Identification of Natural Hazard Areas

Malaspina Peninsula / Okeover Inlet

Marion Blank, P.Geo.
Planterra Environmental Consulting

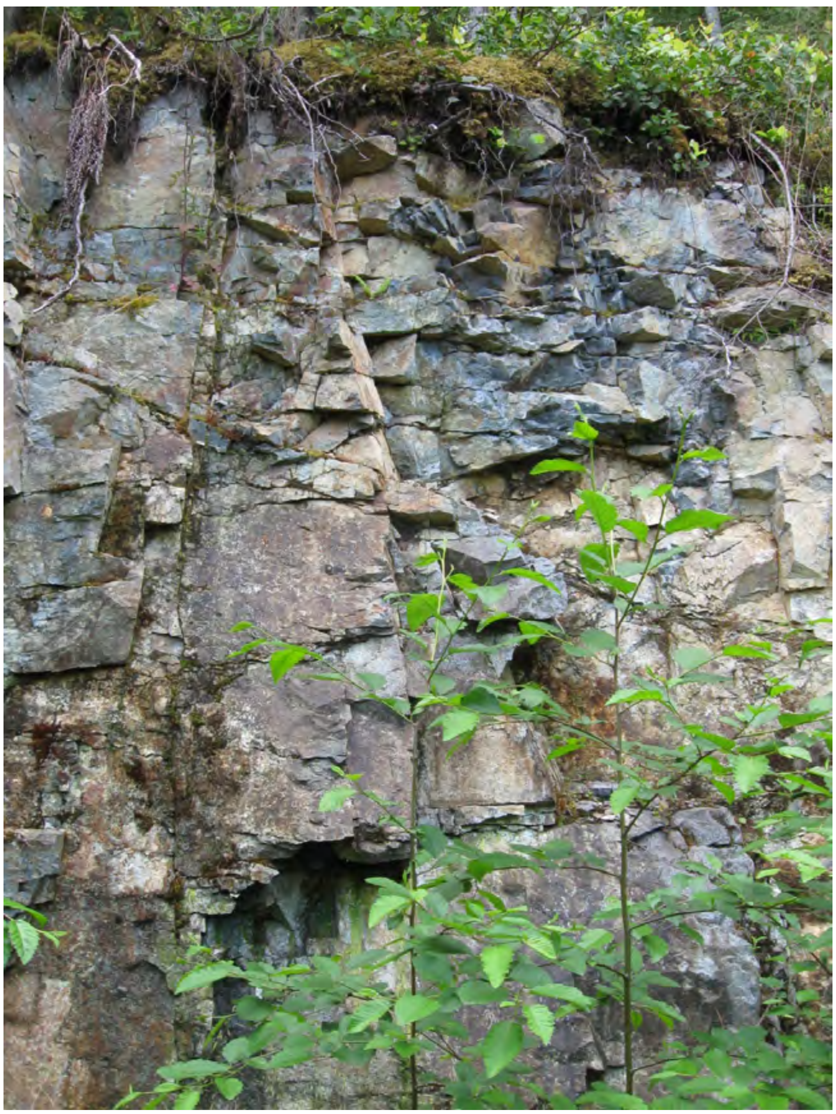


Table of Contents

Executive Summary 1

1.Introduction 2

1.1 Study Area

1.2 Area Geology

2. Methodology 5

3. Discussion 9

3.1 Steep Slopes

3.1.1 Rock Bluffs/ Rock-Fall Hazard

3.1.2 Steep Slopes / Surficial Material

3.2 Shoreline Erosion

4. Specific Areas of Concern 14

4.1 Atrevida Area

4.1.1. Areveda Area A

4.1.2. Atrivida Area B 4.2

Emmonds Beach Drainage Area 4.3

Shoreline Erosion

4.4 Okeover Dock Area

5. Recommendations 24

5.1 Atrevida Area

5.2 Emmonds Beach

5.3Storm Surge/Shoreline Erosion

5.4 Okeover Dock Area

5.5 Steep Slopes

6. Closure 26

7. References 27

Figure 1 Study Area Location

Figure 2 Steep Slopes

Figure 3 Shoreline Erosion

Figure 4 Okeover Dock Area

Map 1 Natural Hazards 1:40,000

Map 1-1, 1-2 Natural Hazards 1:40,000

Map 2-1 Atrevida Area Field Review 1:10,000 11X17 foldout

Map 2-2 Atevida Area Proposed Development Permit Area 1:10,00 11X17 foldout

Map 3 Emmonds Beach Drainage Area 1:10,000 11X17 foldout

Executive Summary

The Powell River Regional District Planning Department requested an overview geotechnical survey be completed to determine natural hazard areas (steep and unstable slopes) along the coastline north of Tla'amin Reserve No. 1 and the City of Powell River and to make recommendation regarding possible development permit areas.

The project area encompasses lands along the shoreline of Malaspina Peninsula including the west side of Okeover Inlet and private land parcels on the east side of Okeover Inlet. Lands designated as park or Tla'amin lands were excluded from the study.

The study identified natural hazard areas that may impact present and/or future development in this area. Methodology included a review of reports, air photos, computer generated slope and coastline analysis and field investigations.

Information has been summarized on three maps at the scale of 1:40 000.

Map 1 , (poster size 18" x 24") covers the entire study area.

Map 1-1 (report size 11" x 17") covers the northern region and Map 1-2 (report size 11" x 17") covers the southern portion of the area.

General recommendations are based on the geology and its associated landforms, slope and drainage. Specific recommendations for development permit areas are based the observation of current active erosional processes, surficial geology, observable groundwater levels and drainage patterns.

1. Introduction

The report analysis is limited to observable geological , topographic and drainage features and how these features may impact land use /human development. It does not attempt to provide risk analysis associated with earthquakes generated from regional plate tectonics.

1.1 Study Area

The study area is located entirely within the Electoral Area A of the Powell River Regional District, within the traditional territory of the Tla'amin First Nation. The project area encompasses lands along the shore line of Malaspina Peninsula north of Tla'amin Reserve No. 1 and Powell River, including the west side of Okeover Inlet and private land parcels lot DL 6987 and DL 4518 on the east side of Okeover Inlet. (Fig.1 Study Area, scale 1:100 000)

1.2 Area Geology

Bedrock Geology

The Malaspina Peninsula and Okeover area is underlaid by the Coast Plutonic Complex, which dominates the entire coastline of British Columbia . These rocks are predominantly granitic with cross cutting dyke complexes of variable chemistry. Radiometric dates from the granitic rocks in southwestern BC range from early to middle Cretaceous (145-66 million years). There are also minor volcanic and sedimentary rock , an area of limestone immediately east of Savary Island has been documented.

Much of the terrain is steeply sloped with exposed bedrock bluffs and knolls that are highly fractured. There is generally a thin layer of soils with deeper glacial/marine deposits in pockets along the coast. The uplands display a hummocky topography with steep sided hills and hollows that micmic the underlying bedrock.

Natural Hazard Report
Study Area
Figure 1

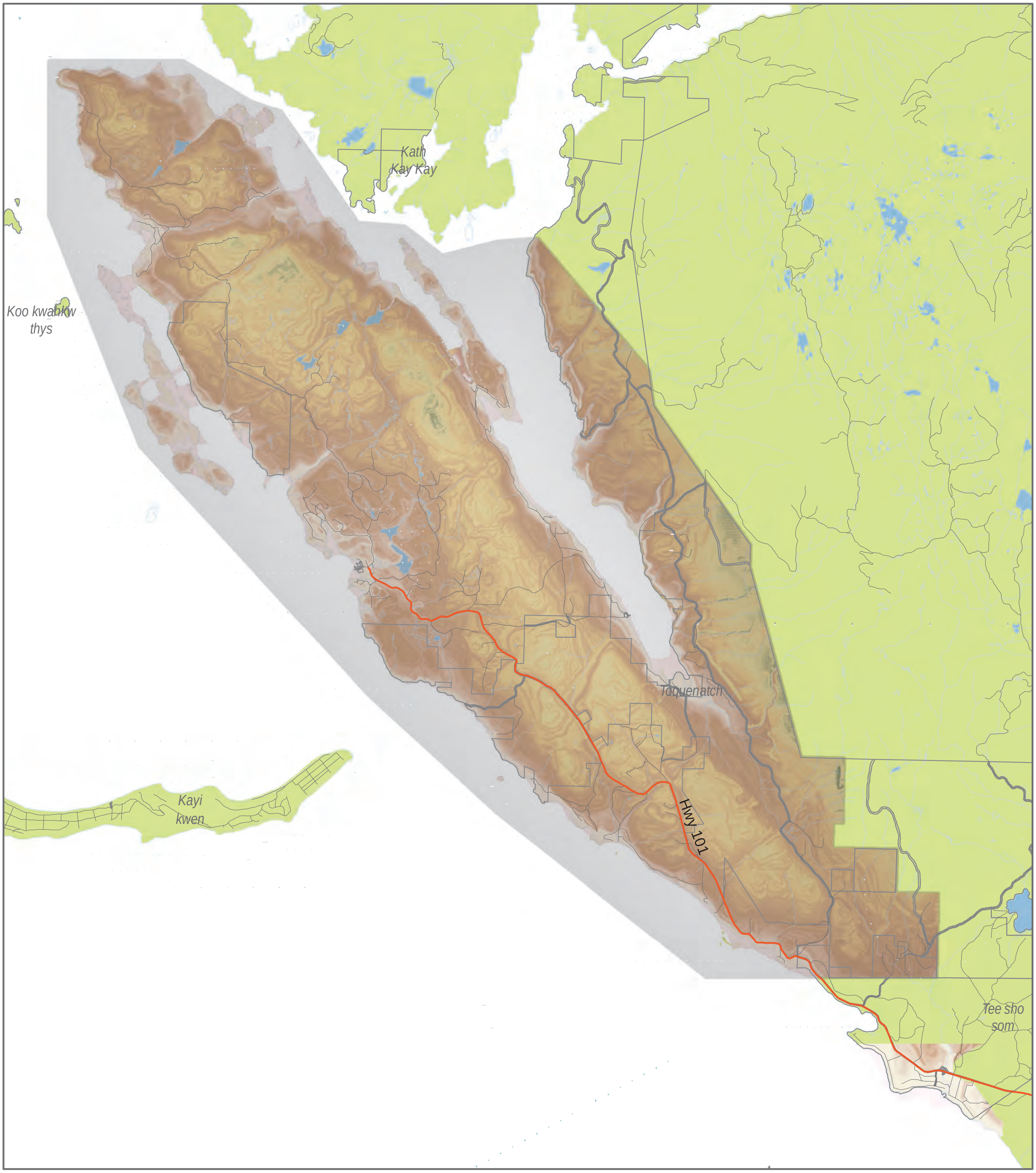
N
W E
S

1:100,000

0 0.5 1 2 3 4 5 Km

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

Data Sources:
Powell River Regional District
Province of British Columbia



Surficial Geology

The area consists of the following types of surficial materials: colluvial (rock falls from bluffs), morainal (basal till/tills), marine (clay/silt with shells) , and organic (boggy areas/raised water tables). These materials generally form a thin mantle over bedrock with localized zones having deep seated glacial tills and marine sediments.

Photo 1. Surficial materials found in the area.

The beaches in the area generally consist of cobble size materials with limited sand deposition . They are found within small lengths of coastline and are controlled by exposed bedrock bluffs .

Photo 2. Typical beach.

2. Methodology

The methodology involved a review of aerial photos, past mapping studies and reports, a computer generated steep slope analysis , and selected field reviews.

Aerial Photo Review:

To identify geological / erosional processes over time.

-1960 Photo Series/ scale 1:15,840 (Ministry of Lands and Forest)
BC5014 #20, 19, 44, 47, 92 1:15,840 /scanned

-Powell River Regional District Aerial images, 2012

A historical aerial photo review was completed for the area, aerial photos from 1960 were scanned to create digital files and then those images were placed over the regions 2012 aerial images . A general sweep of the images was completed for the coast line.

Mapping study review:

To identify surficial geology and areas that may require more detailed investigation.

-The Quadra Project Area Map (1980 Edition)

92F/15 and 92K/2 map sheets

-Surficial Geology and sand and Gravel deposits of the Sunshine Coast,

Powell River and Campbell River Area, 1977, Ministry of Mines and Petroleum Resources

Steep Slope Analysis

To identify areas where steep slopes may be an issue for development.

Contour and Point Elevation data produced by Integrated Mapping Technologies(IMT) using photogrammetry from 2009 was used as the source data. The contour data and point data was combined into a TIN (triangular irregular network) surface model. The triangular

faces with a slope over 60% were extracted and merged into poloygons, then buffered by 5m, and trimmed using a 1:20,000 polygon representing the ground above sea level.

Sea Level Rise/ Storm Surge Areas

To identify areas that may be at risk as a result of rising sea levels.

Contour data produced by Integrated Mapping Technologies (IMT) using photogrammetry from 2009, TRIM Coastline features and PRRD Aerial Imagery 2012. Aerial imagery was visually inspected against the IMT contours to determine an approximate present HWM/ Storm surge elevation in relation to the datum elevation of the contours. Based on this analysis, it appears that 9m to 9.5m is the current high level. The predicted higher levels were determined to be about 11m. Because of the uncertainty of the contour data (2m interval) it was decided to round up to the 12m contour.

Polygons were created between the 12m contour and the outer limits of the foreshore. Areas of steep bluffs and other areas not subject to erosion were analyzed visually and removed from the polygons. The outer limits of the foreshore are interpreted in a different datasets in different positions. An approximation of the foreshore was determined from this information. This approximation is suffienct to show any area below the 12m contour as an area of concern.

Field Investigations

Ground reconnaissance was undertaken to investigate and verify assumptions following in-office reviews and computer analysis. Photographs were taken of the sites and locations were geo-referenced.

Natural Hazard Areas

Northern Key Map 1-1

N
W E
S

1:40,000

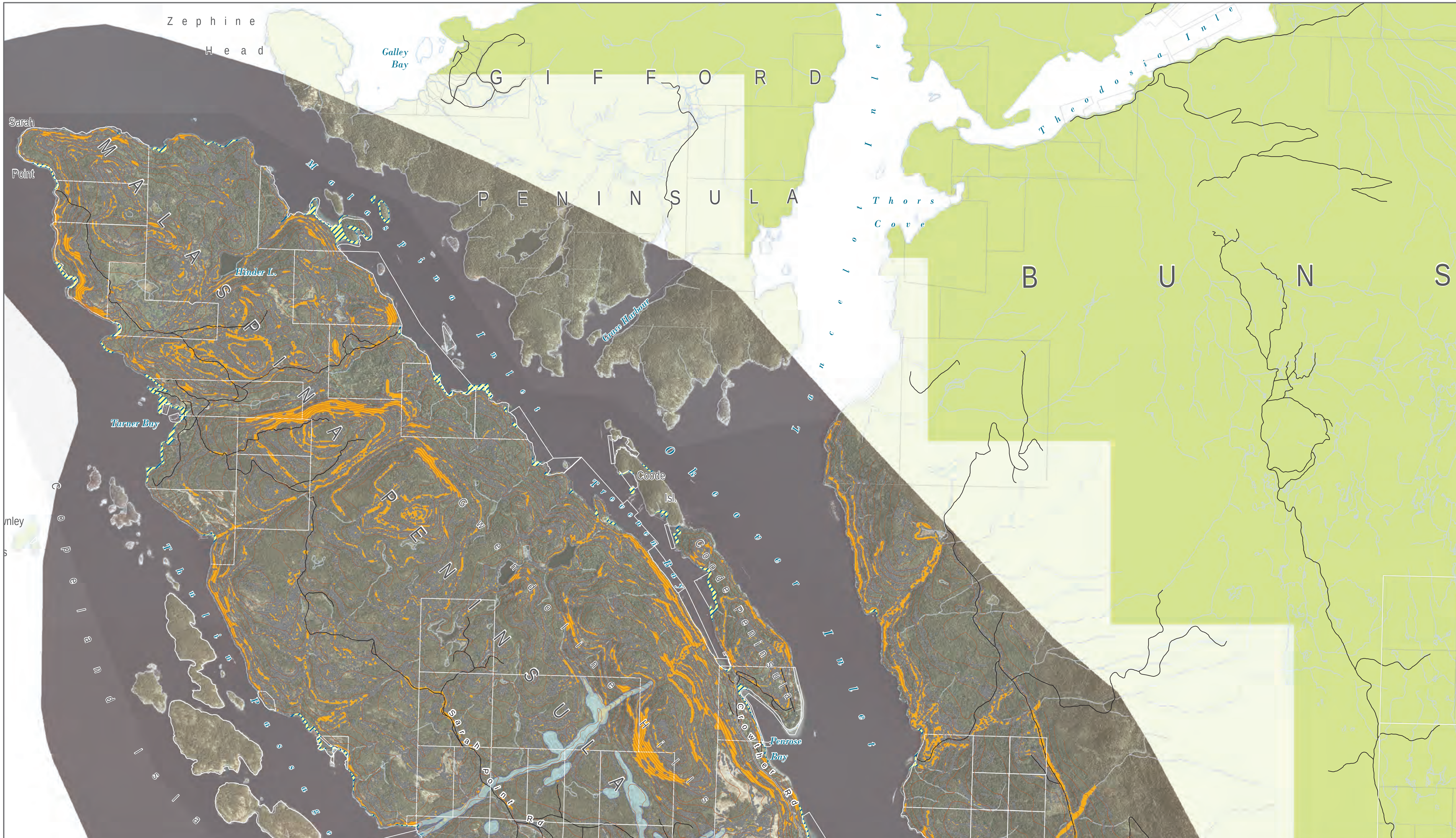
Data Sources:
Powell River Regional District
Province of British Columbia

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

0 0.5 1 2 3 4 Km

Legend

- Possible Storm Surge
- Significant Wetland Areas
- Slopes over 60%
- Emmonds Drainage
- Proposed Development Permit Area



Natural Hazard Areas

Southern Key Map 1-2

N
W E
S

Data Sources:
Powell River Regional District
Province of British Columbia

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

1:40,000

0 0.5 1 2 3 4 Km

Legend

- Possible Storm Surge
- Significant Wetland Areas
- Slopes over 60%
- Emmonds Drainage
- Proposed Development Permit Area

3. Discussion

Slope stability and natural hazard areas are controlled by many factors: slope gradients, overburden depth, structural rock properties, water content and soil pore water pressure, and engineering properties such as cohesion and coefficient of friction within these materials.

3.1 Steep Slopes

Slopes with steep gradients often pose general development challenges. When these slopes are overlaid by surficial materials with various textural and structural characteristics they can have some inherent instability due to these properties. (Map 1-1 and Map 1-2 show slopes over 60%) Downslope dipping surfaces between units with different permeability can serve as boundaries to subsurface water movement creating potential surfaces of failure.

Hydrological conditions have a major influence on slope movement. The discharge rate of water from overburden is probably the most significant hydrologic factor influencing terrain stability. If subsurface flow rates is less than infiltrating rates for extended periods of time a perched groundwater table will form . The groundwater table level depends largely on rain fall intensity and duration.

Development can alter the equilibrium between gravitational forces that pull overburden materials downslope and the shear strength and cohesion of these material creating instability.

3.1.1 Rock bluffs /Rockfall Hazard

Highly jointed and fractured bedrock create avenues for concentration of surface and ground water. Joint and fracture planes can create zones of weakness that provide potential failure surfaces where overlying materials can slide. Much of the steep slopes in the study area consist of bedrock bluffs with thin soil development . Figure 2, shows an access road development in steep rocky slopes in the study area. The access was developed through a highly fractured rock face. Though this development poses limited risk to the general public, it provides information regarding fracture development in the local bedrock.

N
W E
S
1:2,500

Data Sources:
Powell River Regional District
Province of British Columbia

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

Steep Slopes
Figure 2
(April 2012 Aerial Image)

Photo 3 was taken at the Okeover dock and show cars parked under a steep rock bluff that presents some rockfall hazard issues that presently poses some risk to the general public and property.

Photo No. 3 semi detached rock fragment, Okeover Dock

Rock fall hazard assessments are generally completed during initial phase of property development if rockfall hazard is considered a risk. Development in steep rock bluff areas generally involve some blasting during the development phase. It is important to understand rock fractures and how blast waves travel along these fractures. Shock waves can reduce the internal shear strength of surficial material and make them more prone to failure .

3.1.2 Steep Slopes Surficial Material

The surficial materials in the study area have various textures/strata/horizons which facilitate drainage movement differentially. The study area receives significant rainfall each year and global climatic studies predict that rainfall and the intensity of these events will be greater. Surface and subsurface drainage will continue to have an significant impact on slope stability in the area.

There were zones where erosional processes due to surface and subsurface drainage were observed. Photo 4 shows a road cut that is over steepened due to the drainage between the soil layer and the compacted till. The material below the soil is being washed away slowly and the bank is over steepened exposing tree roots and creating cut bank instability.

Photo 4 active erosion between units , Atrevida Road

Surficial materials can have variable textures that range from fine to coarse, sorted to poorly sorted. Photo 5 illustrates the variability of texture within surficial material and how drainage patterns can form within these materials between coarse and fine textured material creating stability issues on steeper slopes.

Photo No. 5 Area of slump, Atrevida Road

Surficial material with very fine grain textures are highly erodible in the presence of water. An example of this type of erosion is located in the study area where a large gully has formed within marine clay, probably attributed to surface drainage. Photo 6.

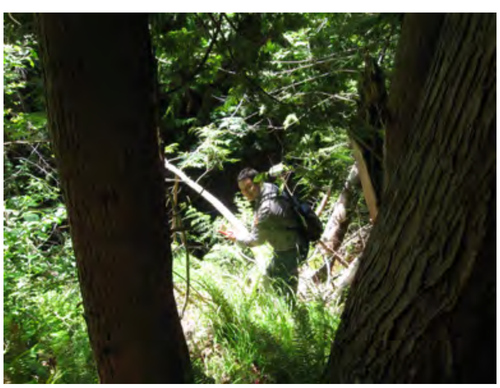


Photo 6. Gully headwall, active erosion in marine clay slopes, south of Atrevida Raod.

3.2 Shoreline Erosion (Map 1-1 , Map 1-2 Possible Storm Surge)

Shoreline erosion has become a significant issue for all land management professionals. The codes regarding shoreline development are presently being reviewed and rewritten to adjust for what is predicted to be a significant changes to sea levels. Types of storms and intensity of these storms are also expected to change and influence land management practices.

No large scale erosional changes were noted from the historic photo review and digital photo analysis but there was some evidence of localized erosion .

The digital analysis of the coastline delineated all low lying beach areas . These are shown on Map 1-1 and Map 1-2 as Possible Storm Surge areas.

On field review of selected beach areas there was evidence that property owners had taken measures to protect their property from erosion by placing rip rap along the banks of their property and the foreshore (photos 7 and 8).

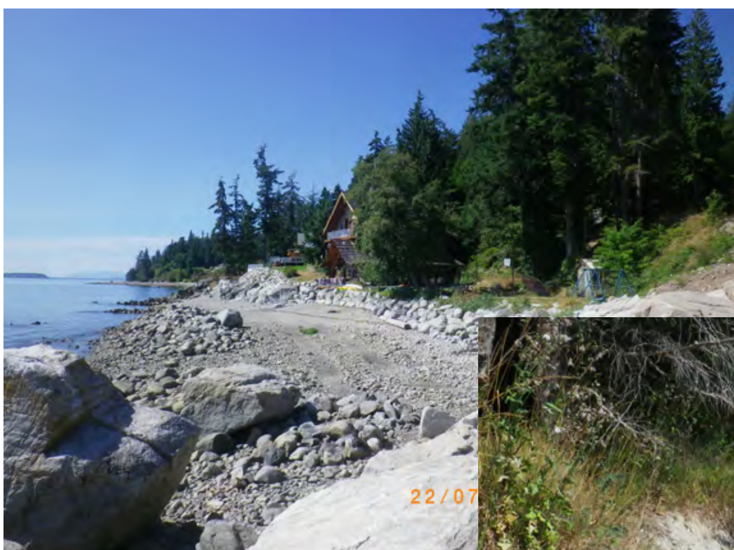


Photo 7. Rip Rap along foreshore, Sturt Rd

Photo 8. Shoreline erosion , Atrevida Rd.

4. Specific Areas of Concern

4.1 Atrevida Area

The Atrevida area has a highly complex and variable surficial geology. It was divided into two areas for the purposes of this study (Map 2-1 provides images and Map 2-2 provides locations/and delineates drainage area).

4.1.1 Atrevida Area A -

The aerial photo review identified a number of topographic and geological features(elevated ground water, highly erodible surficial material and steep slopes) that warranted further field review to assess site conditions and overall stability issues.

A field visit was conducted to determine the extent and cause of these features. Several traverses were completed and features were referenced on Map 2-1. Wet areas and ponds were located on a bench above the steep slopes. The wet area located on Map2-1 had active water movement at the time of the field visit (see Photo 9). The water on the property flowed over the steep escarpment to form a gully headwall as indicated (approximately 80m contour, Photo 10). The material within the gully was identified as marine clay. It appeared that the gully was formed by active erosional processes directly caused from surface drainage.

Photo 9. Surface drainage.

Photo 10. Gully headwall.

A number of abandoned access roads identified on the aerial photos were traversed to determine any present stability issues. Most of the slopes appeared saturated and water was running on the surface and through small developed ditches. There were signs of active erosion in the form of slumps. The surface layer of the clay bank material was soft and lacked cohesion (Photos 11,12, & 13).

Photo 11. Surface drainage in ditch

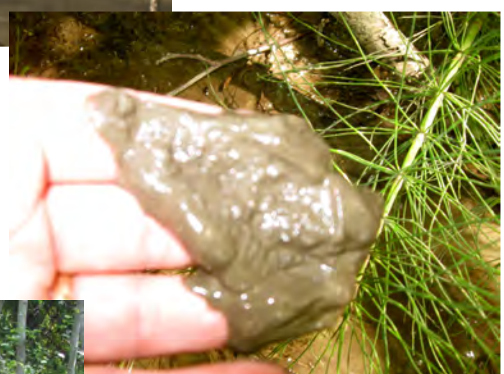


Photo 12. Clay in Road Cut

Photo 13. Small Slump

Atrevida Area

Field Review Map Map 2-1

N
W E
S

1:10,000

0 0.25 0.5 1 Km

Data Sources:
Powell River Regional District
Province of British Columbia

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

Legend

Possible Storm Surge

Atrevida Area

Proposed Development Permit Area Map 2-2

N
W E
S

1:10,000

0 0.25 0.5 1 Km

Data Sources:
Powell River Regional District
Province of British Columbia

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

Legend

Surficial Geology Zones

Drainage Review Area

The surficial material underlying most of this area has been identified as marine clay. Clays are fine textured materials that are cohesive under dry conditions. They usually have high shear strength with high cohesion and angle of internal friction. In the presence of excess water clay has a high potential for deformation and loss of cohesion. Under these conditions failures may occur in slopes of about 5%, with creeps, slumps and earth flows .

4.1.2. Atrivida Area B

This section of the Atrevida Area is characterize by steeps slope. Much of the upper slopes are characterized by a series of steep rock bluffs. The lower slopes are over laid by various surficial materials that range from basal till to out-washed till materials. Most of the surficial material is highly consolidated and tends to withstand erosion even in most vertical cuts faces. There are however issues that appear when these materials are cut and internal drainage is exposed.

Ground water in the area tends to run between the surficial material and the bedrock. During intense rain events surface water is not absorbed into the ground and there is a large amount of runoff.

The development below Atrevida road is vulnerable to upslope development. If drainage patterns change and more water is directed to the lower slopes some slope failure could occur. The are some minor failures noted in the Atrevida Road cut-banks . Any further development upslope may create additional drainage issues for downslope properties and the existing road cuts that have already shown active erosion from small slumps /failures (see Photo 14 & 15).

Photo 14. Slump in cut bank

Photo 15. Cut bank erosion.

Shoreline erosion is also an issue along the northern section of the Atrevida Area. As stated many property owners have taken measures to reduce shoreline erosion by placing rip-rap.

Photo 16. Rip Rap protected shoreline

Photo 17. Erosion of unprotected shoreline

4.2 Emmonds Beach Drainage Area

The Emmonds Beach catchment area was delineated because most of the area surface drainage is directed to a few small creeks. Using the height of land as the approximate boundary to trace out the shape, the area has been approximated at 325 ha.(Map 3). The peak volume and velocity of runoff in a storm event is a function of the soil permeability and speed of run off can be determined through a detailed analysis. Estimating watershed parameters, such as, flood frequency, or surface water flow is beyond the scope of this report.

Photo 18.Emmonds Beach

Data Sources:
Powell River Regional District
Province of British Columbia

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

1:10,000

0 0.25 0.5 1 Km

Legend

Emmonds Road Drainage Basin

Possible Storm Surge

Emmonds Beach Drainage Area

Map 3

Natural Hazard Report
July 2013

Though the risk is low for landslides and other mass movement of materials, the overall size of catchment area and the drainage concentration into a few creeks may pose some future flood risk. Based on the model of probably storm surge, the low lying area of Edmmonds Beach may be vulnerable to sea water inundation.

4.3 Shoreline Erosion/present and future development

Shoreline erosion presents some issues to present development. There are many areas within the study area that show signs of shoreline erosion. The scope of this report did not require any detail shoreline assessment but because erosional issues were identified during field checks the information has been included in this report.

During the review of the 2012 Regional District imagery some small scale shore line protection appears to have been built to abate/protect shoreline erosion. A field check of an area at the end of Sturt Road revealed that shore line protection measures have increased since 2012 . Figure 3 shows a photo taken in July 2013 and the aerial image of 2012. The area in the photograph has been completely rip-rap. There was also evidence of present development beyond the foreshore that may further alter erosional processes.

4.4 Okeover Dock Area

The Okeover Dock Area was selected for a field check to investigate erosional features observed on the aerial images. The field review identified three localized issues illustrated in Fig. 4.

-Rockfall Hazard/ Quarried slopes just above the Okeover dock, where the public is parking may present a risk to public safety.

-Minor slope failure above the access road indicates active erosional slope processes that may lead to further erosional events impacting access.

-Erosional processes were observed on the access road fill slope, it is presently being undercut by shoreline erosion. As the organic material in the road fill decays and the shorline erosion advances the acess to the Okeover dock may be compromised.

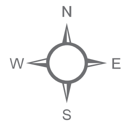
Data Sources:
Powell River Regional District
Province of British Columbia

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

1:1,000

Shoreline Erosion

Figure 3
(April 2012 Aerial Image)



Data Sources:
Powell River Regional District
Province of British Columbia

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator

1:1,500

Okeover Dock Area

Figure 4
(April 2012 Aerial Image)

5. Recommendations

The following recommendation have been developed :

5.1 Atrevida Area (Proposed Development Permit Area)

Atrevida area has natural features that make it prone to land failures. A development permit area is recommended for the area . Map 2-2 shows the propose development permit areas (shade pink and blue). It is recommended that more detailed mapping and collection of information be completed for this area, this could include the following:

-a detail drainage analysis of the lands above Highway 101

-locating and mapping all surface drainages in the pink and blue zones

-detailed surficial /terrain mapping

-all present development/property drainage/domestic wells should be located and mapped -request past geotechnical assessment from Ministry of Transportation and Infrastructure

-locate past development covenant areas / Ministry of Transportation and Infrastructure and/or Land Title Branch

5.2 Emmonds Beach

The Emmonds Beach area appears highly developable, but it may have some risk associated with possible flooding. The area above the beach forms a relatively large catchment areas that drains into a narrow drainage An analysis of the catch basin features should be completed to determine the flood frequency for this area.

The storm surge model indicated that the area may be at risk of sea water inundation and flooding during higher intensity storm surges. A detailed assessment is recommended to determine the extent and/or probability of seawater inundation

5.3 Storm Surge/ Shoreline Erosion (Possible Development Permit Area)

There are presently signs of active shoreline erosion on many of the beaches within the study area. A detailed assessment of the shoreline in these beach areas should be completed by a qualified Marine Engineer to determine present and future risk to low lying development.

Property owners appear to be taking protective measure to protect their properties from erosion. These measures may protect their properties for the present but they may create issues for property owners along the same shoreline. It is important that a proper assessment be completed prior to any shoreline protection measure being taken.

It is predicted that coastline areas will be subjected to greater storm surges due to global climatic changes, therefore, any future development should be subjected to an established setback. This setback should be determined and set within the community plan.

5.3.1 Development within Tidal Zone

It was also noted that development was presently occurring within the tidal waters, any further development proposed for these areas should undergo a detailed assessment to determine potential impact on adjacent shoreline. Any tidal water development can increase erosion up or down the coastline from the development. It is important to assess the risk and understand the movement of tidal waters. A qualified professional should be hired to assess any proposed development within the tidal zone.

5.4 Okeover Dock Area

Review the identified issues at Okeover Dock Area and establish a plan to address rock fall hazard and risk to the public. Seek cooperation with the Okeover Harbour Authority, Ministry of Transportation and Infrastructure to develop a plan/design that will provide long term stable road access to the Okeover Dock.

5.5 Steep Slopes (General Development Requirement)

Areas of steep slopes are inherently difficult to develop and can become unstable under certain conditions. A detailed assessment of surficial geology and drainage is recommended for these areas prior to development approval.

6. Closure

If you have any questions or comments regarding the information in this report please contact the undersigned at your convenience.

Planterra Environmental Consulting
5464 Laburnum Avenue
Powell River BC
V8A 4M8
604-414-0363

Prepared by:

Marion E. Blank, P.Geo.

6. References

-Geological Hazard Mapping Project , North Pender Island, BC . December 11, 2009 C.N. Ryzuk & Associates Ltd, Victoria BC File No 8-4764-1, Island Trust

-Sea Level Rise Adaptation Primer, January 2013
by Arlington Group Planning and Architecture Inc., EBA Engineering Consulting Inc., DE Jardine Consulting and Sustainability Solution Group for British Columbia Ministry of Environment.

-Natural Hazards in British Columbia, January 1996
Ministry of Transportation and Highways, Geotechnical and Materials Engineering Branch, Victoria BC.

-Guidelines for Legislated Landslide Assessments for Proposed Residential Development in British Columbia, May 2012 Association of Professional Engineers and Geoscientist of British Columbia.

-Mapping and Assessing Terrain Stability Guidebook, Forest Service and BC Environment, August 1999, Forest Practices CODE of British Columbia.

-A Guide for Management of Landslide Prone Terrain in the Pacific Northwest, Second Edition, 1994 Land Management Handbook Number 18, Ministry of Forest , British Columbia.

-The Soil Landscapes of British Columbia, 1978, BC Ministry of Environment Third Printing 1986

-A Guidebook for British Columbia , Storm-water Planning, May 2002 Ministry of Water, Land and Air Protection.

-Guidelines for Management of Terrain Stability in the Forest Sector, September 2008, Association of Professional Engineers and Geoscientists of BC and Association of BC forest Professionals

-B.C. Ministry of Forests. 2001 Gully Assessment Procedure Guidebook. 4th ed.,Version 4.1 Forest Prac. Branch B.C. Ministry of Forest , Victoria BC.

-Landslides: Investigation and Mitigation, National Academy Press, 1996, A. Keith Turner and Robert Schuster.

-Landslides in practice: investigation, analysis and remedial/preventive options in soils, J. Wiley 2005 author Derek Cornforth.
-Landslides: Processes, Prediction, and Land Use, Water Resources Monograph Vol. 18, 2006 R.C. Sidleand H. Ochiai.
-Hill-slope Stability and Land Use, copy write 1985 by the American Geophysical Union, Roy C. Sidle, Andrew J. Pearce and Colin L. O'Loughlin.
-Forest Soils of the Douglas Fir Region, Cooperative Extension Washington State University, 1981 Pullman, Washington 99164.
-Stream Stewardship, A Guide For Planners and Developers, Canada and Province of British Columbia, 1994, Department of Fisheries and Oceans Vancouver BC.
-Assessment of hazard from rock fall on a highway, CM Bunce, DM Cuden and NR Morgenster, Canadian Geotech Journal, 34:344-356 (1997).
-Time Saver Standards for Landscape Architecture, Charle W. Harris &Nicholas T. Dines, 1988 by McGraw-Hill.
-Assessment of a Rapid Approach for Estimating Catchment Areas for Surface Drainages Lines, US Geological Survey, Center for Excellence for Geospatial Information Science ACSM-IPLSA 2007, March 9-12 St. Louis MO. L. Stanislawski, M Finn, M. Barnes, E.Usery
-Quantitative rock-fall hazard and risk assessment for Yosemite Valley, Yosemite National Park, California, April 2012, Yosemite National Park, Division of Resources Management and Science, US Geological Survey.
-Landslide Hazards and Their Mitigation Along the Sea to Sky Corridor British Columbia (2008), Andree Blais-Stevens, Geological Survey of Canada, Ottawa, Ontario , Oldrich Hungr Earth and Ocean Sciences, University of British Columbia, In: J. Locat, D. Perret, D. Turmel, D.Demers S. Leroueil, Proceedings of the 4th Canadian Conference on Geohazards: From Causes to Management.
-Preliminary assessment of rockfall hazard based on GIS data, 2003 Jaboyedof M., Labiouse V., LMR EPFL, Rock Mechanics Laboratory Swiss Federal Institute of Technology Lausanne, Switzerland Quaterra, Lausanne, Switzerland.
-Faculty of Geo-Information and Earth Observation of the University of Twente, Determination of peak runoff website. http://www.itc.nl/ilwis/applications/application11.asp.
-Terrain Information, A User's Guide to Terrain Maps in British Columbia, JM Ryder and DE Howes, BC Ministry of Environment, 1984 557.11 C84-092056-3

-Time Saver Standards For Site Planning, Joseph De Chiara and Lee Koppelman, 1984NA2540.5.D4 1984, ISBN 0-07-016266-2 By McGraw Hill Inc.