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# Tongass Corridor - Geotechnical Asset Management Research


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13. ABSTRACT (Maximum 200 words)
This report documents and presents the results of a study developing a Corridor Health Index that incorporates managed pavement and bridge assets as well as geotechnical assets. Geotechnical assets included rock slopes, unstable soil slopes, and retaining walls. Assessment of these assets adhered to the procedures developed and tested here and in the concurrent statewide Geotechnical Asset Management (GAM) program. The research utilized existing pavement and bridge ratings. Culvert ratings followed a simple observation-based evaluation of culvert function.

The Corridor Health Index developed provides a weighted 0 to 1 index score. The index score corresponds to a Poor (0) to Good (1) condition, respectively. Application of the Index to North and South Tongass corridors helps the Department advance projects taking into account a number of potentially poorly performing assets. Research results have matched with Department priority setting, with a major rehabilitation project on South Tongass that repairs unstable slopes and retaining wall assets.

Incorporating risk to the existing narrow Right-of-Way and potential effects of failing geotechnical assets on the adjacent parcels assist in identifying where geohazard and degraded asset conditions coexist within close proximity to private property.

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# TONGASS CORRIDOR
# GEOTECHNICAL ASSET MANAGEMENT RESEARCH

## FINAL REPORT

Prepared for
Alaska Department of Transportation & Public Facilities

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Ketchikan North/South Tongass Highway Stability Reconnaissance
Geotechnical Asset Management Program
Unstable Slope Management Program

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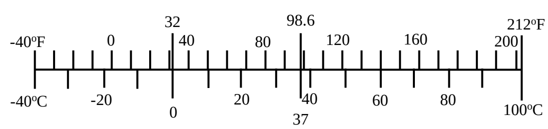
# METRIC (SI*) CONVERSION FACTORS

| APPROXIMATE CONVERSIONS TO SI UNITS | | | | | APPROXIMATE CONVERSIONS FROM SI UNITS | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Symbol | When You Know | Multiply By | To Find | Symbol | Symbol | When You Know | Multiply By | To Find | Symbol |
| | | LENGTH | | | | | LENGTH | | |
| in | Inches | 25.4 | | mm | mm | millimeters | 0.039 | inches | in |
| ft | Feet | 0.3048 | | m | m | meters | 3.28 | feet | ft |
| yd | yards | 0.914 | | m | m | meters | 1.09 | yards | yd |
| mi | Miles (statute) | 1.61 | | km | km | kilometers | 0.621 | Miles (statute) | mi |
| | | AREA | | | | | AREA | | |
| in$^2$ | square inches | 645.2 | millimeters squared | cm$^2$ | mm$^2$ | millimeters squared | 0.0016 | square inches | in$^2$ |
| ft$^2$ | square feet | 0.0929 | meters squared | m$^2$ | m$^2$ | meters squared | 10.764 | square feet | ft$^2$ |
| yd$^2$ | square yards | 0.836 | meters squared | m$^2$ | km$^2$ | kilometers squared | 0.39 | square miles | mi$^2$ |
| mi$^2$ | square miles | 2.59 | kilometers squared | km$^2$ | ha | hectares (10,000 m$^2$) | 2.471 | acres | ac |
| ac | acres | 0.4046 | hectares | ha | | | | | |
| | | MASS (weight) | | | | | MASS (weight) | | |
| oz | Ounces (avdp) | 28.35 | grams | g | g | grams | 0.0353 | Ounces (avdp) | oz |
| lb | Pounds (avdp) | 0.454 | kilograms | kg | kg | kilograms | 2.205 | Pounds (avdp) | lb |
| T | Short tons (2000 lb) | 0.907 | megagrams | mg | mg | megagrams (1000 kg) | 1.103 | short tons | T |
| | | VOLUME | | | | | VOLUME | | |
| fl oz | fluid ounces (US) | 29.57 | milliliters | mL | mL | milliliters | 0.034 | fluid ounces (US) | fl oz |
| gal | Gallons (liq) | 3.785 | liters | liters | liters | liters | 0.264 | Gallons (liq) | gal |
| ft$^3$ | cubic feet | 0.0283 | meters cubed | m$^3$ | m$^3$ | meters cubed | 35.315 | cubic feet | ft$^3$ |
| yd$^3$ | cubic yards | 0.765 | meters cubed | m$^3$ | m$^3$ | meters cubed | 1.308 | cubic yards | yd$^3$ |
| Note: Volumes greater than 1000 L shall be shown in m$^3$ | | | | | | | | | |
| | | TEMPERATURE (exact) | | | | | TEMPERATURE (exact) | | |
| ºF | Fahrenheit temperature | 5/9 (ºF-32) | Celsius temperature | ºC | ºC | Celsius temperature | 9/5 ºC+32 | Fahrenheit temperature | ºF |
| | | ILLUMINATION | | | | | ILLUMINATION | | |
| fc | Foot-candles | 10.76 | lux | lx | lx | lux | 0.0929 | foot-candles | fc |
| fl | foot-lamberts | 3.426 | candela/m$^2$ | cd/cm$^2$ | cd/cm$^2$ | candela/m$^2$ | 0.2919 | foot-lamberts | fl |
| | | FORCE and PRESSURE or STRESS | | | | | FORCE and PRESSURE or STRESS | | |
| lbf | pound-force | 4.45 | newtons | N | N | newtons | 0.225 | pound-force | lbf |
| psi | pound-force per square inch | 6.89 | kilopascals | kPa | kPa | kilopascals | 0.145 | pound-force per square inch | psi |

These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements



## Table of Contents



## List of Tables

## List of Appendices

# 1 INTRODUCTION AND RESEARCH APPROACH

Transportation agencies are increasingly adopting Transportation Asset Management (TAM) procedures and techniques to manage their bridge and pavement inventories. As part of this effort, interest has grown in using similar methods to manage geotechnical assets, ranging from unstable rock slopes to retaining walls to subsurface data, all assets contributing to a functioning transportation system. As a subset of TAM, Geotechnical Asset Management (GAM) focuses on providing the information needed to maintain these resources and extend their service life, enhancing system performance while optimizing the operating cost of the transportation network.

In 2013, Landslide Technology (LT) was authorized to begin a GAM Program Research Study in Ketchikan, Alaska, on the North and South Tongass Highways. This research project would expand on asset inventory and rating work already completed as part of the Unstable Slopes Management Program (USMP) in 2010. In addition to refining that earlier work, it also enabled researchers to test inventory methods for additional geotechnical asset classes, in a defined geographical area before rolling out an inventory and rating method statewide.

## 1.1 Research Objective

This research study focused on the North and South Tongass corridor for its known number of geotechnical assets in a range of conditions, from Good to Poor. Evaluating geotechnical assets over such a wide condition range enabled LT to formulate more robust performance measures and improve later state wide assessment efforts to be more efficient. Likewise, buildable space in the Ketchikan Borough is highly constrained, and right-of-way issues have created liability concerns for the Alaska Department of Transportation and Public Facilities (AKDOT&PF). Because the Borough maintains excellent property maps, this research evaluated both hazard/risk posed by asset failure to both the transportation corridor and the area beyond the narrow Right of Way window. Selecting the Tongass corridor was cost efficient, given the well-defined limits of the corridor, ease of access, and high asset density.

The main research objective of the Tongass Highway Corridor GAM Research Study included:

- Inventory, evaluation criteria development, and testing field procedures for geotechnical assets (described in Chapters 2 and 3)
- Development of a Corridor Health Index for a group of highway assets including (Chapter 4):
    - Bridges,
    - Pavements,
    - Soil and rock slopes;
    - Earth retaining walls; and
    - Culverts

AKDOT&PF is incorporating lessons learned from the Tongass Corridor GAM Research Study, into a statewide GAM program that will track – on a statewide basis – rock slopes, unstable soil slopes and embankments, retaining walls, material sites, and adverse geotechnical events. This GAM program progresses two previously developed asset inventory programs – the Material Site Inventory (MSI), and the Unstable Slopes Management Program (USMP) – and also integrates a newly-developed retaining wall inventory. Many of the methodologies and systems used in the AKDOT&PF GAM Program have their roots in the Tongass Corridor GAM Research Study, which allowed researchers to test and refine GAM procedures and methodologies before applying them on a statewide basis.

The Tongass GAM Research Study Report is a companion report to the final report for Statewide Geotechnical Asset Management Program Development (Landslide Technology 2017), hereafter referred to in this document as the Final GAM Report. The Final GAM Report is the primary reference for detailed descriptions of the techniques, systems, and data used in the Department's GAM Program.

# 2 DATA ACQUISITION AND EXISTING DATA INTEGRATION

## 2.1 Unstable Slopes Inventory

Field work for the unstable slopes inventory on North and South Tongass was conducted between November 2013 and March 2014, with the majority of the work performed in March. Four unstable slopes in the Tongass corridor had been rated as part of the 2010 survey. An additional 206 soil and rock slope sites were added during field work for the Tongass Corridor GAM Project, for a total of 210 evaluated sites on the North and South Tongass Highways. Appendix A contains maps exhibiting the location of each asset.

The Unstable Slope Management Program (USMP) has been completed in three phases. Following the Phase I Literature Review performed by University of Alaska Fairbanks, the second phase involved rating category development, refinement, and rating the 'Top 100' sites in the state. During this Tongass study, the rating categories developed in Phase II of the USMP project were revised slightly to improve the clarity of the category narratives. Observing many small and exceedingly low risk slopes, development of minimum hazard criteria for incorporating sites into the GAM database was a significant project outcome. This need was identified since the work scope included rating all slopes on the Tongass Corridor while previous inventory and assessment work focused on slopes already identified in the 'Top 100' maintenance and hazard risks. Because all the sites on the 'Top 100' list required maintenance attention or were of general concern to the Department, the need to develop minimum acceptance criteria had not been identified. The Final GAM Report incorporates these criteria and they are not duplicated here.

Following the unstable slopes inventory along North and South Tongass in March 2014, it was determined that rating all unstable slopes required an outlay of time and budget that would make statewide implementation of a GAM program very difficult, without dramatically increasing database usefulness. To avoid this, minimum rating criteria were developed that could be used to determine whether or not a site should be entered into the database, based on the level of risk a failure at that location posed to transportation corridor function. The revised USMP slope acceptance criteria were applied to all further USMP inventory work conducted in Alaska to date and are discussed in the Final GAM Report.

## 2.2 Retaining Wall Inventory

As part of the Tongass Study, draft field procedures for inventorying and rating retaining walls were developed. During this initial phase of the Retaining Wall Inventory (RWI), walls along the Tongass Corridor were located, rated, and incorporated into ArcGIS. Prior to field ratings, the approximate locations of walls along the highway corridor were determined through a desk study of available as-built data, conducted by Landslide Technology. This initial desk study was further refined by coordinating with maintenance personnel in the Ketchikan district prior to the start of inventory field work.

The final desk-study product consisted of an Excel spreadsheet and an ArcGIS geodatabase. The spreadsheet contained the as-built source document, construction date, offset, approximate milepost, wall function, wall category, wall type, and wall dimensions. This spreadsheet was then used in conjunction with Google Maps to obtain latitude and longitude coordinates for approximate retaining wall midpoints. These points were added to the existing Retaining Wall Inventory layer maintained by AKDOT. During the field ratings, several walls were added to this initial list, while others were eliminated because they were too small to threaten transportation corridor function in the event of failure (e.g. less than 2 feet tall and part of a bus stop), had been removed during more recent roadway projects, or were buried and could not be evaluated.

Field ratings took place in June and July 2014. All retaining walls were individually inventoried and assessed. Along portions of South Tongass Highway, nested sets of retaining walls support the roadway and the roadside recreation path. The walls in these nested sets were broken out for individual ratings and assessments. A total of 98 retaining walls were rated and entered in the RWI: 37 along North Tongass and 61 along South Tongass. All inventoried retaining walls are presented in Appendix A.

A preliminary evaluation of each retaining wall was conducted prior to entry in the database, assessing walls as “High,” “Moderate,” or “Low” hazard and/or risk based on the initial judgment of the field rater. Walls rated as “Low” risk had limited to no impact to the roadway in the event of failure, generally due to limited height or relatively large setback from the roadway. Only walls described as “High” or “Moderate” risk received detailed ratings. In general, walls with an exposed height of less than 4 feet were not included in the preliminary or detailed site evaluations. The acceptance criteria for retaining walls were refined prior to the start of statewide inventory work, and are described in detail in Section 2 of the Final GAM report.

The field procedures and rating criteria employed during retaining wall inventory work along the Tongass Corridor are identical to those applied elsewhere in Alaska, and are described in Section 2 of the Final GAM Report.

### 2.3 Culvert Inventory

As part of the Tongass Study, culvert inlets along North and South Tongass were located, rated, and added to an ArcGIS layer. This work took place between June and October 2014, with the majority of the work taking place in July 2014. The culvert inlets were entered as points in an ArcGIS geodatabase and are shown in the maps in Appendix A.

Location information for each site was recorded using handheld GPS units programmed with the WGS84 coordinate system and utilizing the real-time ground-based differential correction Wide Area Augmentation System (WAAS) to obtain GPS coordinates. Product literature states an accuracy of ±3 meters when receiving a WAAS signal and ±7 meters without a WAAS signal. The location information consisted of the GPS location of the culvert inlet. The highway map layer used in ArcGIS was provided by AKDOT. A Milepost ArcGIS geodatabase, also provided by AKDOT&PF, was used to determine the culvert inlet location along the highway centerline to the nearest hundredth of a mile.

Culvert inlets were located using the blue culvert inlet maintenance stakes, consulting grading and drainage as-built documents, and by searching sections of ditch the field rater judged likely to contain culvert inlets, even in the absence of stakes or as-built records. It is likely that in highway sections where no as-built documents are available, some existing culvert inlets were not inventoried and added to the database due to vegetation obscuring culvert inlets.

Culverts that were shown in as-built documents, but those not field located were also added to the GIS layer. They were snapped to the highway centerline at their expected location. However, the diameter and functionality cells in the attribute table were left blank, and a comment was added that the culvert was not found. These culverts are assumed to be non-functional.

Unlike slopes and walls, a standalone Access database for culverts was not necessary. A similar database may be needed for subsurface camera inspection or implementation of a formal culvert assessment scheme (Venner, 2014). Instead, all relevant information was incorporated into the attribute table of an ArcGIS geodatabase named Culvert Layer. The approximate culvert location was entered as a point in the layer, and the culvert inlet diameter, functionality rating, and any relevant comments were added to the attribute table. As with other inventoried assets, Culvert IDs were assigned from the CDS Route Number and CDS Milepoint, measured to the nearest hundredth of a mile. The milepoint was determined by digitally measuring the distance along the highway centerline from the nearest milepoint marker to the culvert.

### *2.3.1 Development of Rating Criteria for Culverts*

Culvert assessments did not include detailed, multi-category condition assessment; instead, relatively simple narratives were developed for a single rating category that evaluated culvert function as judged by the field engineer. After locating a culvert, the field rater evaluated its functionality as “Y” (yes), “M” (marginal), or “N” (no). The criteria narratives for these categories are described in Table 2-1 below.

Table 2-1: Rating Criteria for Culverts

| **Letter Rating** | Culvert Functionality -- Category Narrative | Culvert Condition State |
|---|---|---|
| **Y** | Yes. No to slight damage to the culvert inlet; no to little debris in culvert mouth; no impounded water around the culvert inlet; no obvious damage to the roadway over the culvert. | Good |
| **M** | Marginal. Moderate to significant damage to the culvert inlet; slight to moderate debris in the culvert inlet mouth; no evidence of impounded water around the culvert inlet. Damage to the roadway over the culvert is not accompanied by noticeable vertical movement when driving over the culvert at the speed limit | Fair |
| **N** | No. Significant debris in the culvert inlet or the inlet entirely buried; impounded water at inlet or evidence of water regularly impounded behind inlet during storm events; damage to the roadway with noticeable vertical movement when driving over the culvert trace at the speed limit. | Poor |
| -- | Not found. Shown in as-built documents but could not be located in the field. | Poor |

The majority of damaged culvert inlets appeared to be the result of ditch maintenance activities, and damage was more prevalent in areas where the culvert inlets were not staked. Rockfall also accounted for culvert inlet damage along some unstable slopes. The culvert rating was assigned based on the worst of the evaluated criteria, so, for example, a buried culvert was given an “N” even if no damage to the roadway over the culvert was observed.

## 2.4 Right of Way (ROW) Data Acquisition

Developable space in the Ketchikan Borough is highly constrained; many houses and business are very close to AKDOT&PF right-of-way (ROW) limits, often at the edge of potentially unstable slopes. Right of way data is invaluable in helping to assess where AKDOT&PF budget resources may need to be allocated not only to maintain the transportation corridor, but also to prevent damage to private property. Property damage caused by unstable slope activity moving beyond agency ROW has proven to be a liability for the Department in the past.

### *2.4.1 Potential Applications of Right of Way Data*

The Ketchikan Gateway Borough provided a map of AKDOT&PF right-of-way and adjacent privately owned parcels. The Borough also provided high-quality air photos and topographic data that enabled crosschecking the location of various assets.

As obtained and applied, the ROW parcel boundary data obtained from Ketchikan Borough was very useful, both during fieldwork and in office analyses. During fieldwork, it allowed more accurate scoring of the ROW impacts category, discussed in Section 2 of the Final GAM Report. Upon incorporation of the field data into the desktop ArcGIS program for analyses, it allowed new ways of assigning value to an asset that could affect private property in the event of failure, identifying those that could potentially create costs to the Department beyond event cleanup, or which could increase the costs of various proposed mitigation types. This type of expanded asset valuation was applied as part of the project selection criteria in the Southcoast Region planning document, discussed in Section 9 of the Final GAM Report

Appendix B provides an example of how potential right of way impacts can be incorporated into asset inventory maps, in this case showing all private property parcels adjacent to rock slopes along North and South Tongass Highways.

Further filtering of the parcel data layer provided by Ketchikan Gateway Borough could, for example, exhibit only those parcels adjacent to Fair or Poor Condition assets, better highlighting ROW constraints around rock slopes most likely to receive mitigation attention from the Department. Similarly, such a process could be followed to identify ROW constraints around other types of assets.

## 2.5 Incident Data Acquisition from Department Sources

Although unstable slope hazard and risk was assessed in the field by experienced personnel, the best measure of the risk associated with an unstable slope is past performance. To this end, integration of a regularly updated incident report database is crucial in confirming the rate of slope activity and the maintenance costs incurred by these events. Visually displaying the location and cost of past maintenance incidents can help identify sections of the transportation corridor that pose a risk to the travelling public and require non-routine expenditures to maintain the roadway.

### *2.5.1 Incorporation of Maintenance Management System (MMS) Data*

Landslide Technology extracted relevant AKDOT&PF-maintained Maintenance Management System (MMS) job code and cost data for the Ketchikan Borough. This extracted data was filtered and entered into a spreadsheet. To enable integration into an ArcGIS layer, events that could not be constrained to within approximately a half mile were removed from the final dataset. The final layer included the incident date, MMS sequence number, mile post location, and calculated final cost for each event. A total of 38 MMS incidents on North and South Tongass, occurring between 2005 and 2014, were identified and incorporated into the final shapefile and shown in the asset inventory maps in Appendix A.

### *2.5.2 Incorporation of SALLy Geodatabase*

The Southcoast region previously developed the SALLy Database, an ArcGIS layer hosted on AKDOT&PF's internal online GIS system. It was designed to be easily updated by M&O personnel, who could add new unstable slope events as they occurred. Although designed with all unstable slopes in mind, in practice most of the data entered into the SALLy database concerned rockfall activity. The SALLy database has since been largely abandoned by AKDOT&PF personnel. The data already contained in the SALLy database was extracted and imported into a GIS layer for importation into the newly developed Geotechnical Event Tracker Application, which is an online application hosted through AKDOT&PF's ArcGIS Online (AGOL) platform.

### *2.5.3 Development of AGOL-based Geotechnical Event Tracker Application*

As part of the statewide GAM project, a Geotechnical Event Tracker application was developed and linked to an associated layer AGOL layer. This online application will be used to track geotechnical events as they occur, enabling the department to better value long-term risk costs associated with its geotechnical assets. It is described in detail in Section 11 of the Final GAM Report. At this time, the previously extracted MMS and SALLy data has been incorporated and additional efforts to mine the MMS for past geotechnical event data from districts across the state has been accomplished. This will expand the geotechnical event dataset by incorporating historical data to the greatest degree possible.

## 2.6 Bridge Rating Data Acquisition

Bridges throughout the Tongass transportation corridor have been regularly inspected for many years, following FHWA-recommended guidelines. Bridges are also impacted by the performance of geotechnical assets at the bridge abutments, though these are generally identified and addressed during investigation, planning, and construction of the bridge. Including bridges in the GAM program is an example of how the department could tie together its GAM program and the TAM program currently under development. By presenting both GAM and TAM information to the user in a single map, it allows identification of segments of the transportation corridor where multiple asset deficiencies could be addressed by a single project or a set of linked projects, allowing for more efficient allocation of budget resources.

Bridge rating data was acquired from the FHWA's National Bridge Inventory (NBI) website (http://www.fhwa.dot.gov/bridge/). The location, extents, and rating information were integrated into an ArcGIS layer. Existing rating data was not altered. Some additional rating data provided independently by the AKDOT&PF Bridge Section was identical to the NBI data, and confirmed that the data used by Landslide Technology to develop the ArcGIS layer was up-to-date. Bridge locations and sufficiency rating information is incorporated into the asset inventory maps included in Appendix A.

For consistency with other assets, a Good/Fair/Poor evaluation criteria was instituted on the Appendix A maps, outlined below.

- Good: All NBI condition criteria (deck, superstructure, substructure) were in 'Good' condition.
- Fair: One or more NBI condition criteria were in 'Fair' or 'Satisfactory' condition. No criteria were in 'Poor' condition.

- Poor: One or more NBI condition criteria were in ‘Poor’ condition, regardless if other criteria were in better ‘Good’, ‘Fair’, or ‘Satisfactory’ condition. Bridges that were deemed ‘Structurally Deficient’ or ‘Functionally Obsolete’ were in this category.

## 2.7 Pavement Rating Data Acquisition

Pavement data has traditionally been included in TAM programs because it is man-made, easily inspected, and easily maintained. However, pavement functionality is directly related not only to the materials and practices used during construction, but also to the condition of the ground over which the pavement passes. For instance, pavements may be damaged by rockfall from unstable slopes, eroded by debris flows, or deformed by permafrost activity. The negative impacts of any type of geotechnical activity can significantly increase pavement maintenance cost, and cause the pavement condition to deteriorate at a rate faster than anticipated. Pairing pavement condition data with unstable slope condition data can help project-level planners identify sections of the transportation corridor that would most benefit from comprehensive improvement projects. Likewise, this more holistic view decreases the likelihood that a pavement in poor condition will be replaced without consideration of other assets that could be causing the pavement to perform poorly. For example, if an active rock slope regularly damaged pavement, mitigating the rock slope before the next paving project would help protect the investment made by the department.

Pavement Rating Data was obtained from the AKDOT&PF Pavement Management Website (http://www.dot.alaska.gov/stwdmno/pvmtmgt/). The pavement rating data was imported into an Excel spreadsheet and then converted into an ArcGIS layer. The existing rating data was not altered. It is presented in the asset inventory maps included in Appendix A.

In addition to paved highways, AKDOT&PF also administers many unpaved roads. For example, the South Tongass highway is unpaved beyond CDS milepoint 10.63. Instead of being evaluated continuously like paved roads, gravel roads are rated at select locations. Two ratings were obtained from AKDOT&PF for unpaved portions of South Tongass, and these ratings were extrapolated to cover the remainder of the unpaved roadway.

## 2.8 Subsurface Data Acquisition

Within the Tongass study project, subsurface data was treated as an intellectual asset and was also incorporated into the GAM database. For the purposes of this project, subsurface data was defined as borings, test pits, and penetrometers. Lab data for samples collected during drilling or test pit excavation were also included where applicable. Subsurface boring data was obtained with the help of Southcoast region geotechnical personnel, who provided boring log files from AKDOT geotechnical exploration work conducted along North and South Tongass between 1999 and 2012. Logs were printed to pdf so that they could be easily referenced from the GIS map layer. Some additional boring log and test pit data from the bridge section was provided by the Department’s Bridge Design Section. These logs, from 1969, 1973, and 1989, had been included in bridge plans, and were provided in pdf form, as extracts from the bridge plan documents. Additional geotechnical investigation data for the Tongass Corridor may be available in paper form, particularly in paper geotechnical reports prepared for the Bridge Section, but the project budget and time constraints did not allow for the work involved in identifying and scanning these documents.

The locations of subsurface data were determined either from location information included in the boring logs or the investigation project site map. An Excel sheet was created containing the subsurface data point site, CDS route number, project number, ID shown on the investigation log, depth of investigation, and data of investigation. Hyperlinks for subsurface log and laboratory data were also included. This spreadsheet was exported into ArcGIS to make a layer file, and the hyperlinks were enabled. Future users of the ArcGIS map will be able to open and view subsurface data simply by clicking on the point location. Boring locations are shown in the asset inventory maps presented in Appendix A.

The broader incorporation of subsurface information to the GAM program would allow future project planners to quickly survey the results of any investigatory work previously conducted at a site. This would enable limited budget resources to be more efficiently allocated, filling in gaps in site knowledge instead of repeating previously performed work.

# 3 DEVELOPMENT OF GEOTECHNICAL ASSET CONDITION MEASUREMENTS

## 3.1 Unstable Slope Condition Index and Condition State Development

The 210 unstable rock and soil slopes inventoried along the Tongass Corridor were added to the 192 sites surveyed as part of the USMP "Top 100" group. This data set was used to test various methods of measuring asset condition. Multiple models were presented and evaluated in terms of ease of use and how well they differentiated between Good and Poor slopes. This process is discussed in greater detail in Section 3 of the Interim Report for Statewide Geotechnical Asset Management Program Development.

Following group discussions, Condition Indexes and Condition States were developed to describe asset performance at the programmatic planning level. Separate indexes and condition states were developed for rock slope assets and for unstable soil slope and embankment assets. These are presented in Section 4 of the Final GAM Report.

## 3.2 Retaining Wall Condition Index and Condition State Development

The condition index and condition state models developed for retaining wall assets are intentionally similar to those developed for unstable slopes. The RWI data collected as part of the Tongass Study Project were used as a base dataset to evaluate select methods for calculating asset condition. The final version of Condition Index and Condition State for retaining walls are defined in Section 4 of the Final GAM Report.

## 3.3 Condition Measurements for Other Assets Included in the Research Study

For the core asset classes (bridges and pavements) national rating standards are already in place, so the development of new, Alaska-specific, condition measurements were not undertaken. However, the ratings can be incorporated into asset condition maps using the same number of categories and color scheme as the geotechnical assets.

Culverts are geotechnical assets, but, as discussed in section 2.3, a multi-category condition assessment like that developed for unstable slopes and retaining walls was not developed. Rating culvert functionality as "yes," "no," or "marginally" instead of applying a numeric score improved the speed with which culverts could be inventoried and rated. Perceived culvert functionality translates directly to culvert condition state, as shown in Table 2-1.
Right-of-way information and MMS event cost data, although valuable, are not geotechnical assets and cannot be evaluated as such. Instead, they help improve the rating quality for other geotechnical assets. Right-of-way information helps identify areas where poor performance of a geotechnical asset could affect private property and therefore pose a higher risk to the Department, but does not indicate an inherent weakness in the transportation corridor. The utility of right-of-way data is expanded upon in the following section of the report.

Evaluation of the actions of maintenance forces at asset sites is instructive as well. The frequency of response actions, for instance, reflects on the performance of the transportation corridor. The relative distribution and frequency of MMS incidents throughout a transportation corridor can be used to identify where limited repair and rehabilitation dollars would be best allocated to improve roadway function.

# 4 DEVELOPMENT OF A CORRIDOR HEALTH INDEX MODEL

Once all the assets in a highway corridor have been inventoried and rated, a successful GAM program will tie all of this information together into a Corridor Health Index (CHI), assessing the performance of the transportation corridor as a whole. The overall functionality of the transportation corridor relies on support from many different asset types. Which assets are rated and how asset condition is described varies from state to state, but a general framework can be used in integrating a DOT's assets into a programmatic-level health index (Verhoeven & Flintsch, 2011).

The Tongass Study included initial development of a Corridor Health Index, using the framework described by Verhoeven & Flintsch and incorporating the five asset classes inventoried along North and South Tongass Highways (bridges, pavements, slopes, walls, culverts).

The performance measures used to determine asset condition have been defined in this study for unstable slopes, retaining walls, and culverts. AKDOT&PF performance measures for bridges and pavements will be established by the Department's TAM program. Because the department's TAM plan is still under development and because retaining wall and culvert assessments have not yet been expanded statewide, development and application of the CHI remains in a conceptual stage.

As currently envisioned, the CHI will integrate ratings of all the various asset types and evaluate corridor health based on the number of "defects" per mile of roadway. The defects would be assets which are not performing adequately to meet corridor requirements, with different weights placed on the different asset Condition States (discussed in Section 4 of the Final GAM Report). Asset inventory maps present the point location and individual Condition State of rated assets. By extension, these maps also show where Poor condition assets are concentrated, generally as a result of adverse geology or an aging roadway section. The CHI, in contrast, would be used to ascertain the relative health of Alaska's different highways on a macro-level for statewide planning purposes. Once a highway or highway segment is identified as not meeting state performance goals, then the more detailed asset inventory maps assist in determining which asset type(s) are responsible for the poor performance, and where concentrated rehabilitation efforts could have the greatest positive impact on overall corridor health.

## 4.1 Conceptual Corridor Health Index

The current Corridor Health Index is a weighted harmonic mean of the proportion of evaluated assets at or above a minimum Condition State. The minimum acceptable Condition State may not be identical for each asset type. Using the harmonic mean helps suppress the effects of a single asset type being in significantly poorer net condition than the others. The final Corridor Health Index Equation is presented in Equation 4-1 below.

Equation 4-1: Corridor Health Index Equation

$$\text{Corridor Health Index (CHI)} = \frac{\sum w_i}{\sum \left[ w_i \times \left( {}^{1}/_{P_i} \right) \right]}$$

Where $w_i$ is the weight assigned to each asset type, reflecting hazards, risks, public perception, etc., associated with the Poor condition state of each asset type,

$P_i$ is the proportion of assets with Condition States better than or equal to Xi for each asset type,

$X_i$ is the minimum acceptable Condition State for each asset type

## 4.2 Assignment of $X_i$ for Each Asset Type

Bridges. Bridge conditions were obtained from the National Bridge Inventory Database. Bridge assets were considered to be in an acceptable condition as long as their statuses were not "Structurally Deficient" or "Functionally Obsolete."

Culverts. Culvert ratings followed the rating categories presented in Table 2-1. The minimum acceptable Culvert Condition State was determined to be Fair, or "Marginal."

Pavement. The Present Serviceability Rating, or PSR, was obtained from AKDOT&PF for use as a pavement condition measure. New pavements have a PSR value of 5.0 and extremely deteriorated pavements have values near zero. Thus, as with the GAM and TAM condition indexes, higher values mean better conditions. These PSR scores were converted to pavement condition states as shown in Table 4-1.

Table 4-1: Relationship between pavement PSR and Condition State

| **PSR Range** | | |
|---|---|---|
| **High** | Low | Condition State Number/ Condition State Text |
| **5.0** | 4.0 | 1 – Good |
| **3.99** | 3.5 | 2 – Fair |
| **3.49** | 3.0 | 3 – Fair |
| **2.99** | 2.5 | 4 – Poor |
| **2.49** | 0 | 5 – Poor |

For unpaved roadways, rating data at select locations was obtained from AKDOT&PF and extrapolated to cover larger portions of the unpaved highway corridor. Gravel roadways are rated on a Pass/Fail system.

For the Condition Health Index, the minimum acceptable PSR for pavement was determined to be 3, or "Fair," for paved roadways and P, or "Pass" for unpaved roadways.

Slopes. The slope category combines the rock and soil slopes assessed along the Tongass Corridor. Slopes include both rock and soil slopes. Condition State derivation for these assets is discussed in Section 4 of the Final GAM Report, and is summarized in Table 4-2 below for reference. For the Corridor Health Index, the minimum acceptable Condition State for slopes was determined to be 3, or "Fair."

Table 4-2: Relationship between Condition Index and Condition State for unstable slopes and retaining walls

| **Condition Index Range** | | |
|---|---|---|
| High | Low | Condition State Number/ Condition State Text |
| 100 | 80 | 1 – Good |
| 79.99 | 60 | 2 – Fair |
| 59.99 | 40 | 3 – Fair |
| 39.99 | 20 | 4 – Poor |
| 19.99 | 0 | 5 – Poor |

Walls. The condition states of retaining walls along the Tongass Corridor were calculated following the methods described in Section 4 of the Final GAM Report. The relationship between calculated condition index and condition state are summarized in Table 4-2 for reference. For the Corridor Health Index, the minimum acceptable Condition State for walls was determined to be 3, or “Fair.”

## 4.3 Calculation of $P_i$ for Each Asset Type

When calculating $P_i$ (the proportion of assets with Condition States better than or equal to $X_i$ for each asset type) appropriate units must be applied. Culverts and bridges were evaluated on an individual basis, while pavement performance was evaluated using units of length. For slopes and walls, the same units applied to asset valuation work in Section 7 of the Final GAM Report were also used in the Corridor Health Index. For slope assets, where rock slope assets were measured in area and unstable soil slope and embankment assets were measured in linear feet, separate $P_i$s were calculated for the two asset types and then combined on the basis of length to generate a single $P_i$ for slopes.

The units used in calculating the proportion ($P_i$) of assets with Condition States better than or equal to the minimum acceptable value of $X_i$ are summarized in Table 4-3 below.

Table 4-3: Units used to Calculate $P_i$

| Asset Type | Unit Used to Calculate $P_i$ |
|---|---|
| **Pavement** | Length |
| **Slopes** | Area/Length* |
| **Walls** | Area |
| **Culverts** | Each |
| **Bridges** | Each |

* Area was used for rock slopes. Length was used for soil slopes.

## 4.4 Assignment of $w_i$ values for Each Asset Type

Within the Corridor Health Index, Slopes, walls, and culverts were given equal weights. Bridges and pavements were given weights three times that of the other assets. Pavements were given a greater weight because regular public interaction with this asset is much higher than for any of the others, resulting in increased public perception impacts of poor asset performance. Bridges were given a greater weight because they pose a higher risk to mobility and total corridor impassibility and duration of closure and associated effects in the event of poor performance. The final $w_i$ developed for each asset type is summarized in Table 4-4.

Table 4-4: Asset $w_i$ values for Corridor Health Index

| Asset Type | Weight $w_i$ |
|---|---|
| **Bridges** | 3 |
| **Culverts** | 1 |
| **Pavements** | 3 |
| **Slopes** | 2 |
| **Walls** | 1 |

## 4.5 Relating the Corridor Health Index to the Corridor Health Condition State

Since proportions $P_i$ are expressed in real numbers between 0 and 1, the CHI is the weighted harmonic mean of individual $P_i$’s, the CHI will also be a real number between 0 and 1. The proposed relationship between the Corridor Health Index and the Corridor Health Condition State is shown in Table 4-5.

Table 4-5: Relationship between Corridor Health Index and Corridor Health Condition State

| Corridor Health Index Range | | Corridor Health Condition State Number/ Corridor Health Condition State Text |
|---|---|---|
| **High** | **Low** | |
| 1.0 | 0.9 | 1 – Good |
| 0.899 | 0.8 | 2 – Fair |
| 0.799 | 0.7 | 3 – Fair |
| 0.699 | 0.6 | 4 – Poor |
| 0.599 | 0 | 5 – Poor |

## 4.6 Calculated Corridor Health Indices for North and South Tongass Highways

Following the procedure outlined in the previous sections, the Corridor Health Index determinations for North and South Tongass Highways were evaluated. The detailed breakdown of results for North Tongass is shown in Table 4-6 and the detailed breakdown for South Tongass is shown in Table 4-7 and Table 4-8. Details are provided in MS Excel spreadsheets, which are available upon request.

The calculated CHI for North Tongass Highway was 0.859, which corresponds to a Corridor Health Condition state of 2/Fair. Two separate CHIs were calculated for South Tongass Highway. One evaluates only assets along the paved portion of the highway corridor, resulting in a CHI of 0.69, which corresponds to a Condition State of 4/Poor. The other CHI for South Tongass Highway evaluates assets along the entire highway, including those on the unpaved portion beyond Herring Cove, resulting in a CHI of 0.60, which also corresponds to a Condition State of 4/Poor.

Table 4-6: Corridor Health Index Evaluation for North Tongass Highway

| Asset Type | $X_i$ Minimum Acceptable Condition State Criteria | $P_i$ | | Weights ($w_i$) | $w_i$ * 1/$P_i$ |
|---|---|---|---|---|---|
| | | **Proportion of Assets with Condition States Better Than or Equal to $X_i$** | **Unit** | | |
| **Pavement** | 3 | 0.688 | Length | 3.0 | 4.3579 |
| **Slopes** | 3 | 0.941 | Area/Length* | 2.0 | 2.1250 |
| **Walls** | 3 | 1.000 | Area | 1.0 | 1.0000 |
| **Culverts** | 2 | 0.860 | Each | 1.0 | 1.1627 |
| **Bridges** | Not Structurally Deficient or Functionally Obsolete | 1.000 | Each | 3.0 | 3.0000 |
| **Corridor Health Index** | | | | 10.0 | 0.859 (Fair) |

* Area is used for rock slopes. Length is used for soil slopes.

Table 4-7: Corridor Health Index Evaluation for South Tongass Highway – Paved Portion Only

| Asset Type | $X_i$ Minimum Acceptable Condition State Criteria | $P_i$ | | Weights ($w_i$) | $w_i$ * $1/P_i$ |
|---|---|---|---|---|---|
| | | Proportion of Assets with Condition States Better Than or Equal to $X_i$ | Unit | | |
| **Pavement** | 3 | 0.565 | Length | 3.0 | 5.3133 |
| **Slopes** | 3 | 1.000 | Area/Length* | 2.0 | 2.0000 |
| **Walls** | 3 | 0.881 | Area | 1.0 | 1.1354 |
| **Culverts** | 2 | 0.934 | Each | 1.0 | 1.0741 |
| **Bridges** | Not Structurally Deficient or Functionally Obsolete | 0.667 | Each | 3.0 | 4.5000 |
| **Corridor Health Index** | | | | 10.0 | 0.713 (Fair) |

* Area was used for rock slopes. Length was used for soil slopes.

Table 4-8: Corridor Health Index Evaluation for South Tongass Highway – Entire Highway, with gravel road ratings incorporated.

| Asset Type | $X_i$ Minimum Acceptable Condition State Criteria | | $P_i$ | | Weights ($w_i$) | $w_i$ * $1/P_i$ |
|---|---|---|---|---|---|---|
| | | | Proportion of Assets with Condition States Better Than or Equal to $X_i$ | Unit | | |
| **Pavement** | 3 | P | 0.399 | Length | 3.0 | 7.5162 |
| **Slopes** | 3 | | 1.000 | Area/Length* | 2.0 | 2.0000 |
| **Walls** | 3 | | 0.904 | Area | 1.0 | 1.1056 |
| **Culverts** | 2 | | 0.931 | Each | 1.0 | 1.0741 |
| **Bridges** | Not Structurally Deficient or Functionally Obsolete | | 0.700 | Each | 3.0 | 4.2857 |
| **Corridor Health Index** | | | | | 10.0 | 0.626 (Poor) |

* Area was used for rock slopes. Length was used for soil slopes.

## 4.7 Future Considerations for Wider Application of the Corridor Health Index Concept

North and South Tongass Highways are relatively short stretches of road on the extreme south end of the state. Much longer highways exist elsewhere in the state and applying a single CHI score to the entire corridor will mask concentrated problem areas, thus reducing the CHIs strength as a decision support tool. On these longer routes, a subdivision of the CHI into 1, 5, 10, and/or 20 mile segments may provide benefits for more focused project selection and planning, particularly as inventory work on retaining walls and culverts becomes more complete.

The majority of North and South Tongass Highways are paved. Unpaved roadways are not evaluated for PSR and in general the Department lacks the required high-resolution data for road performance evaluation. Unpaved roads are evaluated in select locations, as opposed to the continuous coverage provided by a PSR inspection vehicle, and are given a Pass/Fail grade. A spot check of the evaluations of unpaved roadway conducted by AKDOT&PF personnel revealed that most unpaved roadway sections are given a failing grade. Therefore, application of the current CHI to unpaved segments of the transportation corridor could result in performance measures that are artificially depressed. It may be in the department's long-term interest to develop a separate CHI for unpaved highways, such as the Denali or the Taylor Highways.

Finally, the current CHI does not include different CHI guidelines for different transportation route classes such as interstates, major arterials, and minor arterials. A minor arterial outside of Sterling, for instance, is not as critical to the economic well-being of the state as an interstate route near Palmer, and it may be prudent to develop aspirational and fiscally-constrained Condition Health Index targets similar to the targets developed for individual asset types and presented in Section 9 of the Final GAM Report.

# 5 CONCLUSIONS AND SUGGESTED RESEARCH

## 5.1 Conclusions

The initial inventory, rating, and condition assessment research work conducted along the Tongass Corridor provided valuable test execution for development of the GAM Program at AKDOT&PF. Much of the asset rating data from the Tongass Corridor research has been migrated to appropriate fields in the GAM Program database and is available via the Department's GIS platform (Esri ArcGIS Online). Work on culverts and subsurface data is currently available only by request and has not been expanded beyond the Tongass corridor. However, it provides a valuable roadmap for how a working inventory and rating system for other asset classes can be implemented across the state and incorporated into a corridor assessment process. The proposed methods for integrating traditional transportation assets, such as bridges and pavements, can also be referred to for guidance as AKDOT&PF works towards finalization of its TAM plan.

With the completion of an initial model for assessing overall corridor health, the Tongass Corridor Geotechnical Asset Management Research Study provides a programmatic planning-level model for evaluating how the performance of multiple asset types combine to affect the overall performance of the transportation system. The work done in Tongass will help the department focus on critical geotechnical asset component information helpful for long-term planning at the corridor- and network levels.

## 5.2 Suggested Research

The Alaska Department of Transportation and Public Facilities has developed and a GAM program, surveying thousands of geotechnical assets throughout select routes in the State. Application of the CHI developed here should be applied to other corridors at various subdivision scales on other routes. For instance, application of the CHI on entire routes, and subdivisions thereof of 100, 50, 20, 5, and 1 mile segments can help narrow down where rehabilitation projects can benefit all of the state's managed physical assets.

Application of the CHI, or a derivation thereof, should be evaluated to serve the purpose of a statewide Performance Measure of highway network condition. This simplicity offers benefits of indicating overall network condition that takes into account existing conditions. Application of deterioration rates and life cycle cost estimates permits forecasting a CHI based on economic models developed by AKDOT&PF's TAM and GAM programs.

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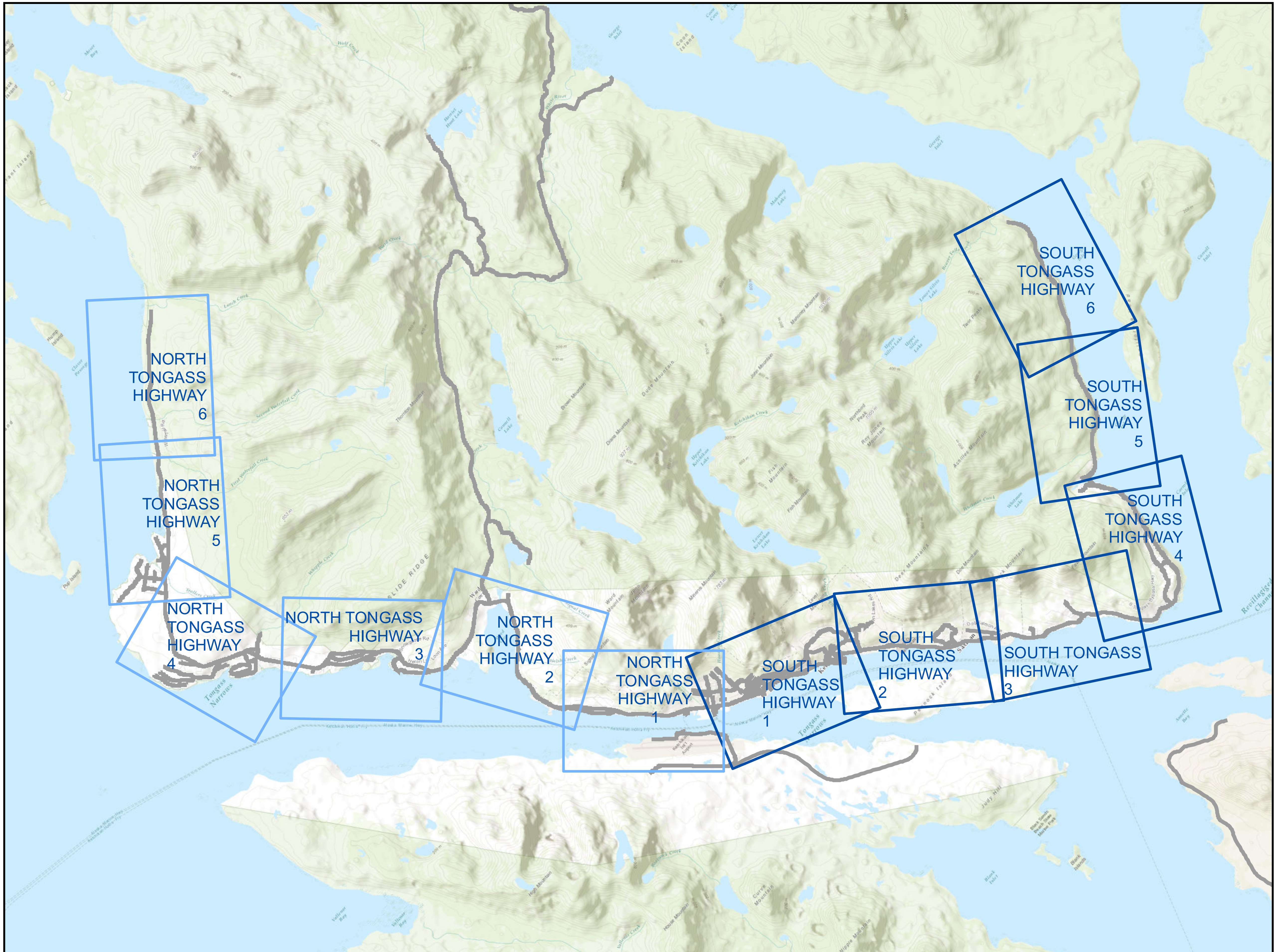
# APPENDIX A

## Asset Inventory Maps

## North and South Tongass Highways





Area shown to left indicated by red outline.

# Asset Inventory Map Index

See following pages for additional detail locations of road features, including culverts, retaining walls, rock slopes, unstable soil slopes and embankments, bridges in the NBI, and pavement condition.

**Legend**

- North Tongass Highway Map Pages
- South Tongass Highway Map Pages
- DOT Road System

August 2017

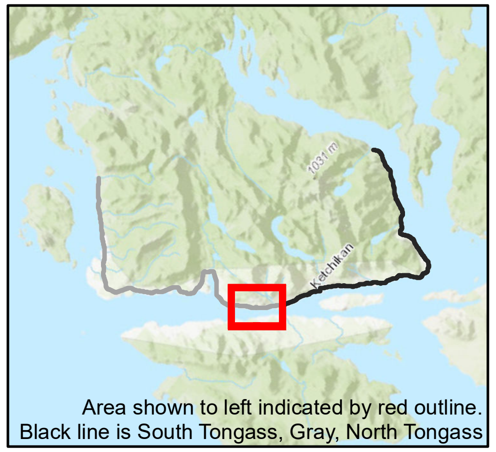
0 4,200 8,400 12,600 Feet

1 inch = 1.5 mile

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 2




# Asset Inventory Map

NORTH TONGASS HIGHWAY
MAP 1 of 6

## Legend

**Getechnical Event Locations**
- Rockfall

**Bridge GAM Evaluation**
- Fair

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

Feet
0 500 1,000 1,500
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
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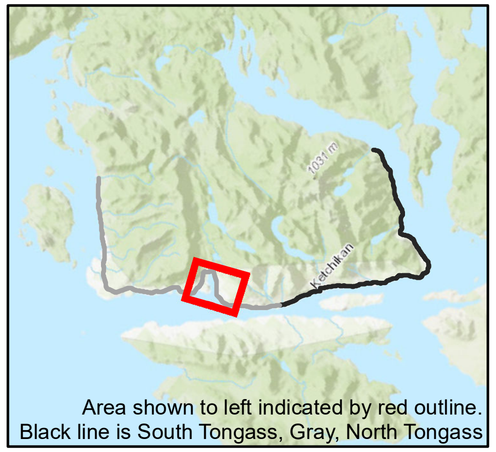
Map 3

Map 1




# Asset Inventory Map

NORTH TONGASS HIGHWAY
MAP 2 of 6

## Legend

**Getechnical Event Locations**

- Rockfall
- Tree Fall

**Bridge GAM Evaluation**

- Good
- Fair
- Borings

**Culvert Condition State**

- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**

- GOOD
- FAIR
- POOR

**Rock Slope Condition State**

- GOOD
- FAIR
- POOR

**Soil Slope Condition State**

- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**

- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

0 500 1,000 1,500 Feet

1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
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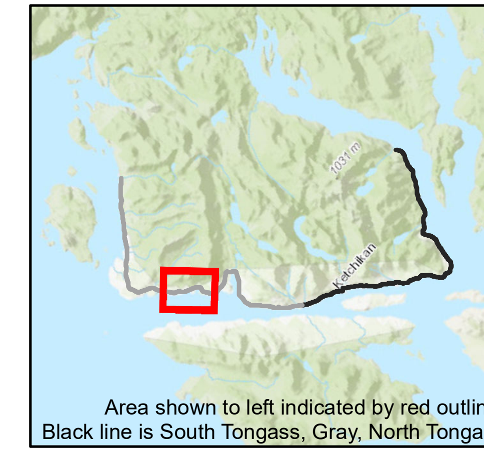
Map 4

Map 2




# Asset Inventory Map

NORTH TONGASS HIGHWAY
MAP 3 of 6

## Legend

- Borings

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

Feet
0 500 1,000 1,500
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
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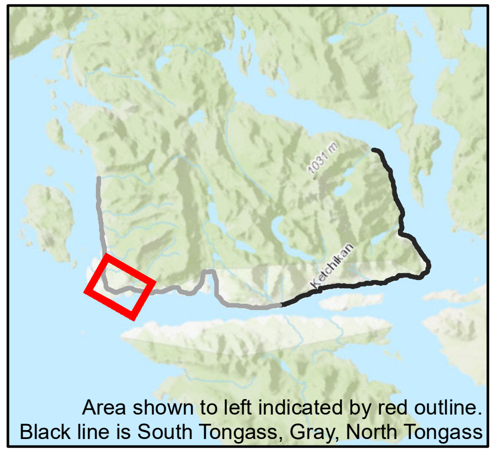
Map 5

Map 3




# Asset Inventory Map

NORTH TONGASS HIGHWAY
MAP 4 of 6

## Legend

**Getechnical Event Locations**
- Landslide and/or Embankment Failure
- Rockfall

**Bridge GAM Evaluation**
- Good

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

Feet
0 500 1,000 1,500
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
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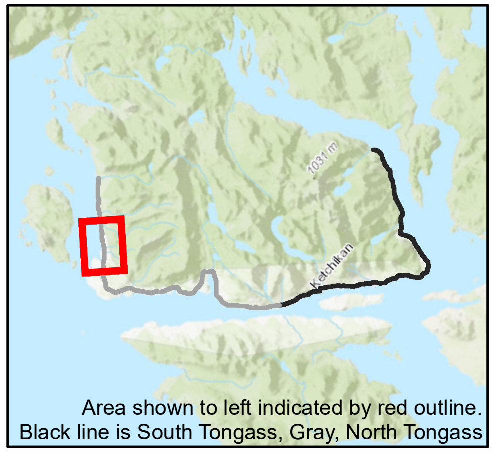


# Asset Inventory Map

NORTH TONGASS HIGHWAY
MAP 5 of 6

## Legend

**Bridge GAM Evaluation**
- Fair

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

Feet
0 500 1,000 1,500

1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
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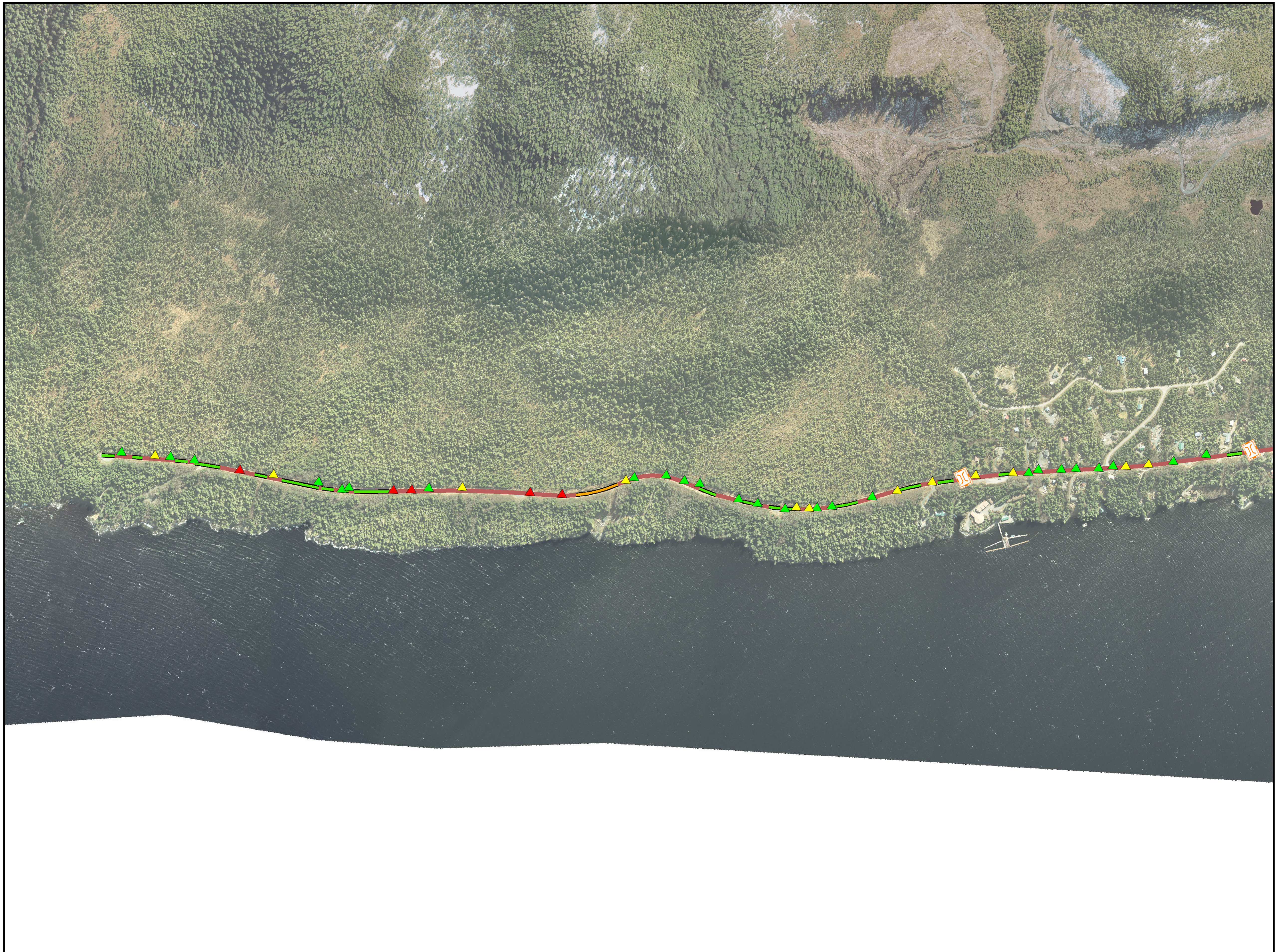
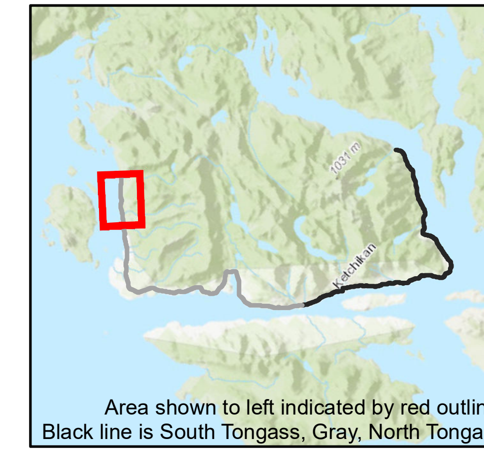



# Asset Inventory Map

NORTH TONGASS HIGHWAY
MAP 6 of 6

## Legend

**Bridge GAM Evaluation**

- Fair

**Culvert Condition State**

- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**

- GOOD
- FAIR
- POOR

**Rock Slope Condition State**

- GOOD
- FAIR
- POOR

**Soil Slope Condition State**

- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**

- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

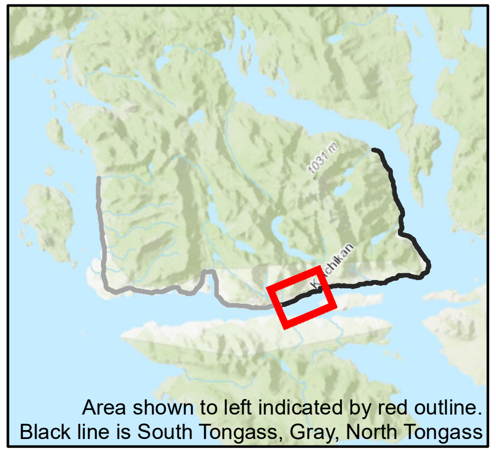
Feet
0 500 1,000 1,500

1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 2




# Asset Inventory Map

SOUTH TONGASS HIGHWAY
MAP 1 of 6

## Legend

**Getechnical Event Locations**
- Rockfall

**Bridge GAM Evaluation**
- Fair
- Poor

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

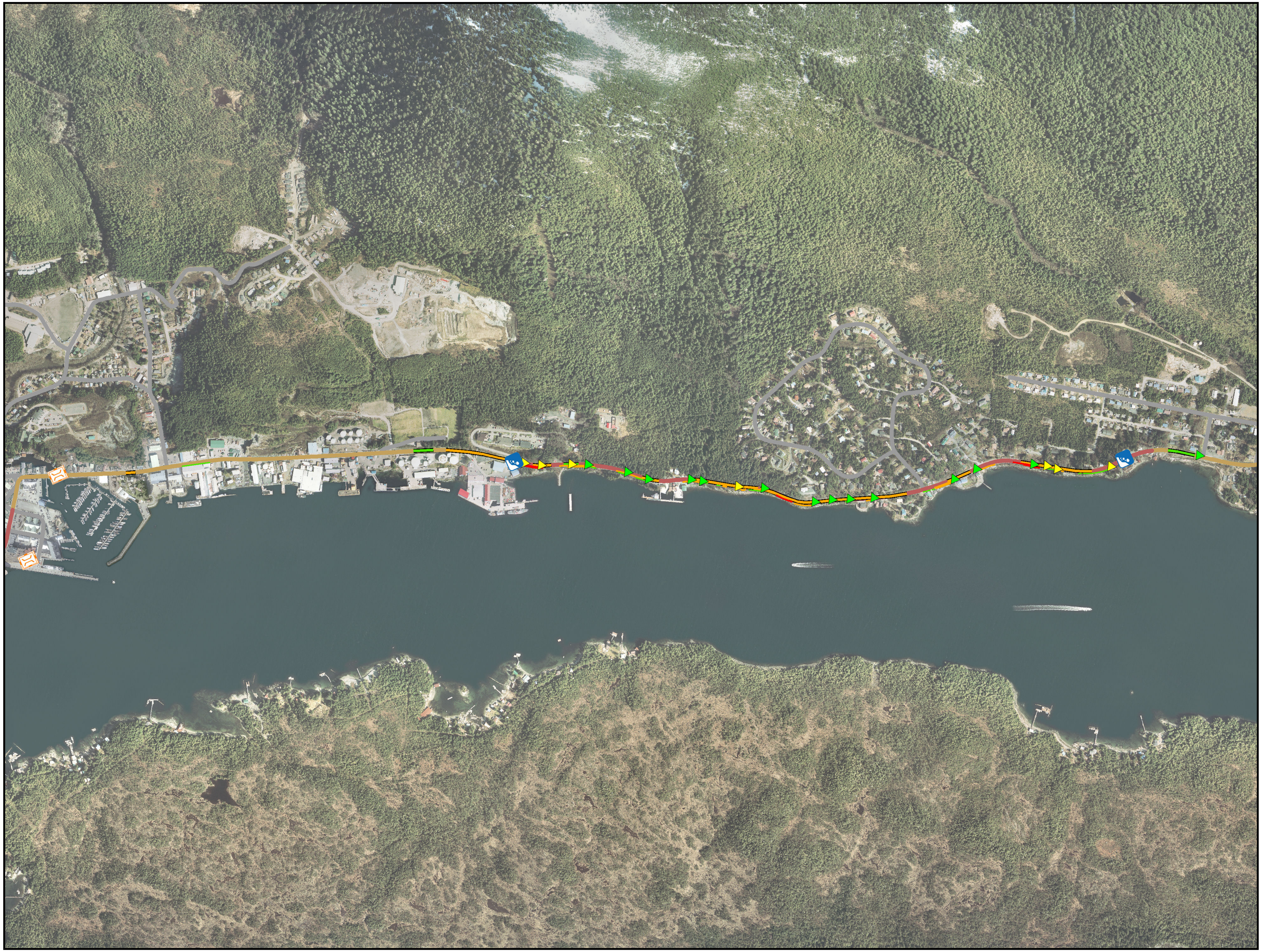
August 2017

Feet
0 500 1,000 1,500
1 inch = 1,000 feet

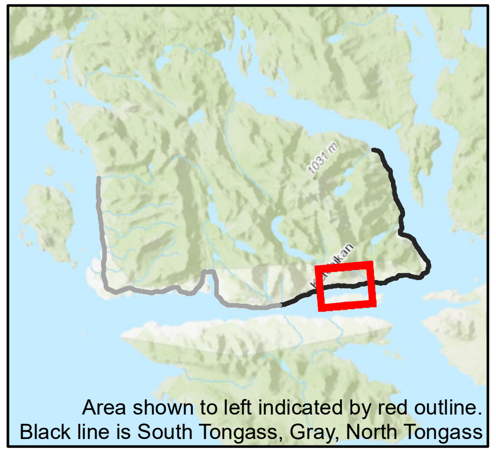
N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 1



Map 3




# Asset Inventory Map

SOUTH TONGASS HIGHWAY
MAP 2 of 6

## Legend

**Getechnical Event Locations**
- Rockfall

**Bridge GAM Evaluation**
- Fair

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

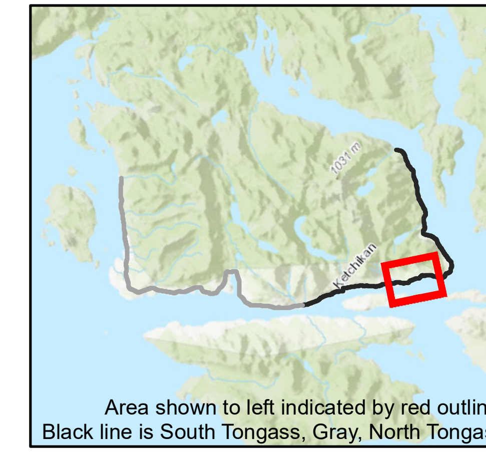
**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

Feet
0 500 1,000 1,500
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS


# Asset Inventory Map

SOUTH TONGASS HIGHWAY
MAP 3 of 6

## Legend

**Getechnical Event Locations**
- Landslide and/or Embankment Failure
- Rockfall
- Tree Fall

**Bridge GAM Evaluation**
- Good

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

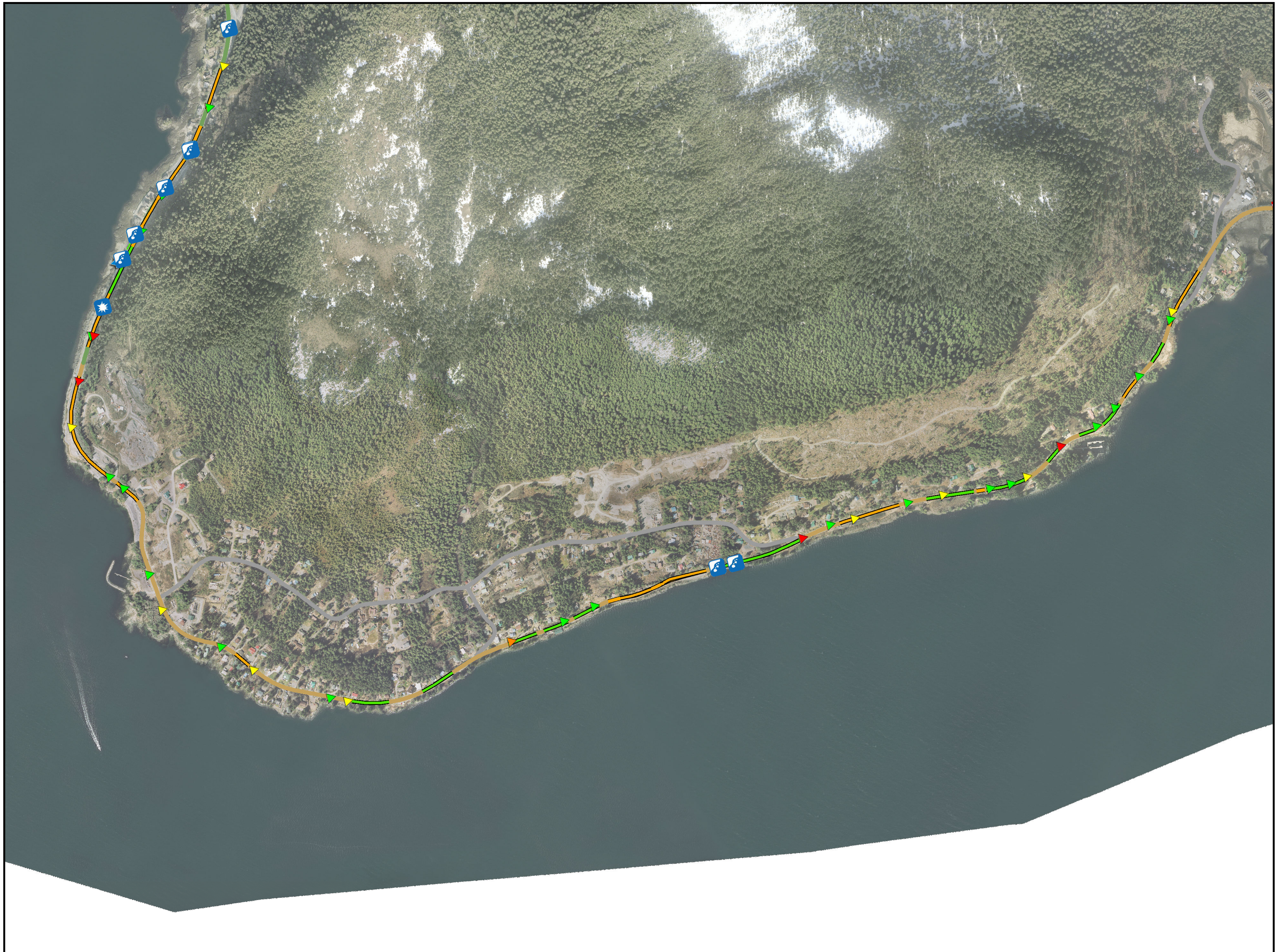
August 2017

Feet
0 500 1,000 1,500
1 inch = 1,000 feet

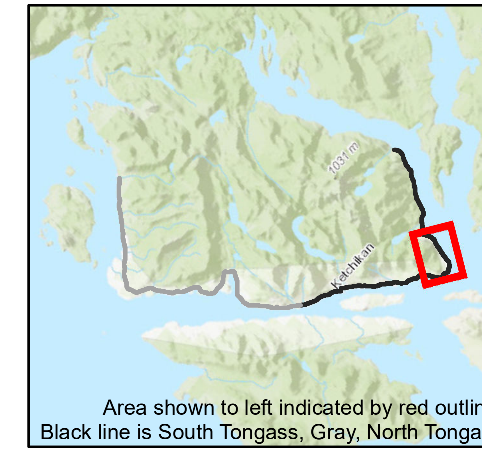
N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 3



Map 5




# Asset Inventory Map

SOUTH TONGASS HIGHWAY
MAP 4 of 6

## Legend

**Getechnical Event Locations**
- Landslide and/or Embankment Failure
- Rockfall
- Tree Fall

**Bridge GAM Evaluation**
- Poor

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

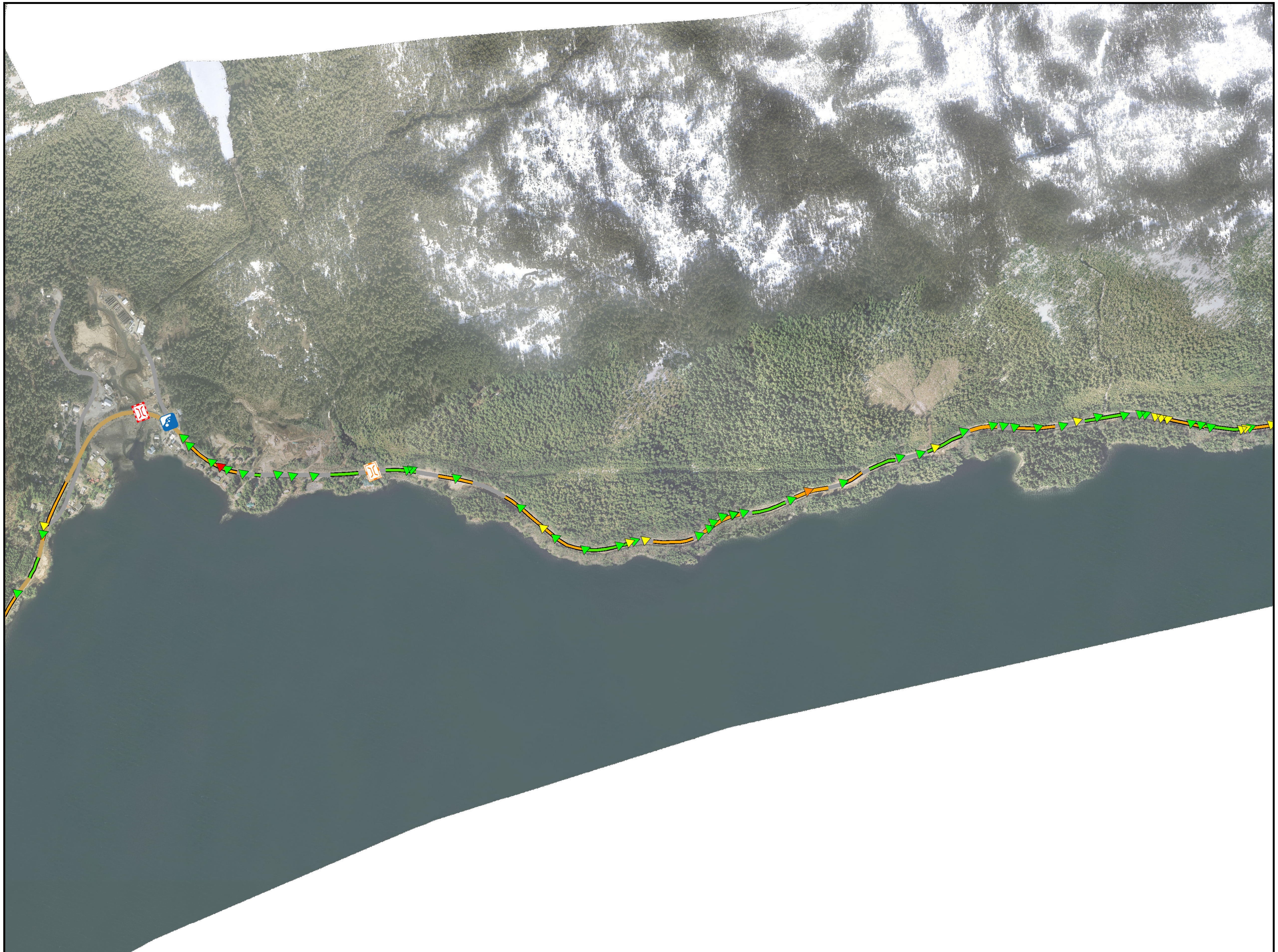
**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

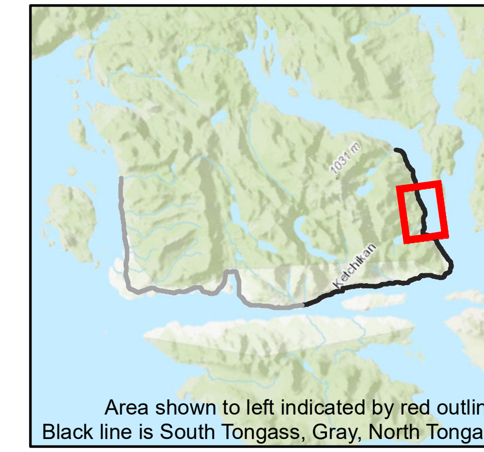
0 500 1,000 1,500 Feet
1 inch = 1,000 feet

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 4



Map 6




# Asset Inventory Map

SOUTH TONGASS HIGHWAY
MAP 5 of 6

## Legend

**Getechnical Event Locations**

- Rockfall

**Bridge GAM Evaluation**

- Fair
- Poor

**Culvert Condition State**

- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**

- GOOD
- FAIR
- POOR

**Rock Slope Condition State**

- GOOD
- FAIR
- POOR

**Soil Slope Condition State**

- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**

- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

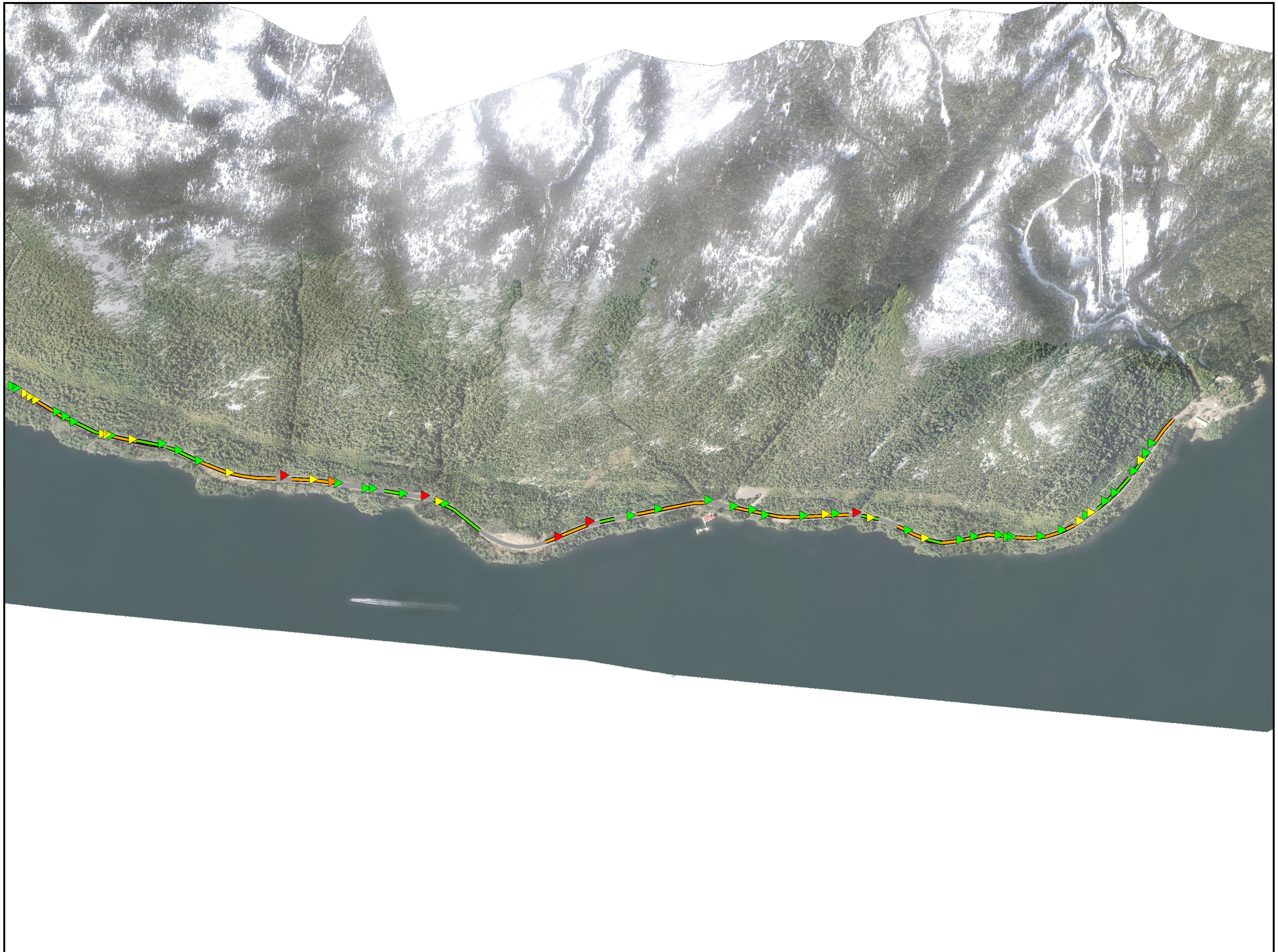
0 500 1,000 1,500 Feet

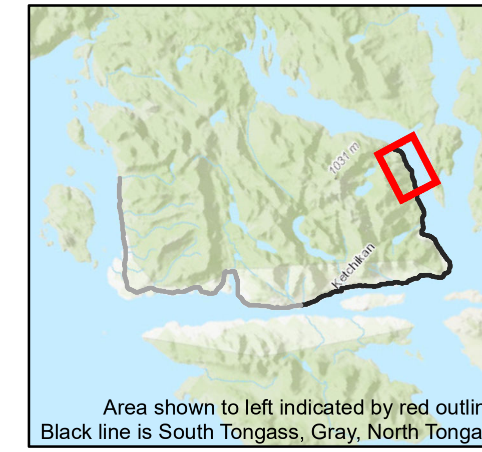
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 5






# Asset Inventory Map

SOUTH TONGASS HIGHWAY
MAP 6 of 6

## Legend

**Culvert Condition State**
- GOOD (Functional)
- FAIR (Marginal Function)
- POOR (Poor/Non Functional)
- NOT FOUND

**Retaining Wall Condition State**
- GOOD
- FAIR
- POOR

**Rock Slope Condition State**
- GOOD
- FAIR
- POOR

**Soil Slope Condition State**
- GOOD
- FAIR
- POOR

**Pavement Condition State (Derived from Pavement Servicability Rating)**
- GOOD
- FAIR
- POOR
- DOT Road System

August 2017

Feet
0 500 1,000 1,500
1 inch = 1,000 feet

N

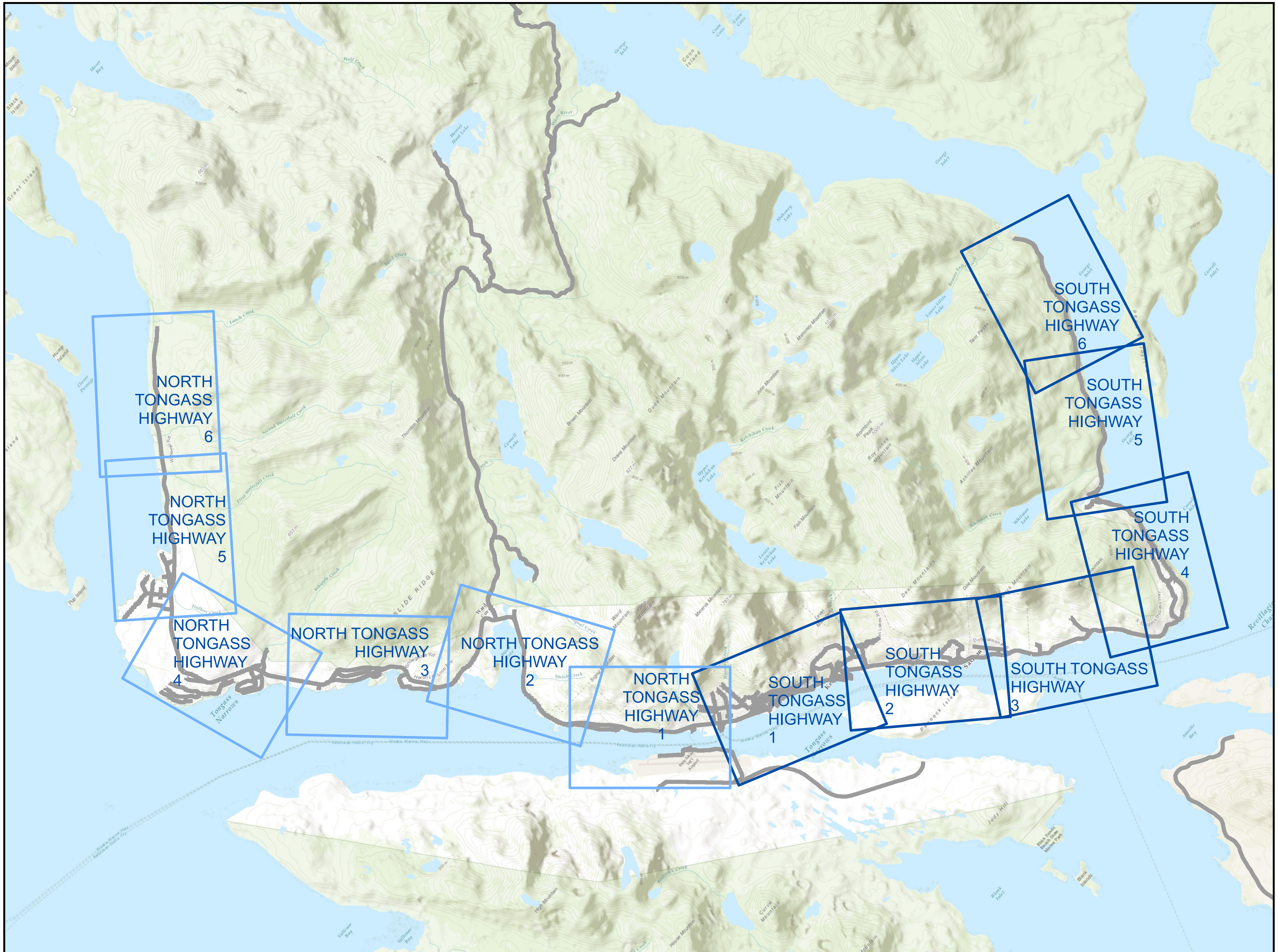
LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

# APPENDIX B

## POTENTIAL ROCK SLOPE FAILURE AND

## PRIVATE PROPERTY IMPACT MAPS

## NORTH AND SOUTH TONGASS HIGHWAYS




Area shown to left

# USMP Right of Way Impacts - Map Index

See following pages for additional detail on lots adjacent to rock slopes with high ratings.

**Legend**

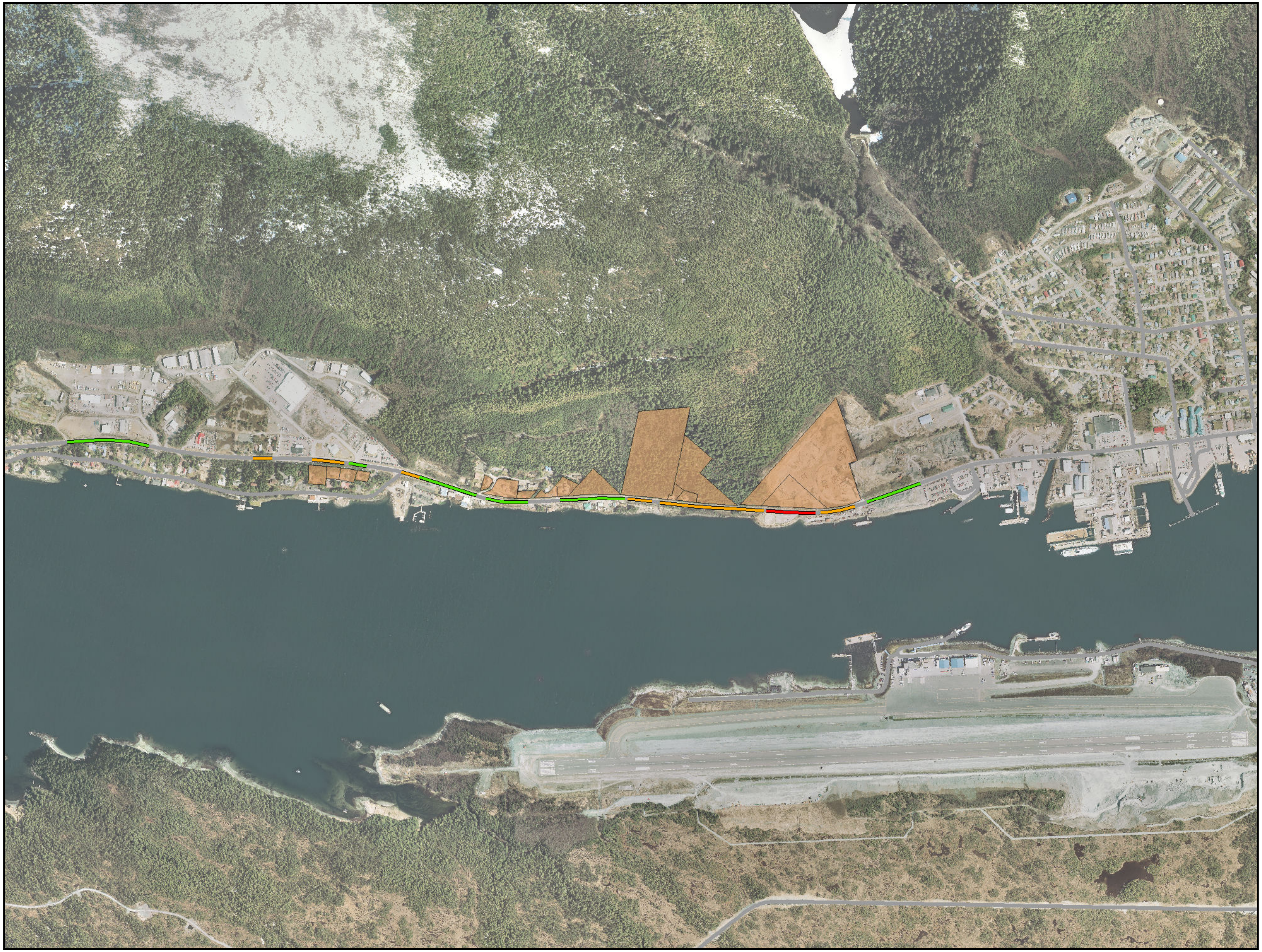
- North Tongass Highway Map Pages
- South Tongass Highway Map Pages
- DOT Road System

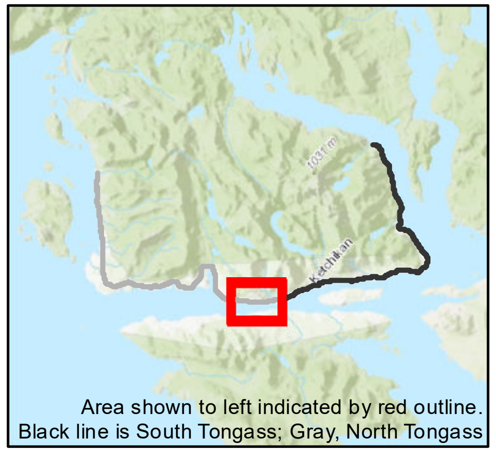
August 2017

Feet
0 4,200 8,400 12,600
1 inch = 1.5 mile

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 2






# USMP Right of Way Impacts Map

NORTH TONGASS HIGHWAY
MAP 1 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

GOOD

FAIR

POOR

DOT Road System

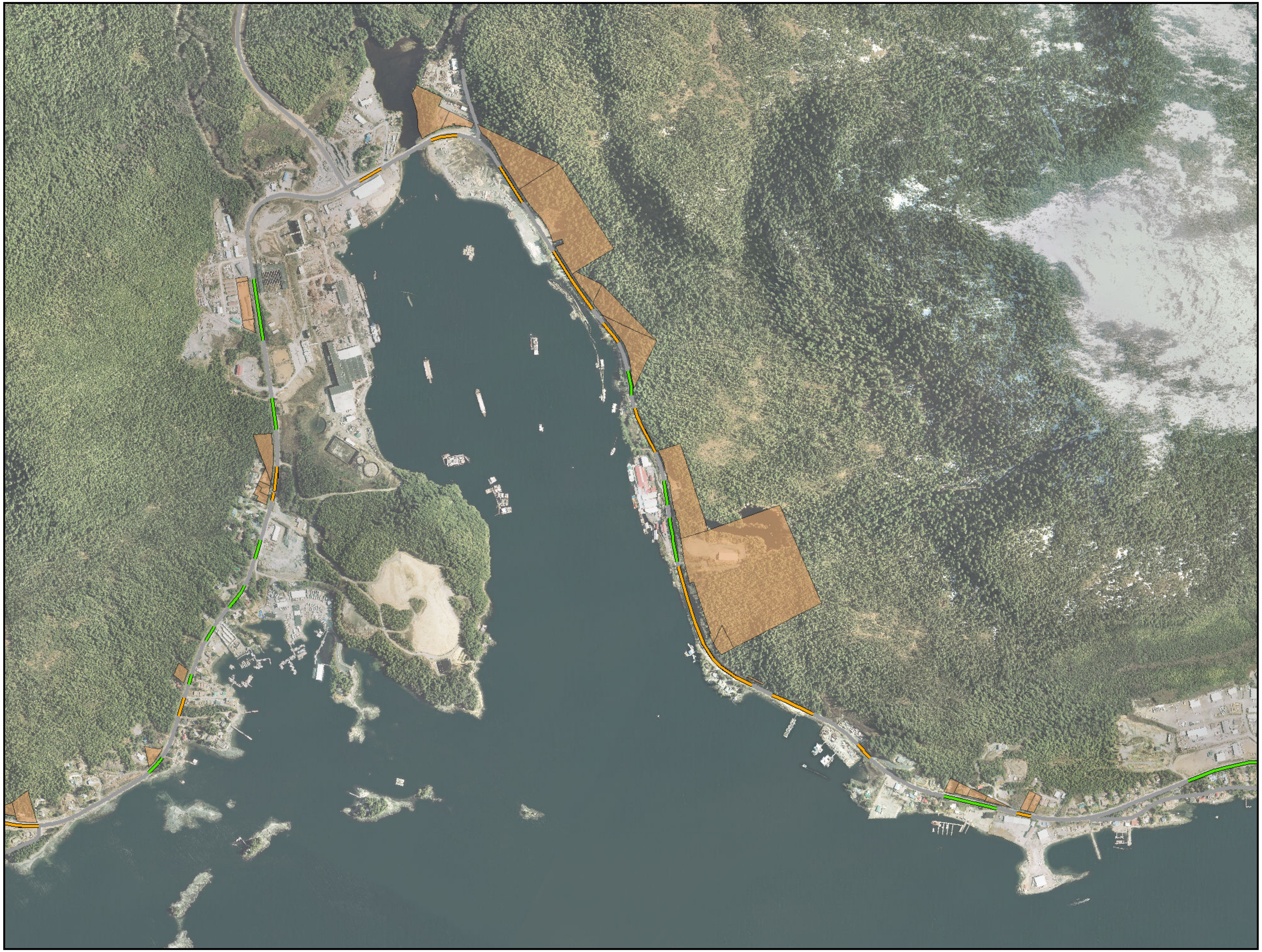
August 2017

Feet
0 530 1,060 1,590
1 inch = 1,000 feet

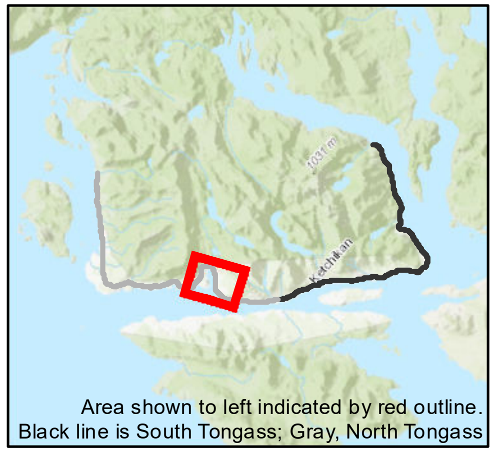
N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 3



Map 1




# USMP Right of Way Impacts Map

NORTH TONGASS HIGHWAY
MAP 2 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

- GOOD
- FAIR
- POOR

DOT Road System

August 2017

Feet
0 530 1,060 1,590
1 inch = 1,000 feet

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 4

Map 2


# USMP Right of Way Impacts Map

NORTH TONGASS HIGHWAY
MAP 3 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

GOOD
FAIR
POOR
DOT Road System

August 2017

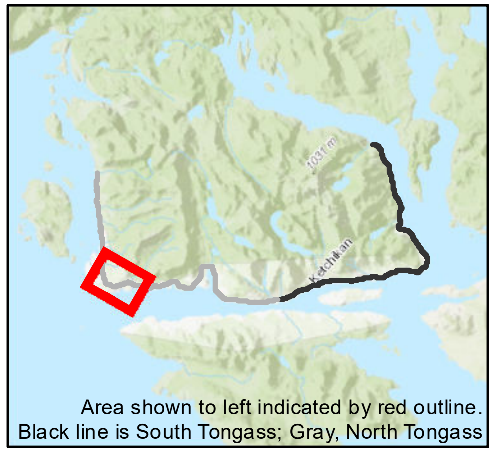
Feet
0 530 1,060 1,590
1 inch = 1,000 feet

N

LANDSLIDE
TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 5

Map 3




# USMP Right of Way Impacts Map

NORTH TONGASS HIGHWAY
MAP 4 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

GOOD

FAIR

POOR

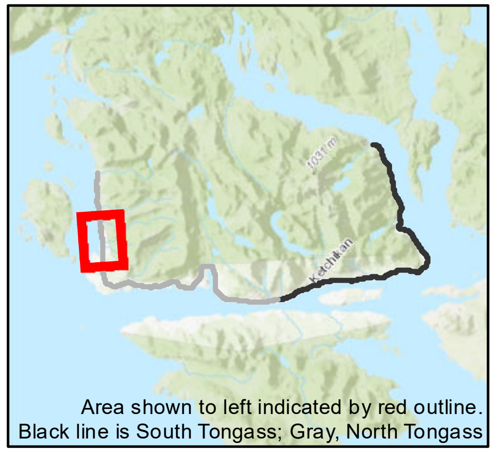
DOT Road System

August 2017

Feet
0 530 1,060 1,590

1 inch = 1,000 feet

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS


# USMP Right of Way Impacts Map

NORTH TONGASS HIGHWAY
MAP 5 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

GOOD

FAIR

POOR

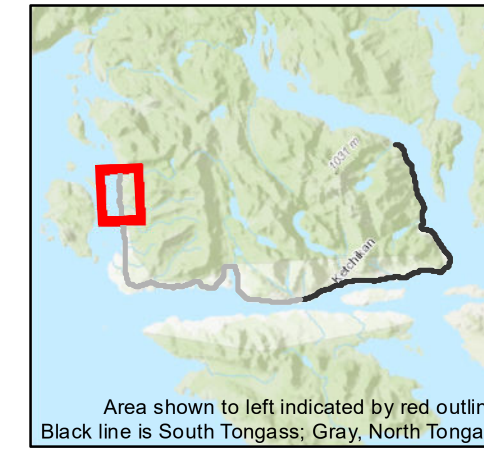
DOT Road System

August 2017

0 530 1,060 1,590 Feet

1 inch = 1,000 feet

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS


# USMP Right of Way Impacts Map

NORTH TONGASS HIGHWAY
MAP 6 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

GOOD

FAIR

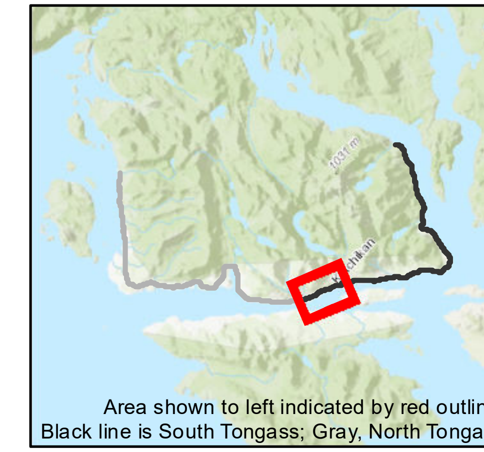
POOR

DOT Road System

August 2017

Feet
0 530 1,060 1,590
1 inch = 1,000 feet

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS


# USMP Right of Way Impacts Map

SOUTH TONGASS HIGHWAY
MAP 1 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

- GOOD
- FAIR
- POOR

DOT Road System

August 2017

0 530 1,060 1,590 Feet

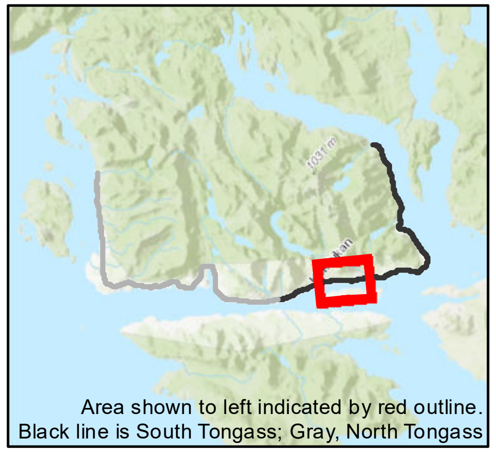
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 1

Map 3




# USMP Right of Way Impacts Map

SOUTH TONGASS HIGHWAY
MAP 2 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

GOOD

FAIR

POOR

DOT Road System

August 2017

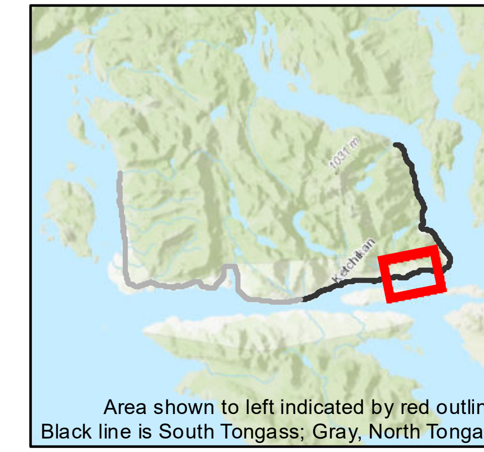
Feet
0 530 1,060 1,590
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 2

Map 4




# USMP Right of Way Impacts Map

SOUTH TONGASS HIGHWAY
MAP 3 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

GOOD

FAIR

POOR

DOT Road System

August 2017

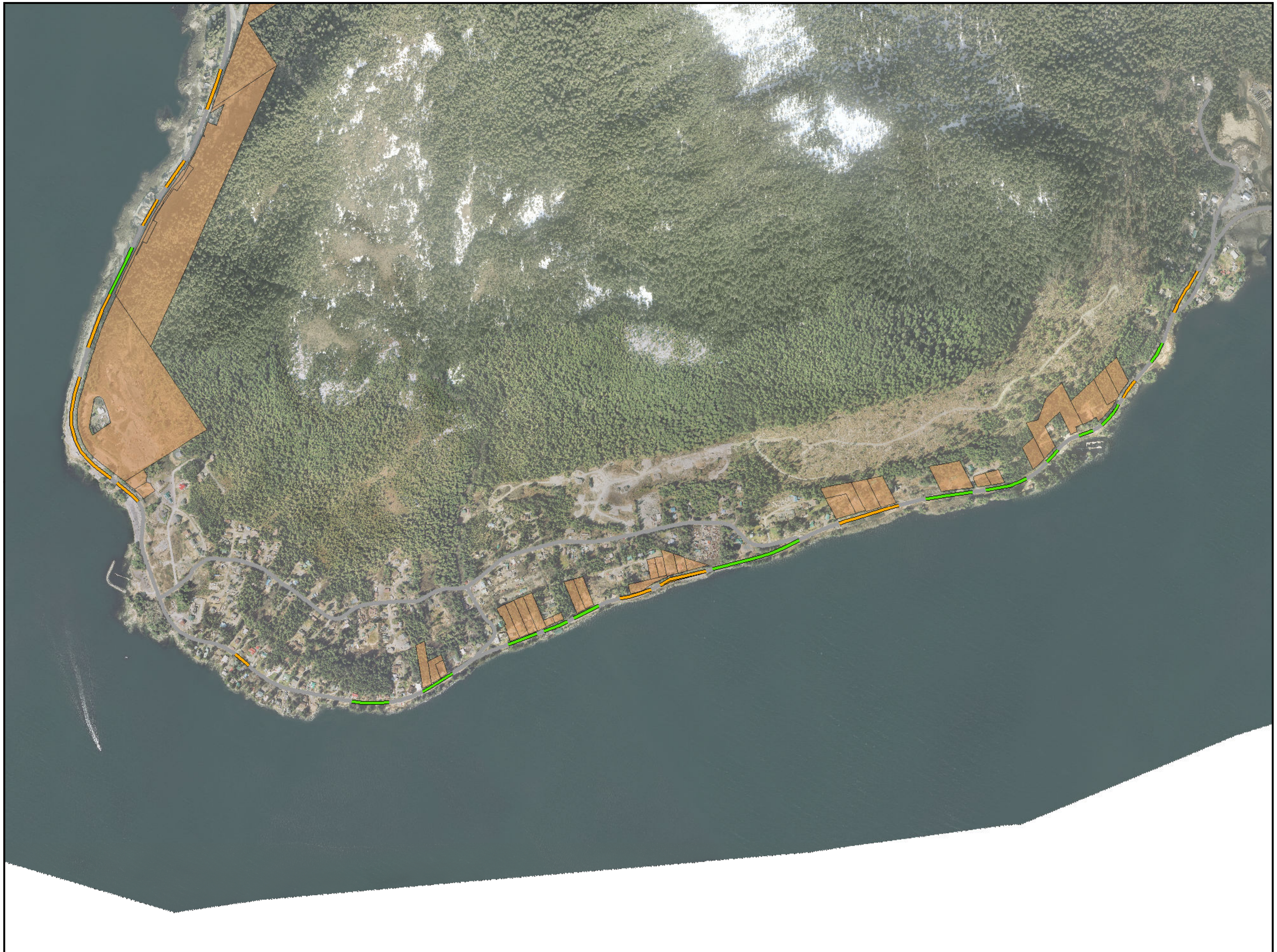
Feet
0 530 1,060 1,590

1 inch = 1,000 feet

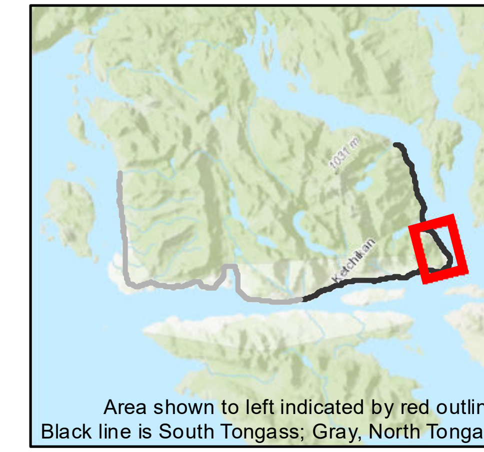
N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 3



Map 5




# USMP Right of Way Impacts Map

SOUTH TONGASS HIGHWAY
MAP 4 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

GOOD
FAIR
POOR

DOT Road System

August 2017

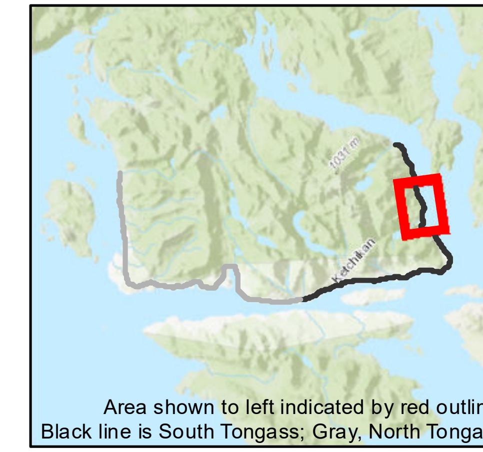
Feet
0 530 1,060 1,590
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 4

Map 6




# USMP Right of Way Impacts Map

SOUTH TONGASS HIGHWAY
MAP 5 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

- GOOD
- FAIR
- POOR

DOT Road System

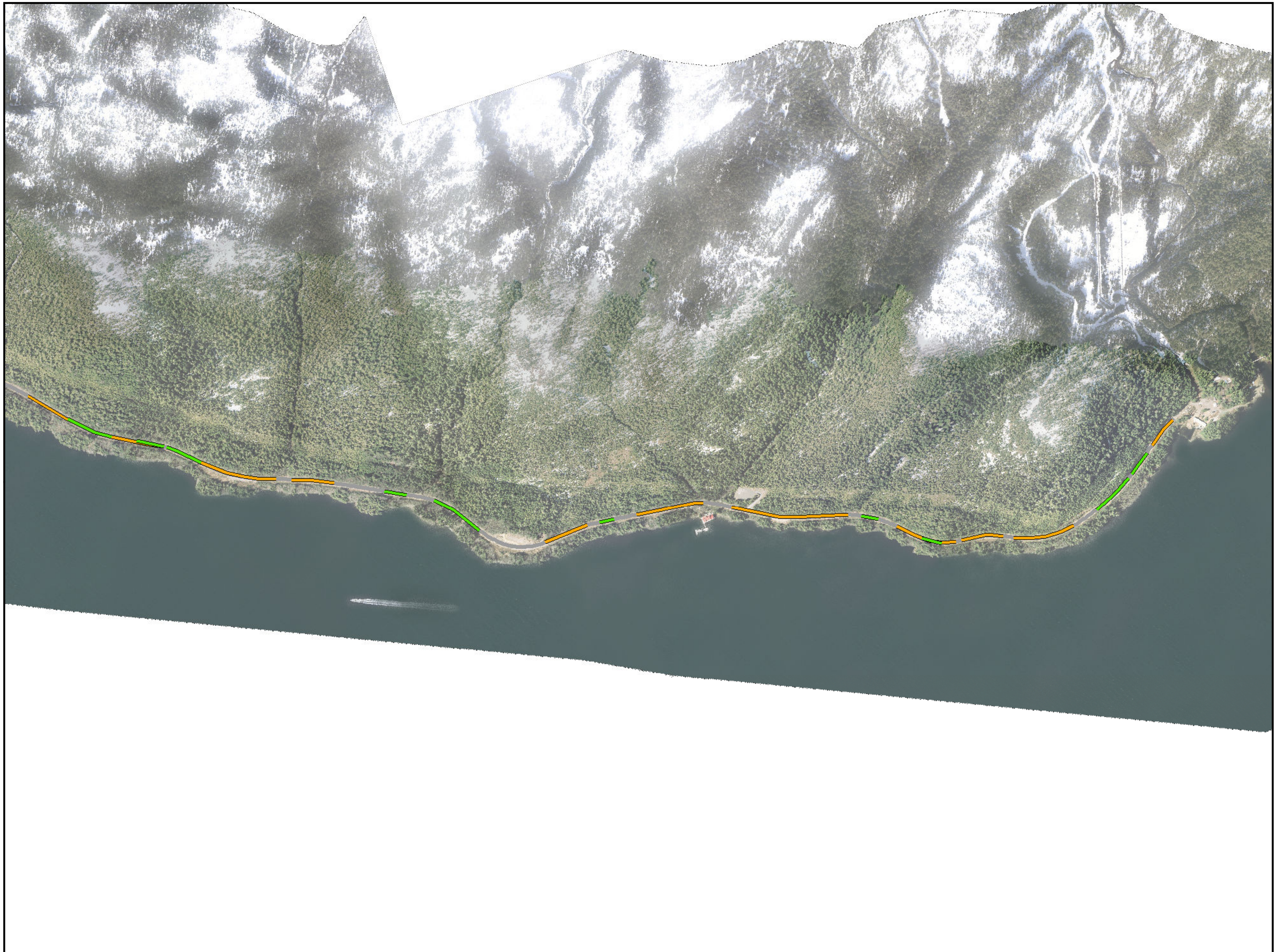
August 2017

Feet
0 530 1,060 1,590
1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Map 5



Area shown to left indicated by red outline.
Black line is South Tongass; Gray, North Tongass

# USMP Right of Way Impacts Map

SOUTH TONGASS HIGHWAY
MAP 6 of 6

**Legend**

Vulnerable Private Property Parcels

**Rock Slope Condition State**

- GOOD
- FAIR
- POOR

DOT Road System

August 2017

Feet
0 530 1,060 1,590

1 inch = 1,000 feet

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS