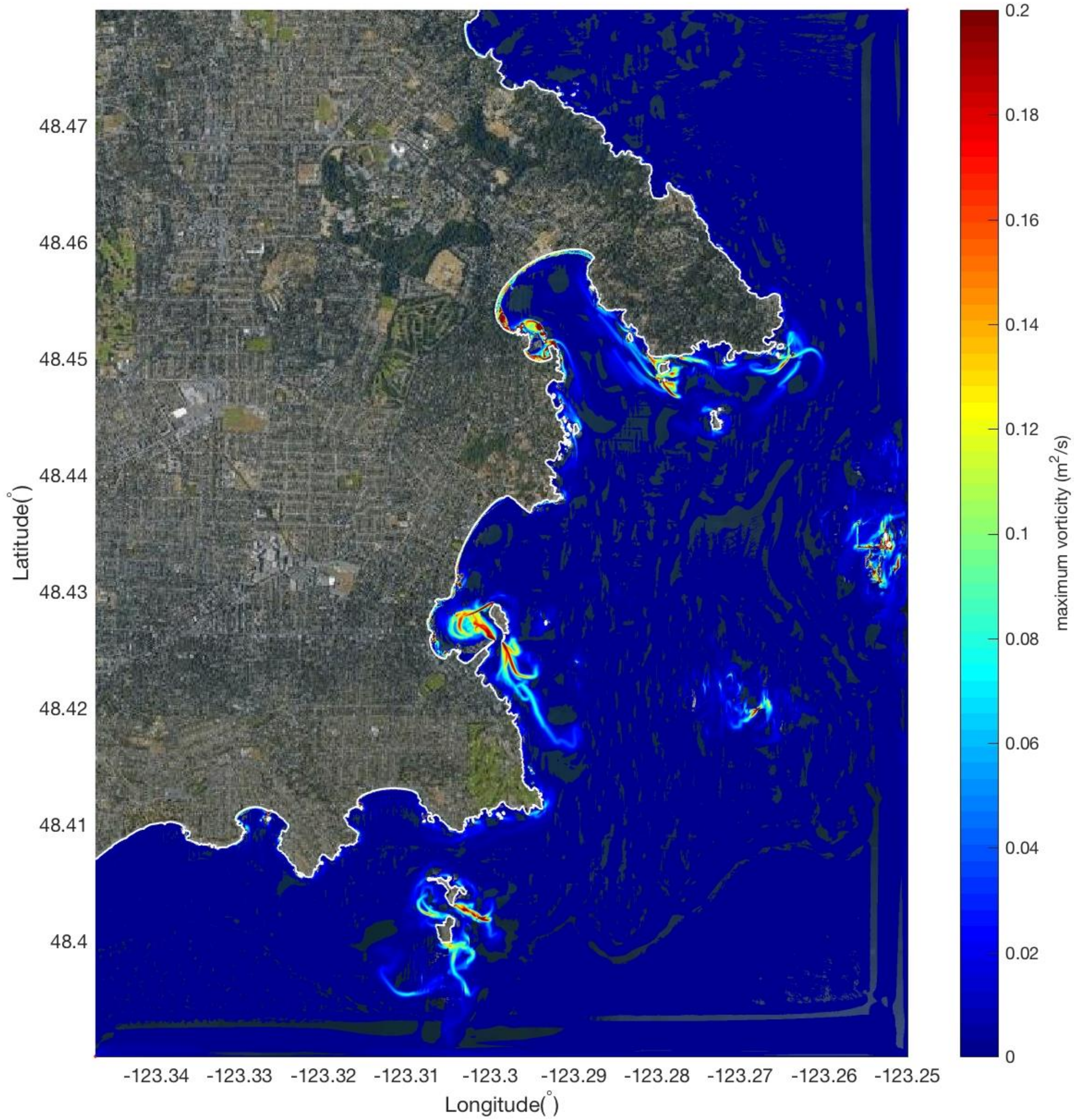


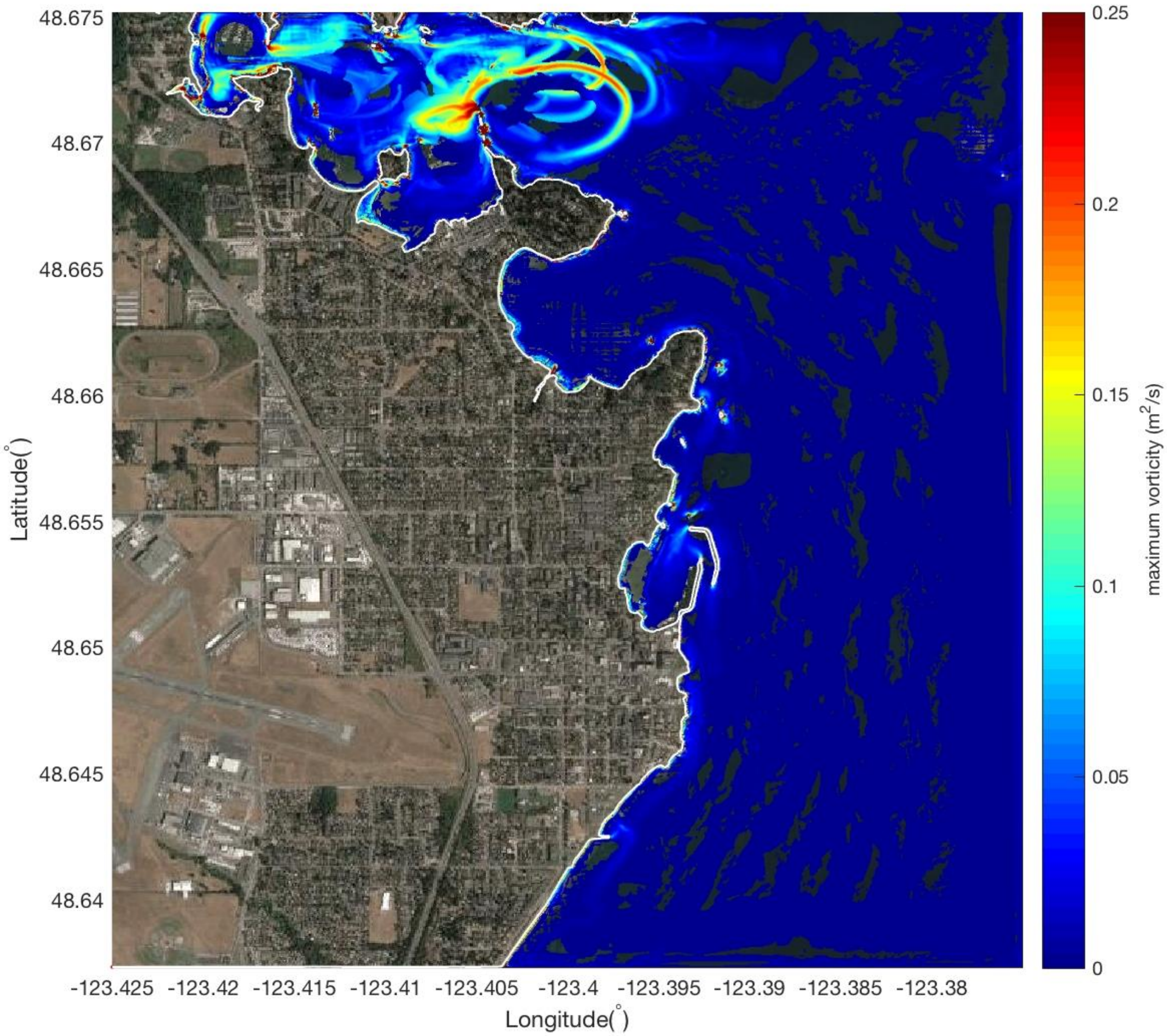

48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
3
2.5
2
1.5
1
0.5
0
maximum flow speed (m/s)


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425
-123.42
-123.415
-123.41
-123.405
-123.4
-123.395
-123.39
-123.385
-123.38
Longitude(°)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum flow speed (m/s)

Maximum Vorticity: SW1




48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
maximum vorticity (m2/s)


48.675
48.67
48.665
48.66
48.655
48.65
48.645
48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
0.25
0.2
0.15
0.1
0.05
0
maximum vorticity (m2/s)

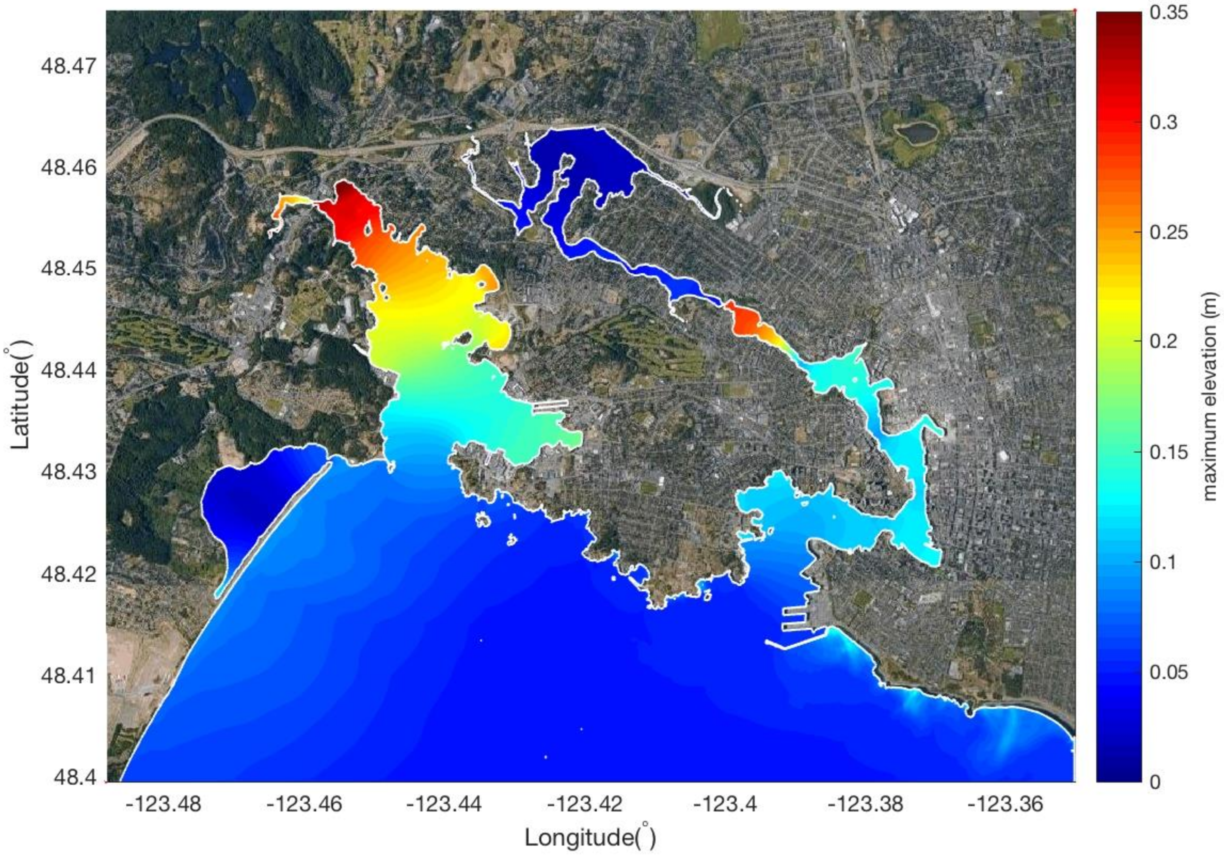
APPENDIX K - DETAILED INUNDATION GRID RESULTS: SOUTHERN WHIDBEY ISLAND, MW 6.5 (SW2)

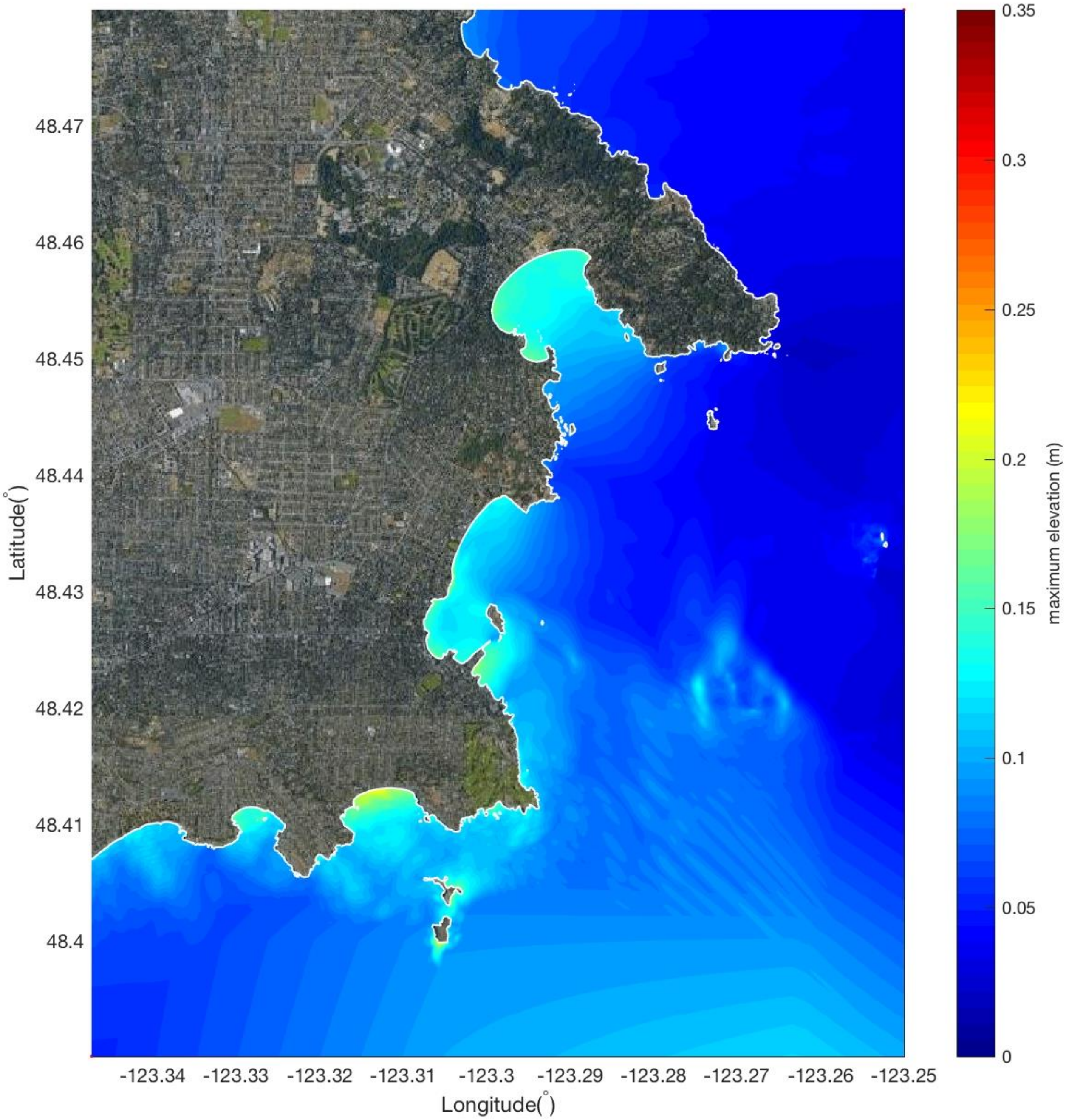
This appendix presents results for the SW2 event, for each detailed modelling domain. For each result parameter, the results are presented in the following order: Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

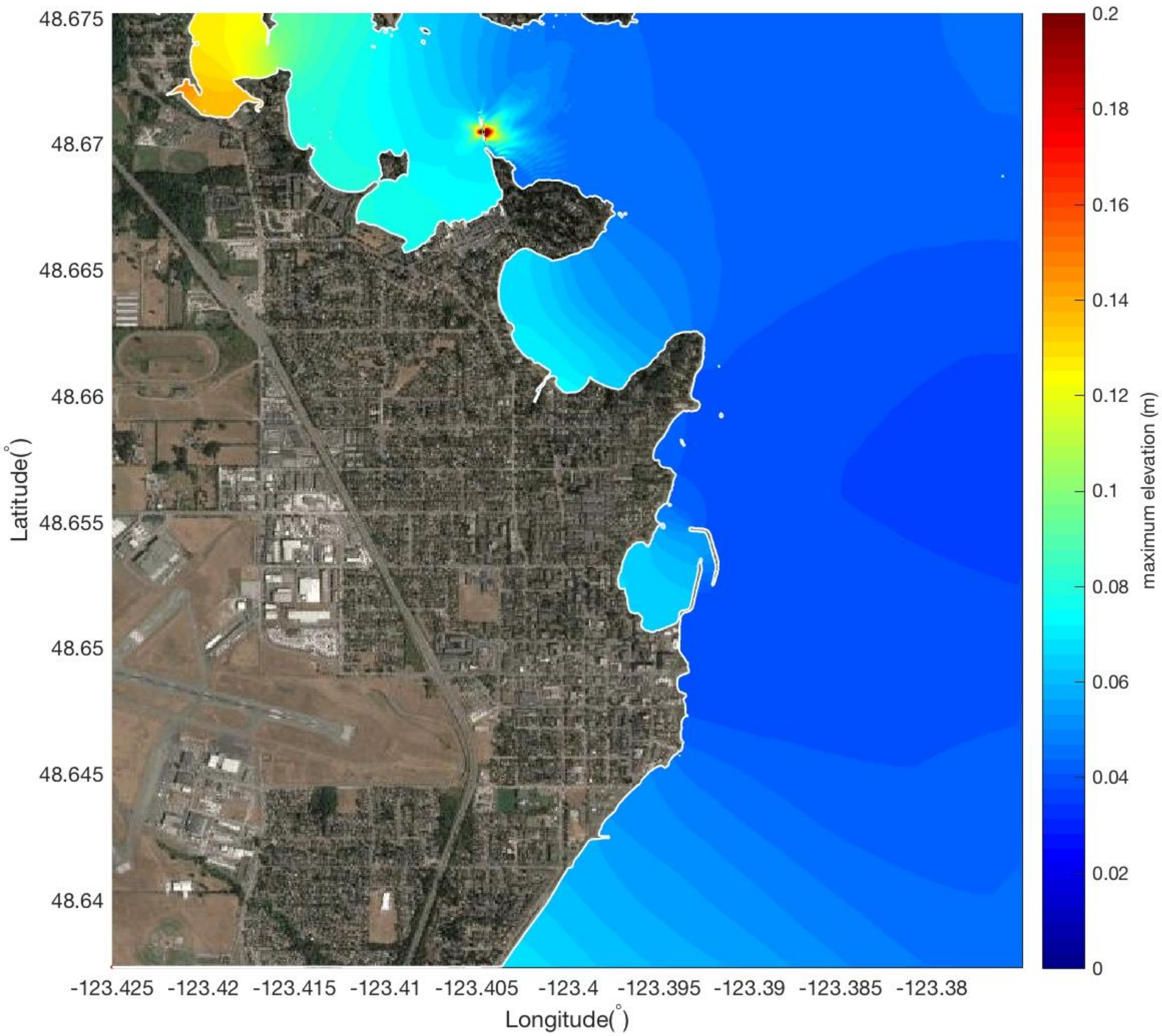
Maximum Water Surface Elevations: SW2

(Elevations are reported to m above HHWMT datum)

SW2 does not have noticeable effect on Sooke and Port Renfrew domains.




48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34 -123.33 -123.32 -123.31 -123.3 -123.29 -123.28 -123.27 -123.26 -123.25
Longitude(°)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum elevation (m)



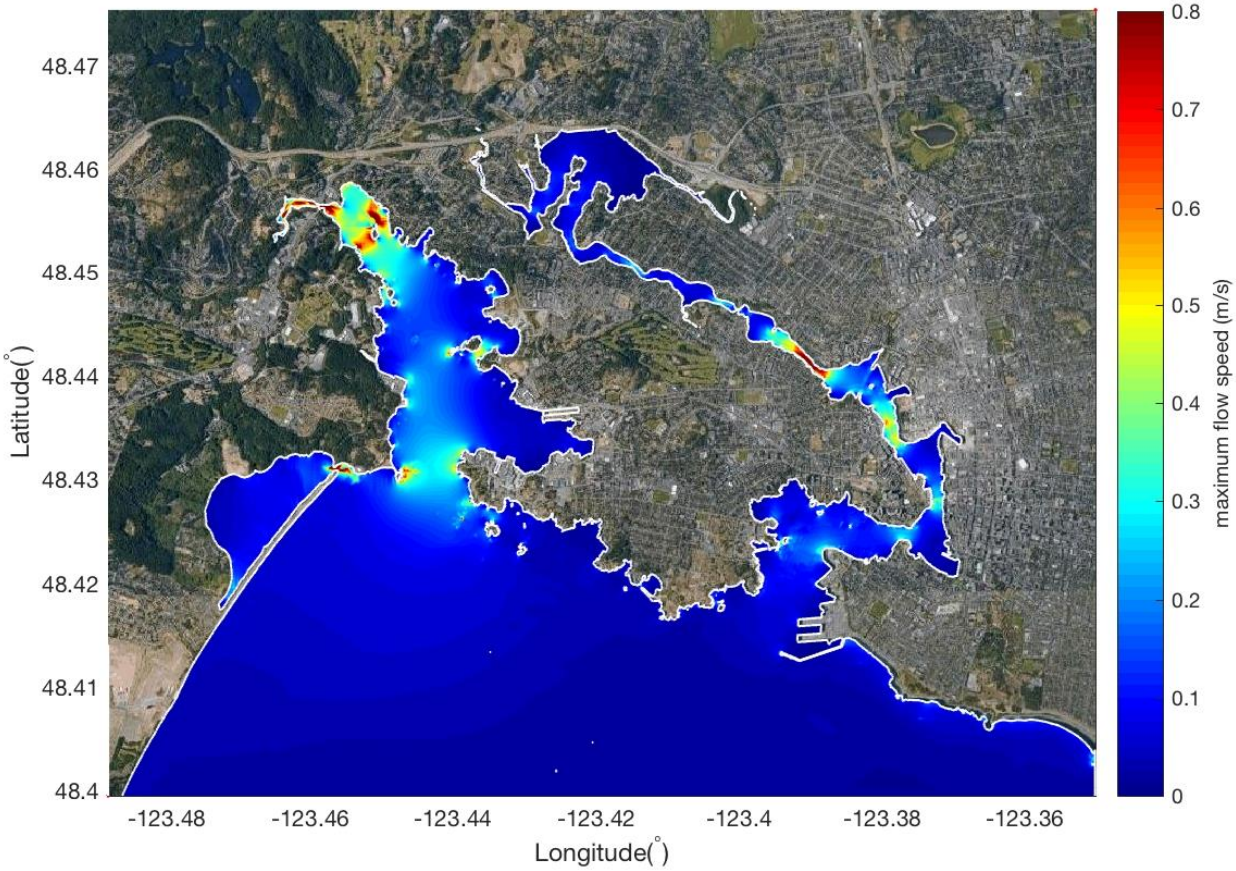
Maximum Inundation Depths: SW2

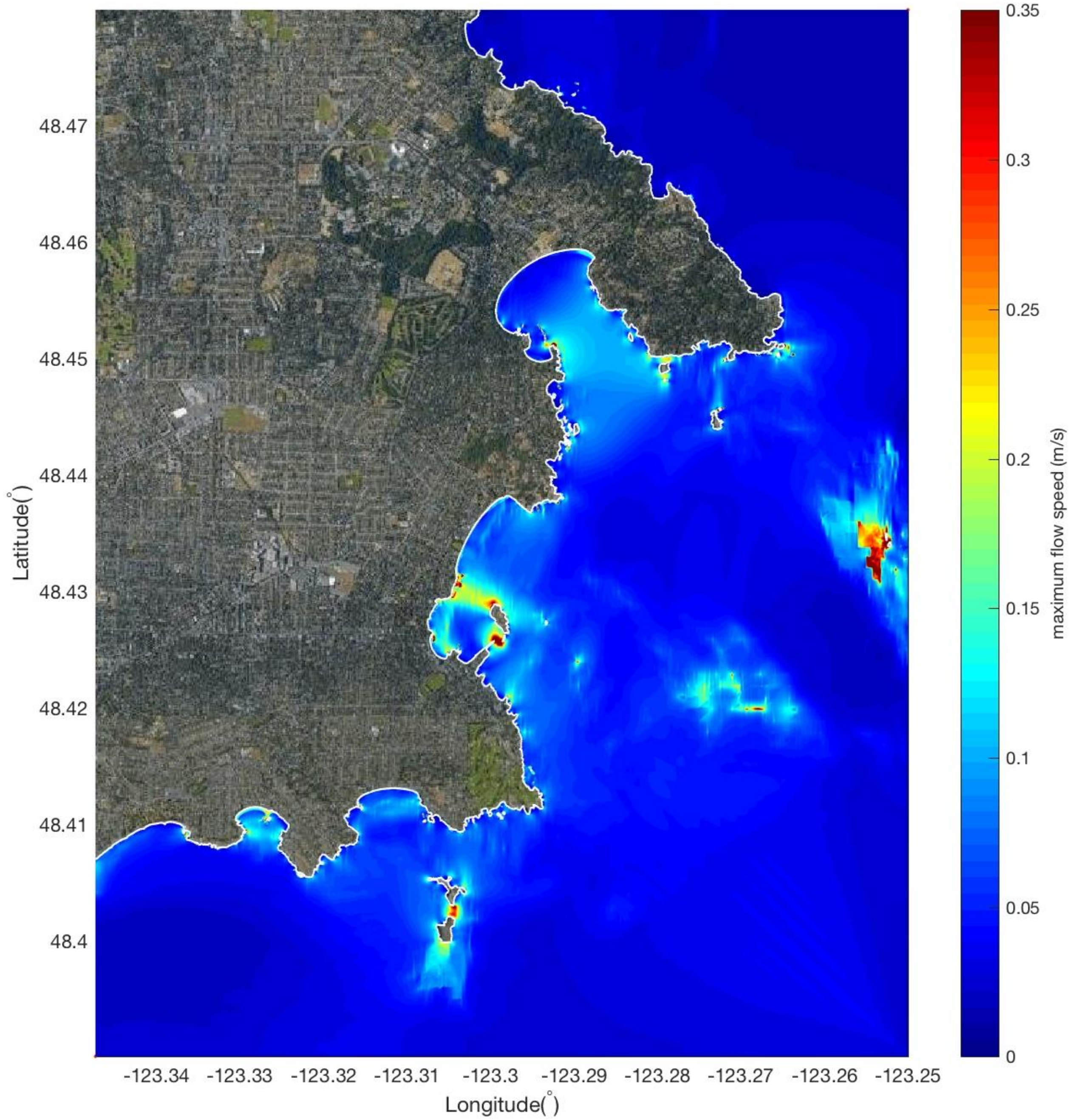
There was no inundation associated with SW2.

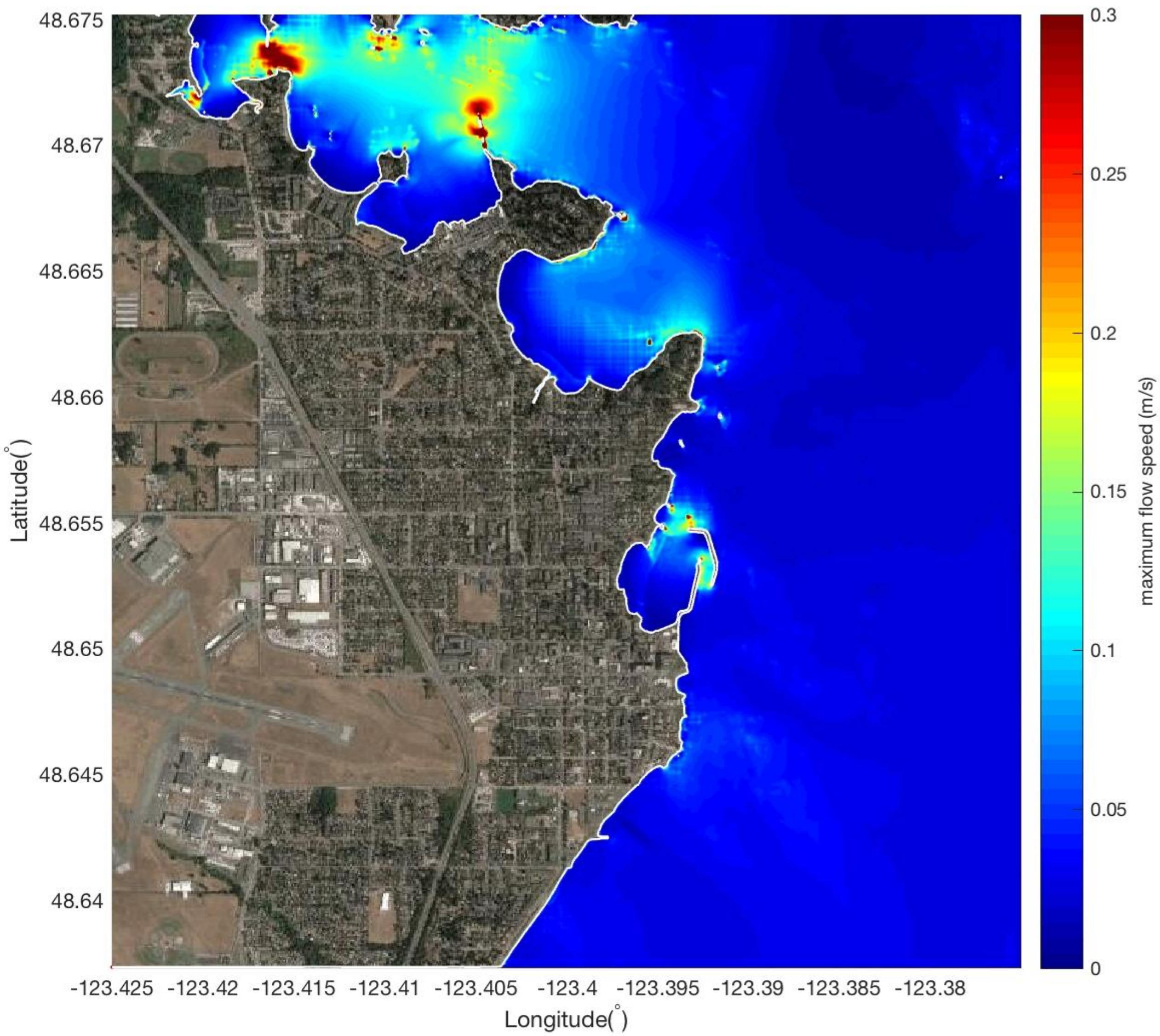
Maximum Momentum Flux: SW2

There were no momentum flux plots produced for SW2.

Maximum Flow Speed: SW2




48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34 -123.33 -123.32 -123.31 -123.3 -123.29 -123.28 -123.27 -123.26 -123.25
Longitude(°)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum flow speed (m/s)



Maximum Vorticity: SW2

There were no vorticity plots produced for SW2 in the detailed model domains.

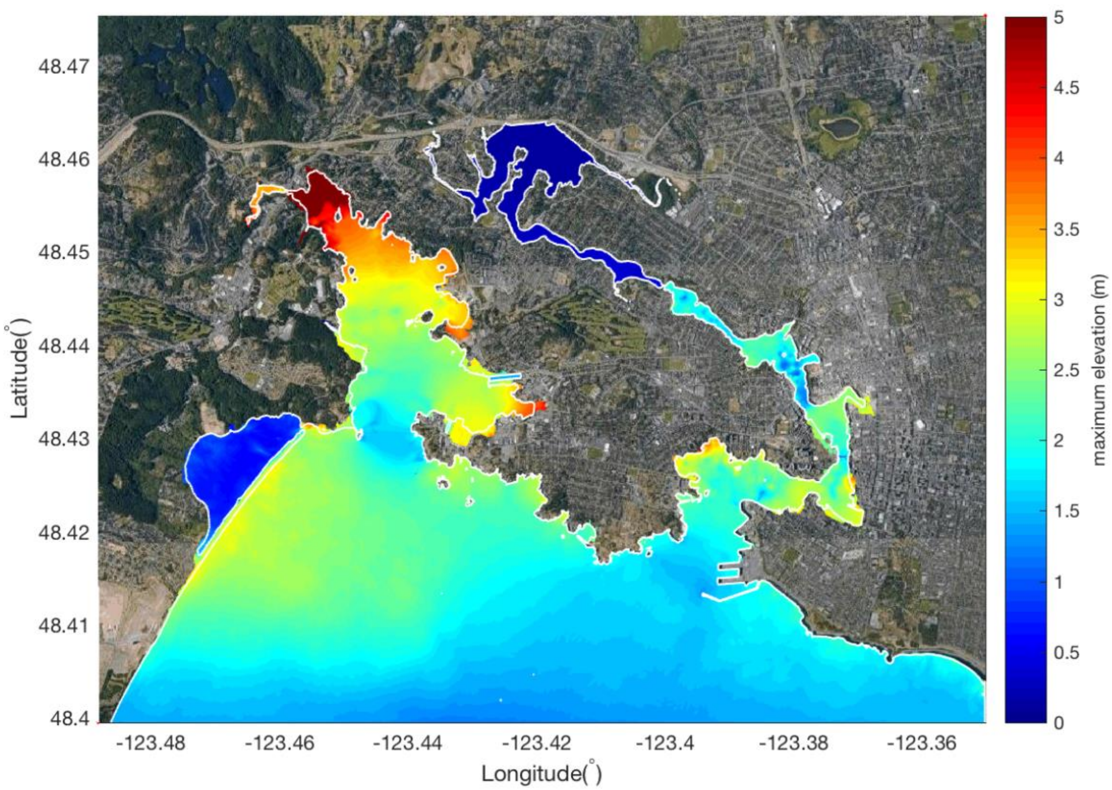
APPENDIX L - DETAILED INUNDATION GRID RESULTS: DEVIL'S MOUNTAIN FAULT, MW 7.5 (DM1)

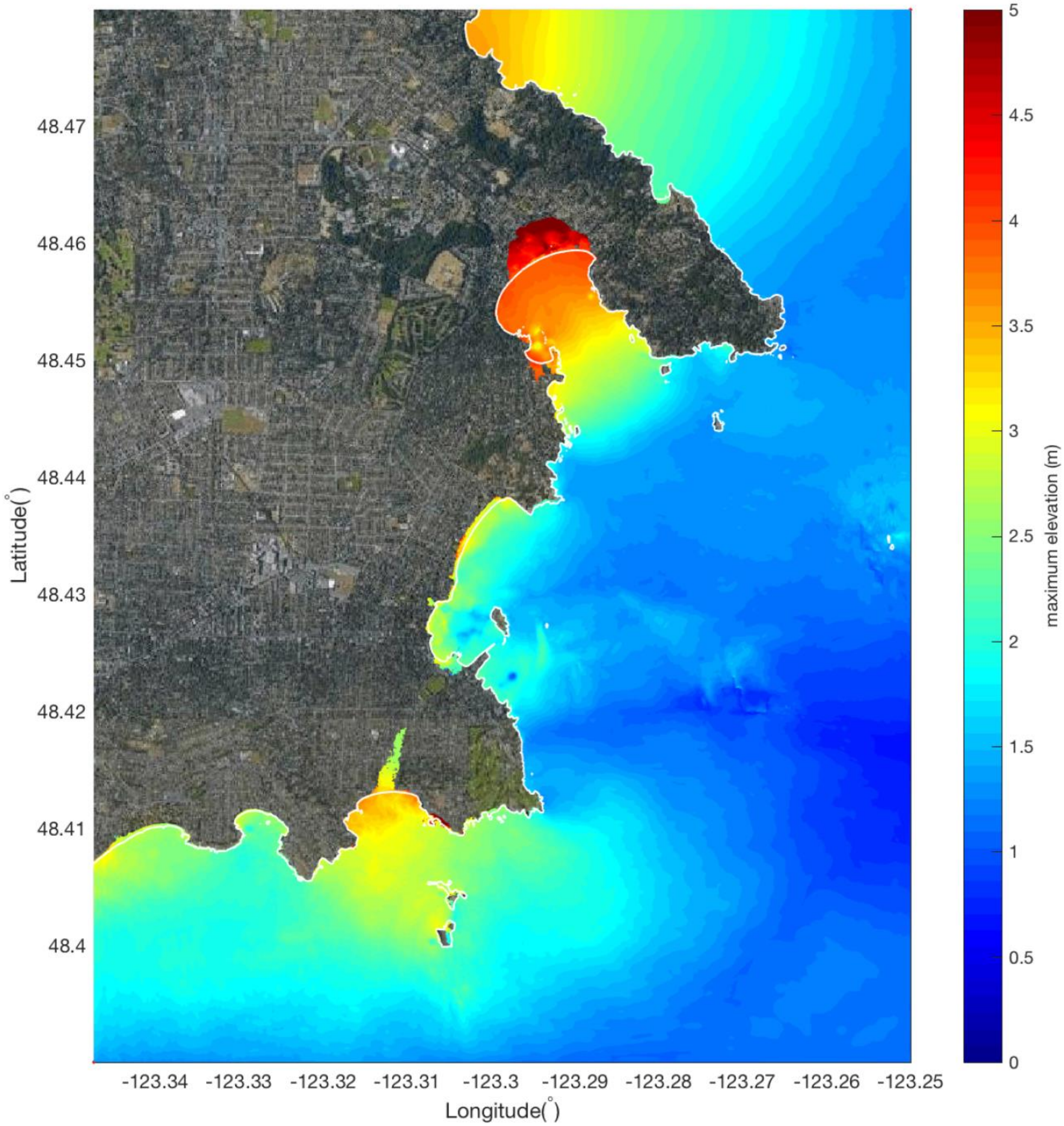
This appendix presents results for the DM1 event, for each detailed modelling domain. For each result parameter, the results are presented in the following order: Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

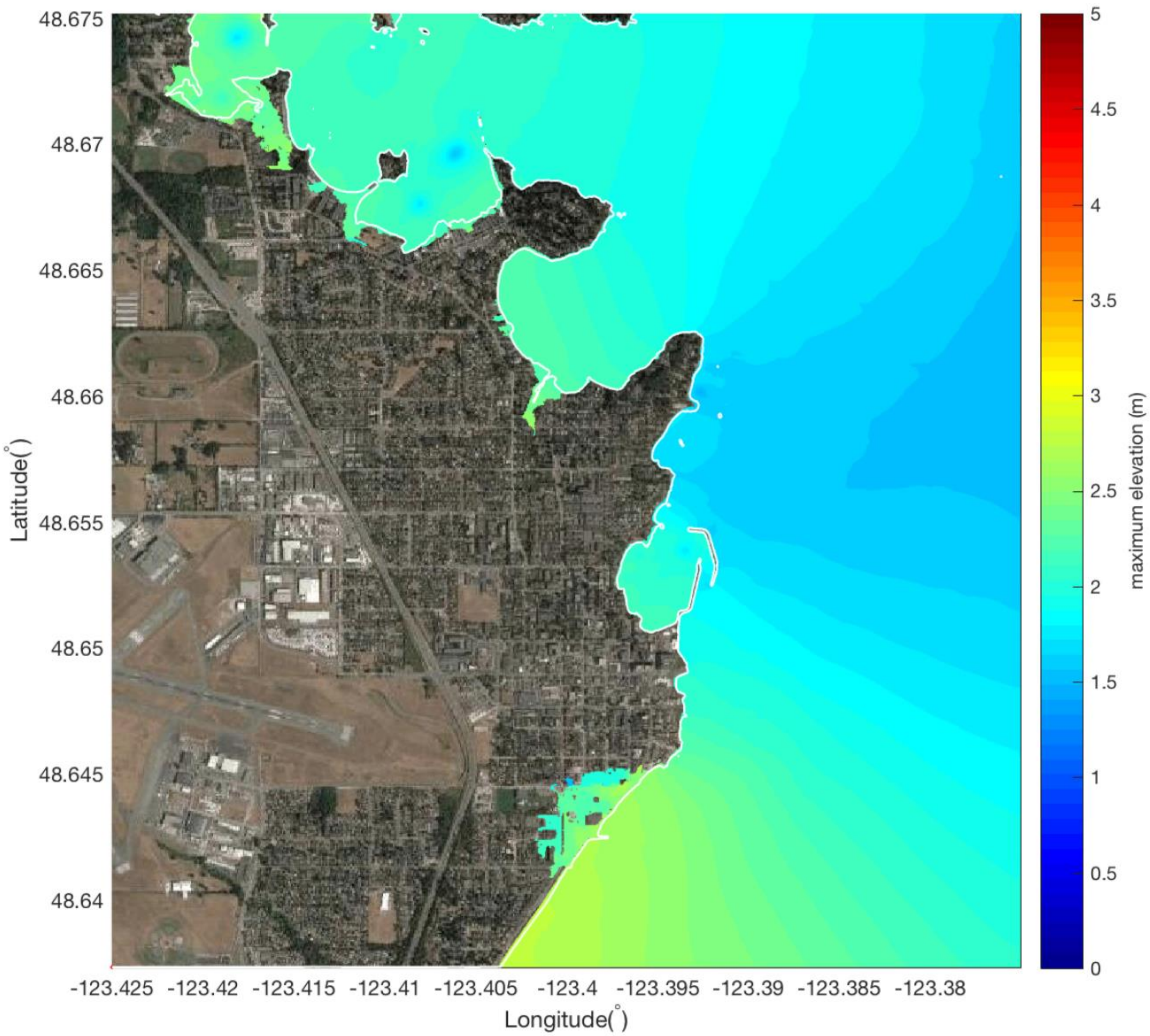
Maximum Water Surface Elevations: DM1

(Elevations are reported to m above HHWMT datum).

DM1 does not have noticeable effect on Sooke and Port Renfrew domains.




48.47
48.46
48.45
48.44
48.43
48.42
48.41
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum elevation (m)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48.645
48.64
Latitude(°)
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Longitude(°)
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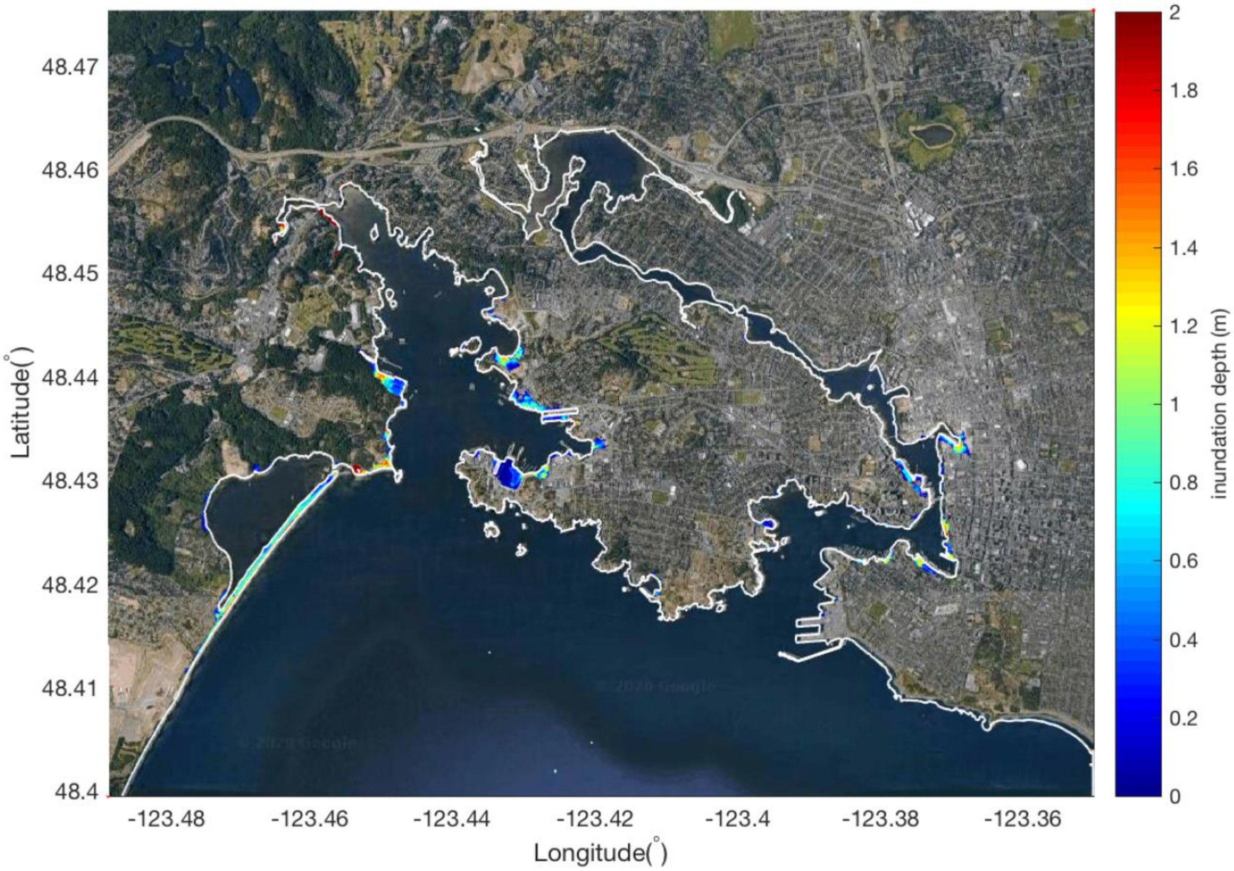
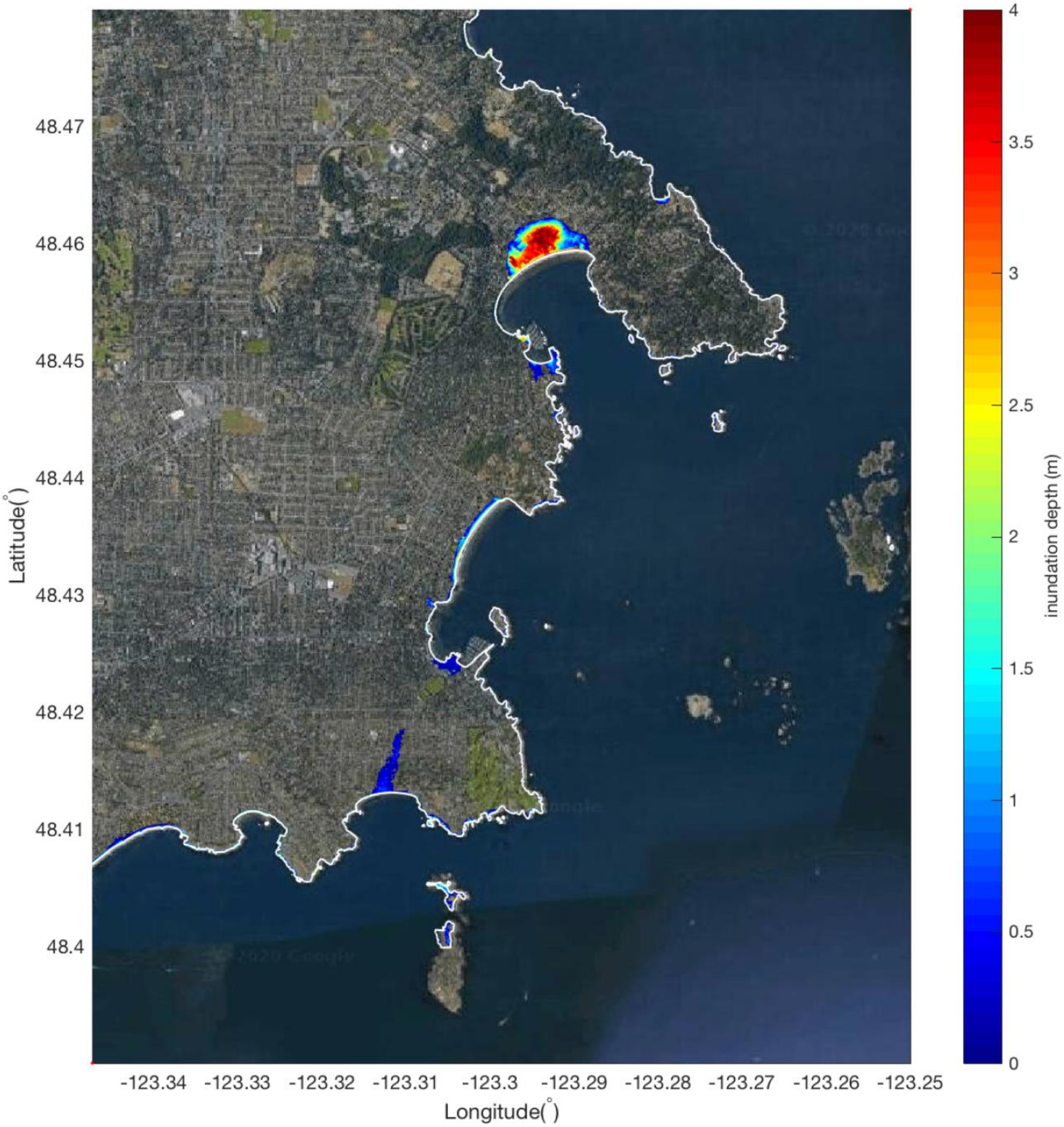
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum elevation (m)

Maximum Inundation Depths: DM1

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48.4
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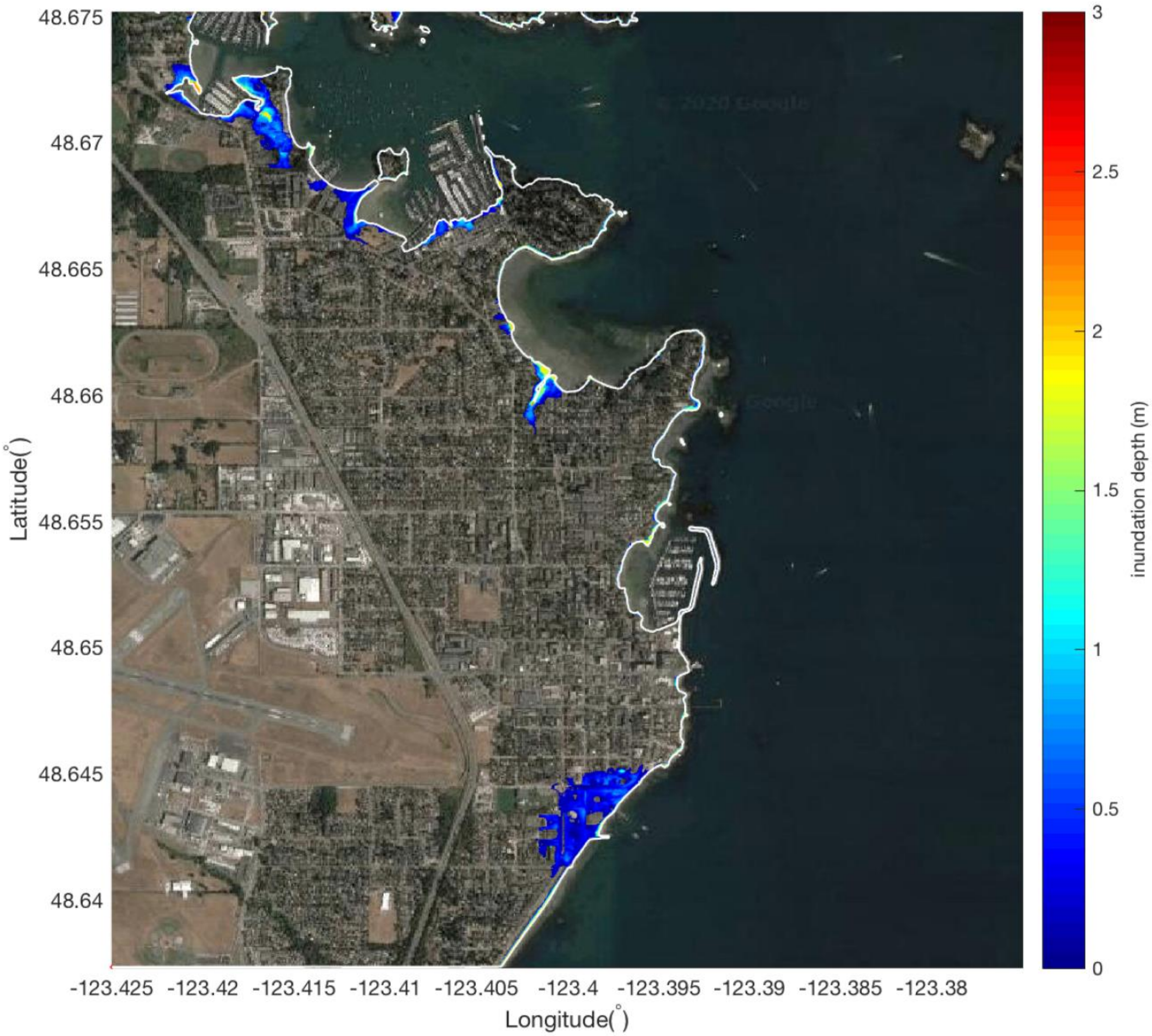
Longitude(°)
4
3.5
3
2.5
2
1.5
1
0.5
0
inundation depth (m)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48.645
48.64
Latitude(°)
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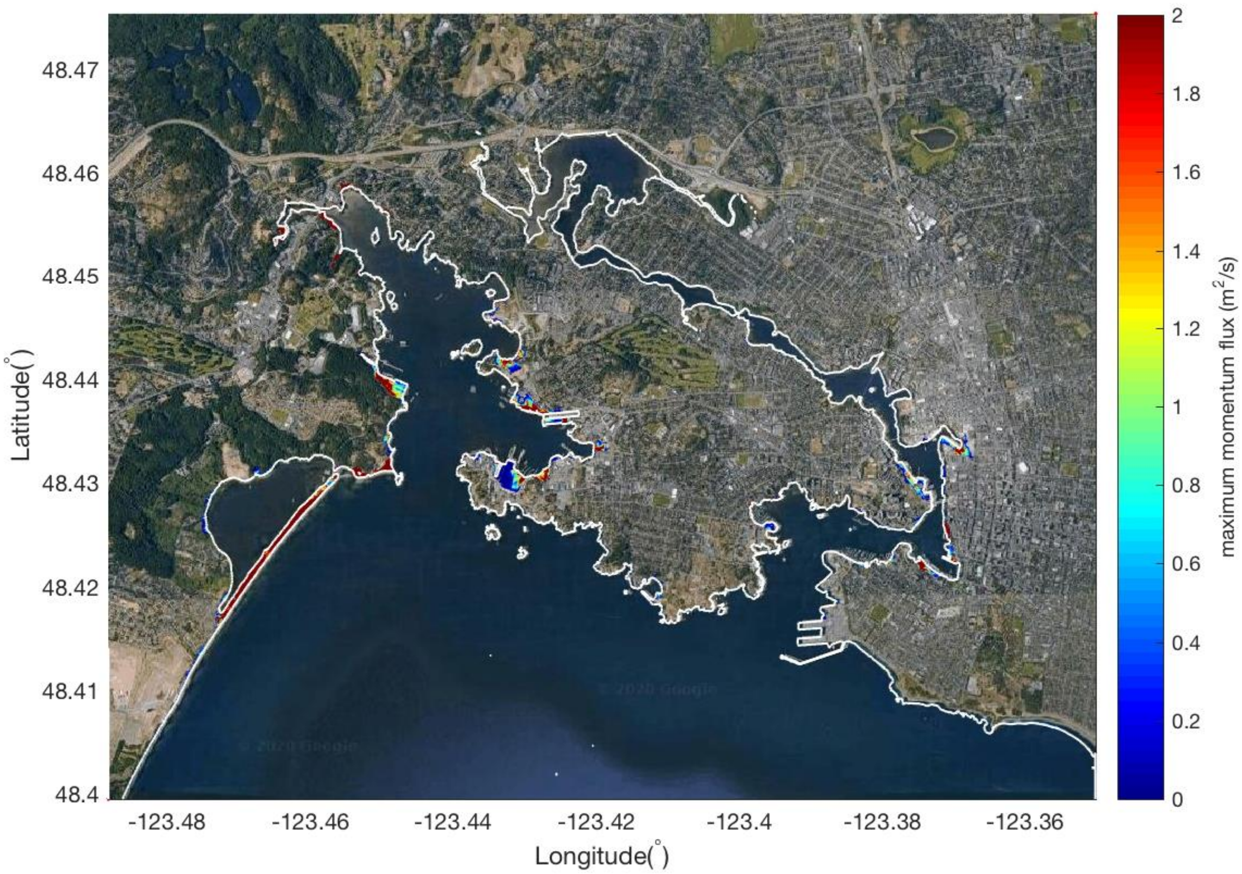
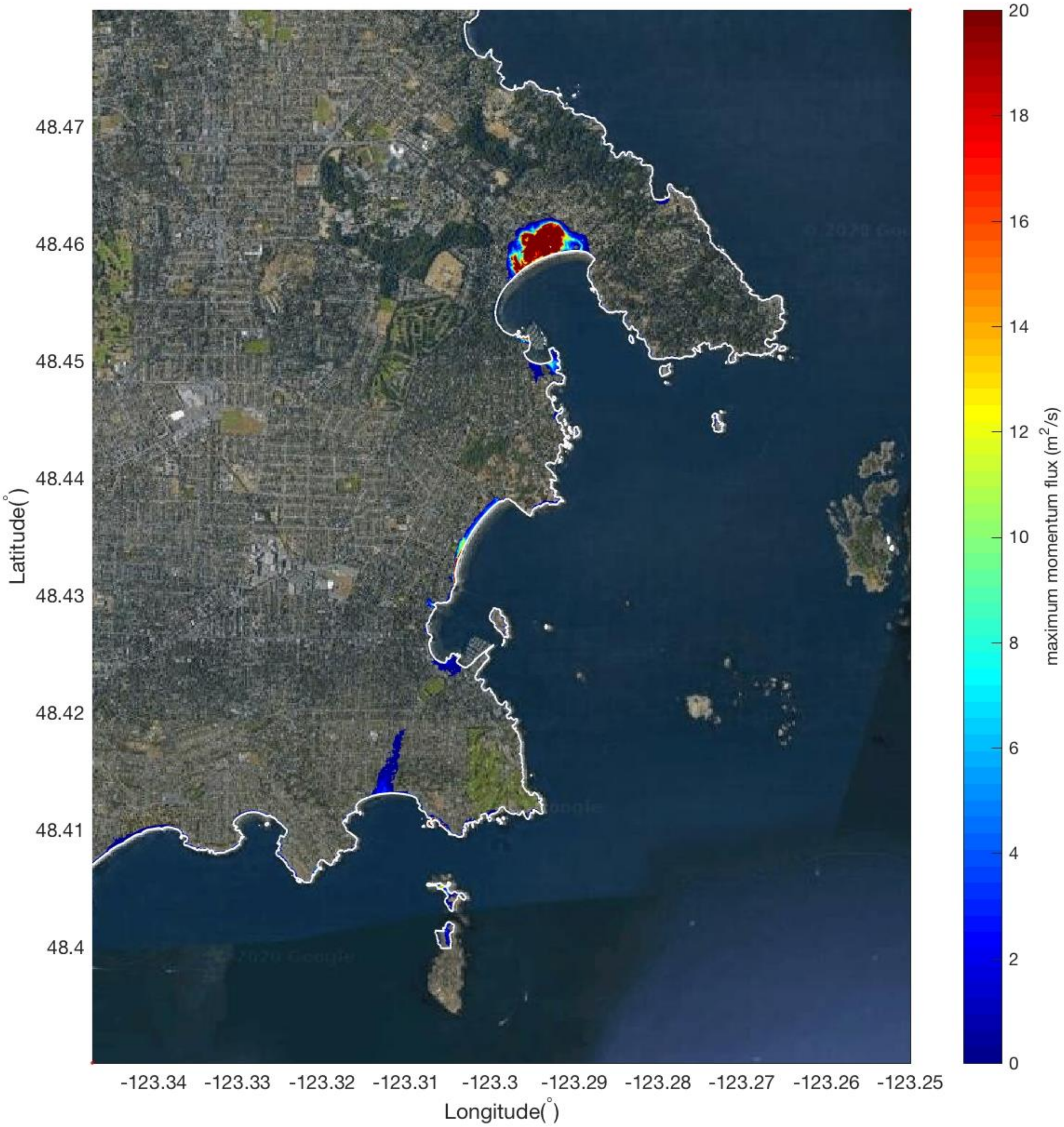
Longitude(°)
3
2.5
2
1.5
1
0.5
0
inundation depth (m)

Maximum Momentum Flux: DM1

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48.4
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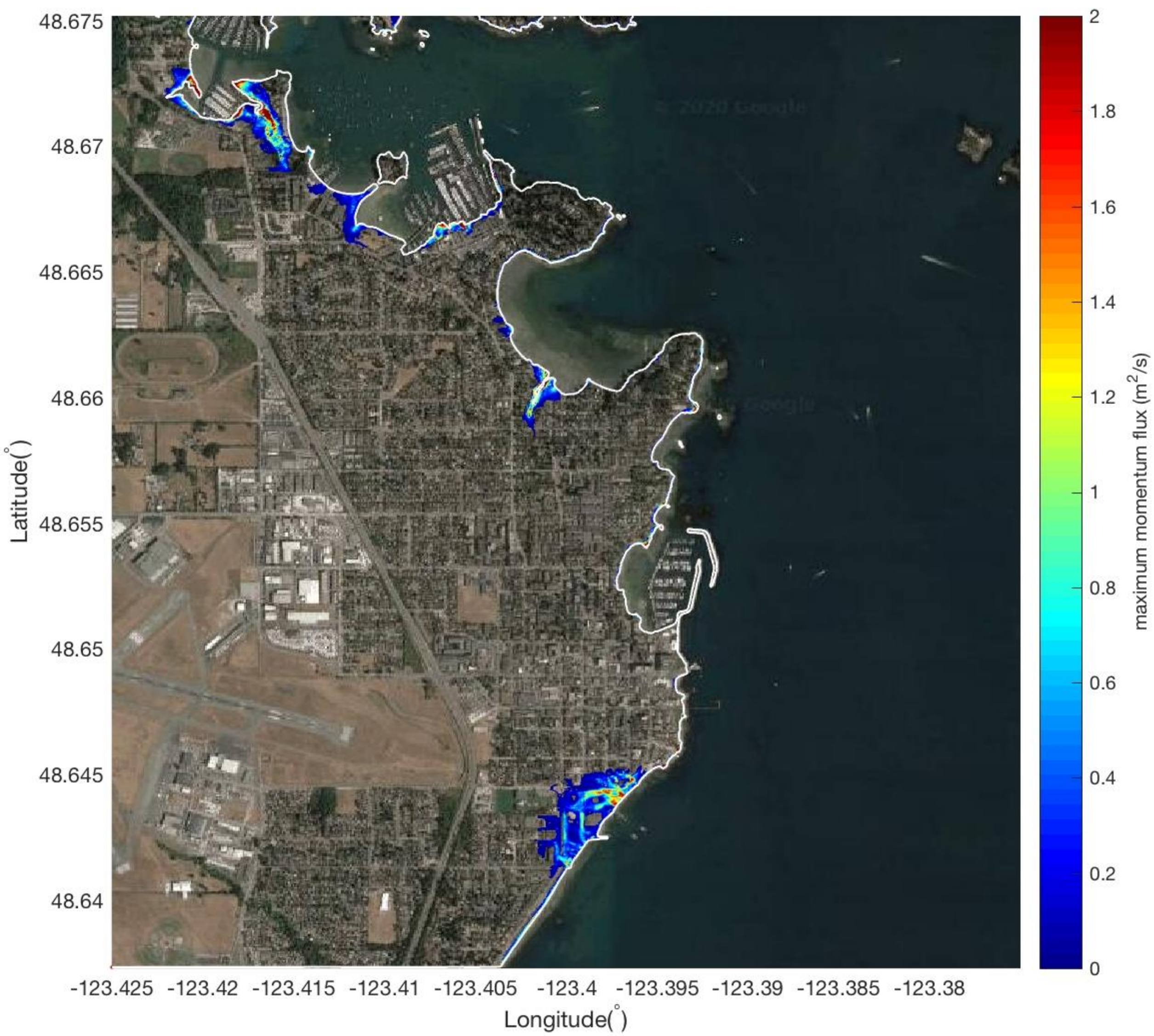
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
20
18
16
14
12
10
8
6
4
2
0
maximum momentum flux (m²/s)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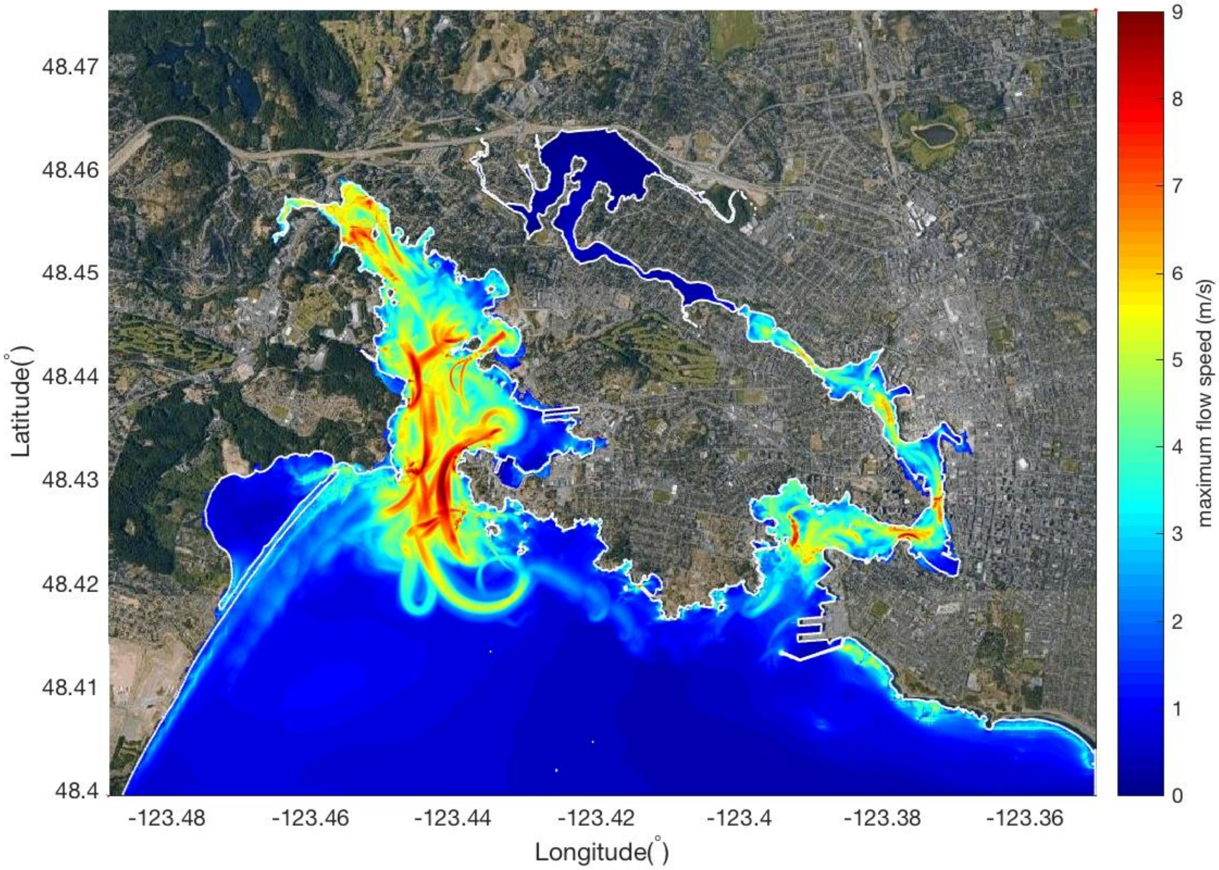
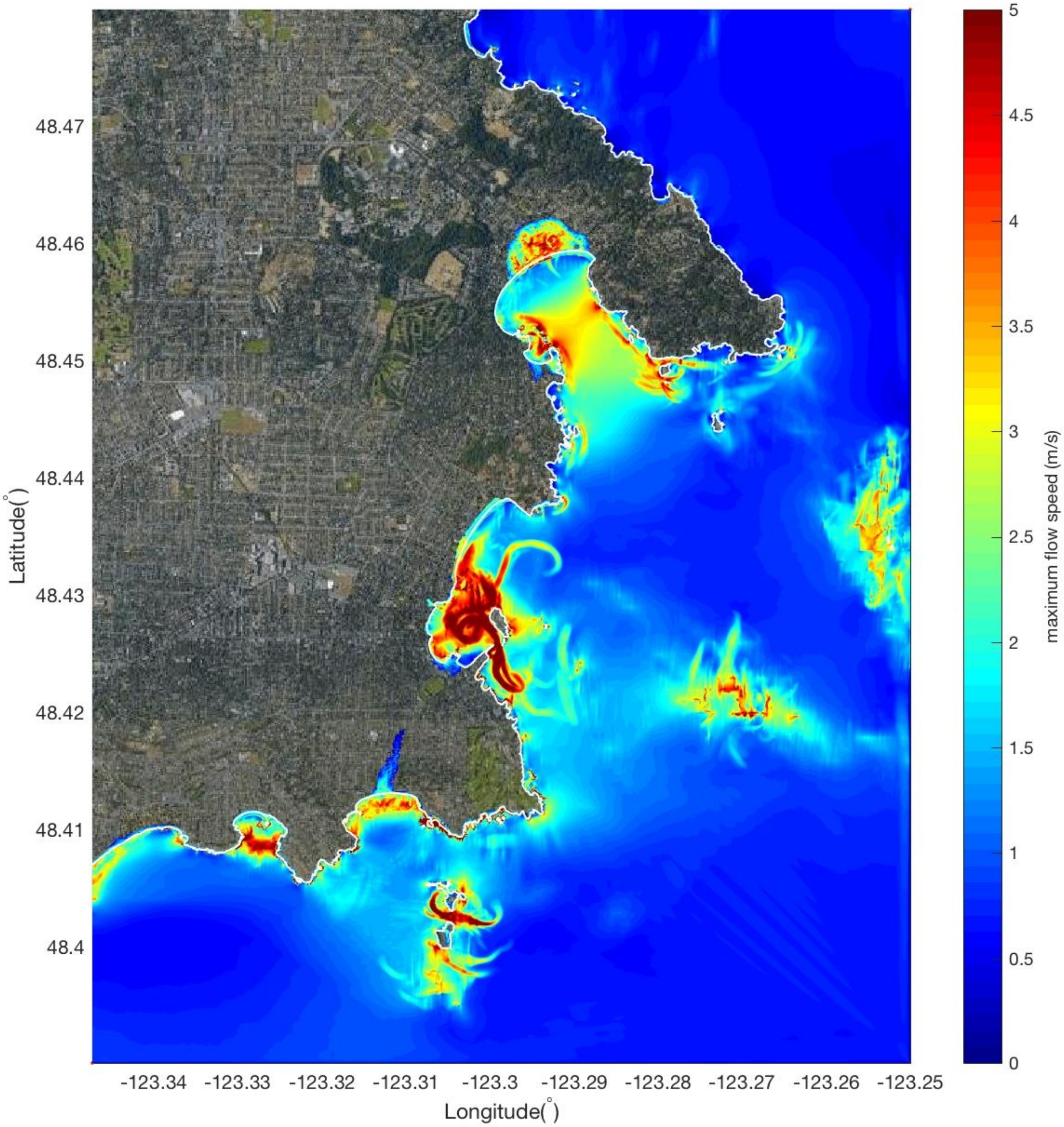
Longitude(°)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
maximum momentum flux (m²/s)
© 2020 Google
Google

Maximum Flow Speed: DM1

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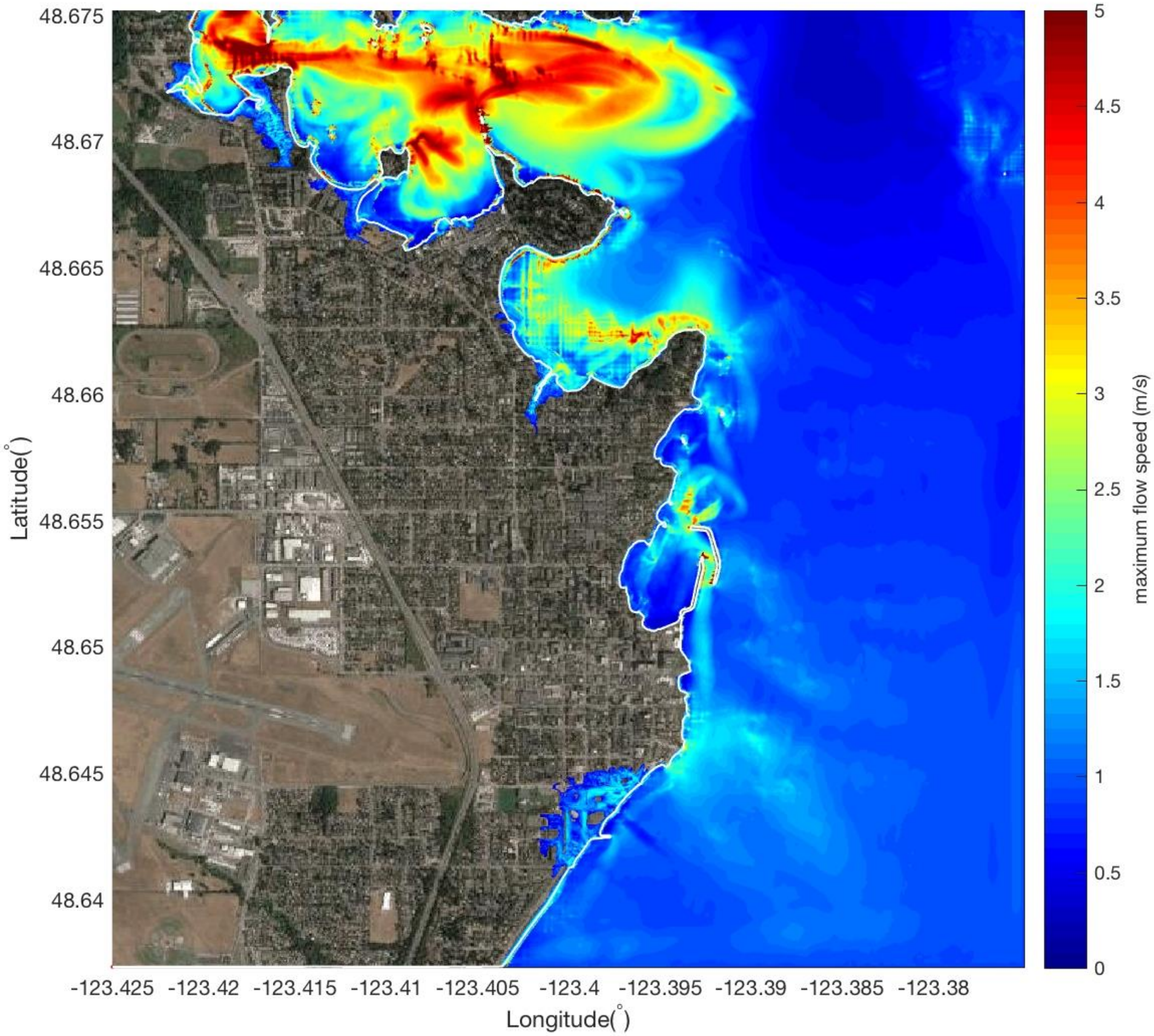
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum flow speed (m/s)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48.64
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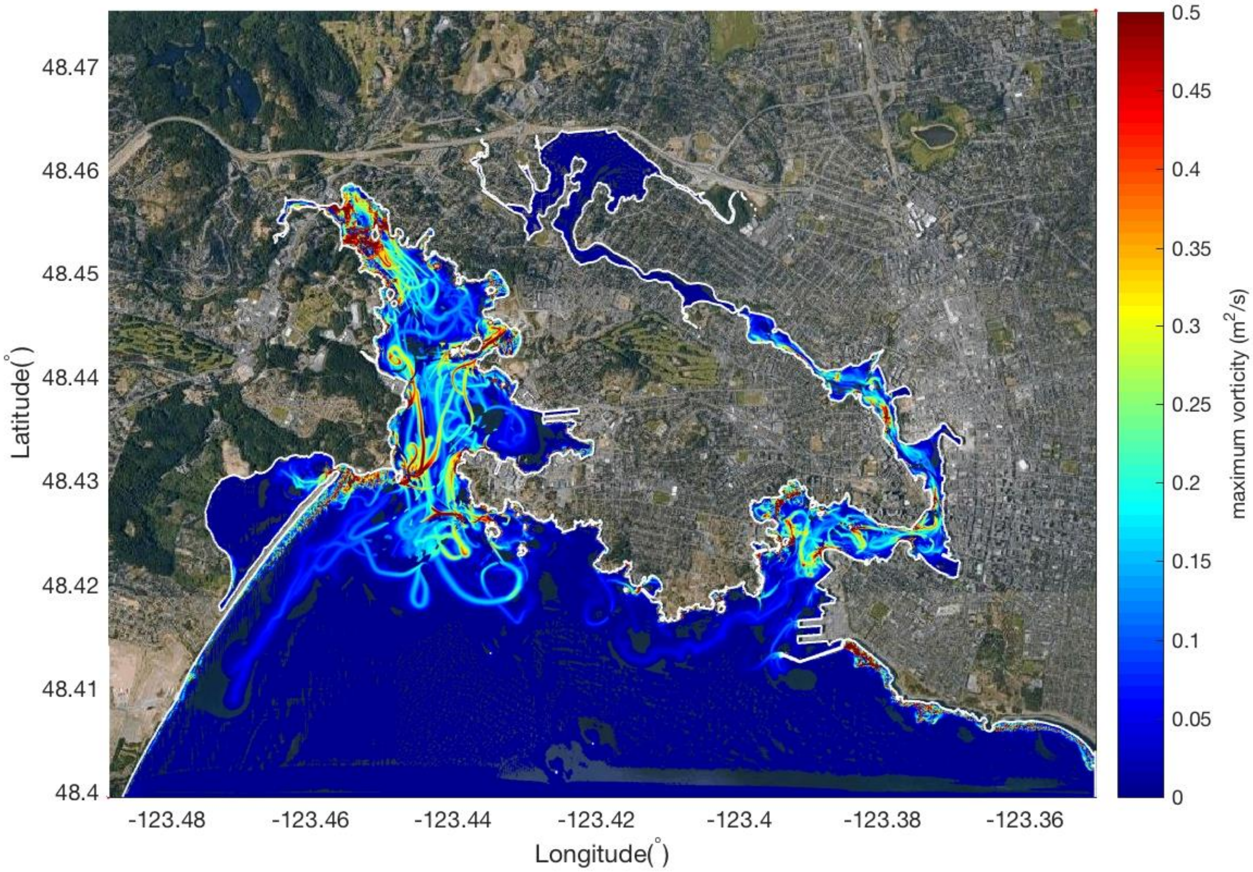
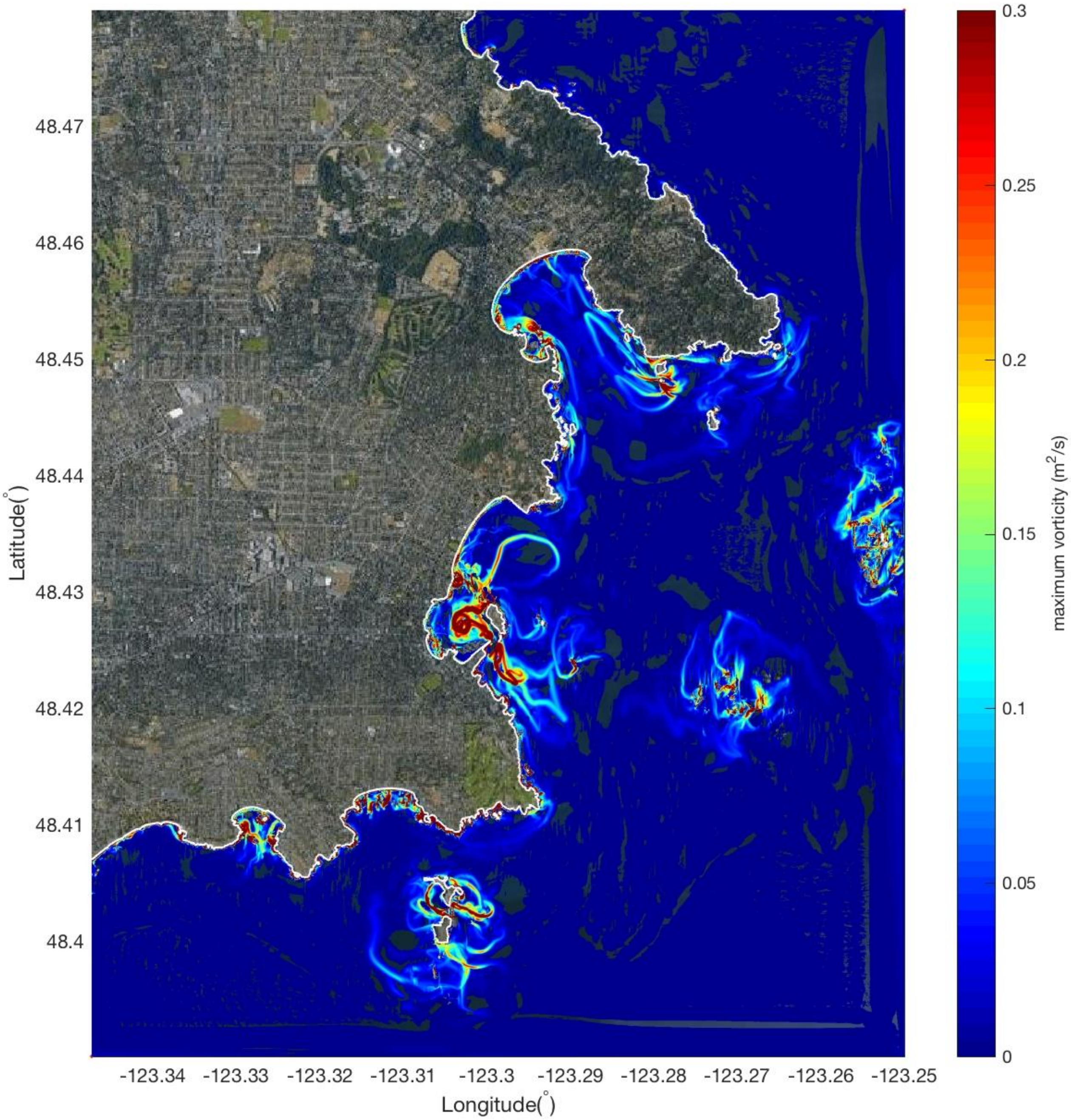
Longitude(°)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
maximum flow speed (m/s)

Maximum Vorticity: DM1





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48.46
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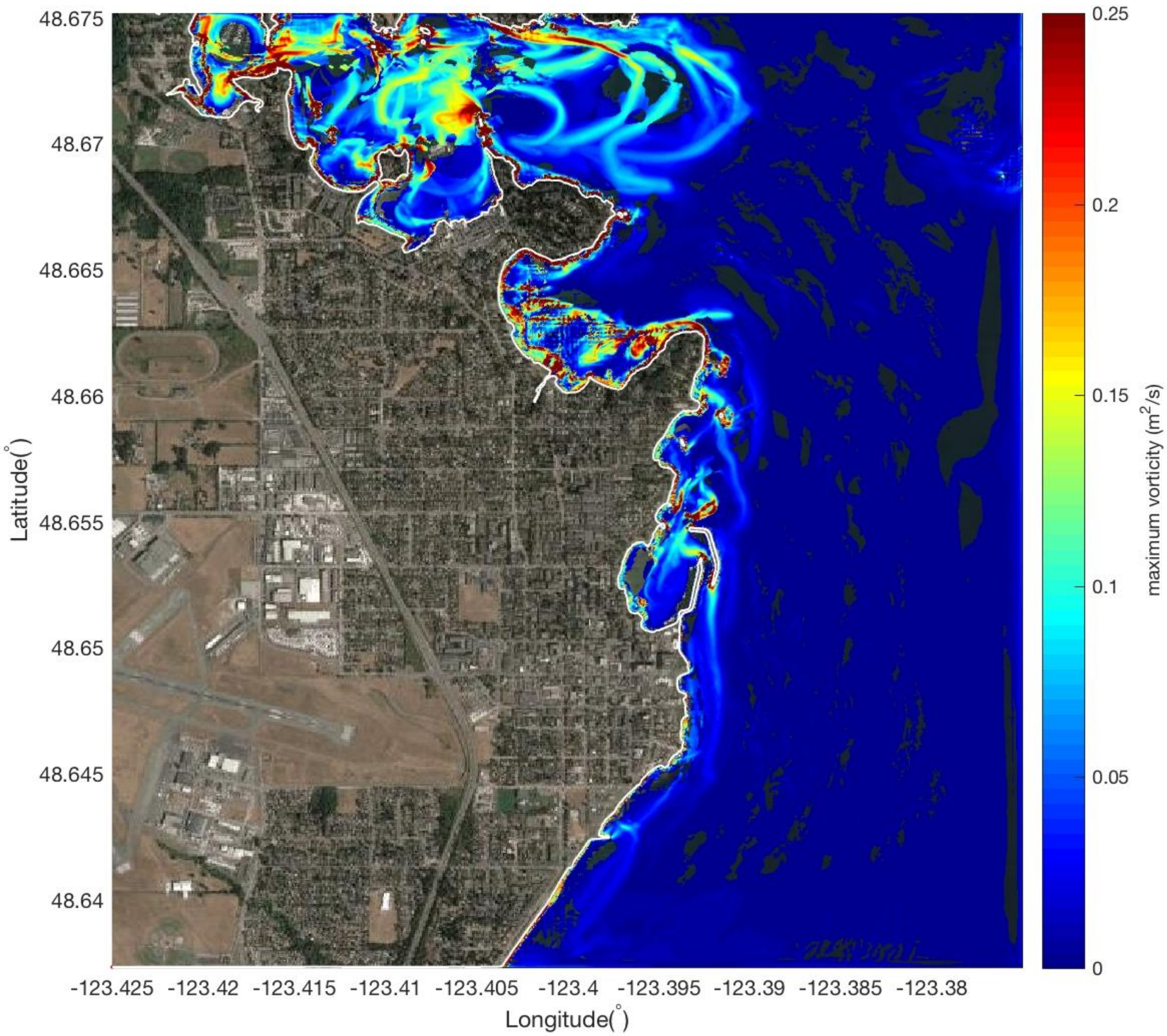
48.4
Latitude(°)
-123.34
-123.33
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
0.3
0.25
0.2
0.15
0.1
0.05
0
maximum vorticity (m2/s)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48.64
Latitude(°)
-123.425 -123.42 -123.415 -123.41 -123.405 -123.4 -123.395 -123.39 -123.385 -123.38
Longitude(°)
0.25
0.2
0.15
0.1
0.05
0
maximum vorticity (m²/s)

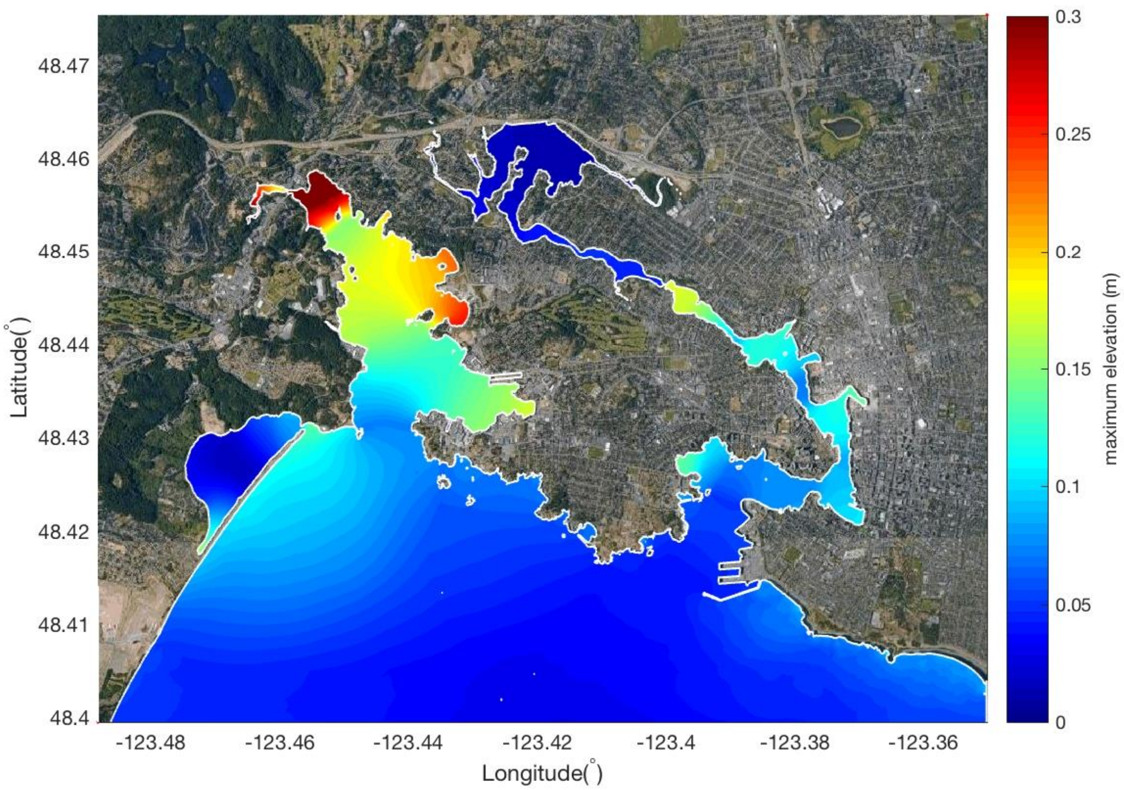
APPENDIX M - DETAILED INUNDATION GRID RESULTS: DEVIL'S MOUNTAIN FAULT, MW 6.5 (DM2)

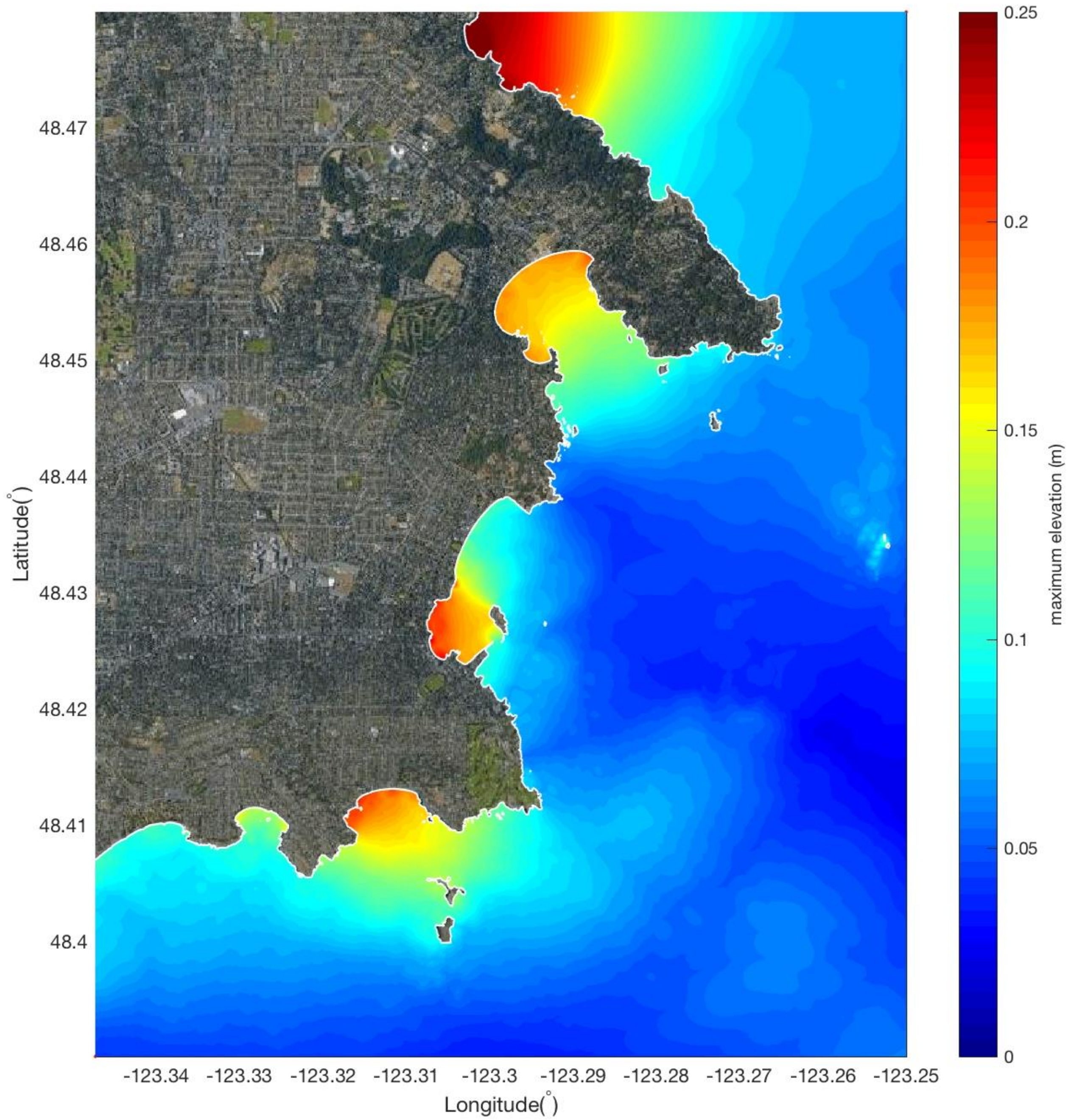
This appendix presents results for the DM2 event, for each detailed modelling domain. For each result parameter, the results are presented in the following order, Port Renfrew, Sooke, Victoria / Esquimalt, Saanich / Oak Bay and Sidney. Any events not presented in **Appendices E - M** were deemed not critical for that particular location (e.g. HG1 does not result in noticeable tsunami waves at Saanich).

Maximum Water Surface Elevations: DM2

(Elevations are reported to m above HHWMT datum).

DM2 does not have noticeable effect on Sooke and Port Renfrew domains.

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Latitude(°)
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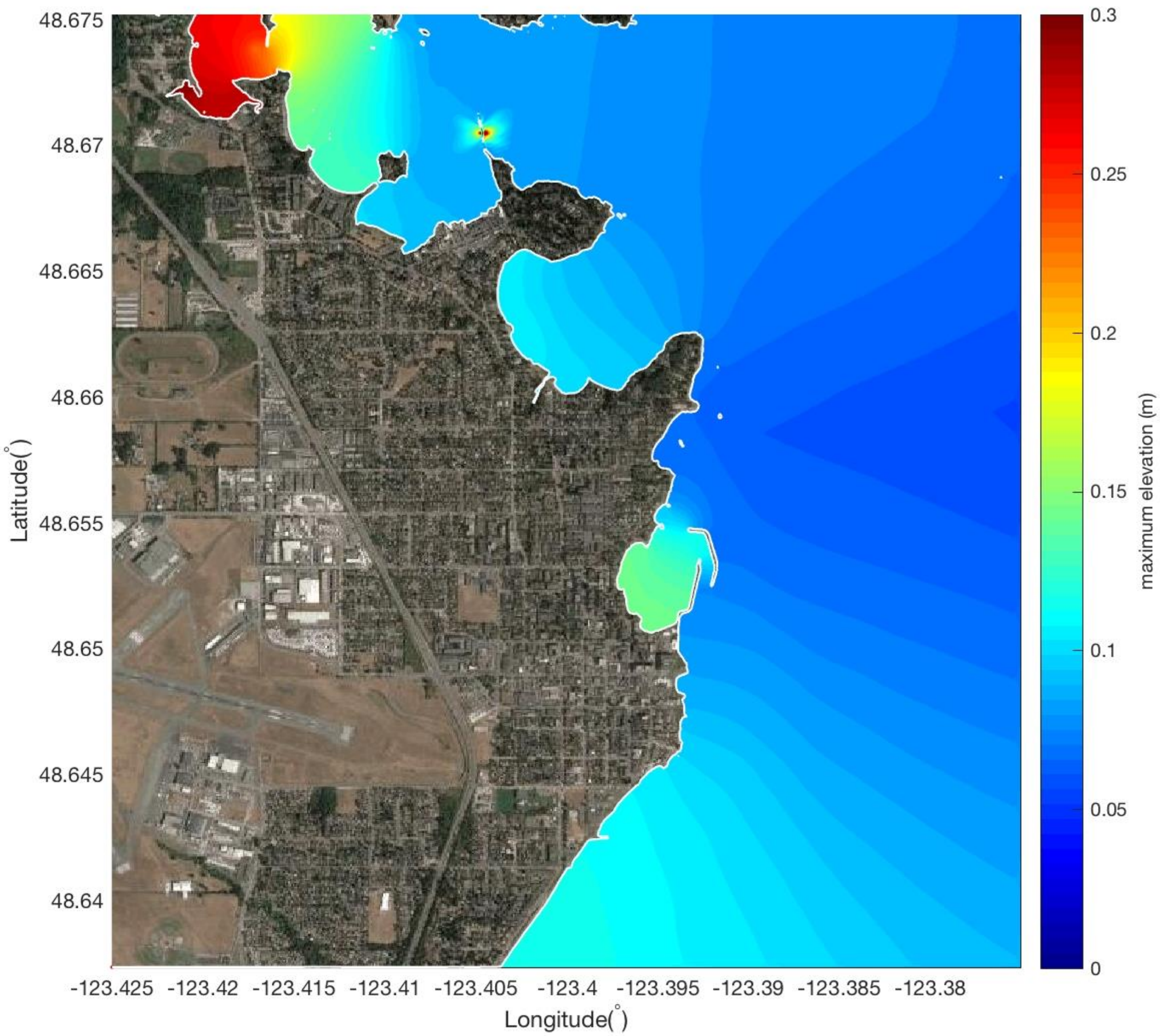
-123.32
-123.31
-123.3
-123.29
-123.28
-123.27
-123.26
-123.25
Longitude(°)
0.25
0.2
0.15
0.1
0.05
0
maximum elevation (m)



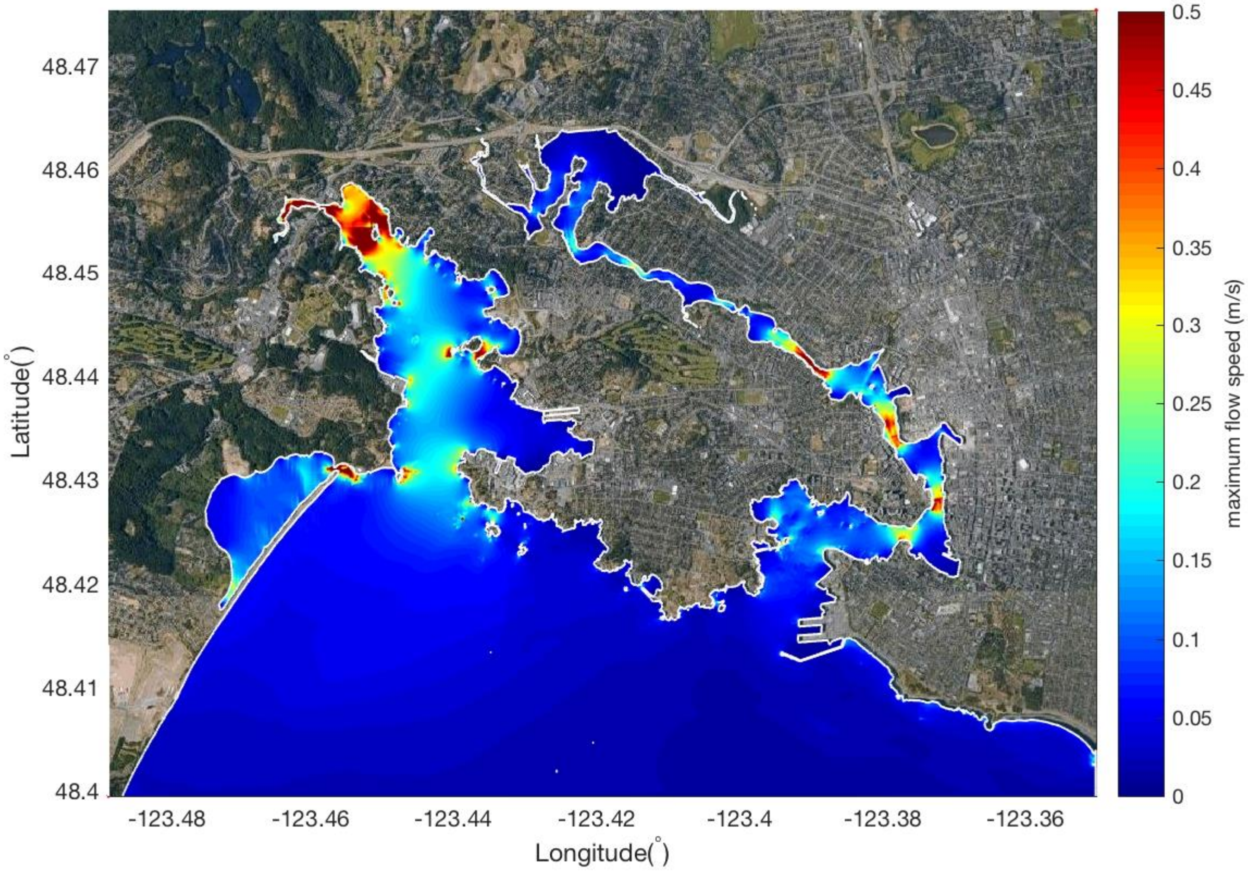
Maximum Inundation Depths: DM2

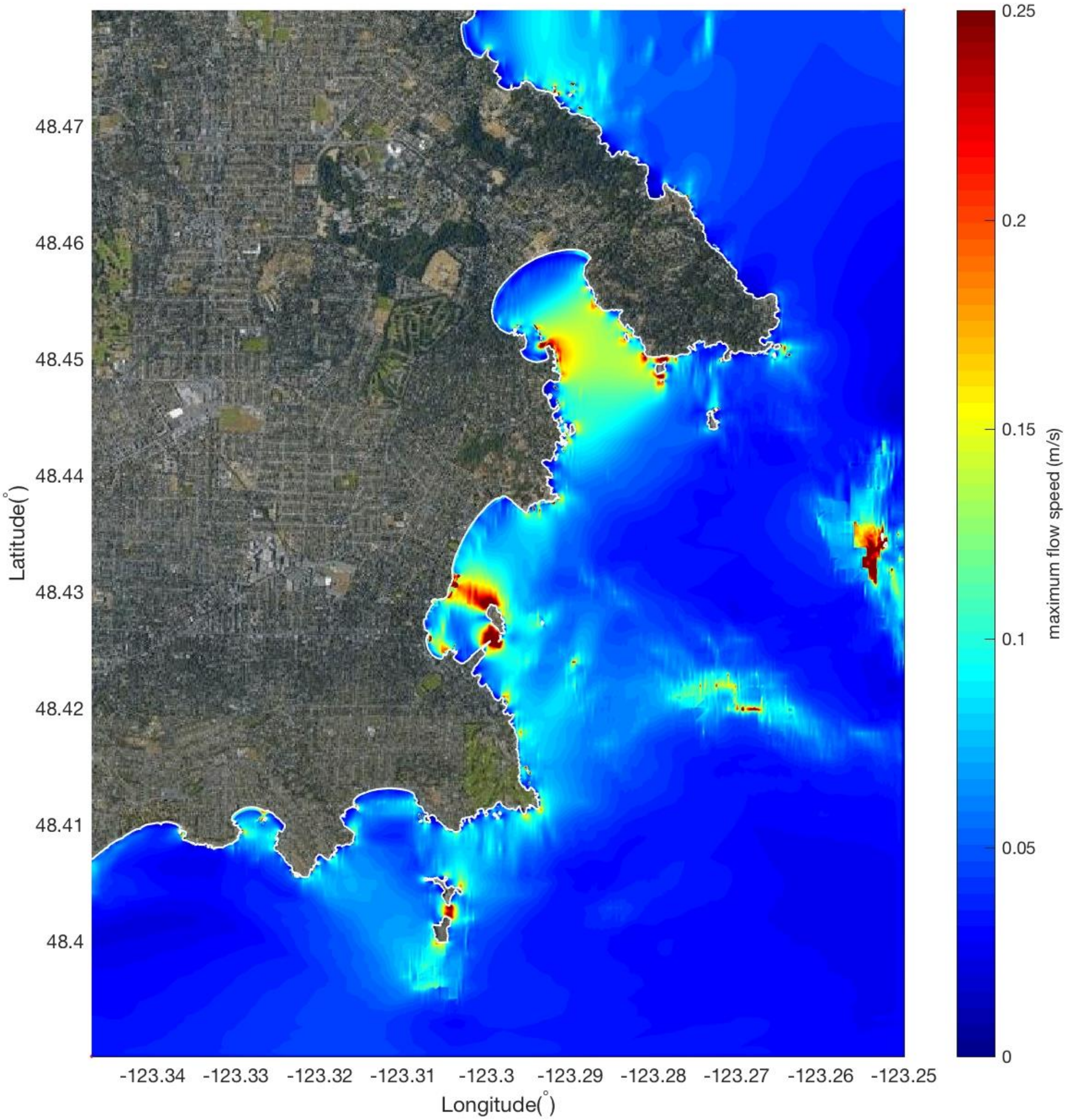
There was no inundation associated with DM2.

Maximum Momentum Flux: DM2

There were no momentum flux plots produced for DM2.

Maximum Flow Speed: DM2

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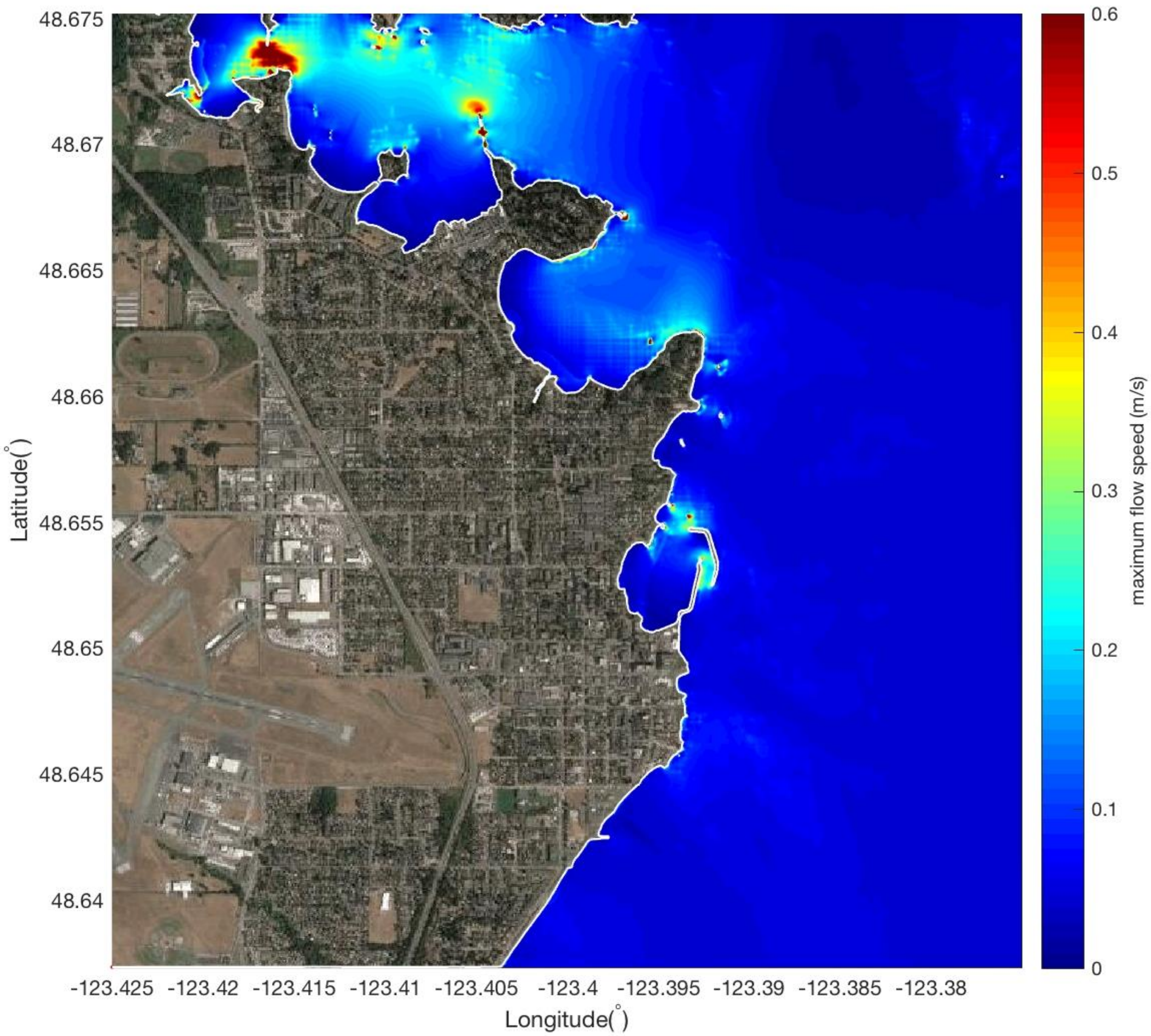
48.4
Latitude(°)
-123.34 -123.33 -123.32 -123.31 -123.3 -123.29 -123.28 -123.27 -123.26 -123.25
Longitude(°)
0.25
0.2
0.15
0.1
0.05
0
maximum flow speed (m/s)



Maximum Vorticity: DM2

There were no vorticity plots produced for DM2 in the detailed model domains.

APPENDIX N - DATUM CONVERSION

CGVD28 – CGVD2013 Relationship

A complicating factor of this project is the necessity of handling topographic data with two different vertical datums: Canadian Geodetic Vertical Datum 1928 (CGVD28) and Canadian Geodetic Vertical Datum 2013 (CGVD2013).
A vertical datum is the benchmark against which elevations are reported. Historically, elevations were reported using the CGVD28 vertical datum. It is a tidal datum defined by the mean water level at five different tide gauges: Yarmouth and Halifax on the Atlantic Ocean, Pointe-au-Père on the St. Lawrence River, and Vancouver and Prince Rupert on the Pacific Ocean. The datum was propagated throughout the country using geodetic levelling measurements, which yielded 94,000 benchmarks for surveyors to tie into. Typically, when someone states that an elevation is at 'X' m geodetic, they are most likely referring to an elevation using the older CGVD28 datum.

However, with the advent of contemporary Global Navigation Satellite Systems (GNSS) such as GPS, a more precise system was achievable. Thus, Natural Resources Canada (NRCan) released CGVD2013 to modernize Canada's vertical reference system. CGVD2013 is defined by the equipotential surface W0=62,636,856.0 m^2 s-2; the coastal mean sea level for North America. It enables measurements of elevations with respect to a consistent vertical datum everywhere across Canada using GNSS and emerging technologies.

However, problems occur when applying the change in vertical datum to existing and future datasets. The difference between CGVD2013 and CGVD28 is not a constant; it varies spatially, depending on where you are in Canada, as shown in **Figure N-1**.

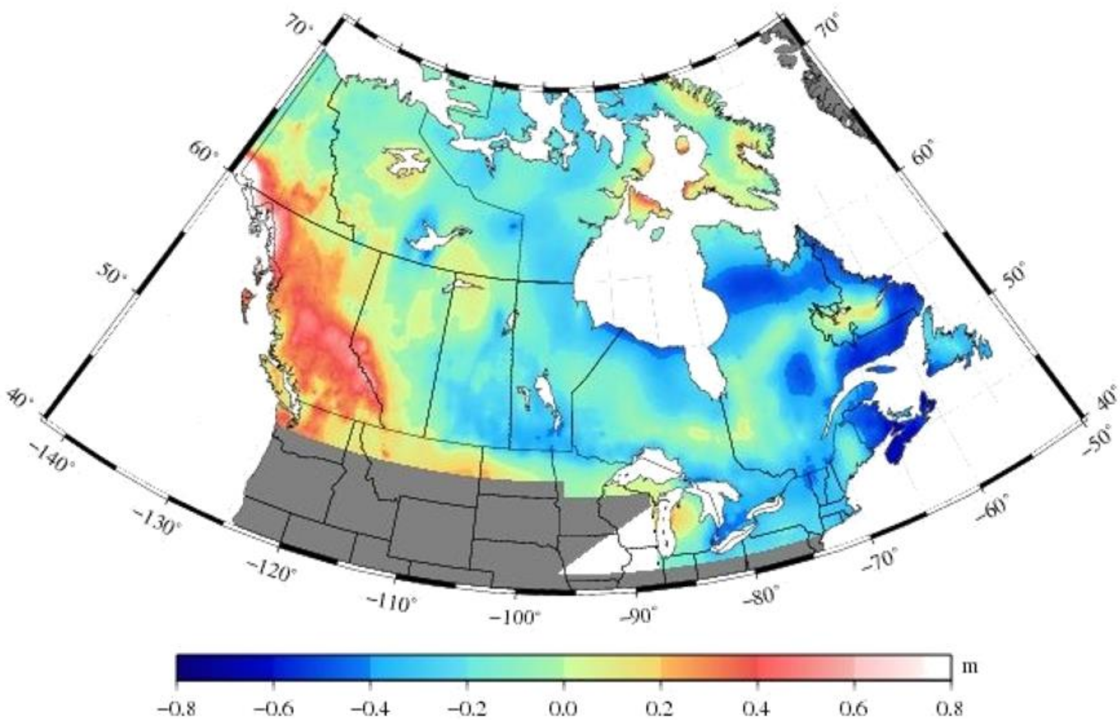


Figure N-1
Conversion between CGVD28 and CGVD2013 across Canada

Locally, for most places in BC, CGVD2013 datum is below CGVD28 datum. For example, reporting CGVD28 elevations in CGVD2013, requires a shift of +0.40 m in Revelstoke, whereas South Vancouver Island requires a +0.13 m shift. Even at a regional scale, the difference between datums is not a constant, as evident in **Figure N-2** which shows the relative change between CGVD2013 and CGVD28 across the capital region. Therefore, it will be difficult for local governments and interested stakeholders to convert their existing reports, record drawings, and datasets to the new datum.

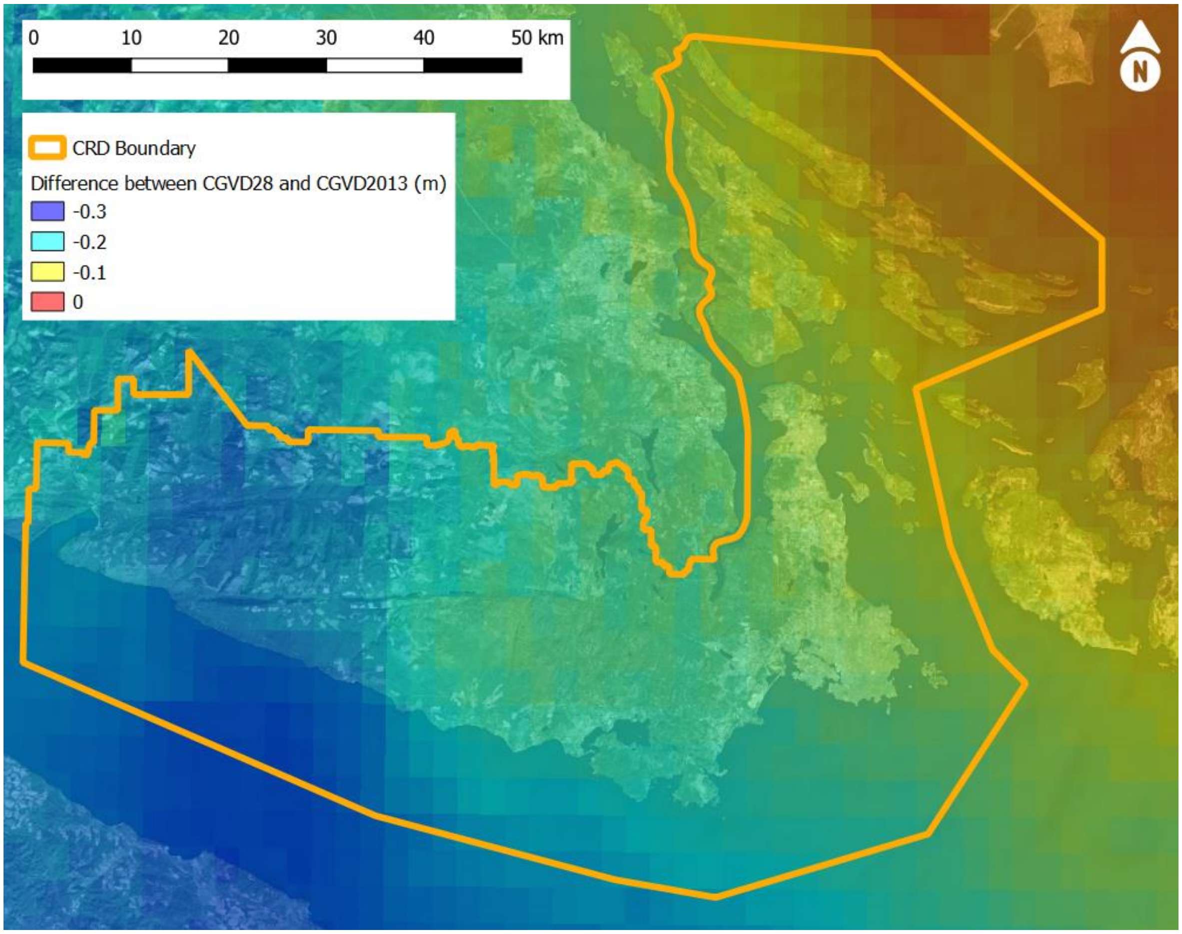


Figure N-2
Conversion between Elevations Reported in CGVD2013 to CGVD28 within the capital region

The new GeoBC LiDAR was flown to CGVD2013, however all of the existing capital region elevation datasets are to CGVD28. For the purposes of this project, CGVD2013 was adopted as the reporting datum. Therefore, all deliverables for this project will be referenced to CGVD2013:

$$Elevation\ reported\ to\ CGVD2013 = Elevation\ reported\ to\ CGVD28\ + Site\ Specific\ Conversion$$

As demonstrated in **Figure N-2**, there is not a consistent conversion across the capital region between the datums. NRCan's conversion grid[21], which can be downloaded from their website, was used to convert elevations reported in

[21] https://webapp.geod.nrcan.gc.ca/geod/data-donnees/geoid.php

CGVD28 to CGVD2013. A quick rule of thumb number that could be used is + 0.13 m, however, refer to the site-specific conversion for more detailed analyses.

For the time being, NRCan intends for both vertical reference systems to exist side-by-side in the short-medium term, to allow users to smoothly transition to the new geoid model. For site-specific work, like subdivision development or municipal structure replacement / construction, the disruption due to the new datum should be minimal, as it will only require one site-specific conversion. However, the greatest impact will be felt on projects like this one, which encompass large areas. In these cases, conversions between CGVD28 and CGVD2013 could be significantly different, depending on location. This will continue to be a problem that public bodies and private businesses must resolve in the years to come. As previously stated, this has manifested itself on this project as some background GIS information is referenced to CGVD28 (i.e. the old datum), thereby necessitating a conversion. **It is also important to note that all deliverables produced as part of this project are to be referenced to CGVD2013**. **Any users / readers of this report, as well as Task 2 deliverables, must ensure that they understand the difference between the old and new datum for their particular interest area.**

For more information related to the CGVD28 / CGVD2013 relationship, refer to the following:

Provincial Guidance
https://www2.gov.bc.ca/gov/content/data/geographic-data-services/georeferencing/vertical-reference-system

Federal Guidance
https://www.nrcan.gc.ca/height-reference-system-modernization/9054

Online Conversion Tool
https://webapp.geod.nrcan.gc.ca/geod/tools-outils/gpsh.php

HHWMT – CGVD2013

As has been repeated throughout this document, the tsunami inundation modelling was undertaken on a base water level of Higher High-Water Mean Tide (HHWMT). This means that any reported Hmax values must undergo a conversion to relate these values to CGVD2013 elevations. The relevant conversion factors are given below:

Table N-1
CGVD 2013 values of common tide levels at various ports in the capital region

2013

Port	Higher High Water		Lower Low Water		Recorded Extreme		Mean Water Level
	Mean Tide (m)	Large Tide (m)	Mean Tide (m)	Large Tide (m)	HHW (m)	LLW (m)	(m)
Port Renfrew	1.222	1.922	-0.978	-1.778	2.522	-1.978	0.122
Victoria	0.767	1.367	-0.933	-1.833	2.067	-2.233	0.167

Table N-2
Common tide levels, to chart datum, at various ports in the capital region[22]

Chart Datum (CD)

Port	Higher High Water		Lower Low Water		Recorded Extreme		Mean Water Level
	Mean Tide (m)	Large Tide (m)	Mean Tide (m)	Large Tide (m)	HHW (m)	LLW (m)	(m)
Port Renfrew	3.0	3.7	0.8	0.0	4.3	-0.2	1.9
Sooke	2.8	3.4	0.9	0.3	3.9	-0.2	1.9
Victoria	2.5	3.1	0.8	-0.1	3.8	-0.5	1.9
Fulford Harbour	3.3	3.7	0.9	-0.1	4.4	-0.5	2.3

[22] http://charts.gc.ca/documents/publications/tables/2020_vol5.pdf

Example Calculation:

Higher High-Water Mean Tide @ Port Renfrew =	3 m, relative to Chart Datum (CD)
To convert tsunami results @ Port Renfrew =	-1.778 m (from CHS conversion grid[23])
Thus, HHWMT @ Port Renfrew =	1.22 m CGVD2013
10 m Hmax tsunami result @ Port Renfrew relative to HHWMT become =	11.22 m CGVD2013

[23] Task 1 - DEM Development Report, Associated Engineering, 2020