Powell River Regional District Landslide and Fluvial Hazards Study Electoral Area D – Texada Island

PRESENTED TO

POWELL RIVER REGIONAL DISTRICT

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LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Powell River Regional District and their agents. Tetra Tech EBA Inc. (Tetra Tech EBA) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Powell River Regional District, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech EBA's Services Agreement. Tetra Tech EBA's General Conditions are provided in Appendix A of this report.

1.0 INTRODUCTION

1.1 General

Tetra Tech EBA Inc. (Tetra Tech EBA) has been retained by the Powell River Regional District (the PRRD) to carry out a study to delineate landslide and fluvial hazard areas in the communities of Van Anda and Gillies Bay on Texada Island, which are located within Electoral Area D of the PRRD. This study was carried out under the terms of a Tetra Tech EBA Services Agreement signed August 26, 2016.

1.2 Objective

The objective of this study is to identify areas within the communities of Van Anda and Gillies Bay which may be vulnerable to landslide and/or fluvial hazards. This report and the attached figures are intended to be used by the PRRD for <u>planning purposes only</u>, and provide <u>limited overview mapping</u> of landslide and fluvial hazards. The results of this study will provide the PRRD with a technical basis to determine if there is a need to integrate the hazard areas into Development Permit Areas (DPAs) for future developments.

1.3 Scope of Services

As outlined in our July 2016 proposal to the PRRD, our scope of work for this study was limited to the following:

- Desktop study of: existing information provided by the PRRD; readily available geotechnical reports; Tetra Tech EBA project archives; documents, records and web-based information relating to site setting, topography, geology, terrain, bedrock and soil deposits; and water well records.
- Comparative review of the slope development policies in other, nearby regional districts.
- Review and interpretation of available aerial imagery and topographic data in order to identify landforms and geomorphological processes to facilitate the identification of landslide and fluvial hazards within the study area.
- Site reconnaissance fieldwork in key areas identified from the above tasks, in order to assess the terrain and slope features, soil and bedrock conditions as well as landslide and fluvial hazard processes.
- Regional hydrological analysis and modeling of flood flows along the major creeks and watercourses.
- Delineation of landslide and fluvial hazard areas based on the topography of the study area and additional engineering criteria established from the results of the above.
- Presentation of the results of the above in a summary report (this report).

1.3.1 Exclusions

The following items are excluded from our scope, as previously discussed and agreed to with the PRRD:

- Assessment of subsidence / sinkhole hazards on Texada Island related to historical underground mine workings and karst terrain in areas underlain by limestone bedrock.
- Assessment of coastal hazards including sea level rise, storm surges, wave hazards and coastal erosion.
- Assessment of climate change implications on landslide and fluvial hazards.
- Assessment of tsunami hazards, which are addressed in a 2007 study completed for the PRRD.
- Assessment of seismic (earthquake) hazards or related phenomena.
- Assessment of wildfire or snow avalanche hazards.

2.0 INFORMATION REVIEWED

2.1 General

The following information was reviewed as part of this study:

- 2 m topographic contours, orthophotographs (for the years 2006 and 2012) and various other GIS datasets provided by the PRRD.
- Available 1:20,000 scale TRIM topography and watercourse mapping.
- Available water well logs from the BC Water Resources Atlas (http://maps.gov.bc.ca/ess/sv/wrbc/).
- BC Ministry of Forests Biogeoclimatic Ecosystem Classification Mapping.
- Canadian Hydrographic Service (CHS) Nautical Chart Nos. 3513 and 3536, Strait of Georgia.
- Environment Canada Climate Normals and Averages (period 1981-2010).
- Historical aerial photographs of the study area obtained from the UBC Air Photo Library for the years 1946, 1952, 1960, 1968, 1978, 1988, 1992, 1999 and 2003.
- Landsat 8 satellite imagery dated May 13, 2016.
- Meteorological Services of Canada Hourly Climate Data as well as Water Survey of Canada (WSC) streamflow information for all weather stations and gauged watercourses in the vicinity.
- Relevant geological maps and papers published by the Geological Survey of Canada, BC Geological Survey, Canadian Geotechnical Journal and other information sources.
- Relevant historical articles and archival photographs published by the Texada Island Heritage Society.

2.2 Development Permit Areas

Most local governments in British Columbia identify critical natural features within the boundaries of their jurisdiction that are particularly sensitive to the impacts of future development, such as areas of potential landslide hazard. For such areas, further review may be needed before development takes place. Development permits are a tool which provides for review and management of development at the site level. Areas of particular concern may be designated as Development Permit Areas (DPA) and within these areas, a development permit may be needed prior to development work being undertaken. Development permits are issued by the local municipality, regional district, or other governing body as authorized by the Local Government Act, based on the objectives and guidelines outlined in the Official Community Plan (OCP). In most cases, an owner must obtain a Development Permit before:

- Subdividing land within the DPA;
- Starting construction of, addition to or alteration of a building or other structure; or
- Altering the land within the DPA.

In most instances, the OCP designates all DPA as areas for which, in specified circumstances, development approval information may be required, meaning that information on the anticipated impact of the proposed activity or development on the community is needed.

2.3 Review of Slope Development Policies in Other Jurisdictions

Tetra Tech EBA reviewed the current slope development policies of other nearby islands and regional districts bordering the Strait of Georgia (Salish Sea), including Denman Island, Hornby Island, Gambier Island, Bowen Island, the Comox Valley Regional District and the Sunshine Coast Regional District. These are discussed in more detail below.

2.3.1 Denman Island

The Denman Island OCP (Bylaw No. 185) identifies a total of three (3) DPAs for steep slopes and other potentially hazardous lands. The steep slopes DPA is intended to apply to land with slope gradients of 60% or greater. The other DPAs encompass the Komas Bluff and the coastline along Lacon Road.

2.3.2 Hornby Island

The Hornby Island OCP (Bylaw No. 104) identifies a DPA for hazard areas that defines such lands as having a slope gradient in excess of 30%. A large slump feature located along the south-west side of Mount Geoffrey between Ford Cove and Shingle Spit is also included in the DPA.

2.3.3 Gambier Island

The Gambier Island OCP (Bylaw No. 73) identifies a DPA for hazardous lands that defines such lands as having a slope gradient in excess of 35%. The OCP states that land use and development should be protected from hazardous conditions and should generally avoid locating below or on slopes until further studies are completed.

2.3.4 Bowen Island

The Bowen Island OCP (Bylaw No. 282) identifies a DPA for steep slope areas which applies to slopes with a slope gradient of 30% or greater for a minimum horizontal distance of 10 m. The OCP stipulates that proposed developments within or downslope of the DPA require the applicant to provide a geotechnical report indicating how the land may be used safely for the proposed development. The report must also specify measures that the applicant must remediate in order to enable the proposed development to better withstand the effects of the hazard.

2.3.5 Comox Valley Regional District

The Comox Valley Regional District (CVRD) has established a DPA for steep slope areas which applies to slopes greater than 3 m in height with a gradient exceeding 30%, slopes designated as hazard lands by a professional engineer with experience in geotechnical engineering, as well as areas within 7.5 m of the top or bottom of the aforementioned slopes. Proposed developments within the DPA require a geotechnical report submitted by a professional engineer with experience in geotechnical engineering.

2.3.6 Sunshine Coast Regional District

The Sunshine Coast Regional District (SCRD) has seven electoral areas, each of which has an individual Official Community Plan (OCP). These OCPs include Geotechnical DPAs adjacent to shorelines, ravines, steep slopes and other potentially hazardous areas, although the type and number of Geotechnical DPAs (and the criteria/rationale which was used to develop the DPAs) varies by electoral area.

According to the SCRD website, *"all Development Permits within a geotechnical hazard area must include a report completed by a qualified geotechnical engineer. The assessment report on the proposed development is required that meets the SCRD's risk assessment and liability standards prior to the SCRD issuing a Development Permit:*

- *Minimum acceptable risk threshold for flooding is 1:200 years.*
- *Minimum probability for other geotechnical occurrences must be less than 2% in 50 years (or 1:2475 years).*
- *The report must state that the proposed development is safe for the use intended".*

2.3.7 Summary

A comparative summary of geotechnical development permit areas for each of the above jurisdictions is provided in Table 1:

Table 1: Summary of Slope Development Policies in other Jurisdictions

Local Government	DPA Criteria (Steep Slopes / Hazardous Lands)
Denman Island (1)	▪ Slopes 60% or greater. ▪ Komas Bluff and Lacon Road coastline.
Hornby Island (1)	▪ Slopes 30% or greater. ▪ The south-west side of Mount Geoffrey between Ford Cove and Shingle Spit.
Gambier Island (1)	▪ Slopes 35% or greater and adjacent downslope areas.
Bowen Island (1)	▪ Slopes 30% or greater for a minimum horizontal distance of 10 m and adjacent downslope areas.
Comox Valley Regional District	▪ Slopes 30% or greater with minimum vertical height of 3 m, other hazardous slopes as designated by a professional geotechnical engineer, including areas within 7.5 m of the top or bottom of these slopes.
Sunshine Coast Regional District	▪ DPAs defined based on broad criteria, which vary by electoral area, but generally include steep slope areas, ravines and shorelines.

(1) Island municipality within the Islands Trust federation of local governments serving islands in the Salish Sea.

3.0 STUDY AREA

3.1 General

The study area comprises two parcels of land measuring approximately 7.3 km^2 and 5.7 km^2 in size which encompass the communities of Van Anda and Gillies Bay, respectively (Figure 1). Texada Island is sparsely populated with a total of approximately 1,000 permanent residents according to the 2011 Canadian Census. Further details of development and land uses on the island can be found in the Texada Island OCP (2005).

The community of Van Anda is located on the north side of Texada Island (Figure 1), about 9 km from the ferry terminal at Blubber Bay. The terrain is predominantly bedrock-controlled and includes several areas of steep bluffs and northwesterly-trending ridgelines. The coastline is fairly rugged, generally comprised of moderate to steep slopes interspersed with pocket beaches and small embayments (Golder, 2004).

The community of Gillies Bay is located on the south side of Texada Island (Figure 1), about 20 km from the ferry terminal at Blubber Bay. The terrain is characterized by a moderate to steep coastal escarpment up to 30 m high comprised of thick deposits of dense glacial soils. The escarpment gradually decreases in height towards the head of the bay, as well as towards Shelter Point Regional Park in the southeast corner of the study area. The terrain is relatively flat to the north of the head of the bay, and in this area the dense glacial soils are mantled by younger marine and fluvial deposits. Along the east and west sides of the bay, the areas upslope of the coastal escarpment comprise shallow to gently undulating slopes which give way to steeper bedrock-controlled terrain further inland.

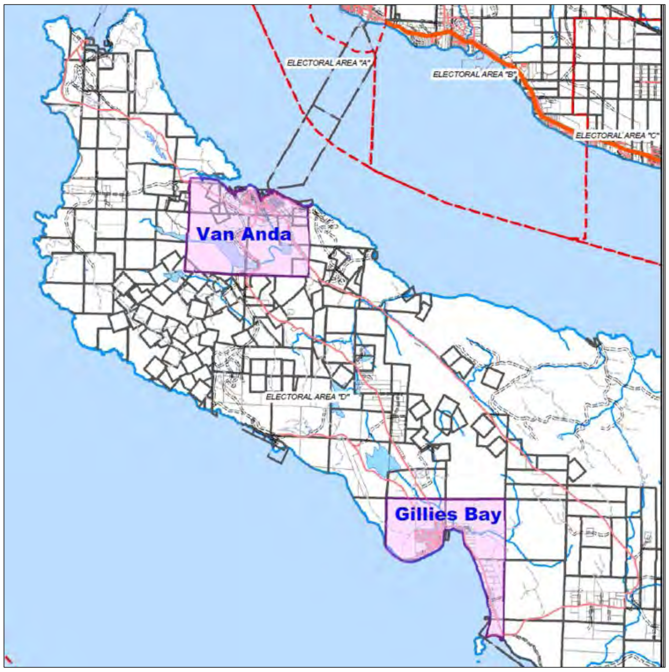

Figure 1: Extent of study area on Texada Island (pink shading), encompassing the communities of Van Anda and Gillies Bay. Base plan provided by PRRD.

3.2 Physiography, Climate and Vegetation

The study area ranges in elevation from sea level to about 175 m above sea level. Texada Island is contained within a larger physiographic region known as the Georgia Lowland, which extends along much of the Strait of Georgia and the adjacent mainland coast. According to Holland (1976), these lowlands rise eastward, away from the Strait of Georgia, merging with the Coast Mountain Range at an elevation of approximately 1300 m above sea level.

The study area is contained entirely within the Coastal Douglas Fir biogeoclimatic zone and experiences relatively warm, dry summers and mild, wet winters. Environment Canada weather records from Powell River (period 1985 to 2015) indicate that mean annual precipitation is about 1200 mm and mean annual snowfall is about 25 cm. Watercourses within the study area will typically experience their annual peak flow between October and February, coinciding with the autumn and winter rain and/or rain-on-snow storm events.

3.3 Bedrock Geology

The bedrock geology of Texada Island is described in detail by Webster and Ray (1990). The northern part of the island, including Van Anda, is generally comprised of volcanic rocks (basalt) of the Triassic Texada Formation overlain by massive limestone of the Marble Bay Formation. These formations are also locally intruded by younger igneous rocks ranging in composition from gabbro to quartz monzonite. At Gillies Bay, the volcanic rocks are overlain by sedimentary rocks including sandstone, shale and conglomerate of the Cretaceous Nanaimo Group.

A simplified bedrock geology map of northern Texada Island is presented in Figure 2. It can be seen that the rock units are cut by a series of primarily northwesterly-trending faults including the Holly, Ideal, Kirk Lake and Marble Bay faults. These faults are ancient geologic structures which are unrelated to the current tectonic regime, and to our knowledge no known active faults have been identified on Texada Island or on the adjacent mainland coast.

However, the potential for active shallow-crustal faulting in this region cannot be entirely ruled out, given that recent studies in Washington State have identified active faults within 5 km of the USA / Canada border.

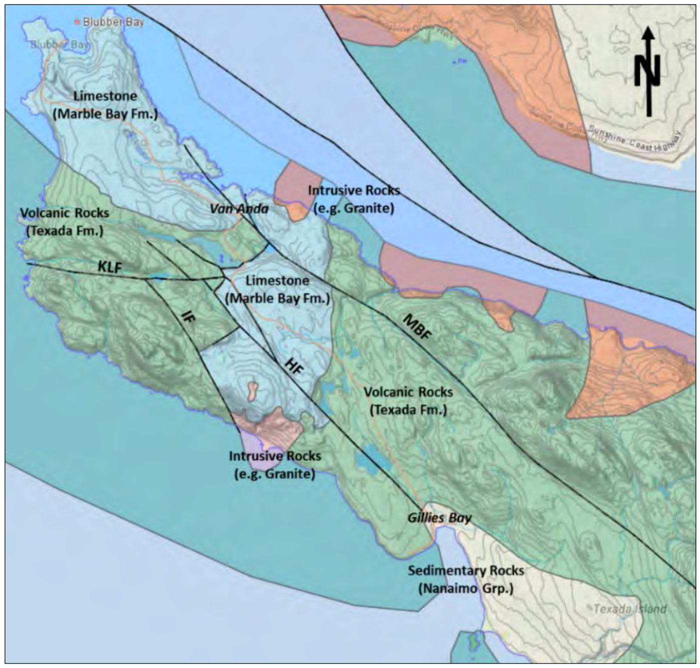

Figure 2: Simplified bedrock geology map of northern Texada Island (modified from BCGS, 2016 and Webster and Ray, 1990). HF = Holly Fault; IF = Ideal Fault; KLF = Kirk Lake Fault; MBF = Marble Bay Fault.

3.3.1 Mineral Deposits

The northern part of Texada Island contains a varied suite of polymetallic skarn and quartz/carbonate vein mineral deposits. According to Webster and Ray (1990), a total of 10 million tonnes of magnetite iron ore, 36,000 tonnes of copper, 40 tonnes of silver and 3.3 tonnes of gold were produced from various mines on the island between 1896 and 1976. Limestone deposits on the island have also been extensively mined by open pit methods for the production of lime, cement and other construction materials.

Mining-related hazards are beyond the scope of this study and would need to be addressed on a site-specific basis.

3.4 Surficial Geology and Soils

The surficial geology of the Sunshine Coast, including Texada Island, is described in detail by Bichler et al. (2002). Like much of British Columbia, the terrain in this area has been largely shaped by the repeated advance and retreat of glaciers over the Quaternary Period (2.6 Million years ago to present). However, the current landscape of the area and the underlying soil stratigraphy were largely formed during the last (Fraser) glaciation, which ended approximately 12,000 years ago. Glacial ice flowed out of the Coast Mountains, then moved southward and southeastward over the Georgia Lowland, depositing a complex assemblage of glacial sediments (till) overlying a thick sequence of older marine and glaciofluvial sediments known locally as the Quadra Sediments. At the time when the area was de-glaciated, relative sea levels were approximately 200 m above the present datum due to glacio-isostatic depression of the earth's crust by the weight of the ice sheet that covered most of British Columbia. Glaciomarine, marine, and glaciofluvial sediments were deposited into the high-level sea, forming an irregular surficial mantle over the till at present day elevations below about 200 m above sea level. These sediments have been subsequently reworked in post-glacial time by fluvial downcutting and mass-wasting processes (for example, in the form of modern stream channel deposits) as the earth's crust rebounded and sea levels fell to the current datum.

Further details of the surficial geology at Van Anda and Gillies Bay are discussed below, based on the published 1:50,000 scale terrain maps, provincial water well logs and other information reviewed as part of this study.

3.4.1 Van Anda

No water well logs are available for the Van Anda area; however, according to the available terrain mapping (Bichler et al. 2002), the surficial geology generally comprises veneers (0.1 to 1 m thick) to blankets (>1 m thick) of glacial till overlying bedrock. Localized areas of organic deposits are also present in the low-lying areas surrounding Spectacle, Priest and Emily Lakes.

3.4.2 Gillies Bay

Available water well logs for the Gillies Bay area indicate that the soils comprise up to 10 m of glacial till, underlain by at least 30 m of Quadra Sediments. The latter consists of interbedded layers sand and silty sand, grading with depth into beds of silt and clay. Quadra Sediments are found in abundance throughout the Strait of Georgia at elevations up to 100 m above sea level, most notably along the eastern coastline of Vancouver Island and on several islands in the Strait including Cortes, Denman, Harwood, Hernando, Marina, Quadra, Savary and Thormanby (Clague, 1977).

3.5 Groundwater

Little is known about the groundwater regime at Van Anda; however, conditions are likely complex based on the bedrock geology and the possible effects of historical underground mine workings and any karst landforms which have developed in limestone, which would act as preferential drainage pathways.

Available water well logs for the Gillies Bay area indicate that the soils underlying the coastal escarpment are "practically dry", although perched water is likely present within the Quadra Sediments near the base of the escarpment, at the contact between the sands and the lower-permeability beds of silt and clay.

4.0 LANDSLIDE HAZARD ASSESSMENT

4.1 Background

The southwest coast of British Columbia is subject to high volumes of precipitation and runoff, which can trigger a number of mass-wasting (landslide) hazards that have the potential to impact developed areas in addition to the general environment. As described below, these hazards may originate in bedrock or soil, and exhibit various modes of movement including falls, slides and flows.

The southwest coast of British Columbia is also situated in a seismically active area. A seismic event may trigger debris slumps, rock falls or other landslide processes; however, in general, the seismic hazard for a specific property must be considered on a site-specific basis. In the case of a proposed development, this is generally captured under the jurisdiction of the British Columbia Building Code (BCBC) 2012.

4.2 Terminology

Landslide hazard terminology referenced in the following sections of the report is summarized in Table 2. Diagrams of typical landslide processes are also shown on the accompanying figure from Varnes (1978).

Table 2: Landslide Hazard Terminology

Mode of Movement		Landslide Process / Material Type [1]	
		Bedrock	**Soil ("Debris") [2]**
Falls		Rock fall	Debris fall
Slides	Rotational	Rock slump	Debris slump
	Translational	Rock slide	Debris slide
Flows		Rock flow	Debris flow
		Rock avalanche	Debris avalanche
Lateral Spreads		Rock spread	Debris spread
Topples		Rock topple	Debris topple
Creep		Slope creep	
Complex and compound		Combination in time and/or space of two or more principal types of movement.	

[1] Table modified from Varnes 1978 and Cruden and Varnes (1996). Terminology also based on Hutchinson (1988) and Hungr et al. (2001).
[2] The term "Debris" refers to coarser soils with at least 20% of particles greater than 2 mm in diameter. Finer soils which do not satisfy this criteria are referred to as "Earth". Most of the soils within the Van Anda and Gillies Bay study areas are comprised of Debris.

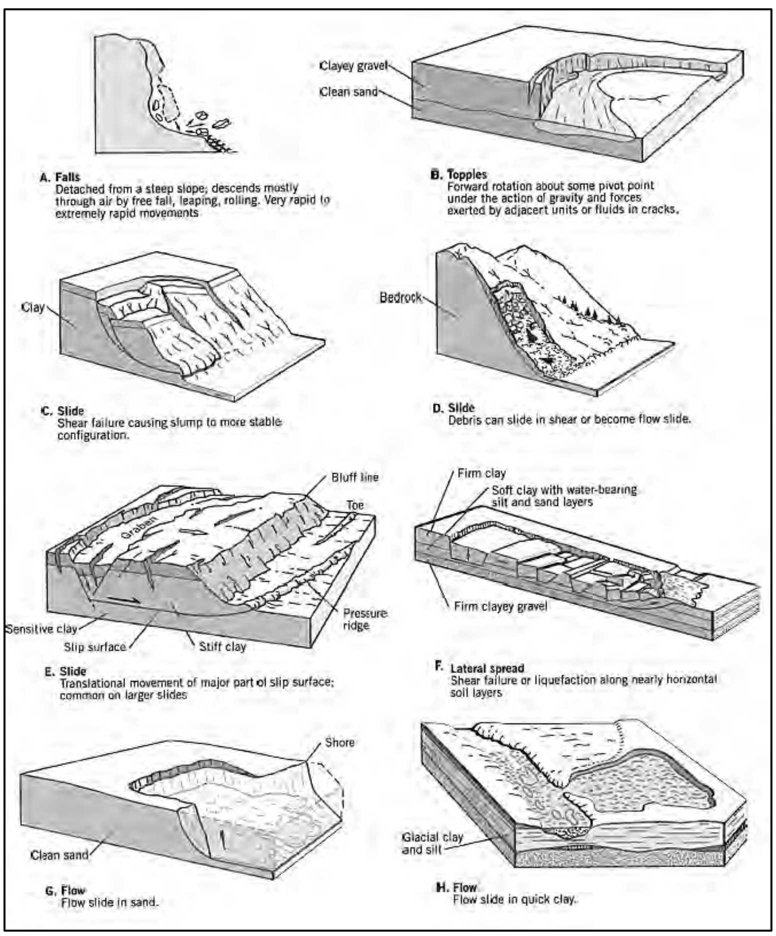

Figure 3: Examples of landslide processes (after Varnes, 1978 and Cornforth, 2005).

4.3 Methods

4.3.1 Desktop Mapping

Digital elevation models (DEMs) and slope gradient maps of the Van Anda and Gillies Bay study areas were created using ArcGIS software based on the 2 m topographic contour information provided by the PRRD. These maps were augmented with the results of the air photo interpretation and desktop review of other information sources (see Section 2.1) to assist in the interpretation of the terrain conditions and slope stability in the study area. The slope gradient mapping and landslide hazards identified from the desktop review are shown on the attached figures in Appendix B.

4.3.2 Site Reconnaissance

A total of two days of ground reconnaissance fieldwork were completed during the week of October 10, 2016 in order to verify the terrain features and landslide processes identified from the desktop mapping. No aerial reconnaissance or subsurface investigations were carried out. Fieldwork consisted of short foot traverses at selected stopping points along the coastline and other areas of interest, and included visual assessment of the general topography, slope gradients, landforms, soil and bedrock exposures, hydrologic conditions, and vegetation. Detailed field notes and photographs were collected on georeferenced maps of the study areas using a tablet computer. The location of field observation waypoints are shown on the attached figures in Appendix B and the key findings are discussed in the following sections of the report.

4.4 Hazards Identified

4.4.1 Rock Fall

Rock fall is the dominant landslide hazard process within the Van Anda study area. Rock fall hazards were identified at the following locations (see Photos 1 to 4, attached):

- Along the steep bedrock escarpment located north of Blubber Bay Road, west of the Van Anda town site. This escarpment is up to 30 m high and is possibly the site of a historical limestone quarry based on information contained in CHS Nautical Chart 3536. Occasional large wedges / pillars of loose rock up to 5 m in diameter were observed on the face of the escarpment.

- Along the bedrock headland (Marble Bluff) which forms the coastline between Caesar Cove and Van Anda Cove. This headland is up to 20 m high and is comprised of interbedded limestone and volcanic rock (basalt). Localized areas of rock fall were observed at the base of these bluffs, along the coastline.

- Along the steep bedrock bluffs forming Van Anda Point and the adjacent section of coastline to the east. Angular wedge-shaped masses of limestone and intrusive (granitic) bedrock were observed at the base of these bluffs, along the coastline, with fallen blocks up to 4 m in diameter.

- Along the steep bedrock bluffs on the upslope (south) side of Smelter Avenue, east of the Van Anda town site, near the boundary of the study area. No visible signs of rock fall were identified at road level; however, variably-sized masses of loose rock were observed near the crest of the bluffs, from which smaller rock fragments approximately 0.5 to 1 m in diameter appear to have recently detached.

- Along the steep bedrock bluffs located near the intersection of Kirk Lake Road and Gillies Bay Road, as well as the area to the south of Emily Lake.

Other portions of the Van Anda and Gillies Bay study areas in proximity to bedrock bluffs may be potentially susceptible to rock fall hazards, in addition to the locations described above. Likely causal mechanisms for rock fall include blasting or other significant construction disturbance, freeze-thaw events, heavy rainfall and seismic loading.

4.4.2 Debris Slides and Slumps

Debris slides and slumps are the dominant landslide hazard process within the Gillies Bay study area. In general, these events range from shallow failures of weathered soil and topsoil, to deeper failures in dense glacial soils along the coastal escarpment. Debris slide/slump hazards were identified at the following locations (see Photos 5 to 8):

- Along the section of coastal escarpment located immediately west of the runway at the Texada/Blubber Bay Airport, where a very large, arcuate (bowl-shaped) slump in glacial soils was identified on moderately steep, 70 to 80 m high slopes; see Figure B2 in Appendix B. The slump measures approximately 450 m long by 300 m wide, and has a total estimated volume on the order of 2 to 3 Million m^3. A water well drilled at the airport in 1983 encountered 1.5 m of till, overlying 33 m of "brown to grey clay", overlying limestone bedrock. Based on this description of the soil conditions, and our understanding of the surficial geology, the slump is likely seated in the clay (Quadra Sediments). The age of this slump is unknown; however, based on field observations and our review of historic air photos, likely pre-dates settlement of the island (i.e. it is likely an ancient landslide). No signs of recent movement were observed based on the condition of the headscarp and mature trees growing within the slide mass. This slump is located outside of the Gillies Bay study area, but warrants discussion in this report based on the size of this feature and the broadly similar nature of the terrain and surficial geology.

- Along the section of coastal escarpment located west of Gillies Bay in an area known locally as the "Sand Banks", where there are steep eroding bluffs up to 50 m high exposing glacial till over a thick sequence of fine, light coloured sand (Quadra Sediments); see Figure B2. As identified in the Golder (2004) report, these bluffs are incised by steep, V-shaped gullies, with localized recession of the bluff face to a distance of up to 30 m. Evidence of fresh erosion and landslide activity was noted from the 1946, 1960, 1978 and 2003 air photos. Logging of the upland area in the 1960s and 1970s and associated road construction may have contributed to the erosion and landslide activity observed in the air photos, and indicate the slopes may be sensitive to disturbance. The bluffs generally appear to be in a state of recovery, with some areas having re-vegetated with grass and shrubs, although some erosion of the bluff face is likely ongoing, particularly in the gullies. These bluffs are also located outside of the Gillies Bay study area; however, it is understood this area is used as a recreation site by Gillies Bay residents and visitors to the island. As such, they are referenced in this report.

- Along the section of coastal escarpment near the cable TV tower in Gillies Bay, approximately 100 to 200 m west of the end of Sanderson Road; see Figure B2. Evidence of shallow landslides (debris slides) and erosion of the slope in the form of steep, V-shaped gullies was noted from the 1960 and 1968 air photos. The disturbed areas have re-vegetated and appear to be in a state of recovery, and no tension cracks or other signs of slope instability were observed upslope of the crest of the escarpment. Thick deposits of glacial till were observed in soil exposures along this section of the escarpment, which suggests that the slopes may be somewhat stronger and relatively more resistant to erosion compared to the Sand Banks area located further to the west.

- Along the coastal escarpment on the east side of Gillies Bay, approximately 300 m north of the intersection of Gillies Bay Road and Carter Road. At this location, a large, arcuate slump in glacial soils was identified on moderate to steep, 20 m high slopes; see Figure B3. The slump measures approximately 70 m long by 50 m wide, and has a total estimated volume on the order of 50,000 to 100,000 m^3. Based on field observations, the slump appears to have occurred in Quadra Sediments, with sandy soils exposed along the headscarp and very stiff grey silt and clay exposed at low tide along the beach. The age of this slump is unknown; however, as with the larger slump located near the airport (see first bullet above), is likely an ancient landform. No signs of recent movement were observed based on the condition of the headscarp and mature trees growing in this area.

In north Nanaimo, the silt and clay beds forming the base of the Quadra Sediments (see Section 3.4) contain a weak layer known as a pre-shear; slope movements have occurred preferentially along this weak layer in the form of large block slides. It is possible that the large slump features identified near the Texada/Gillies Bay airport and along the east side of Gillies Bay were caused or exacerbated by the occurrence of a pre-shear in these deposits. Further, detailed geotechnical studies beyond the scope of this study would be required to investigate the likely cause of these landslides.

4.4.3 Submarine Landslides

An assessment of submarine landslide hazards is outside of the scope of this study. However, we understand from a historical article published by the Texada Island Heritage Society that a submarine landslide occurred on December 4, 1956 at the (now former) site of the Cox Lagoon wharf, located approximately 0.5 to 1 km west of the Texada/Blubber Bay Airport. An excerpt from this article is provided below, a copy of which can be downloaded from http://texadaheritagesociety.com/Musings/2015/Dec/Wharf%20Disappears.2.pdf:

"$250,000 WHARF MISSING - So proclaimed the Powell River News headline on December 5, 1956, reporting the overnight disappearance of the Texada Mine dock. The 500-foot structure was constructed only four years earlier but its pilings rested on clay amidst accumulated tailings. Under pressure from a 60-mph gale, the fill probably slumped down the steep undersea slope taking the wharf pilings with it. By morning one could just make out the top of the 50-foot steel tower (at the end of the wharf) poking out above the waves."

Although outside of the Gillies Bay study area, the proximity of this failure to the large slump feature located near the airport runway (see Section 4.4.2) is curious, and provides another indication that the clay soils underlying this area of Texada Island may be susceptible to deep-seated instability. However, it is possible that this landslide was triggered by other mechanisms, such as the spontaneous liquefaction of loose submarine sands.

4.4.4 Slope Creep

Slope creep is a common hillslope process which involves the slow, downslope movement of rock and soil particles due to gravity; this process can occur in localized areas, or over a broad area. Slope creep is generally an indicator of slope instability, and can be a precursor to landslide activity. Slope creep is often identified by the presence of mature trees with tilted or curved trunks, tilted fence lines and retaining walls, or by the cracking of roadways and building foundations located near slopes.

Evidence of slope creep was observed during the site visit at several locations in the study area, most notably along the coastal escarpment at Gillies Bay and adjacent coastline to the west; see photos 9 and 10.

4.4.5 Coastline Erosion

An assessment of coastal hazards is outside the scope of this study; however, evidence of minor coastline erosion was observed during the site visit at Gillies Bay and along the adjacent coastline to the west, in the form of fallen trees, erosion rills and shallow slope failures along the bottom 3 to 5 m of the coastal escarpment. See photos 11 and 12.

4.5 Landslide Hazard Polygons

Based on the findings of the desktop mapping and site reconnaissance, and in keeping with the slope development policies adopted in other local jurisdictions (Table 1), landslide hazard areas (polygons) have been mapped for planning purposes using a slope gradient-based approach. Table 3 summarizes the criteria used to delineate the landslide hazard polygons, which include an additional setback distance from the top and bottom of the slope to account for the potential runout of landslide debris and/or the retrogression of unstable slopes over time. These criteria were developed from the results of the following:

- Field observations and engineering judgment.
- Review of published literature (Jaboyedoff and Labiouse, 2011) to estimate rock fall runout (travel distance) using empirical methods.
- Generic, limit-equilibrium slope stability analyses of the coastal escarpment at Gillies Bay, based on the approximate soil stratigraphy and estimated depth to groundwater.

As shown in Table 3, more stringent criteria were adopted for coastal escarpment at Gillies Bay, based on the large slump features identified from our study. The landslide hazard polygons are presented on Figures 4 to 16, which include separate overview-level maps of the Van Anda and Gillies Bay study areas and on 1:5,000 scale maps.

Table 3: Landslide Hazard Polygon Criteria

Study Area		Mapping Criteria (Landslide Hazard Polygons)
Van Anda		▪ Slopes at least 3 m high with a gradient of 50% or greater, plus: – Additional 7.5 m setback from the crest of the slope. – Additional 7.5 m to 15 m setback from the toe of the slope (setback distance increases as a function of the slope height).
Gillies Bay	Coastal Escarpment – Sanderson Road (west side of bay)	▪ Slopes at least 3 m high with a gradient of 35% or greater, plus: – Additional setback from crest of slope to a distance equivalent to the height of the slope or 15 m, whichever is greater. – Additional setback from toe of slope extends to the shoreline.
	Coastal Escarpment – All other areas	▪ Slopes at least 3 m high with a gradient of 35% or greater, plus: – Additional setback from crest of slope to a distance equivalent to <u>twice</u> the height of the slope or 15 m, whichever is greater. – Additional setback from toe of slope extends to the shoreline.
	Inland areas	▪ Slopes at least 3 m high with a gradient of 35% or greater, plus: – Additional 7.5 m setback from the crest of the slope. – Additional 7.5 m setback from the toe of the slope.

4.5.1 Limitations

The landslide hazard study is intended to be a preliminary guide for development planning. Limitations to the study include the age and low resolution of the available contour data, the brief nature of the site reconnaissance, and uncertainties inherent to the geotechnical assessment of subsurface conditions and the stability of slopes. Information assessed in this study is limited to the sources listed in Section 2.1.

The landslide hazard polygons were derived from the 2 m topographic contour data provided by the PRRD. We understand these contours were produced by Integrated Mapping Technologies in 2007-2008 from photogrammetric interpolation of 20 cm (1:20,000 scale) aerial imagery flown in 2006. As such, the accuracy of these contours, and the derived polygons, is uncertain due to the age of this imagery and the technical limitations of photogrammetric techniques.

5.0 FLUVIAL HAZARD ASSESSMENT

5.1 Terminology and Dominant Fluvial Processes

Rivers, creeks and streams can experience different water flow (fluvial) processes, ranging from floods to debris floods to debris flows. Distinction between these processes is important as they differ in flow mechanics and potential consequences. Transitions between processes are common within space and time during an event, with floods transitioning into debris floods and eventually debris flows through progressive sediment entrainment. Conversely, dilution of a debris flow through partial sediment deposition and tributary injection of water can lead to a transition towards debris floods and eventually floods.

As a preliminary measure to predict which regime (flood, debris flood or debris flow) is likely to be the predominate process in a watershed, we have reviewed the topography of the study area and concluded that the dominant fluvial process for the water bodies assessed in this study is flooding.

For the practical purposes of this study, floods are defined as water flows with sediment concentrations of up to 10% by volume. Sediment in floods is transported as suspended load and bed load.

5.2 Methods

A regional hydrological analysis was conducted to estimate flood flows. Subsequently, the flood flows were routed through along the creeks to model flood inundation. Methods applied are described below.

5.2.1 Regional Hydrological Analysis

To estimate the flow in a subject watercourse for a given return period, we have completed a regional hydrologic analysis. A regional hydrologic analysis uses flow data from WSC stream gauging stations near the study area and applies that information to the ungauged watercourses within the study area.

The process for conducting a regional hydrologic analysis is as follows:

1. Identify WSC stations near the project area, with similar physiographic characteristics and with sufficient period of record.
2. Delineate the WSC stations catchment and determine physiographic properties (GIS analysis).
3. For annual peak instantaneous flow data, perform flood frequency analysis to predict flows for various return periods.
4. Plot estimated flow vs. watershed area and perform a regression analysis to derive a regional curve for each return period.
5. Apply the regression curve equation to each watershed to predict flows for specified return periods.

We identified nine WSC stations near the study area that we used for the regional analysis. These watersheds were selected based on the availability of historical data, watershed size, and the proximity to the study area.

5.2.2 Flood Inundation Modelling

The flood inundation modeling routes the flood flows estimated from the regional analysis along each of the creeks within the study area. The model predicts inundation extents associated with each flood flow. By their very nature, extreme flood flows will not be confined to their established channels; they will overtop the banks and occupy the floodplain adjacent to the watercourse. To assess this condition, we employed a 2-dimensional (2D) flood model which can simultaneously simulate channel and floodplain flows.

The HEC-RAS 2D (V 5.0.3) model was used to simulate the flood flow and inundation extents associated with the 200 year flood of each of the watercourses within the study area. HEC-RAS 2D is a model developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers, with the capabilities of modelling various scenarios including: channel, floodplain, reservoir and hydraulic structures flood routing; steady flow water surface profiles; 1D/2D unsteady flow simulation; levee and dam breach; sediment transport; water quality analysis; and hazard mapping.

A composite channel roughness (Manning's n) coefficient of 0.06 was selected for the modeling area. The topography of the model was based on a 2 m x 2 m DEM, based on the topographic contours provided by the PRRD. A period of 24 hours was selected for the modeling duration time.

5.3 Estimated Peak Flows

A flood frequency analysis was performed on the flow data from each station and the 100-year and 200-year return period peak flows were estimated for each of the gauged stations. Figure 17 presents the relationship between watershed area and estimated flow for each return period for the nine stations analysed.

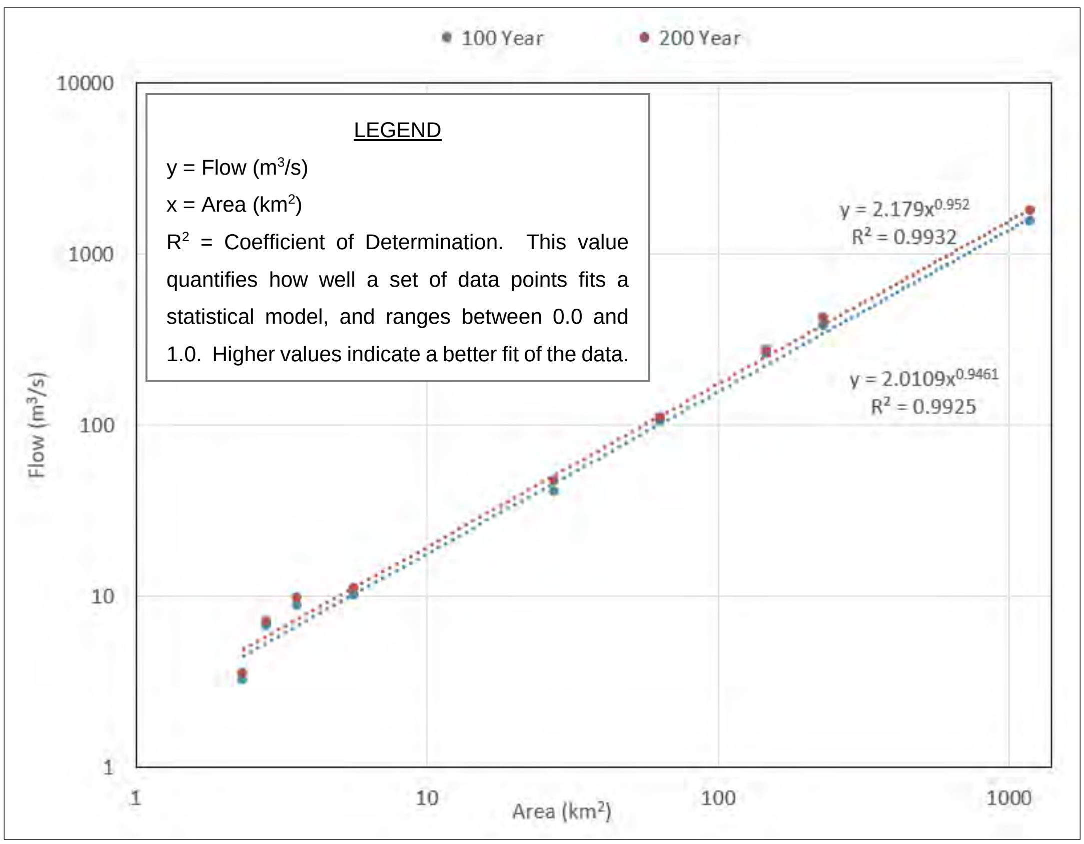

Figure 17: Relationship between peak flow and watershed area for nine WSC stations adjacent to study area for the 100-year and 200-year return periods.

Regression analysis was performed to develop a relationship between the peak flow values and the watershed area. This relationship was then applied to the watersheds within the study area to predict the peak flows for each watercourse. The estimated peak daily flows for each watercourse are presented in Table 4.

Table 4: Estimated Peak Daily Flow for 100 year and 200 year return periods

Study Area	Watershed	Drainage Area (km^2)	Flow (m^3/s)	
			100-year Return Period	200-year Return Period
Van Anda	Kirk Creek	6.6	11.9	13.1
	Priest Creek	2.6	5.0	5.4
	Unnamed Creek 1	0.1	0.3	0.3
Gillies Bay	Cranby Creek	4.0	7.5	8.2
	Unnamed Creek 2	3.1	5.9	6.4
	Unnamed Creek 3	15.6	27.1	29.8

5.4 Inundation Results

The results of the inundation modeling are summarized in Table 5 stating the extent of inundation.

In the Van Anda study area, water levels rise in Priest Lake and Emily Lake. The smaller seasonal lakes in the area inundate. The flood flow is sufficiently contained within the main channel with inundation extending immediately adjacent to the top of bank. By contrast, the Gillies Bay study area experiences wide dispersion of flood flows, resulting in a higher flood hazard. This is due to the large drainage area discharging to the head of Gillies Bay and the flatter topography of the area.

Table 5: HEC-RAS 2D Predicted Flood Depths (200-year Return Period)

<table>
<tr><th rowspan="2">Study Area</th><th rowspan="2" colspan="2">Watershed</th><th colspan="2">Absolute Flood Depth (m)</th></tr>
<tr><th>Centerline</th><th>Outside of the Overbanks</th></tr>
<tr><td rowspan="5">Van Anda</td><td colspan="2">Kirk Creek</td><td>0.2 to 2.8</td><td>0.07 to 1.0</td></tr>
<tr><td rowspan="3">Priest Creek</td><td>Upstream of Priest Lake</td><td>1.6 to 2.6</td><td>0.1 to 1.4</td></tr>
<tr><td>Between Priest and Emily Lakes</td><td>0.2 to 2.0</td><td>0.02 to 1.0</td></tr>
<tr><td>Downstream of Emily Lake</td><td>2.5 to 3.0</td><td>0.02 to 1.0</td></tr>
<tr><td colspan="2">Unnamed Creek 1</td><td>0.02 to 2.5</td><td>0</td></tr>
<tr><td rowspan="3">Gillies Bay</td><td colspan="2">Cranby Creek</td><td>0.2 to 1.8</td><td>0</td></tr>
<tr><td colspan="2">Unnamed Creek 2</td><td>0.2 to1.8</td><td>0.02 to 0.5</td></tr>
<tr><td colspan="2">Unnamed Creek 3</td><td>0.1 to 2.2</td><td>0.02 to 0.4</td></tr>
</table>

5.5 Fluvial Hazard Polygons

The fluvial hazard polygons are presented on Figures 18 to 30. For this assignment, the fluvial hazard polygons correspond to all areas that are predicted to have some level of inundation under the 200-year flood event.

5.5.1 Limitations

The fluvial hazard study is intended to be a preliminary guide for development planning. Limitations to the study include the low resolution of the topographic data, limited hydrometric data for the subject watercourses, and the uncertainty inherent with the frequency analysis and flood routing modeling. In addition, no infrastructure, such as roads, bridges and culverts were included in the model. As such, backwater inundation due to malfunctioning or plugging of drainage infrastructure is not considered. Avulsion processes (i.e. abandonment of flow channel and formation of new flow channel) are not considered in this study. The study also does not address the potential impacts to flood hazards due to climate change.

Cranby Creek, within the Gillies Bay study area, is downstream of Cranby Lake. The outlet of Cranby Lake is dam controlled for water supply, with flood levels influenced by operations of the dam. Fluvial hazards in this watershed, including outburst floods in the event of a dam failure fall under the purview of a Dam Safety Review, and are outside the scope of this study.

6.0 RECOMMENDATIONS

6.1 General

Based on the above discussion, Tetra Tech EBA recommends the following:

1. The PRRD should consider adopting the landslide and fluvial hazard areas into DPAs for the lands within PRRD's jurisdiction, given the potential impacts of these hazards to the general public, land base and the environment. This includes:
    a. The landslide hazard areas in the Van Anda study area (Figure 4 and Figures 6 to 11).
    b. The landslide hazard areas in the Gillies Bay study area (Figure 5 and Figures 12 to 16).
    c. The fluvial hazard areas in the Van Anda study area (Figure 18 and Figures 20 to 25).
    d. The fluvial hazard areas in the Gillies Bay study area (Figure 19 and Figures 26 to 30).
2. Proposed developments located within the landslide and fluvial hazard areas shown on Figures 4 to 16 and Figures 18 to 30 should, as a condition of development, be required to complete a site-specific assessment of these hazard(s) by a qualified professional engineer or geoscientist. These assessments should be carried out in accordance with the following provincial guidelines, as applicable:
    a. Association of Professional Engineers and Geoscientists of British Columbia. 2010. Guidelines for Legislated Landslide Assessment for Proposed Residential Developments in BC. Revised May 2010.
    b. Association of Professional Engineers and Geoscientists of British Columbia. 2012. Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC. June 2012.
3. Proposed developments along the coastal escarpment in Gillies Bay requiring a site-specific geotechnical assessment should include analysis of deep-seated slope stability of the clay layer (Quadra Sediments) under both static and seismic loading, based on the large slump features identified from our study. This analysis should be undertaken in accordance with the methods described in the APEGBC (2010) guidelines.
4. In addition to the above, it would be prudent for the PRRD to require that all proposed developments in Van Anda, regardless of location, must provide a site-specific geotechnical assessment of potential ground subsidence hazards related to historical underground mine workings and karst terrain.
5. The PRRD should develop an education or public awareness program about landslide and fluvial hazards and how residents can manage their slopes to mitigate potential impacts to the public, property and the environment.

6. The PRRD should hold a public meeting or information session(s) to inform residents of any upcoming policy changes and for general awareness of landslide and fluvial hazard issues in the area.
7. If the PRRD decides to adopt the landslide and fluvial hazard areas into DPAs, Tetra Tech EBA should be provided the opportunity to review the proposed amendments to the OCPs in order to comment on whether the contents of this report have been appropriately understood and applied.
8. This study should be repeated approximately every 10 years in order to update the hazard maps based on then-current knowledge and data.

6.2 Suggested Future Work

Tetra Tech EBA suggests that the PRRD also consider the following future work in order to supplement and expand upon the results of this study:

1. Commission a study to assess potential ground subsidence hazards in the Van Anda area with regards to historical underground mine workings and karst terrain.
2. Obtain more detailed geotechnical information of soil and bedrock conditions (particularly along the coastal escarpment in Gillies Bay), and undertake more detailed stability analyses, seismic slope assessments and slope deformation analysis for the refinement of slope setbacks. In this regard, further geotechnical assessment of the large slump feature adjacent to the runway at the Texada/Gillies Bay airport may be warranted.
3. Complete an airborne LiDAR survey of the Van Anda and Gillies Bay study areas in order to enhance the landslide and fluvial hazard maps which have been provided to the PRRD for planning purposes only.
4. Assess coastal hazards including sea level rise, storm surges, wave hazards and coastal erosion within the entirety of PRRD lands in Electoral Area D.
5. Commission a study to assess the potential effects of climate change and related impacts to slopes, watercourses and coastlines in the PRRD, in accordance with the APEGBC (2012) guidelines.

7.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

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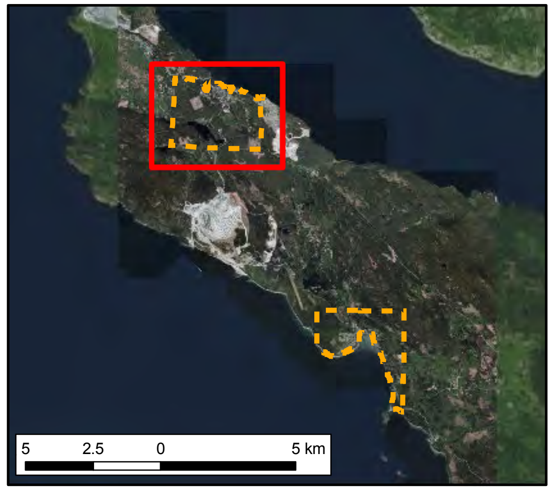
FIGURES

LEGEND

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 50% Gradient
- Recommended Additional Setback
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Van Anda Overview

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:15,000

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Metres

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Figure 4

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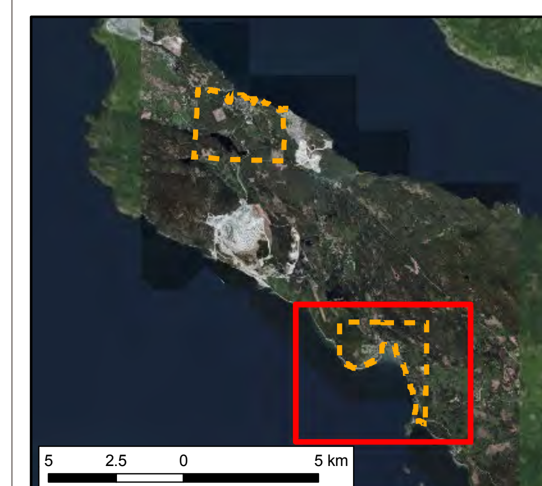
LEGEND

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 35% Gradient
- Recommended Additional Setback
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Watercourse / Waterbody



NOTES
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2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Gillies Bay Overview

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:20,000

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Metres

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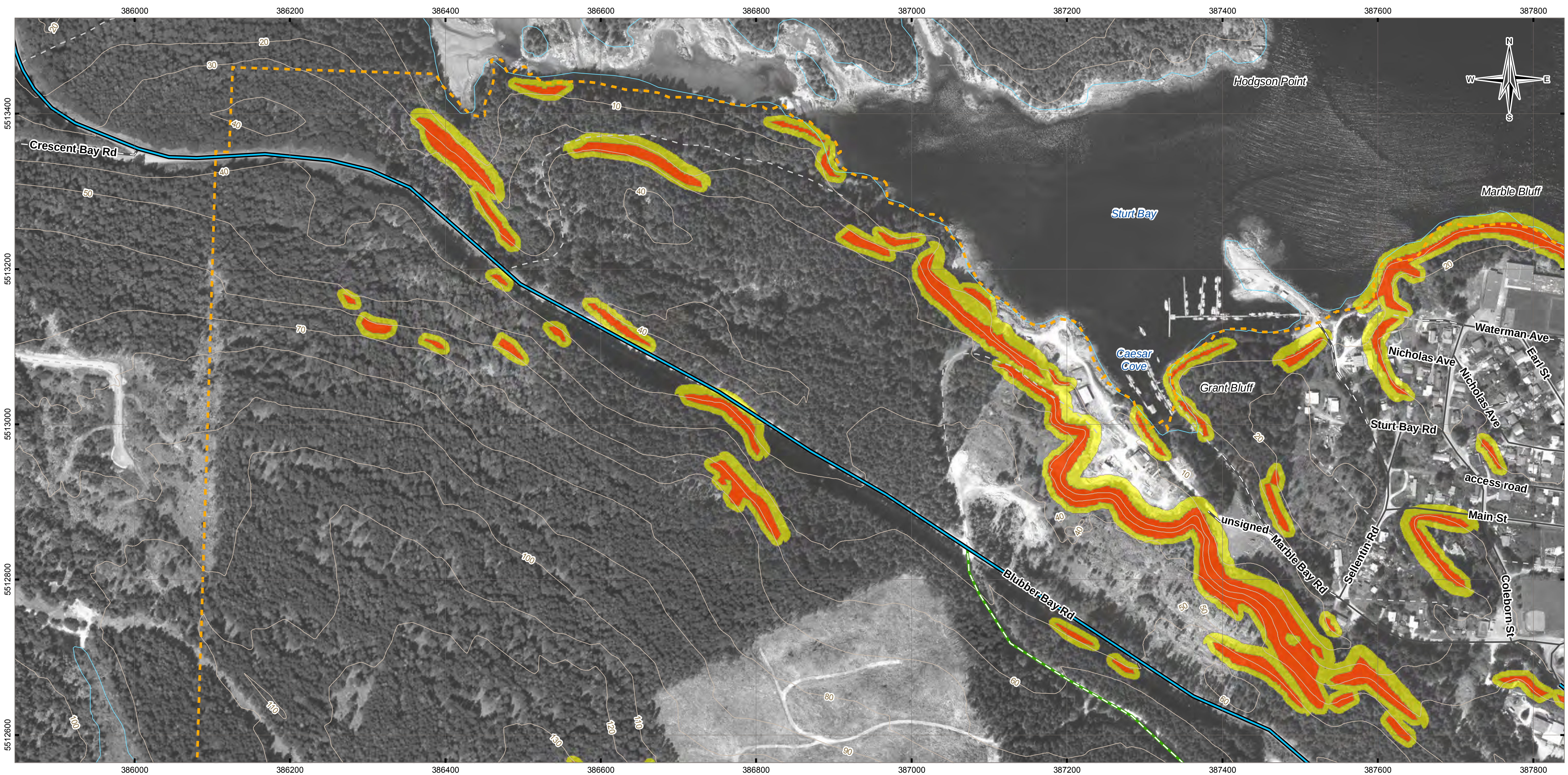
Figure 5

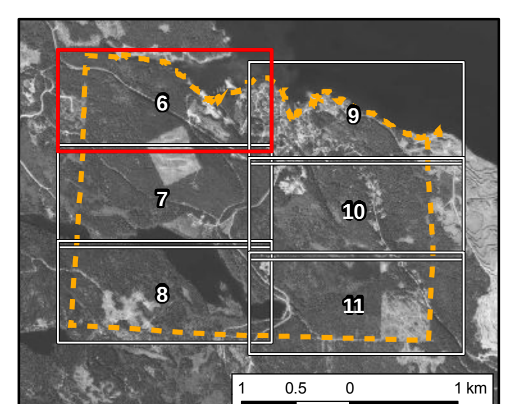


LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 50% Gradient
- Recommended Additional Setback



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
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LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Powell River Regional District

Scale: 1:5,000
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Metres

FILE NO.
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PROJECT NO.: V13103482-01

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Figure 6

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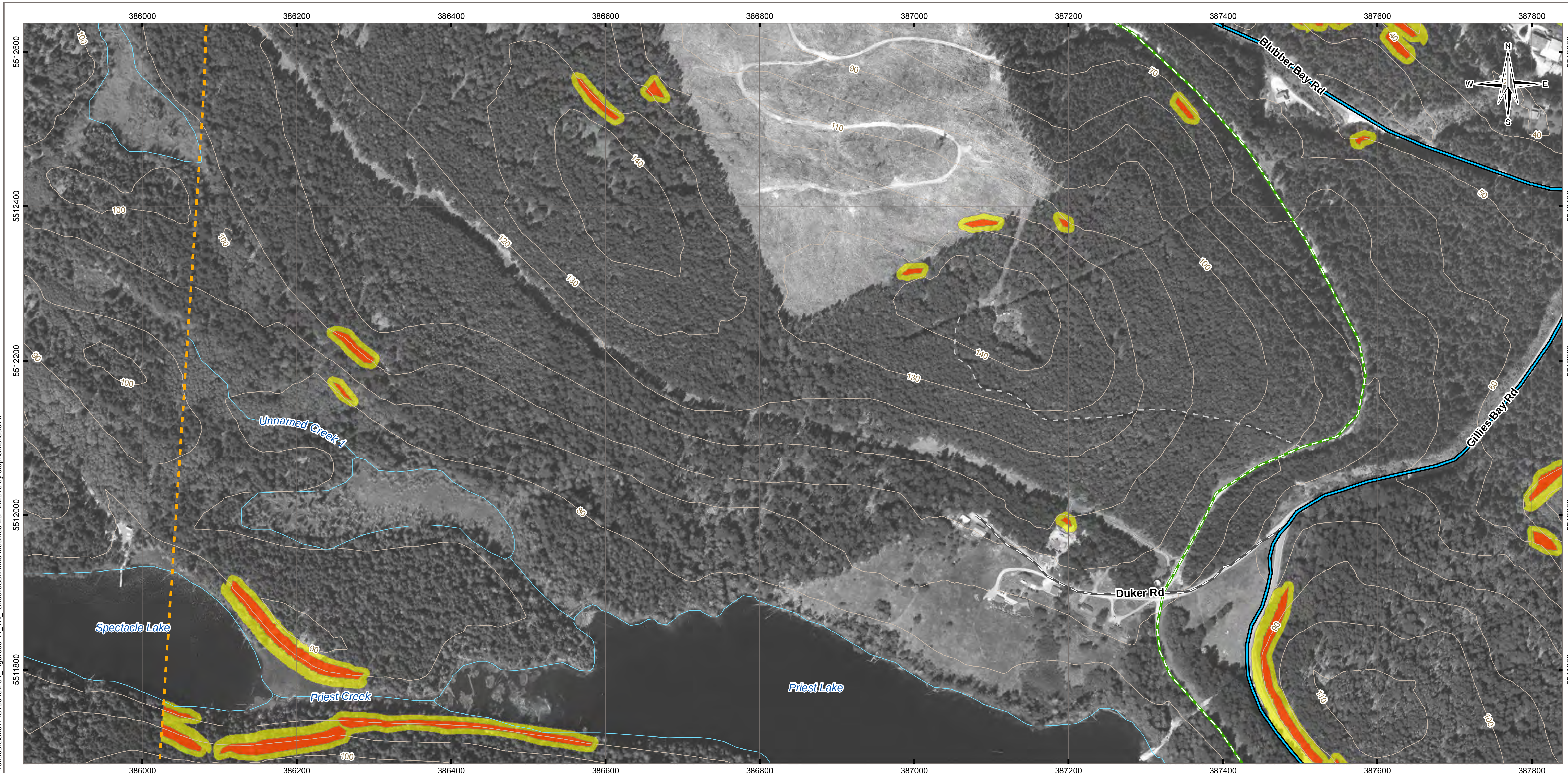
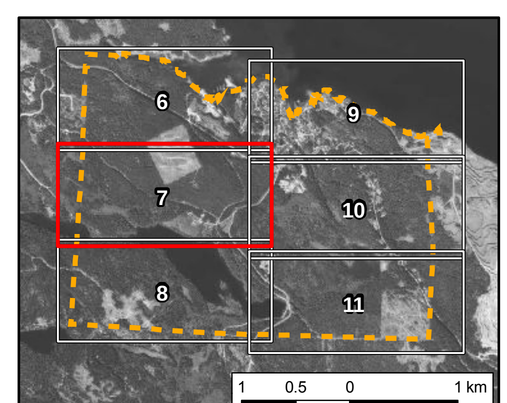


LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 50% Gradient
- Recommended Additional Setback



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000

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Metres

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Figure 7

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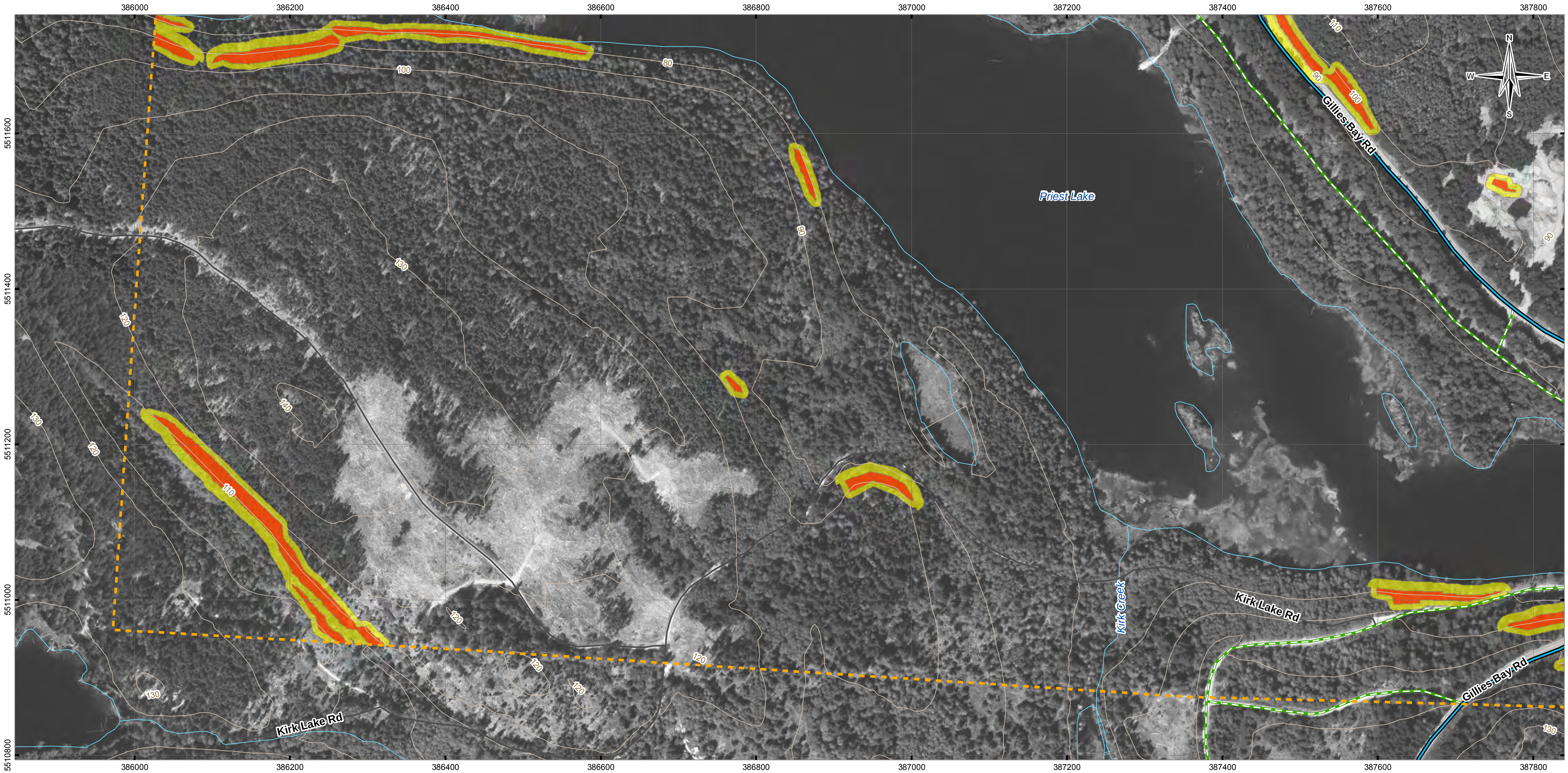
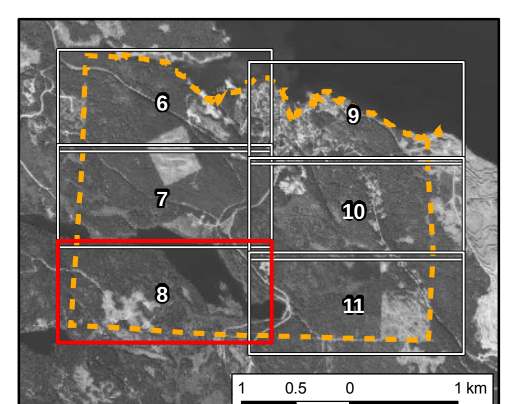


LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Resource Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 50% Gradient
- Recommended Additional Setback



NOTES

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2. Slope gradients derived from 2 m topographic contours provided by PRRD.

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LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Powell River Regional District

Scale: 1:5,000

100 50 0 100

Metres

FILE NO.
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Figure 8

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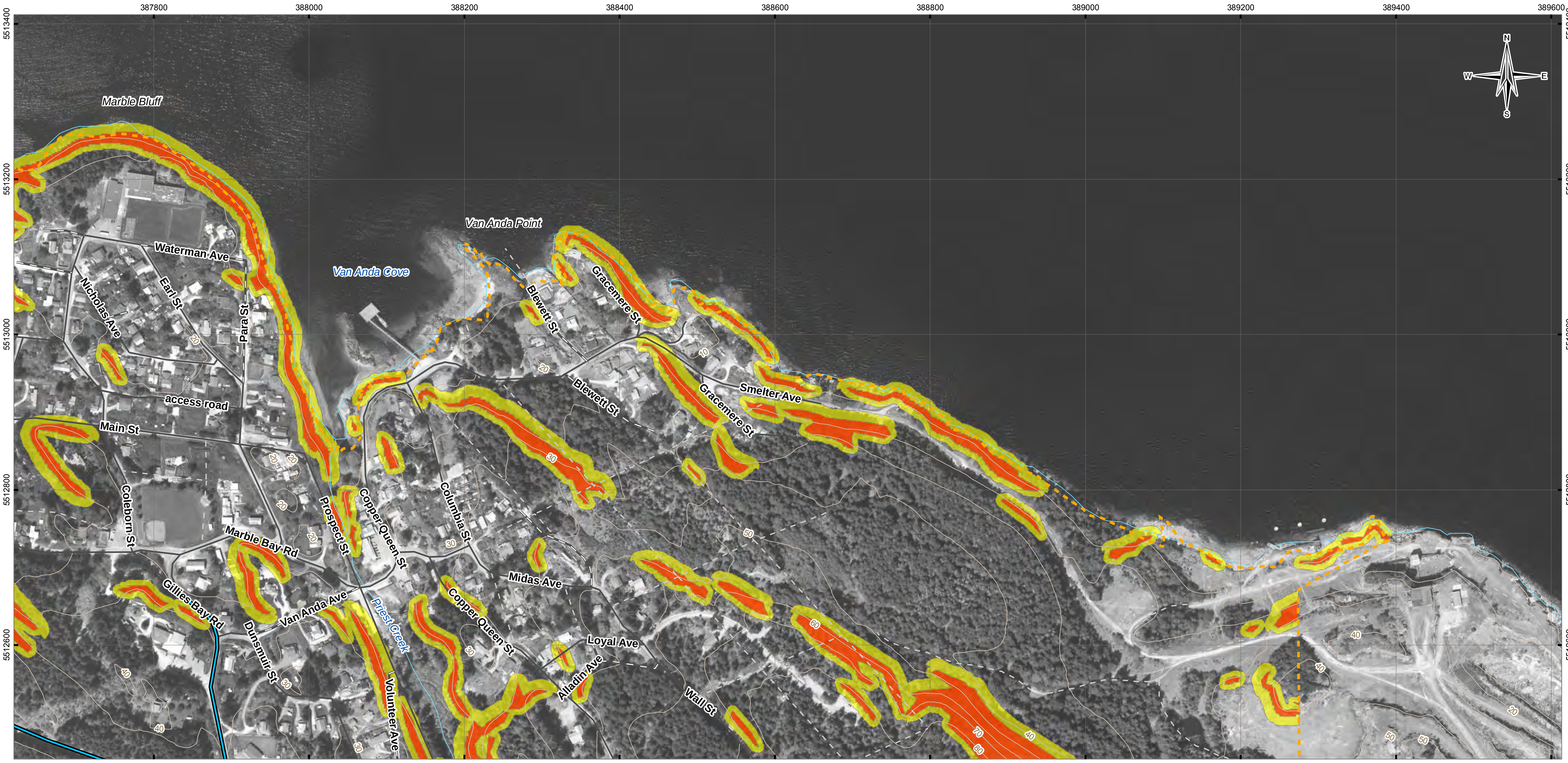
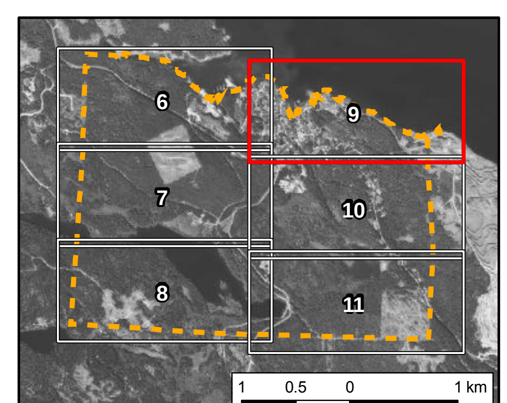


LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 50% Gradient
- Recommended Additional Setback



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY
ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons
Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Powell River Regional District

Scale: 1:5,000

100 50 0 100

Metres

FILE NO.
V13103482-01_Figure06-11_VA_Landslide5K.mxd

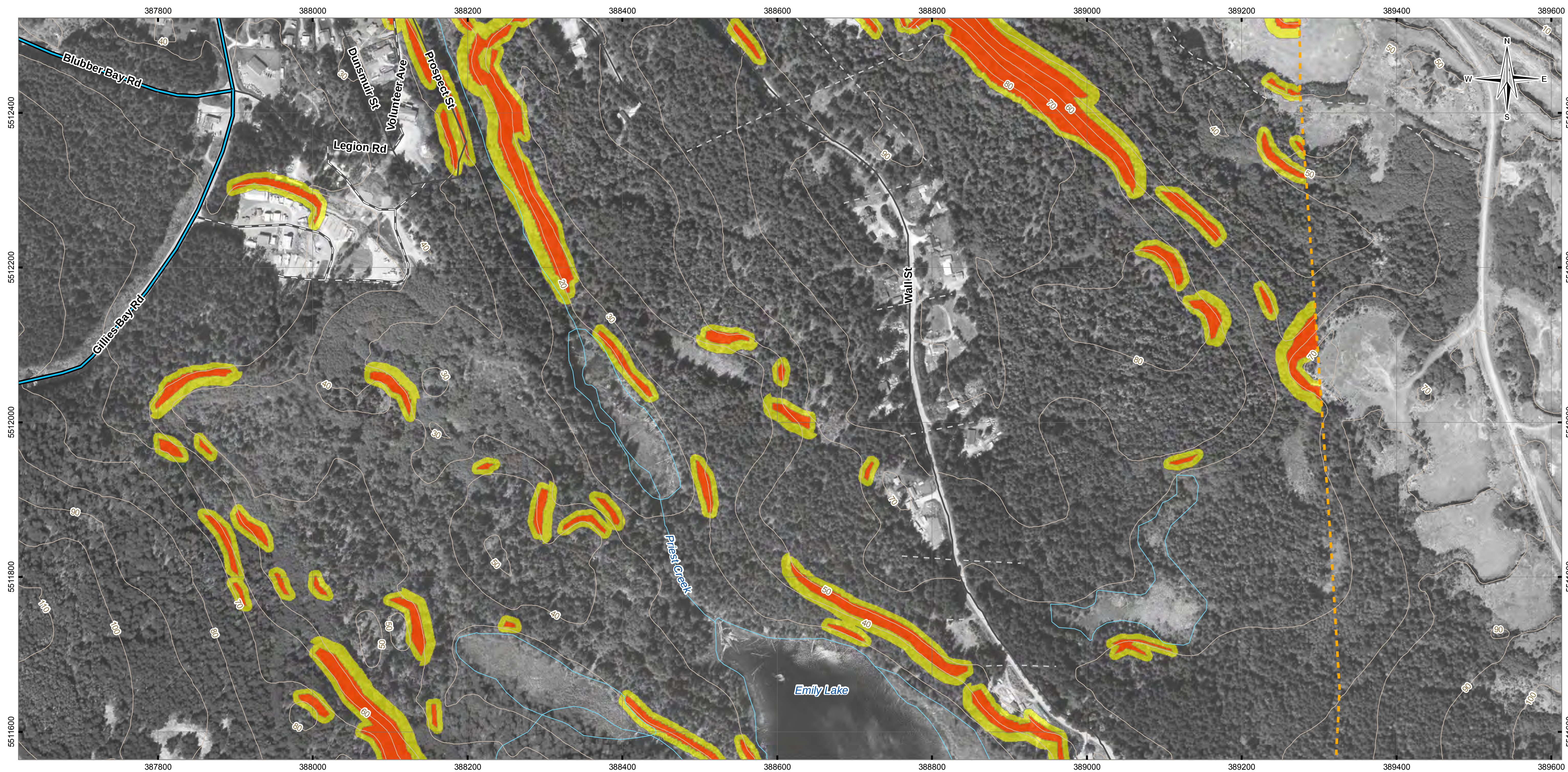
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

TETRA TECH

Figure 9

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure06-11_VA_Landslide5K.mxd modified 20/12/2016 by stephanie.leusink

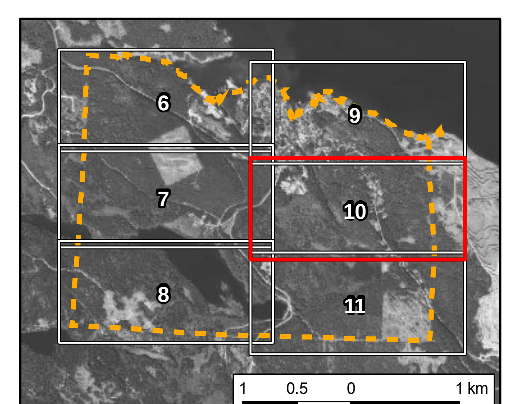


LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 50% Gradient
- Recommended Additional Setback



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY
ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons
Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000
100 50 0 100
Metres

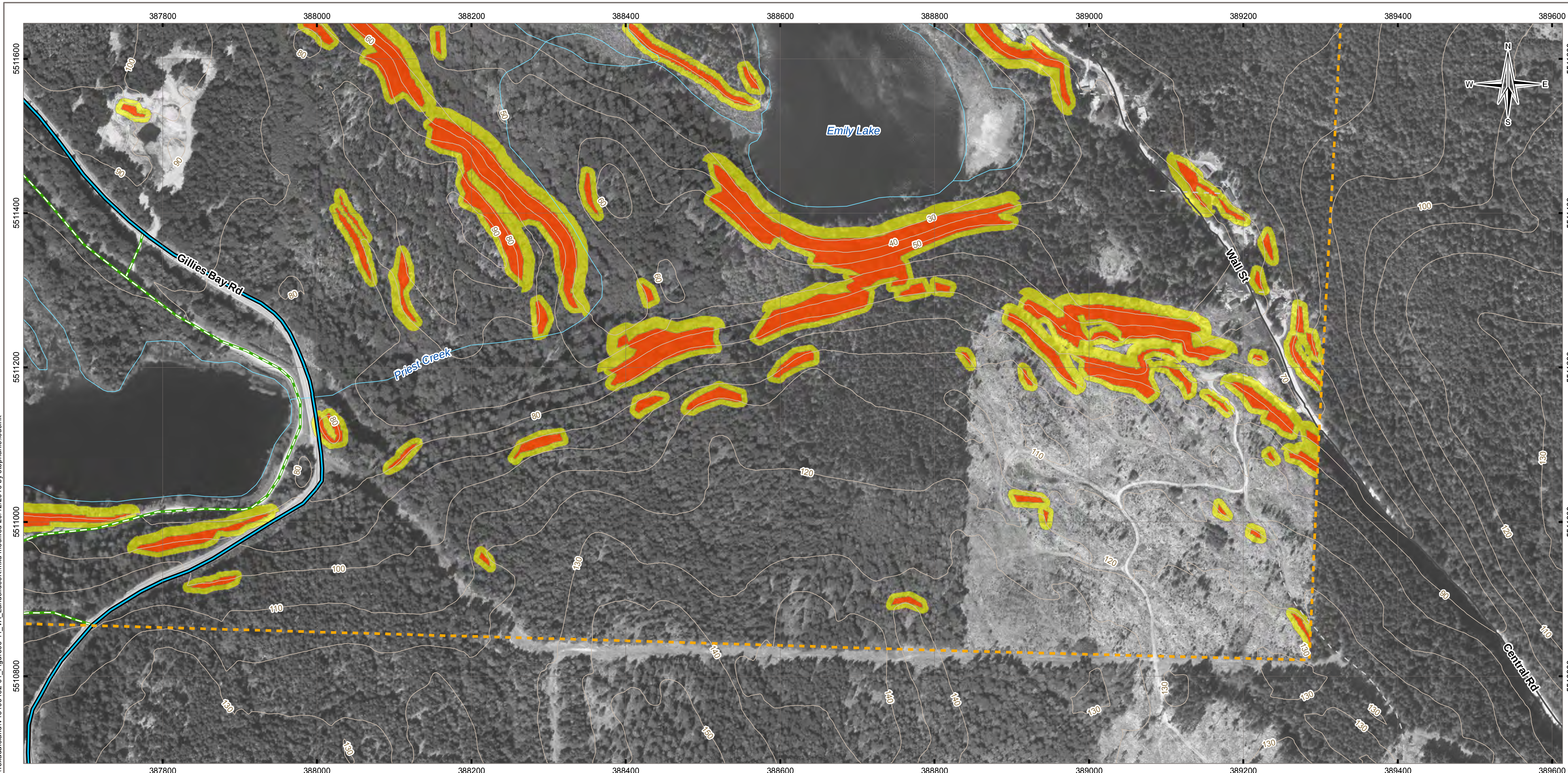
FILE NO.
V13103482-01_Figure06-11_VA_Landslide5K.mxd

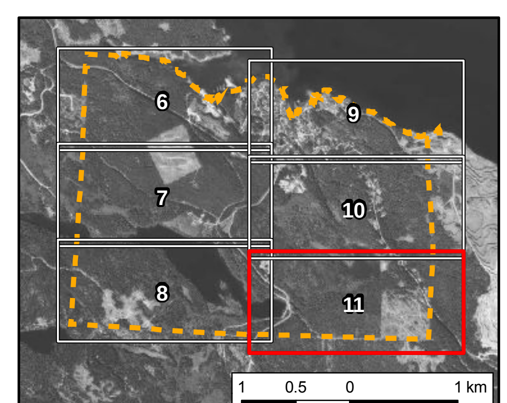
TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 10





Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure06-11_VA_Landslide5K.mxd modified 20/12/2016 by stephanie.leusink

LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Resource Road
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 50% Gradient
- Recommended Additional Setback

NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000
100 50 0 100
Metres

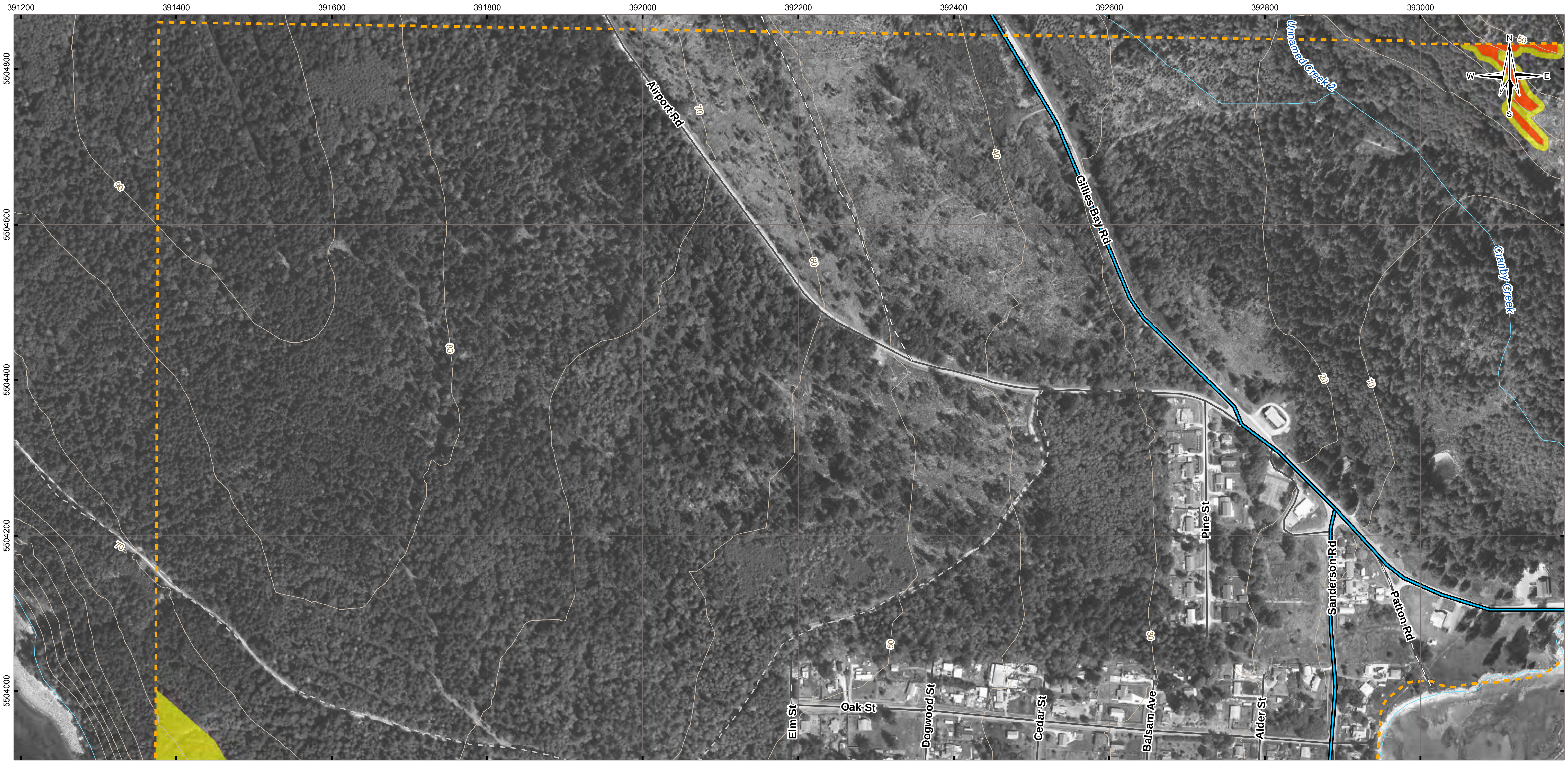
TETRA TECH

FILE NO.
V13103482-01_Figure06-11_VA_Landslide5K.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 11

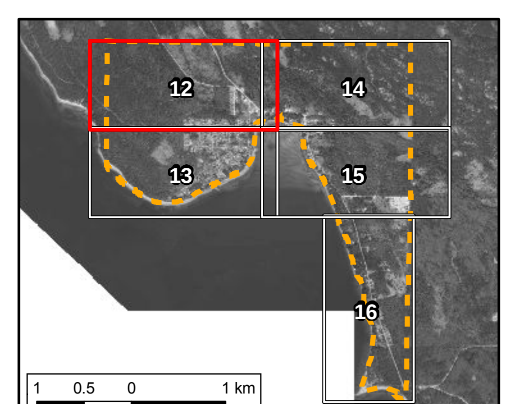


LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 35% Gradient
- Recommended Additional Setback



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Gillies Bay

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000

100 50 0 100

Metres

FILE NO.
V13103482-01_Figure12-16_GB_Landslide5K.mxd

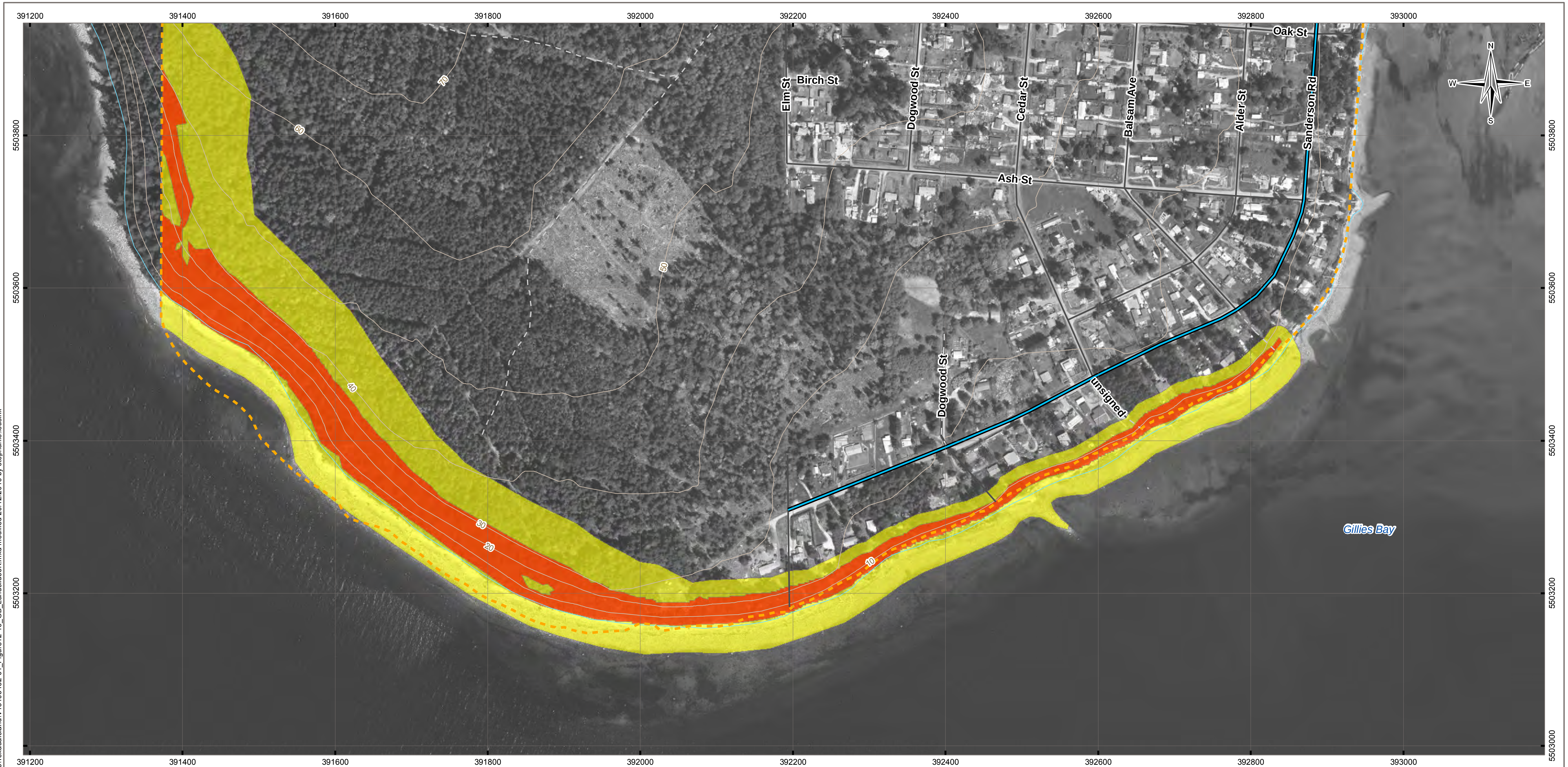
TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 12

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure12-16_GB_Landslide5K.mxd modified 20/12/2016 by stephanie.leusink

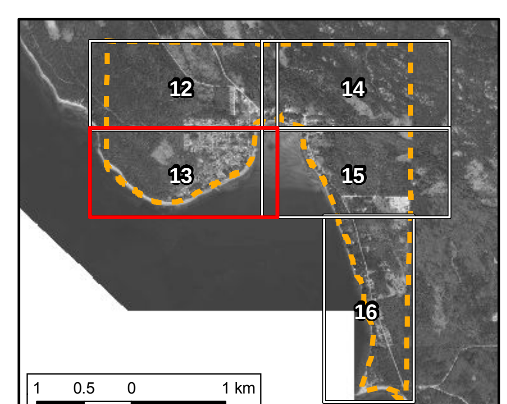


LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 35% Gradient
- Recommended Additional Setback



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Gillies Bay

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Powell River Regional District

Scale: 1:5,000

100 50 0 100

Metres

FILE NO.
V13103482-01_Figure12-16_GB_Landslide5K.mxd

TETRA TECH

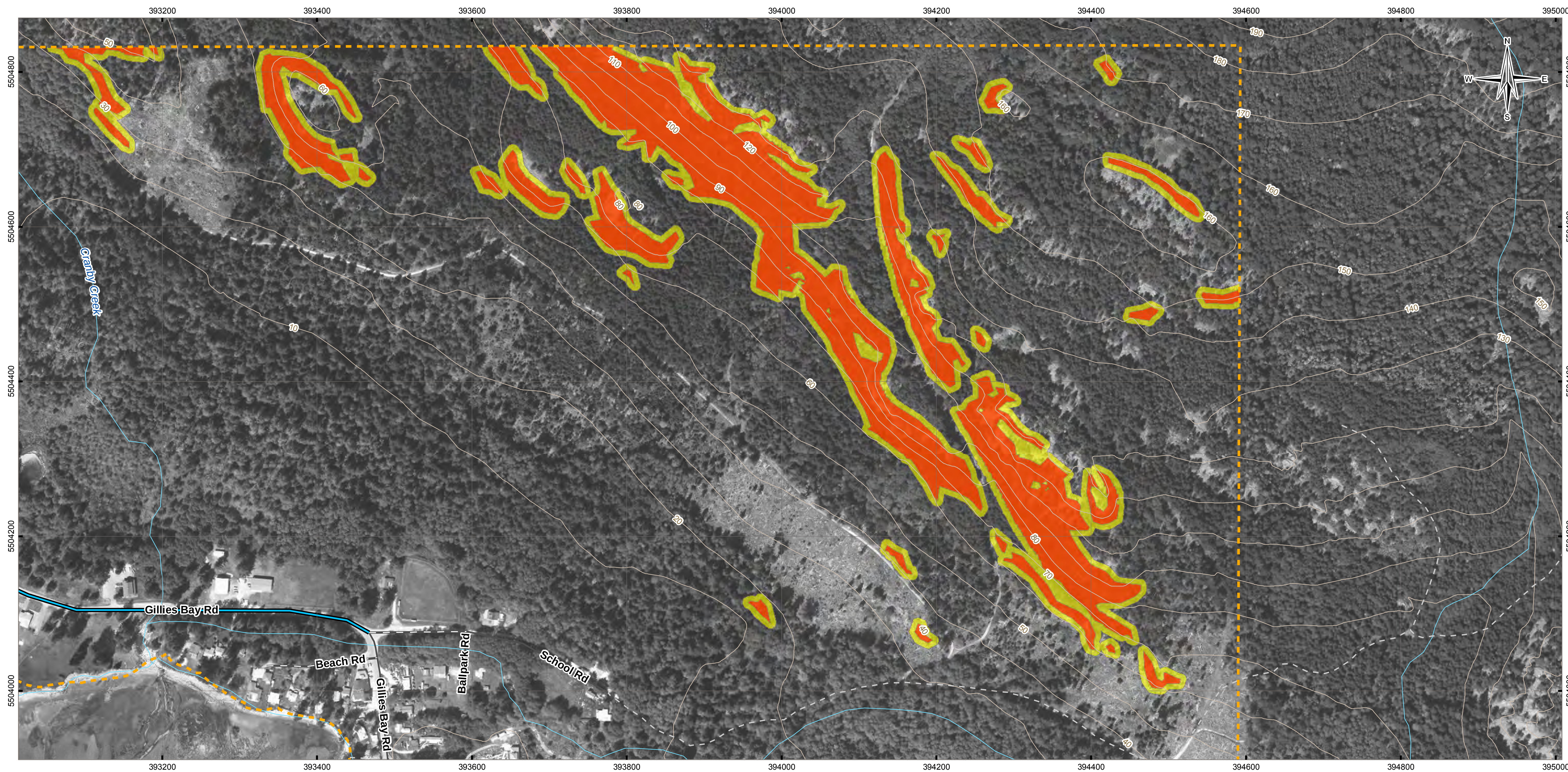
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE
December 21, 2016

PROJECT NO.
V13103482-01

Figure 13

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure12-16_GB_Landslide5K.mxd modified 20/12/2016 by stephanie.leusink

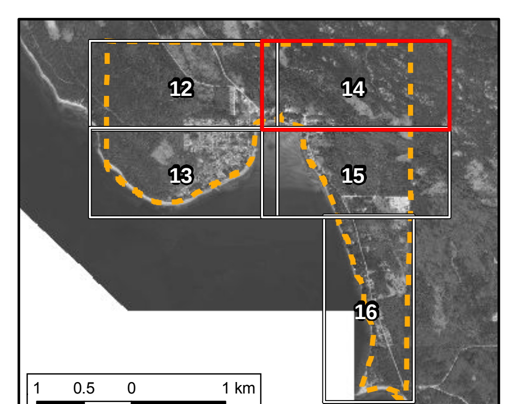


LEGEND

- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 35% Gradient
- Recommended Additional Setback



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Gillies Bay

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000

100 50 0 100

Metres

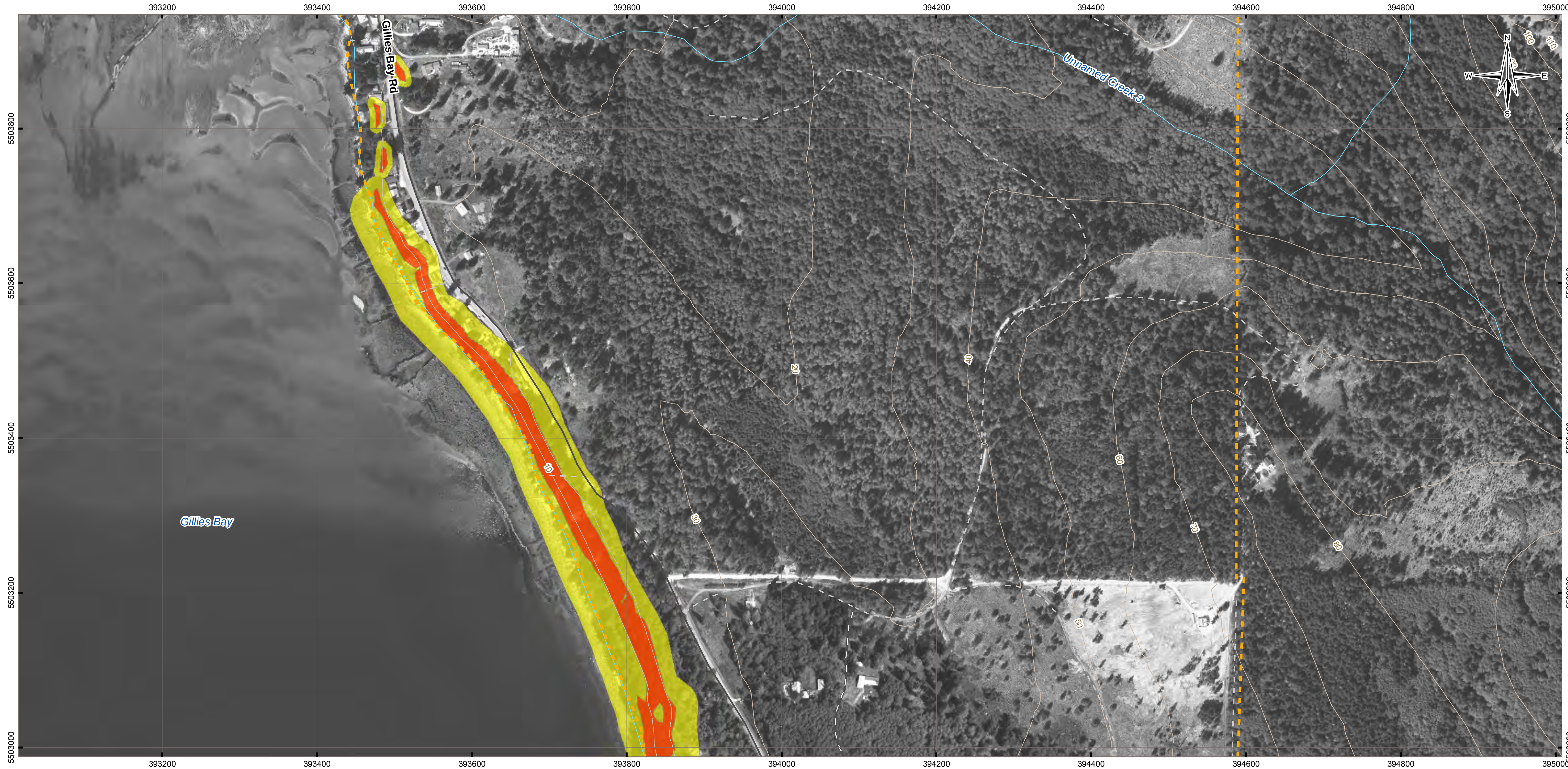
FILE NO.
V13103482-01_Figure12-16_GB_Landslide5K.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 14

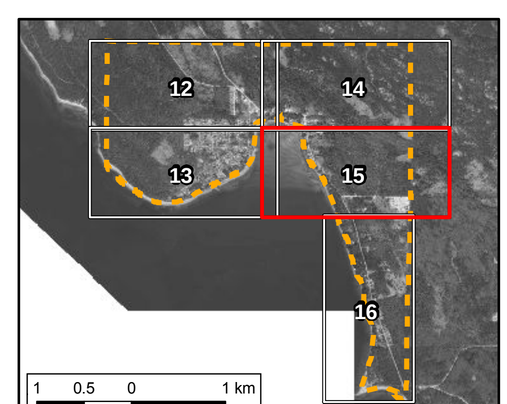


LEGEND

- Limit of Study Area
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 35% Gradient
- Recommended Additional Setback



NOTES
1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons Gillies Bay

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Powell River Regional District

Scale: 1:5,000

100 50 0 100

Metres

FILE NO.
V13103482-01_Figure12-16_GB_Landslide5K.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

TETRA TECH

Figure 15

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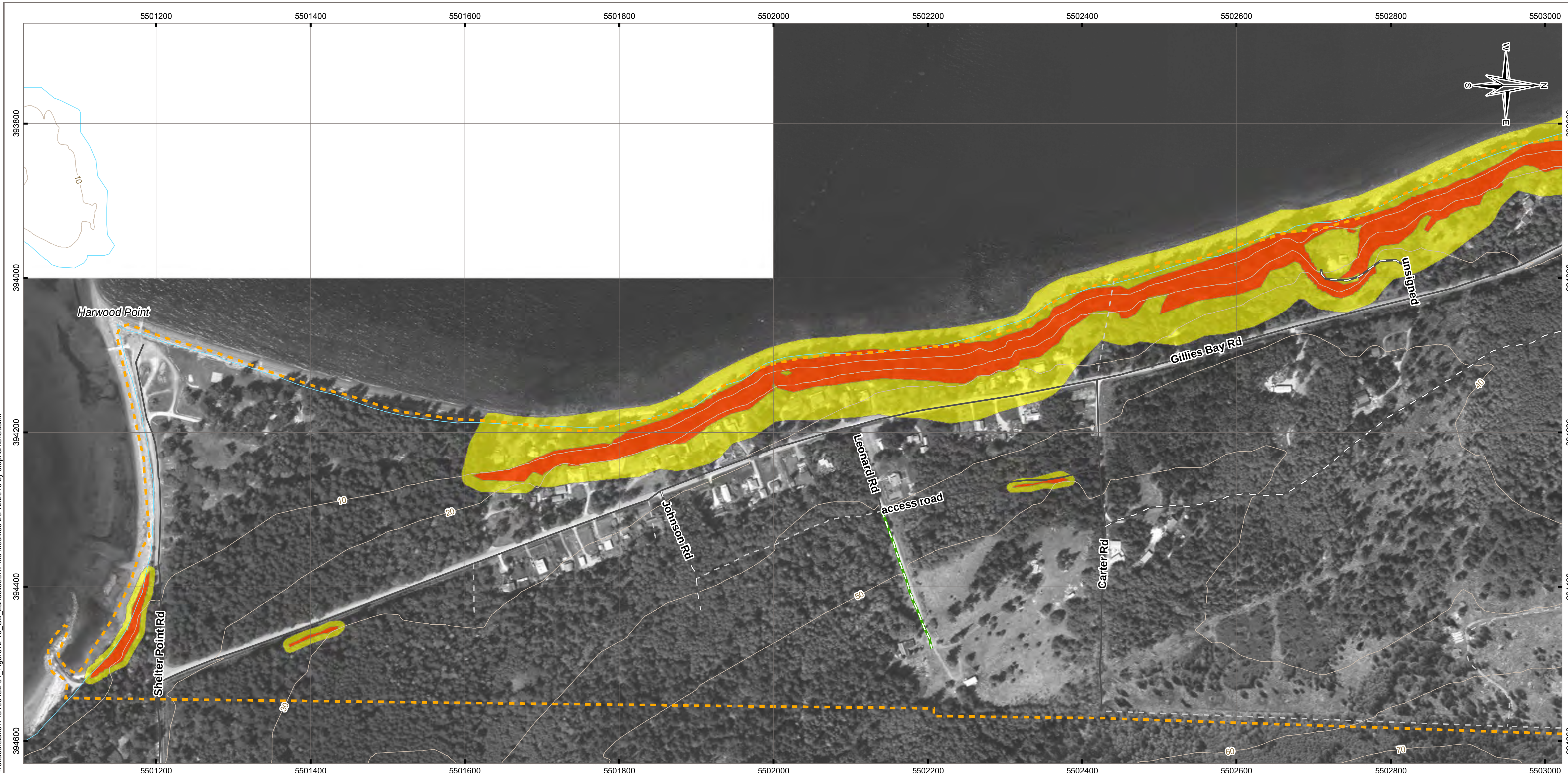
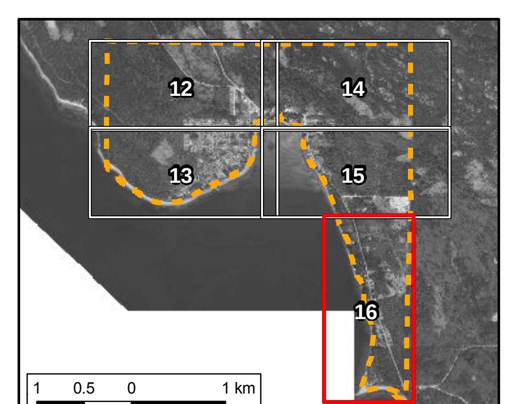


LEGEND

- Limit of Study Area
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

Landslide Hazard Polygon

- Slopes ≥ 3 m High and ≥ 35% Gradient
- Recommended Additional Setback



NOTES
1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
2. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Landslide Hazard Polygons
Gillies Bay

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000
100 50 0 100
Metres

FILE NO.
V13103482-01_Figure12-16_GB_Landslide5K.mxd

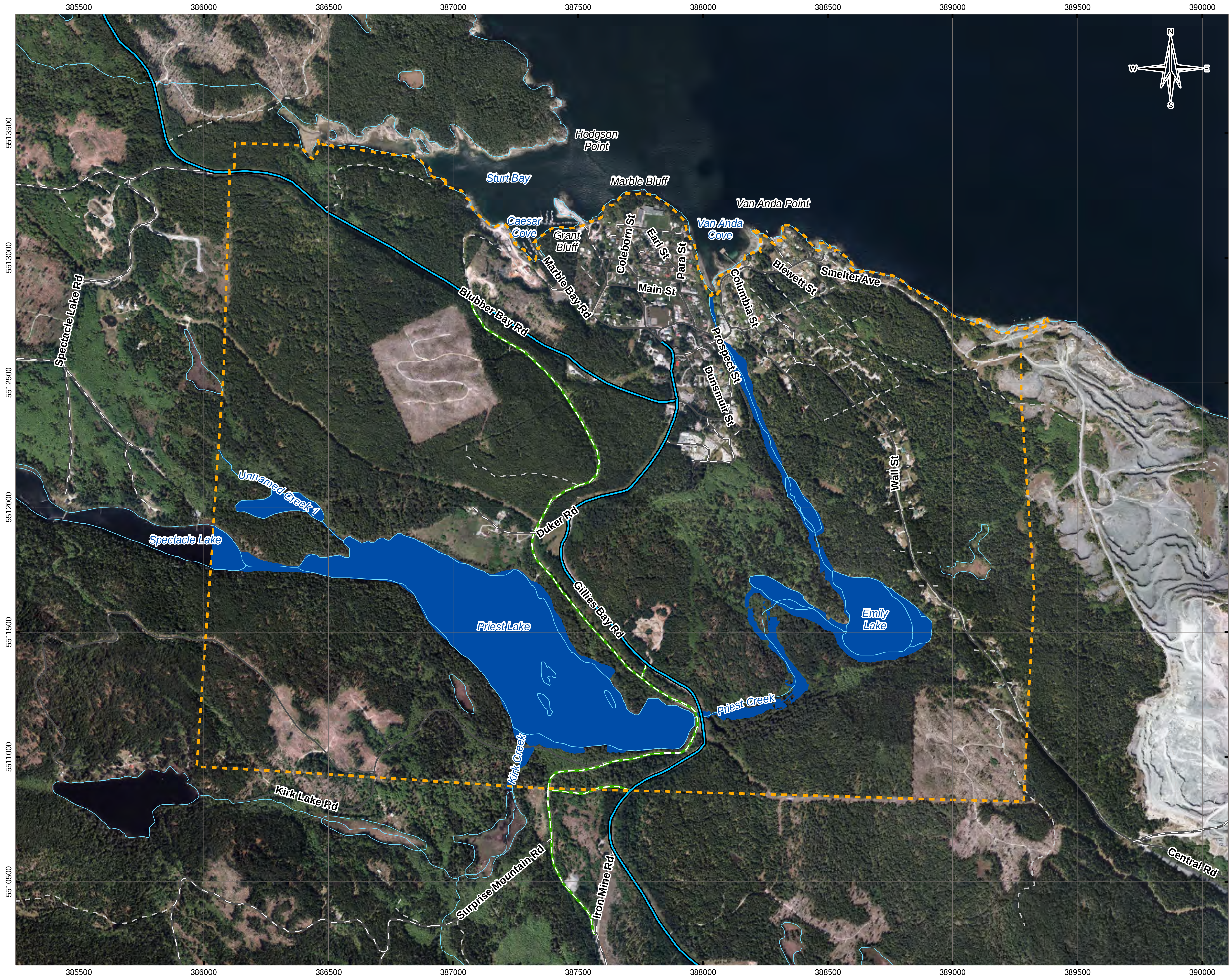
TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

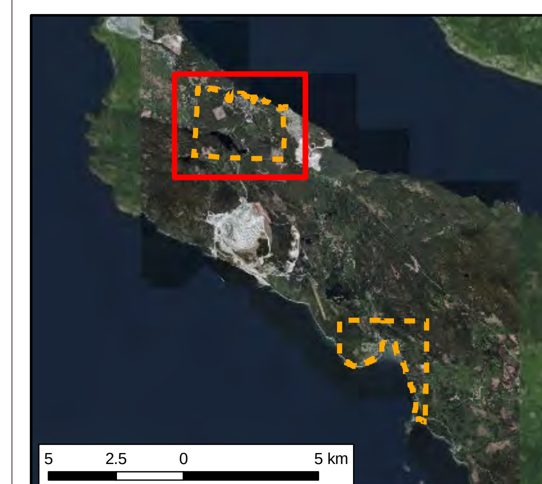
Figure 16

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure12-16_GB_Landslide5K.mxd modified 20/12/2016 by stephanie.leusink



LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Watercourse / Waterbody



NOTES
1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Van Anda Overview

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:15,000
200 100 0 200
Metres

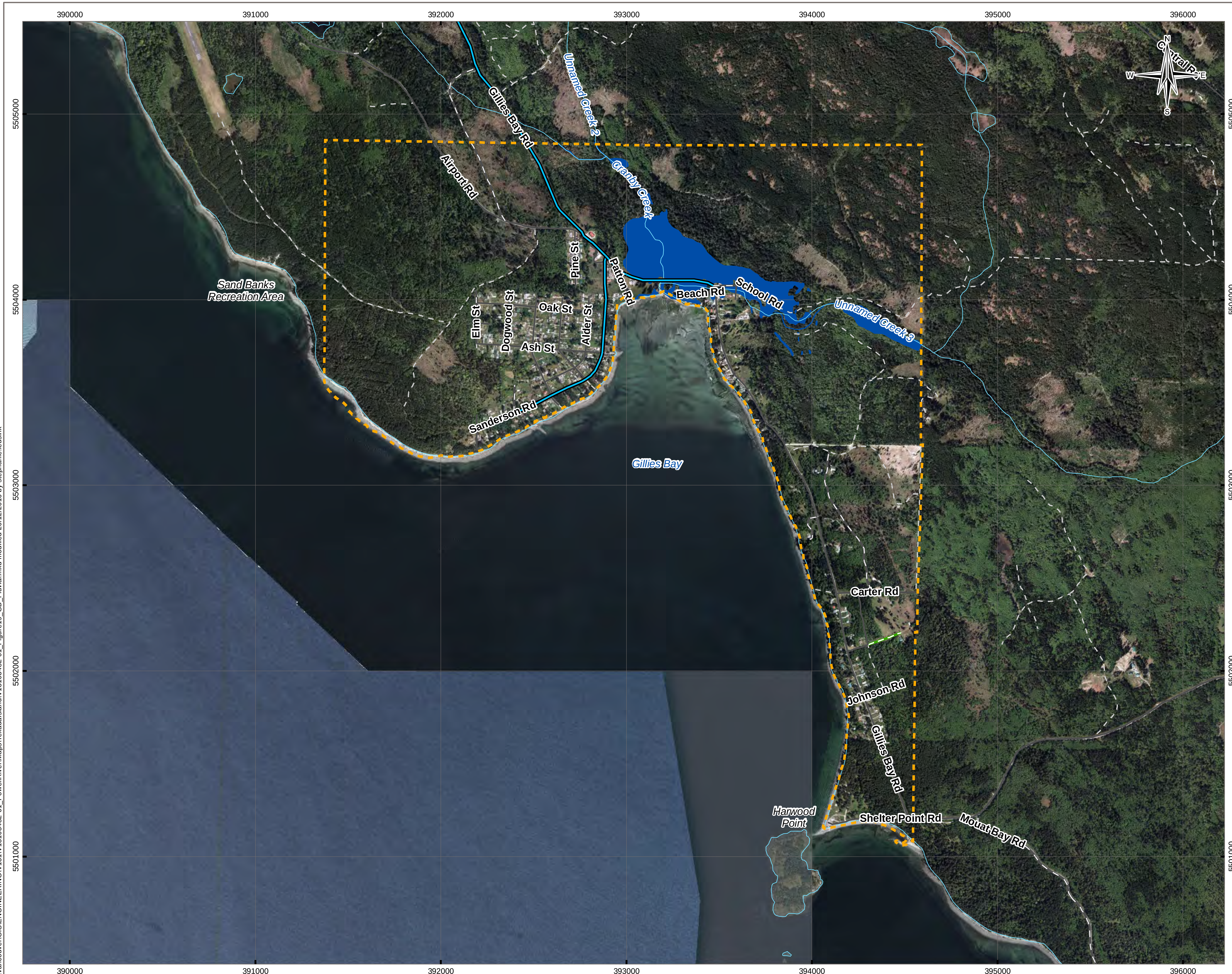
FILE NO.
V13103482-01_Figure18_VA_Fluvial.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

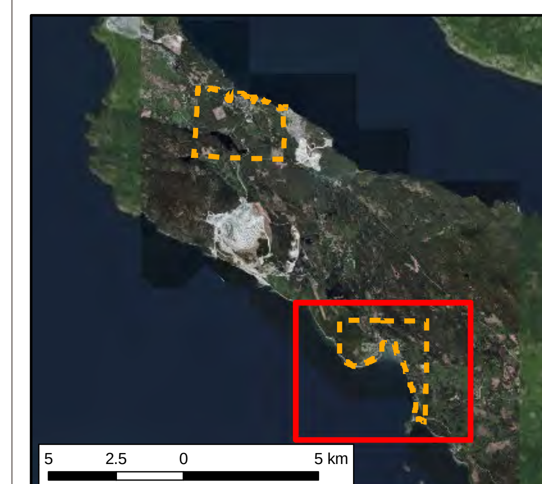
DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 18



LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Gillies Bay Overview

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:20,000

400 200 0 400

Metres

FILE NO.
V13103482-01_Figure19_GB_Fluvial.mxd

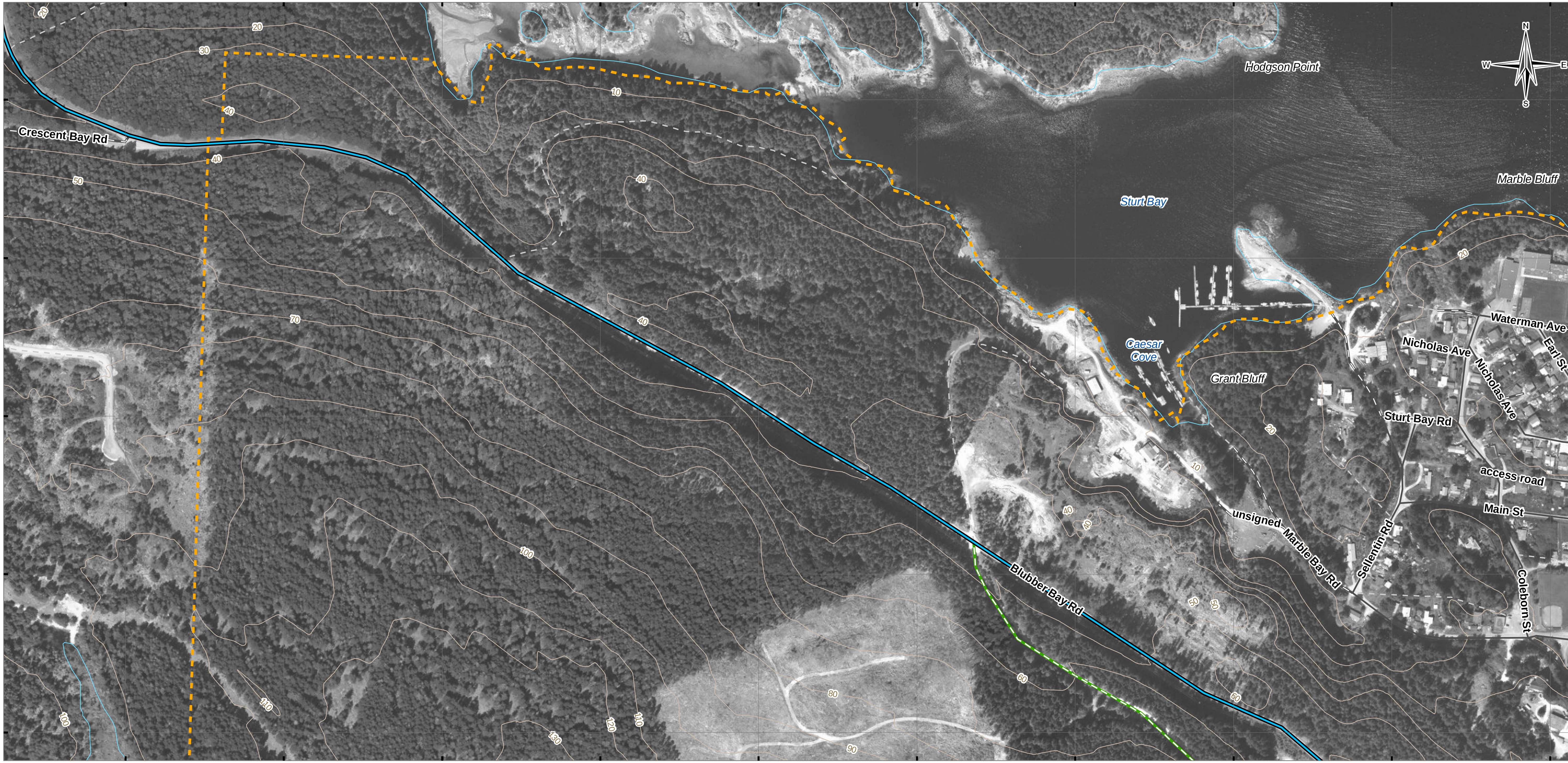
TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

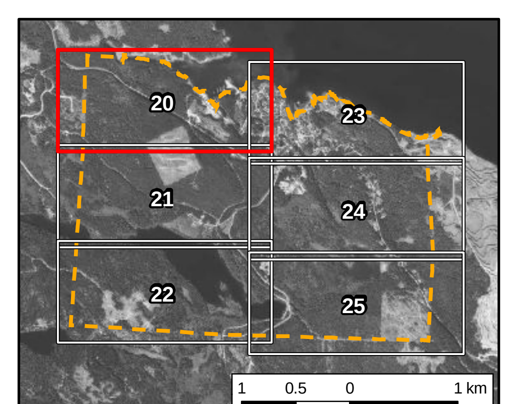
Figure 19

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure19_GB_Fluvial.mxd modified 20/12/2016 by stephanie.leusink



LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES
1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000

100 50 0 100

Metres

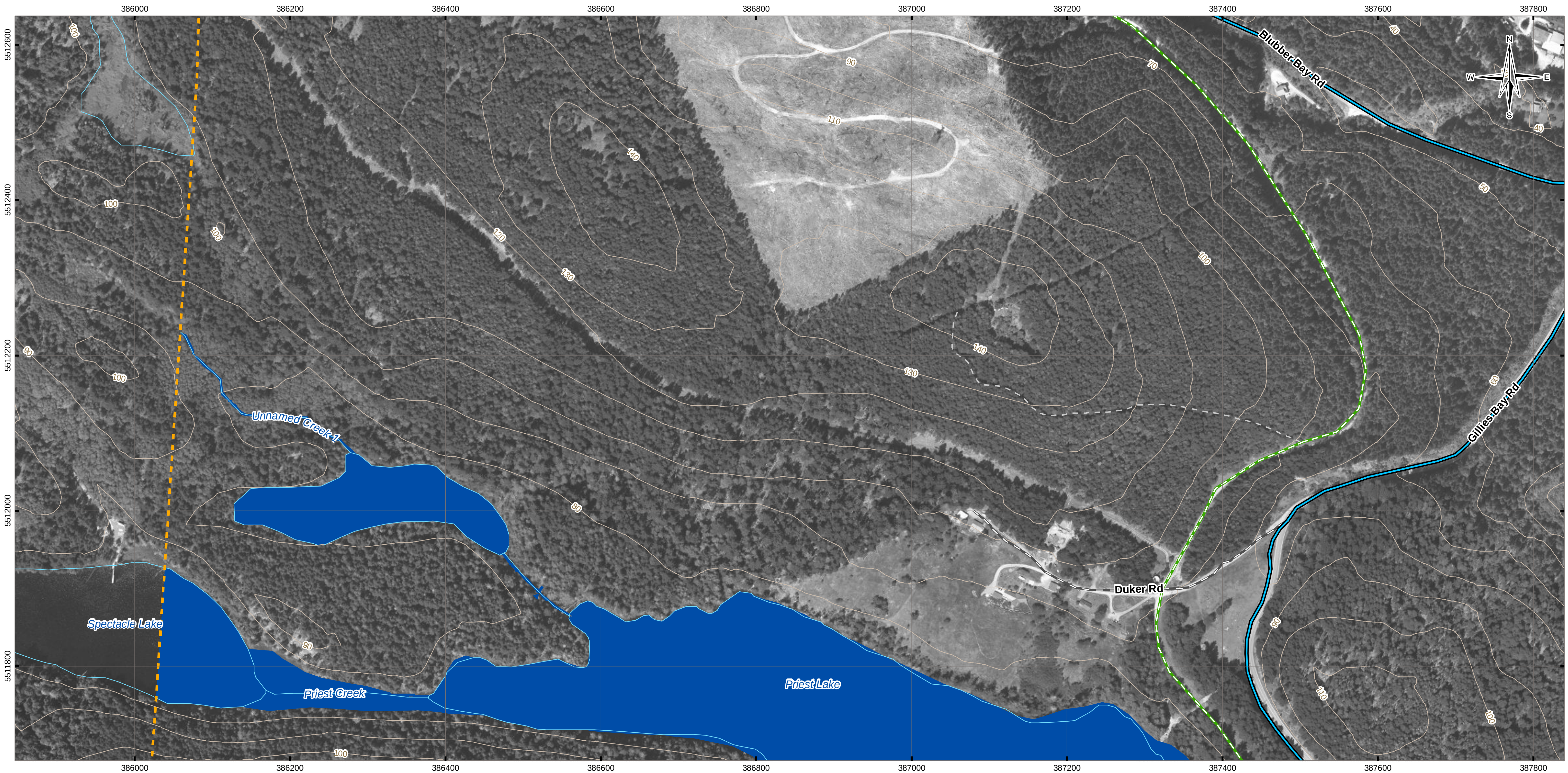
TETRA TECH

FILE NO.
V13103482-01_Figure20-25_VA_Fluvial5K.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

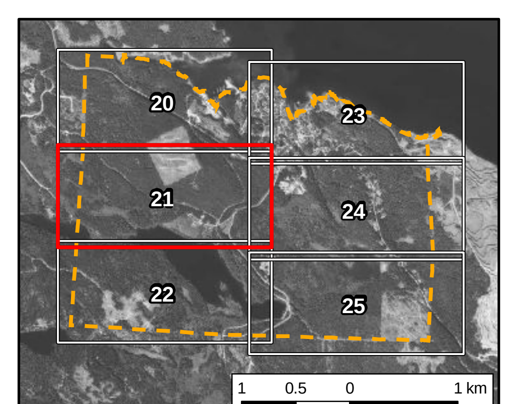
DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 20



LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY
ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons
Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Powell River Regional District

Scale: 1:5,000
100 50 0 100
Metres

FILE NO.
V13103482-01_Figure20-25_VA_Fluvial5K.mxd

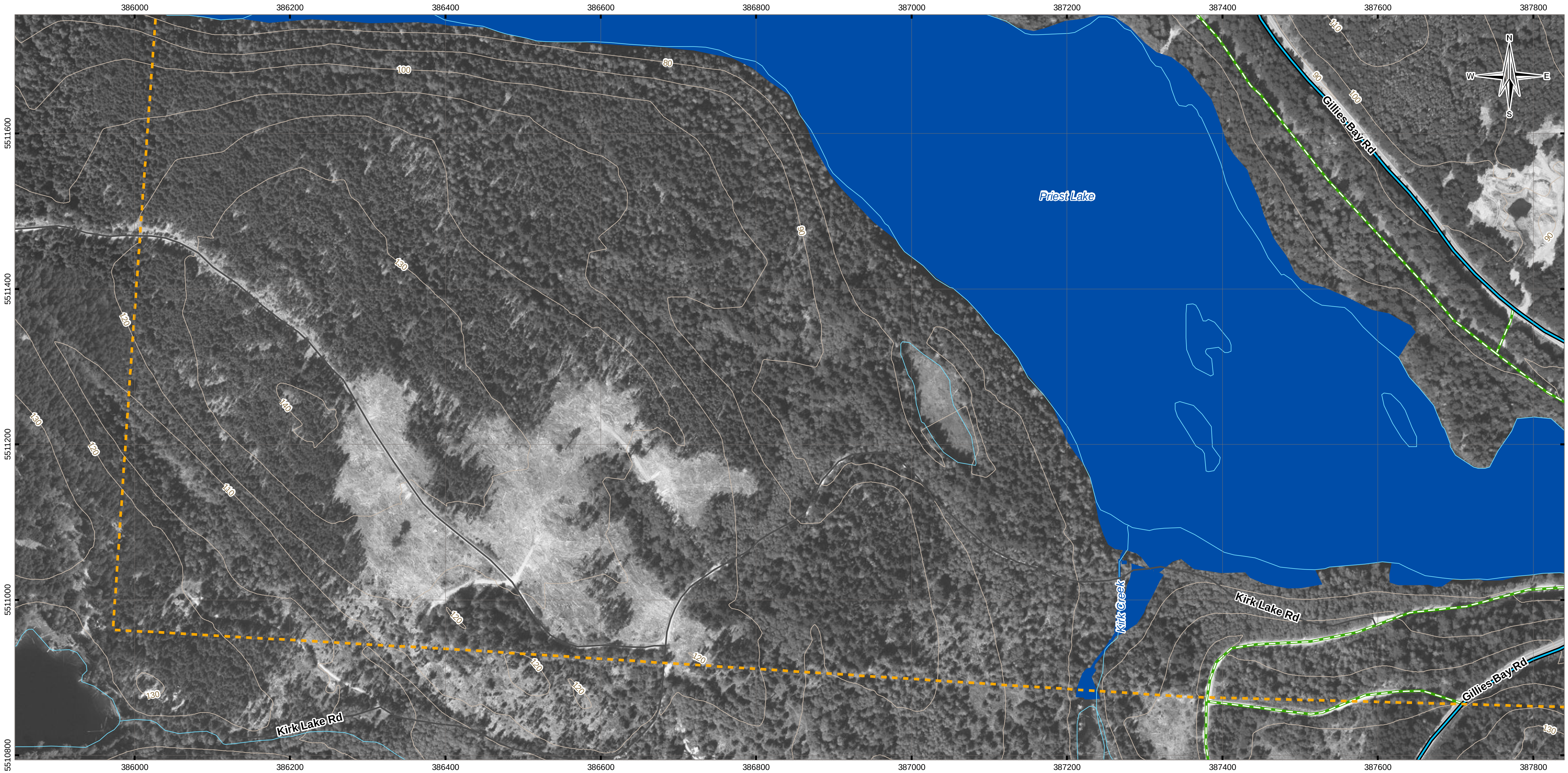
TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

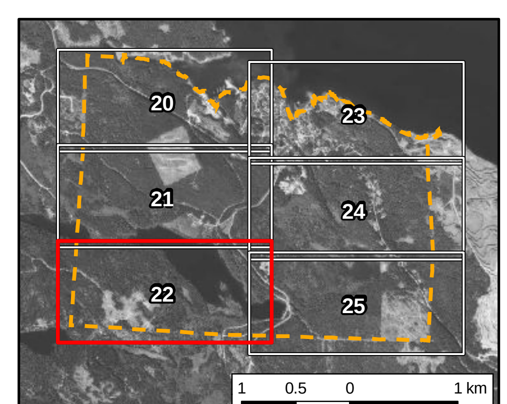
Figure 21

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure20-25_VA_Fluvial5K.mxd modified 20/12/2016 by stephanie.leusink



LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Resource Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Powell River Regional District

Scale: 1:5,000

100 50 0 100

Metres

FILE NO.
V13103482-01_Figure20-25_VA_Fluvial5K.mxd

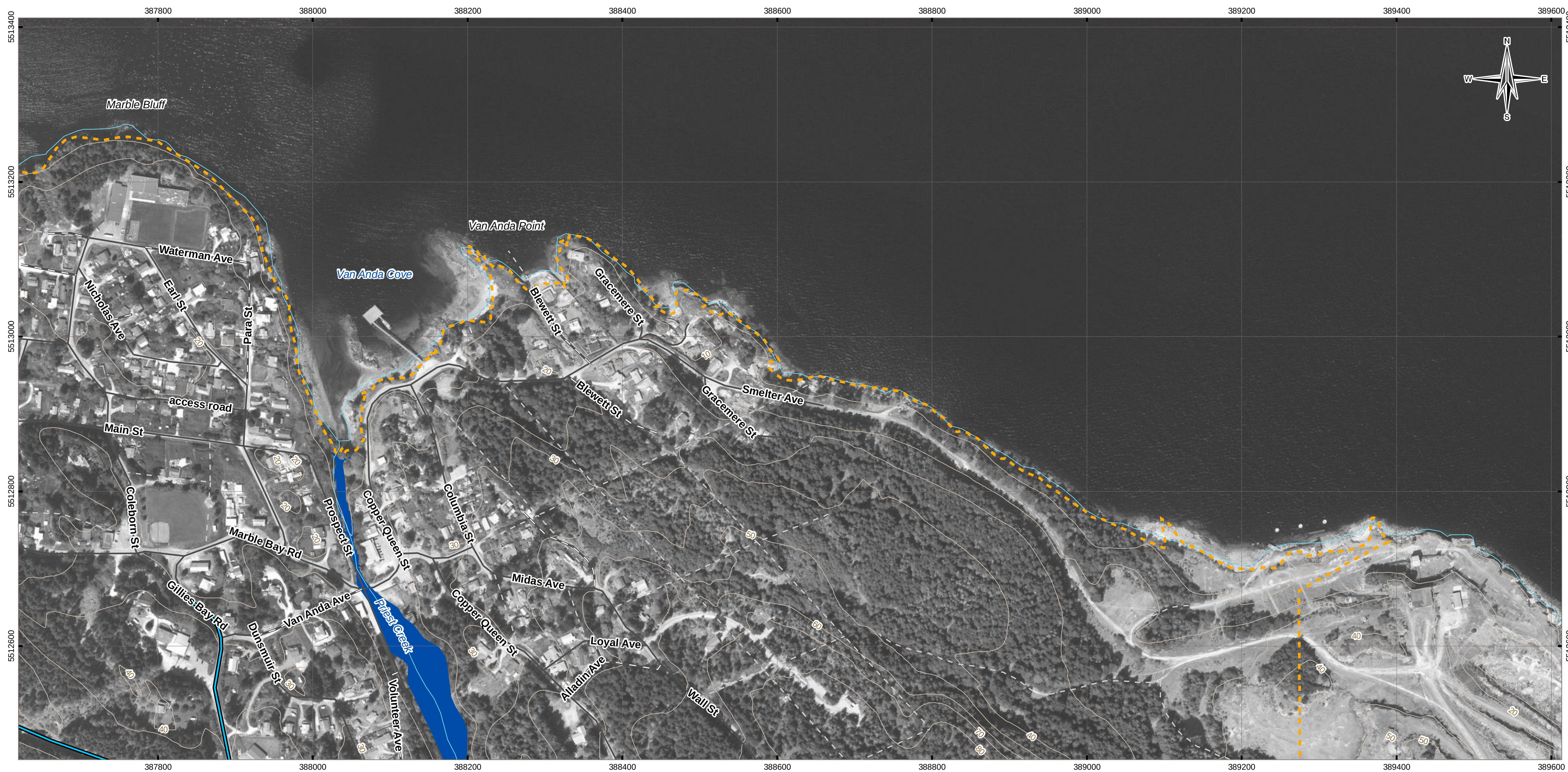
TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 22

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure20-25_VA_Fluvial5K.mxd modified 20/12/2016 by stephanie.leusink



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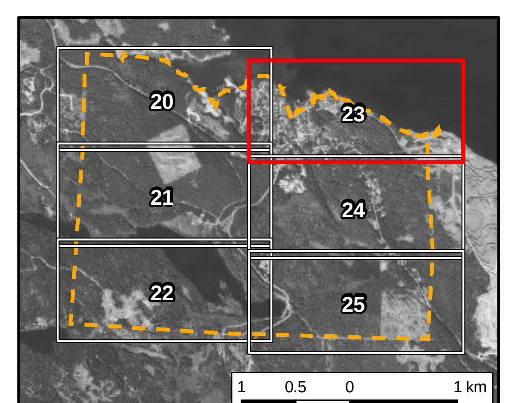
LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES
1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Van Anda

PROJECTION
UTM Zone 10

DATUM
NAD83

Scale: 1:5,000

100 50 0 100

Metres

CLIENT
POWELL RIVER REGIONAL DISTRICT

TETRA TECH

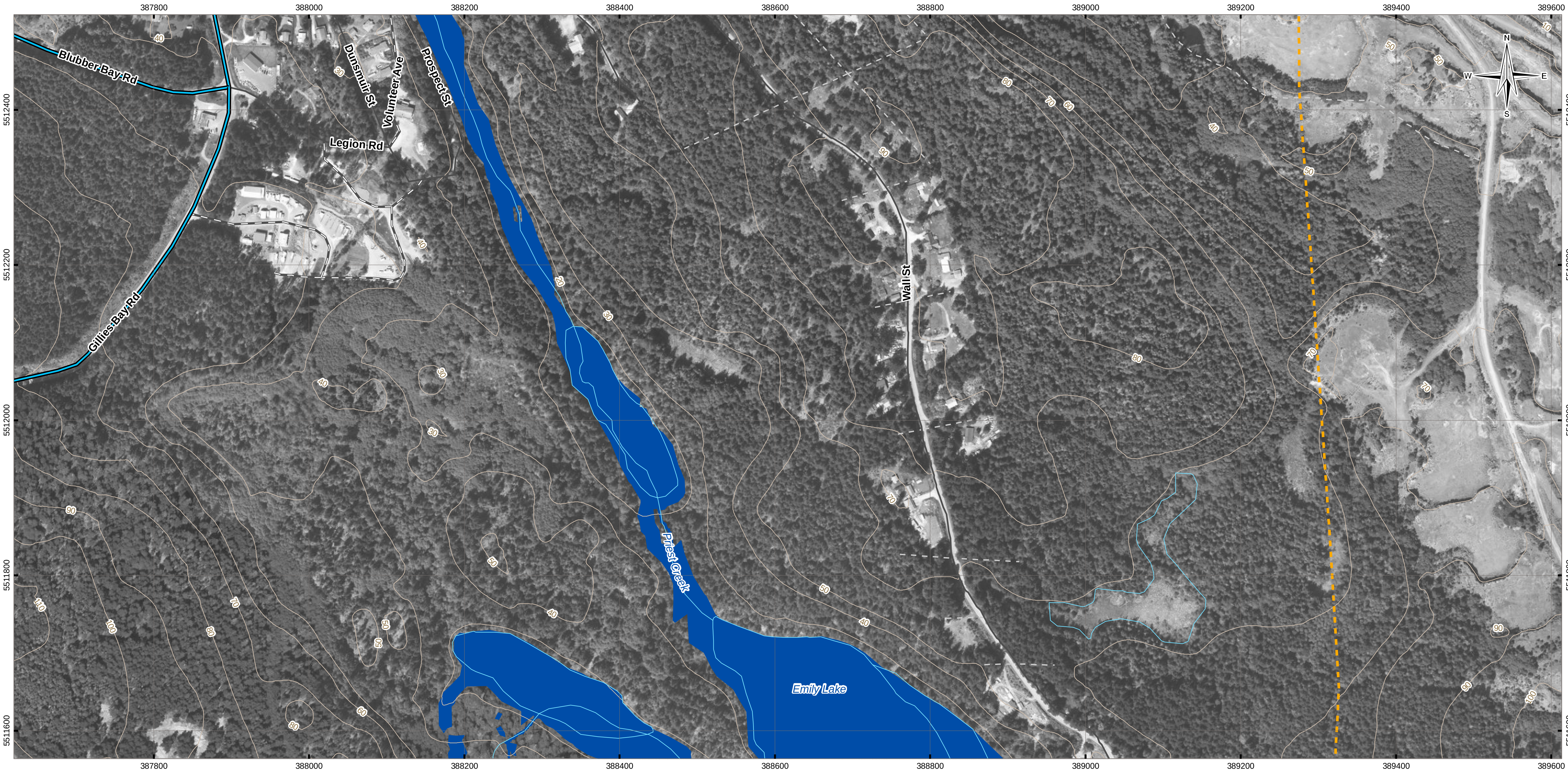
FILE NO.
V13103482-01_Figure20-25_VA_Fluvial5K.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE
December 21, 2016

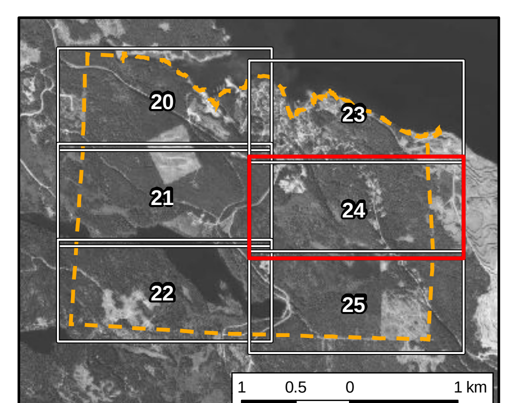
PROJECT NO.
V13103482-01

Figure 23



LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000

100 50 0 100
Metres

FILE NO.
V13103482-01_Figure20-25_VA_Fluvial5K.mxd

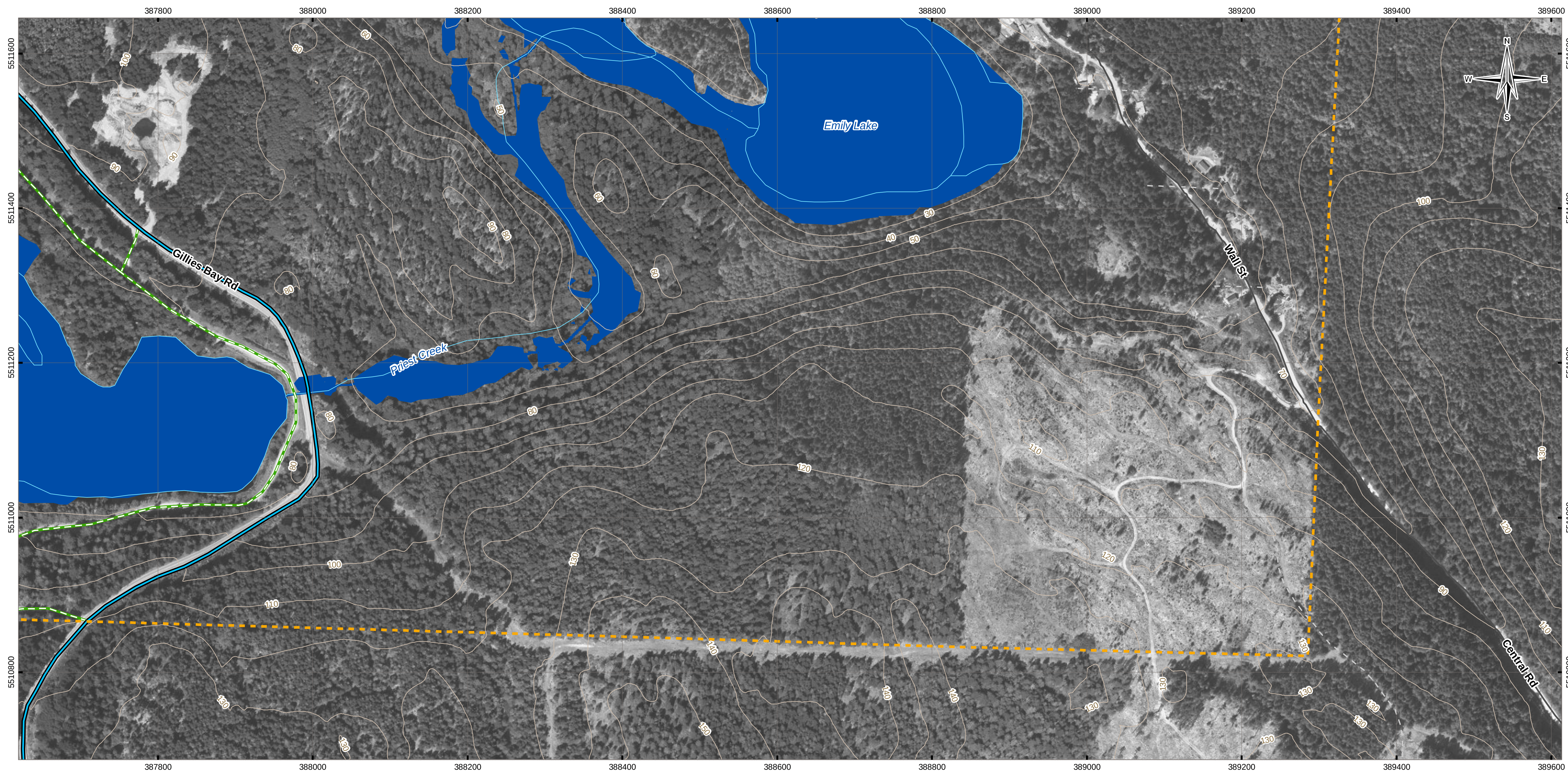
TETRA TECH

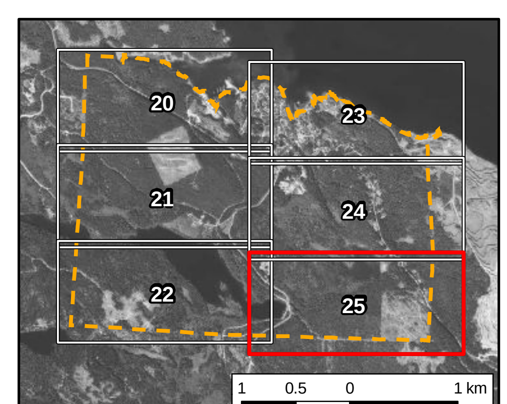
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE: December 21, 2016
PROJECT NO.: V13103482-01

Figure 24

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure20-25_VA_Fluvial5K.mxd modified 2016/12/20 by stephanie.leusink





LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Resource Road
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000
100 50 0 100
Metres

TETRA TECH

FILE NO.
V13103482-01_Figure20-25_VA_Fluvial5K.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE December 21, 2016
PROJECT NO. V13103482-01

Figure 25

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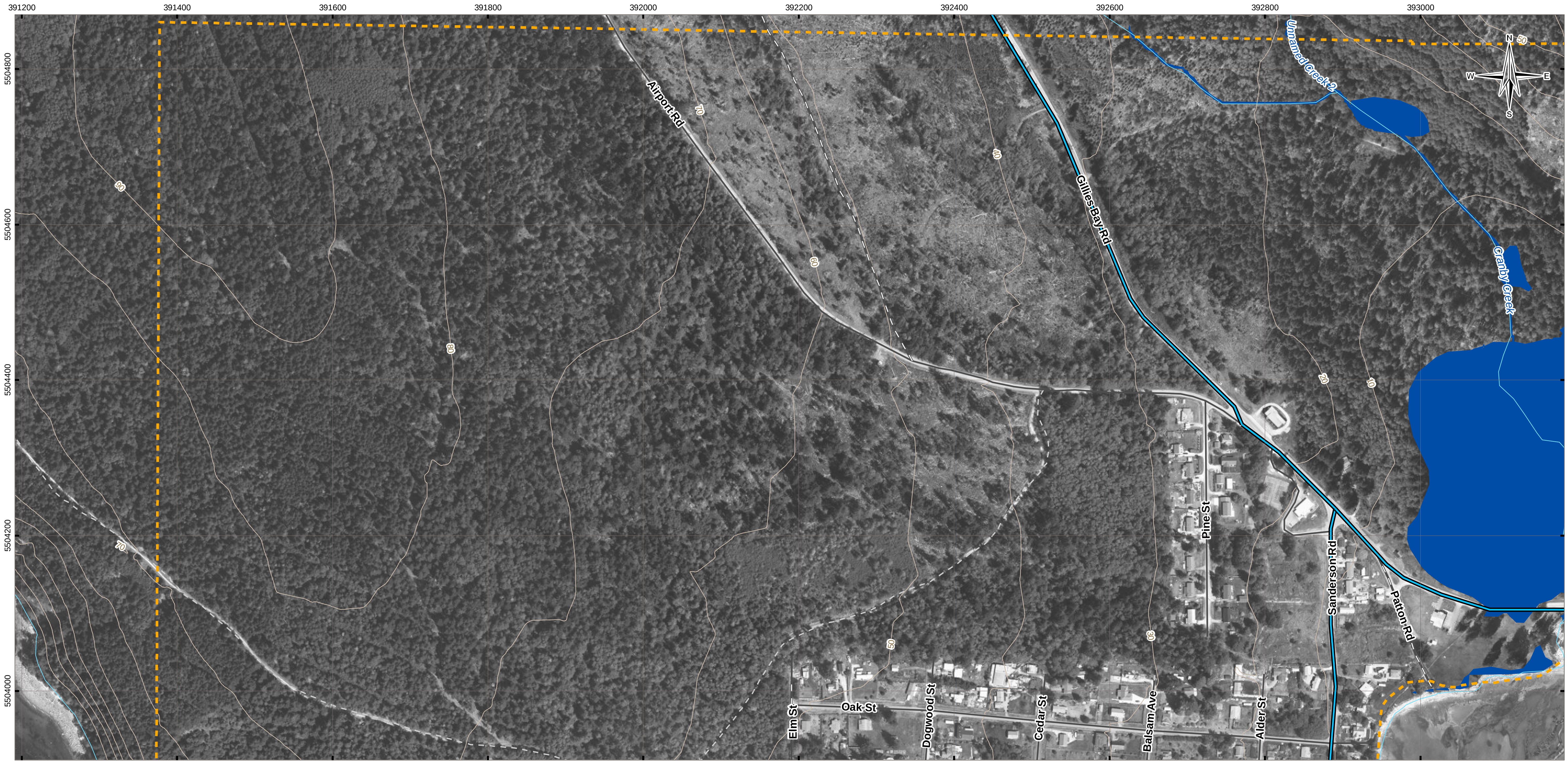
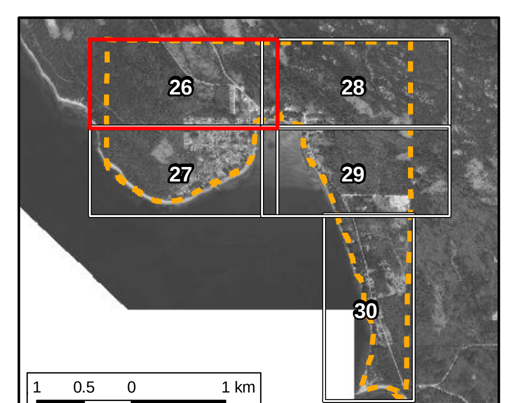


LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Gillies Bay

PROJECTION	DATUM
UTM Zone 10	NAD83

Scale: 1:5,000

100 50 0 100 Metres

CLIENT: POWELL RIVER REGIONAL DISTRICT

TETRA TECH

FILE NO.
V13103482-01_Figure26-30_GB_Fluvial5K.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

STATUS
ISSUED FOR USE

Figure 26

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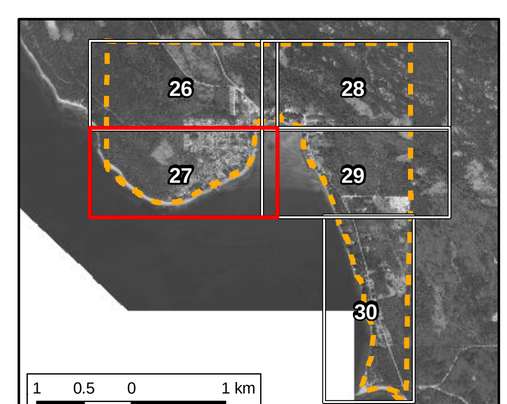
LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Gillies Bay

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000

100 50 0 100
Metres

TETRA TECH

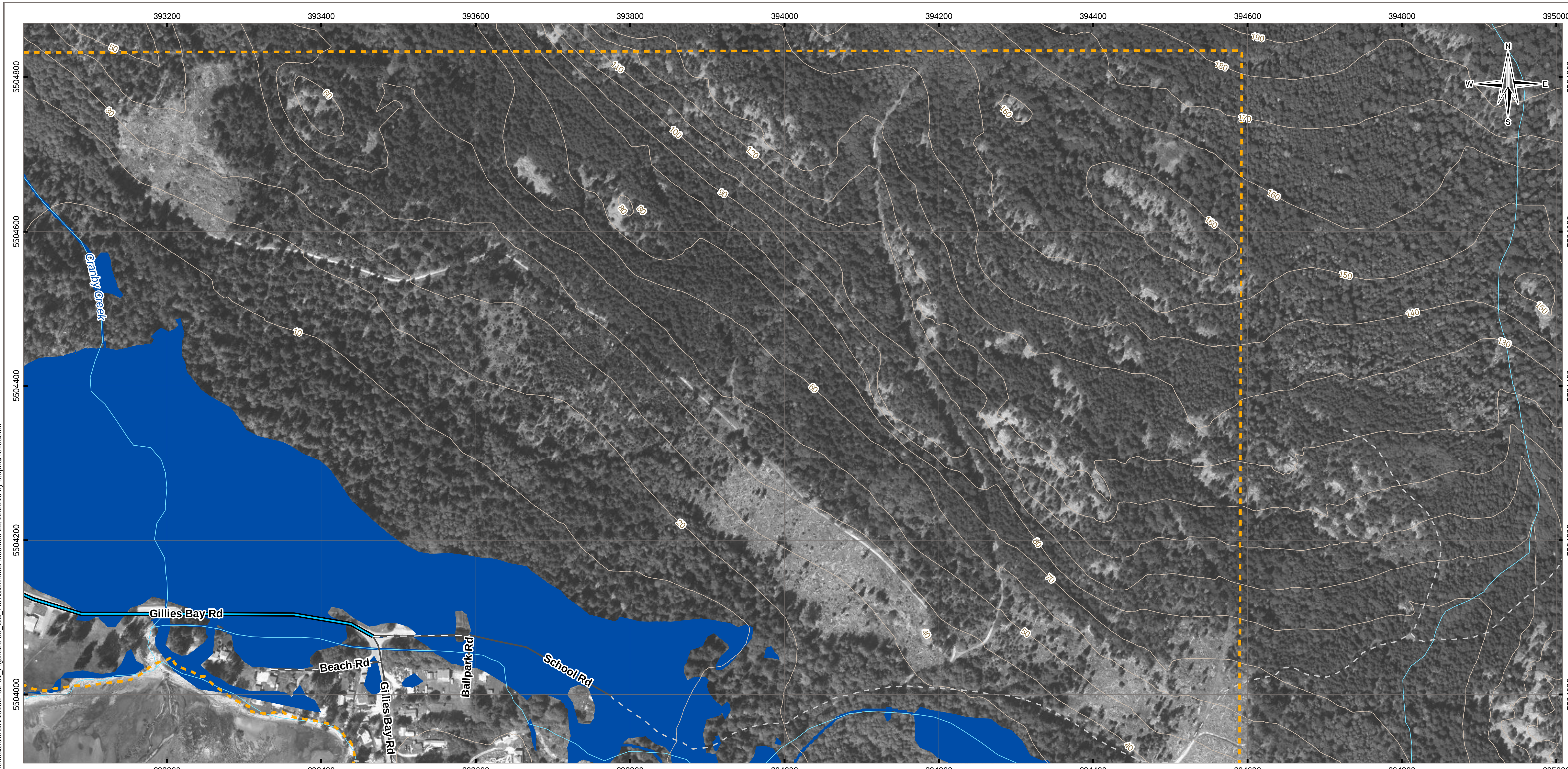
FILE NO.
V13103482-01_Figure26-30_GB_Fluvial5K.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 27

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure26-30_GB_Fluvial5K.mxd modified 20/12/2016 by stephanie.leusink



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LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody

NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Gillies Bay

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000
100 50 0 100
Metres

TETRA TECH

FILE NO.
V13103482-01_Figure26-30_GB_Fluvial5K.mxd

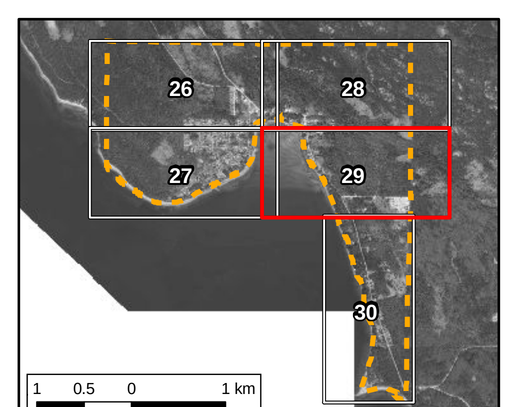
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 28

LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Gillies Bay

PROJECTION	DATUM
UTM Zone 10	NAD83

Scale: 1:5,000
100 50 0 100
Metres

CLIENT
POWELL RIVER REGIONAL DISTRICT

TETRA TECH

FILE NO.
V13103482-01_Figure26-30_GB_Fluvial5K.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

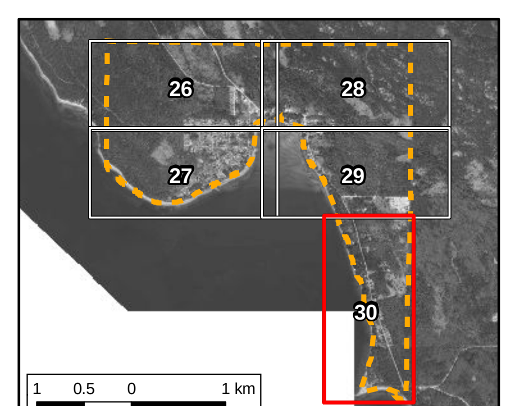
DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 29

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_Figure26-30_GB_Fluvial5K.mxd modified 20/12/2016 by stephanie.leusink

LEGEND

- Fluvial Hazard Polygon (200-year Flood)
- Limit of Study Area
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Contour (10 m)
- Watercourse / Waterbody



NOTES

1. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Fluvial Hazard Polygons Gillies Bay

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:5,000

100 50 0 100
Metres

FILE NO.
V13103482-01_Figure26-30_GB_Fluvial5K.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure 30

PHOTOGRAPHS

Photos 1 to 12

Photo 1: View of bedrock escarpment located north of Blubber Bay Road, west of Van Anda town site. Yellow dashed lines show loose and potentially unstable rock wedges on the slope. Note shovel in bottom-left corner for scale. (Photo taken October 2016).

Photo 2: View of coarse talus (rock fall debris) comprised of large angular boulders up to 4 m in diameter. Photo taken east of Van Anda along a section of coastline near Van Anda point. (Photo taken October 2016).

Photo 3: View of steep bedrock bluffs upslope of Smelter Avenue, east of Van Anda. Note areas of loose, fractured rock near the crest. Lighter shaded areas on the bluff indicate where more recent rock fall activity has occurred. (Photo taken October 2016).

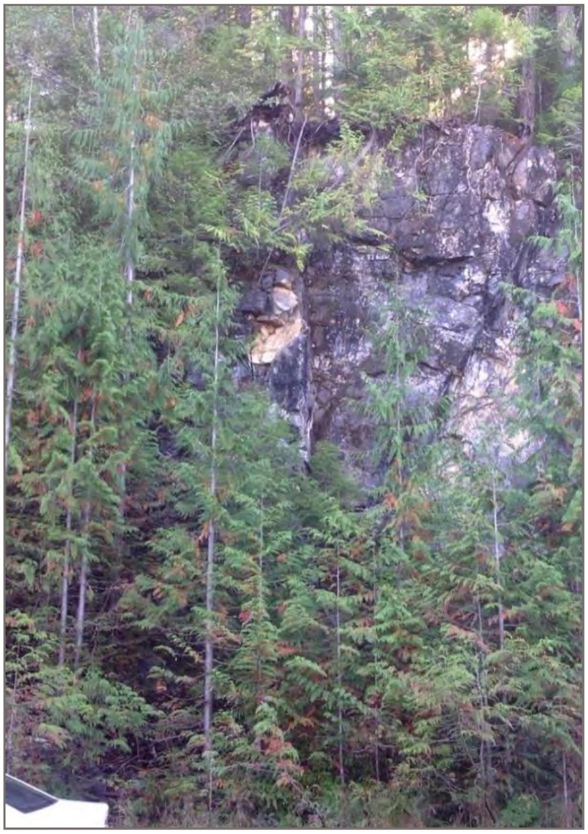


Photo 4: View of steep bedrock bluffs along Kirk Lake Road near intersection with Gillies Bay Road. Lighter shaded areas on the bluff indicate where more recent rock fall activity has occurred. (Photo taken October 2016).

Photo 5: View of coastal escarpment west of Gillies Bay looking towards the area known locally as the "Sand Banks". Lighter shaded area (red arrow) indicates where active erosion and landslide activity are occurring. (Photo taken October 2016).

Photo 6: View of coastal escarpment looking up at cable TV tower at the west end of Gillies Bay. Yellow dashed line delineates approximate crest of slope; note v-shaped gully and exposed soil near the crest. (Photo taken October 2016).

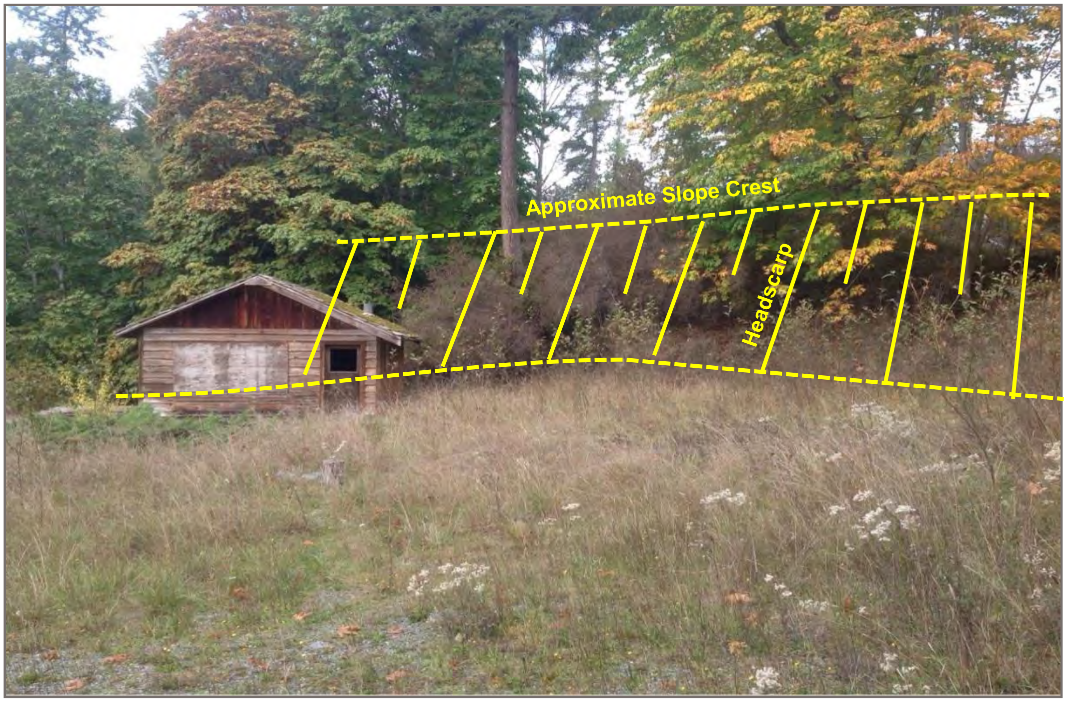


Photo 7: View of ground surface within the ancient (?) landslide (slump) located along the east side of Gillies Bay. Yellow dashed lines delineate approximate crest of slope and the height of the exposed headscarp. (Photo taken October 2016).

Photo 8: Aerial view of ancient (?) landslide (slump) located near the runway at Texada/Gillies Bay Airport. Yellow dashed line delineates approximate location of the headscarp. (Image from Bing Maps; date of image unknown).

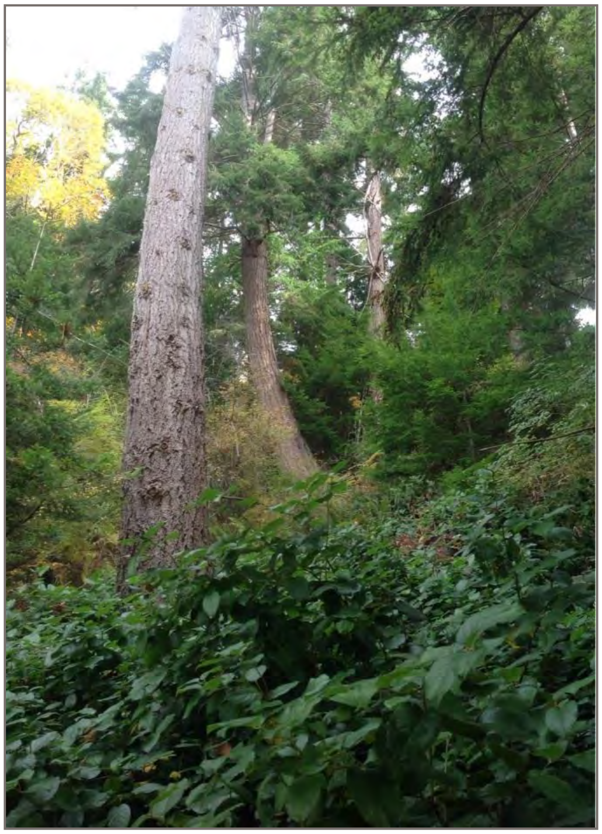


Photo 9: View of coastal escarpment along east side of Gillies Bay. Curved tree trunks indicative of slope creep and potential slope instability. (Photo taken October 2016).

Photo 10: View of coastal escarpment along east side of Gillies Bay. Curved / tilted tree trunks indicative of slope creep and potential slope instability. (Photo taken October 2016).

Photo 11: View of coastline erosion along the west side of Gillies Bay. (Photo taken October 2016).

Photo 12: View of coastline erosion to the west of Gillies Bay, along the section of coastline between the cable TV tower and the “Sand Banks” area. (Photo taken October 2016).

APPENDIX A

TETRA TECH EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA’s Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA’s Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA’s instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of testholes and/or soil/rock exposures. Stratigraphy is known only at the locations of the testhole or exposure. Actual geology and stratigraphy between testholes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

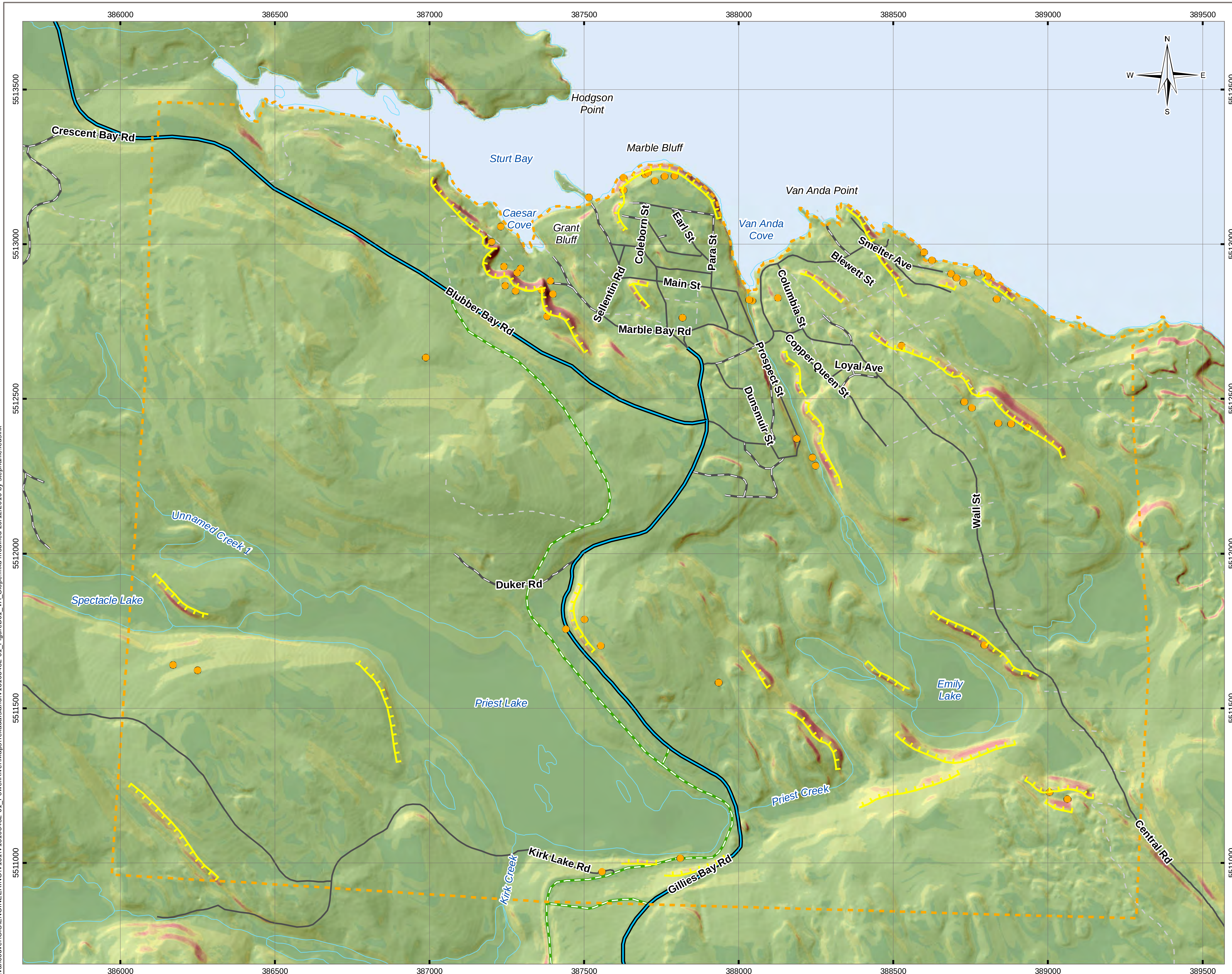
Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client’s expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

APPENDIX B

SLOPE GRADIENT AND LANDSLIDE INVENTORY MAPPING

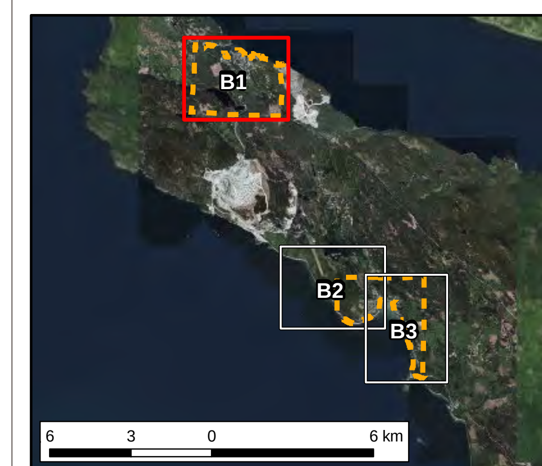


LEGEND

- Waypoint
- Rock Bluff
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Watercourse / Waterbody

Slope Gradient (%)

- < 5%
- 5% - 27%
- 27% - 50%
- 50% - 60%
- 60% - 70%
- 70% - 80%
- 80% - 120%
- > 120%



NOTES

1. The terrain features noted on the figures are based on desktop review of the available imagery and limited field checking.
2. The years noted on the figures correspond to the year of the air photo where this feature was observed.
3. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
4. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Slope Gradient and Landslide Inventory Mapping Van Anda

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:12,000

200 100 0 200

Metres

TETRA TECH

FILE NO.
V13103482-01_FigureB01_VA_Slope.mxd

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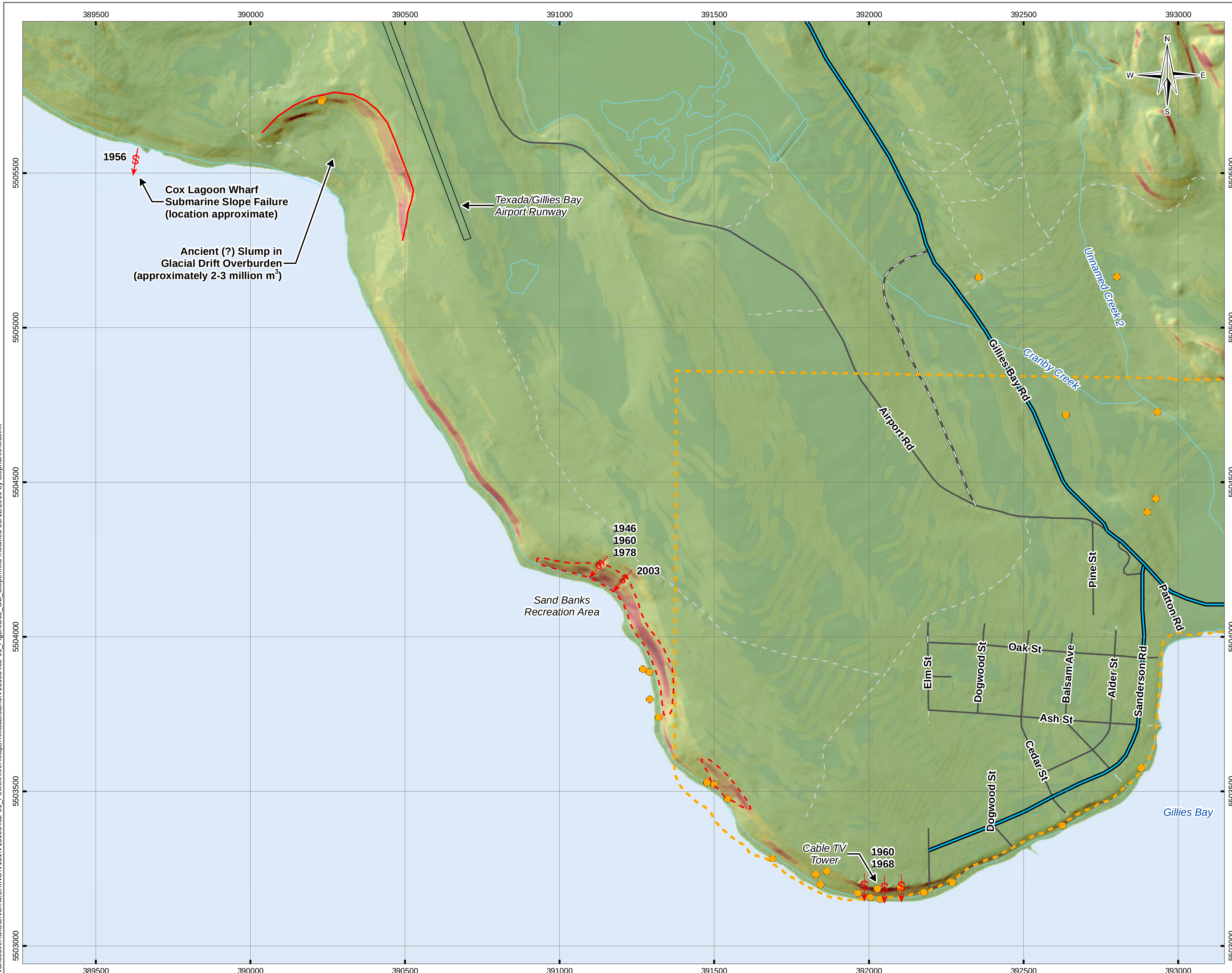
Tt-VANC	SL	MEZ	JP	0

DATE
December 21, 2016

PROJECT NO.
V13103482-01

Figure B1

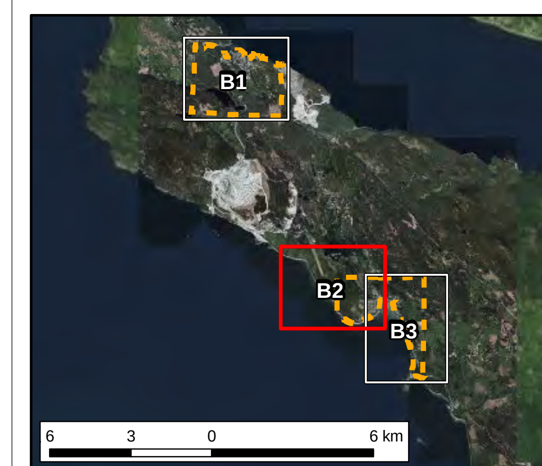


LEGEND

- Waypoint
- Historical Erosion/Landslide Event
- Visible Scarp
- Gullied Terrain
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Unclassified Road
- Watercourse / Waterbody

Slope Gradient (%)

- < 5%
- 5% - 27%
- 27% - 50%
- 50% - 60%
- 60% - 70%
- 70% - 80%
- 80% - 120%
- > 120%



NOTES

1. The terrain features noted on the figures are based on desktop review of the available imagery and limited field checking.
2. The years noted on the figures correspond to the year of the air photo where this feature was observed.
3. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
4. Slope gradients derived from 2 m topographic contours provided by PRRD.

STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Slope Gradient and Landslide Inventory Mapping Gillies Bay (West)

PROJECTION: UTM Zone 10 | DATUM: NAD83 | CLIENT: Powell River Regional District

Scale: 1:12,000

200 100 0 200

Metres

TETRA TECH

FILE NO.
V13103482-01_FigureB02_GB_Slope.mxd

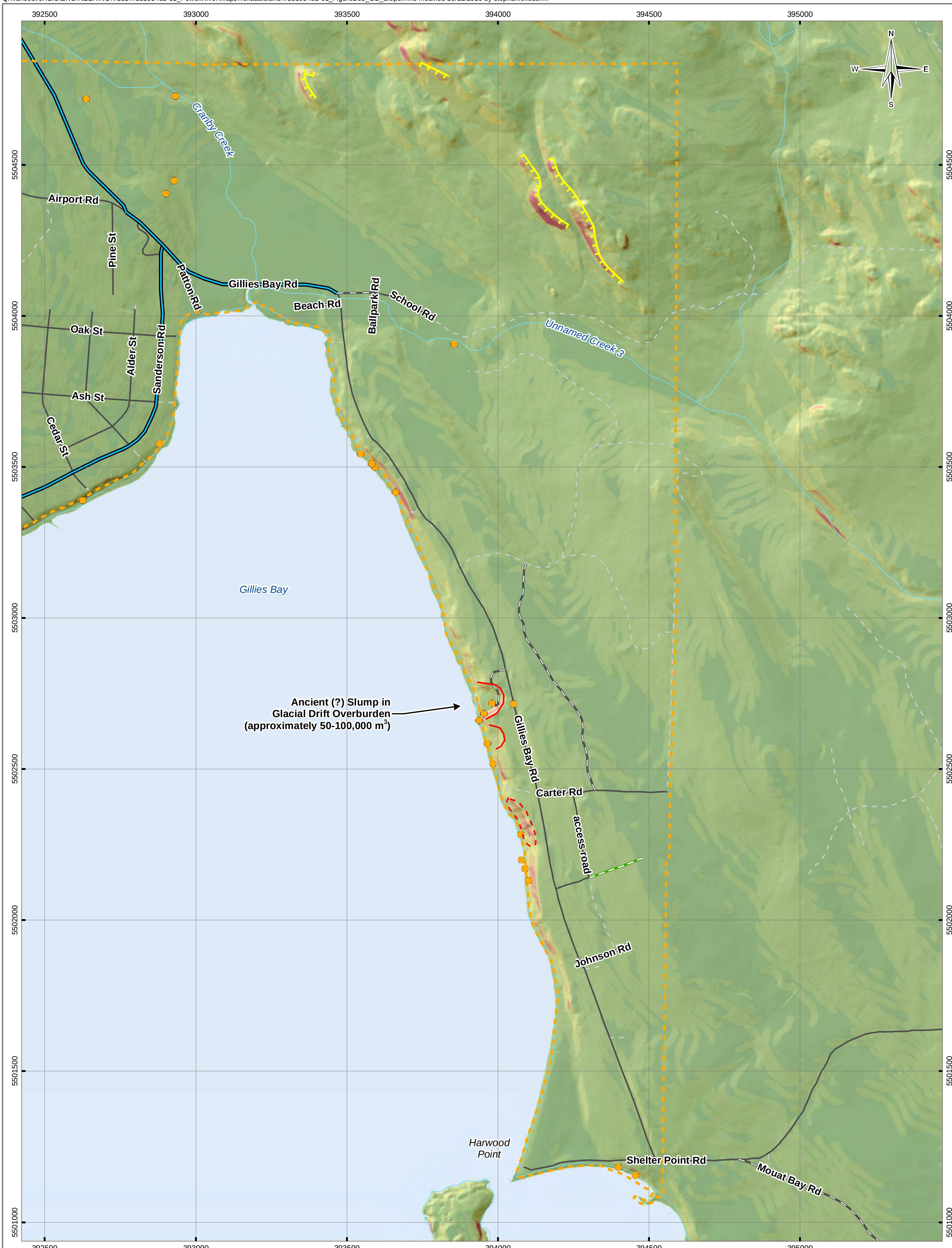
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE: December 21, 2016

PROJECT NO.: V13103482-01

Figure B2

Q:\Vancouver\GIS\ENGINEERING\V131\V13103482-01_PowellRiver\Maps\TexadaIsland\V13103482-01_FigureB02_GB_Slope.mxd modified 20/12/2016 by stephanie.leusink



LEGEND

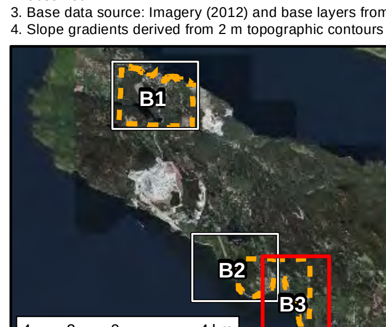
- Waypoint
- Visible Scarp
- Rock Bluff
- Gullied Terrain
- Limit of Study Area
- Major Road - Paved
- Minor Road - Paved
- Minor Road - Loose surface
- Resource Road
- Unclassified Road
- Watercourse / Waterbody

Slope Gradient (%)

- < 5%
- 5% - 27%
- 27% - 50%
- 50% - 60%
- 60% - 70%
- 70% - 80%
- 80% - 120%
- > 120%

NOTES

1. The terrain features noted on the figures are based on desktop review of the available imagery and limited field checking.
2. The years noted on the figures correspond to the year of the air photo where this feature was observed.
3. Base data source: Imagery (2012) and base layers from PRRD; TRIM; BC Digital Road Atlas.
4. Slope gradients derived from 2 m topographic contours provided by PRRD.



STATUS
ISSUED FOR USE

LANDSLIDE AND FLUVIAL HAZARDS STUDY ELECTORAL AREA D - TEXADA ISLAND

Slope Gradient and Landslide Inventory Mapping Gillies Bay (East)

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	POWELL RIVER REGIONAL DISTRICT

Scale: 1:12,000
200 100 0 200
Metres

FILE NO.
V13103482-01_FigureB03_GB_Slope.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MEZ	JP	0

DATE	PROJECT NO.
December 21, 2016	V13103482-01

Figure B3