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Alaska Department of Transportation & Public Facilities

Statewide Geotechnical Asset Management Program Development

Final Report for Rock Slopes, Unstable Soil Slopes and Embankments, Retaining Walls, and Material Sites

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13. ABSTRACT (Maximum 200 words)
The Alaska Department of Transportation and Public Facilities (AKDOT&PF) has developed the nation's first Geotechnical Asset Management Program. The program encompasses rock slopes, unstable slopes and embankments, retaining walls, and material sources along the State's highway system. Like bridges and pavements, geotechnical assets are subject to deterioration and when not actively managed, maintained, and mitigated; high life cycle costs, reduced mobility, and life-safety risks are the unfortunate result. This proactive program has inventoried and assessed the condition of 1,636 slopes on the National Highway System (NHS) and select portions of the Alaska Highway System (AHS), or about 45% of AKDOT&PF's road miles. Assessments of over 400 retaining walls on portions of the NHS and AHS, or about 17% of AKDOT&PFs inventory, are in the program. Geographic scarcity of quality aggregate materials is assessed on a Maintenance Station basis. All assets are evaluated within a consistent rubric of five condition states and classified in terms of Good, Fair, or Poor condition. Life cycle cost estimation and investment analysis, using first-of-its-kind condition-based programmatic cost estimation, deterioration rates and maintenance costs permit the Department to make informed decisions, all in terms of hazard, risk, and cost as stewards of the Public trust.

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STATEWIDE GEOTECHNICAL ASSET MANAGEMENT PROGRAM DEVELOPMENT

ROCK SLOPES
UNSTABLE SOIL SLOPES AND EMBANKMENTS
RETAINING WALLS
MATERIAL SITES

FINAL REPORT

Prepared for
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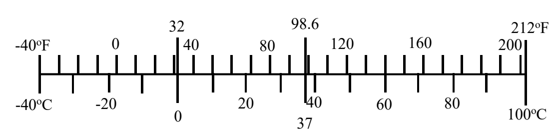
METRIC (SI*) CONVERSION FACTORS

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



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LIST OF ACRONYMS

AADT	Average Annual Daily Traffic
AGOL	ArcGIS Online
AHS	Alaska Highway System
AKDOT&PF	Alaska Department of Transportation and Public Facilities
CDS	Coordinated Data System
CI	Condition Index
CR	Central Region of AKDOT&PF
CS	Condition State
CSES	Condition State Element Scores
DGGS	Alaska Division of Geological & Geophysical Surveys
DOT	Department of Transportation
ESRI	Earth Systems Research Institute
FHWA	Federal Highway Administration
GAM	Geotechnical Asset Management
GIS	Geographic Information System
HSIP	Highway Safety Improvement Program
IT	Information Technology
LiDAR	Light Detection and Ranging
LT	Landslide Technology
M&O	Maintenance and Operations Section of AKDOT&PF
MDT	Montana Department of Transportation
MMS	AKDOT&PF's Maintenance Management System
MP	Mile Post (as opposed to CDS Milepoint)
MSI	Material Source Inventory
NHS	National Highway System
NR	Northern Region of AKDOT&PF
QR	Quick Reference Code
RHRS	Rockfall Hazard Rating Program
RWI	Retaining Wall Inventory
RWMP	Retaining Wall Management Program
SC	Southcoast Region of AKDOT&PF
STIP	Statewide Transportation Improvement Plan
TAM	Transportation Asset Management
TGIS	Transportation Geographic Information Section of AKDOT&PF
TIN	Triangulated Irregular Network
UAF	University of Alaska Fairbanks
USMP	Unstable Slope Management Program
USMS	Unstable Slope Management System (WSDOT's program)
VMS	Valuable Material Site
WSDOT	Washington Department of Transportation

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Finally, the research team is grateful for the vision of David Stanley, former AKDOT&PF Chief Engineering Geologist and now consulting, without whose vision for and championing of Geotechnical Asset Management this research would not have occurred.

EXECUTIVE SUMMARY

Transportation agencies around the nation are increasingly adopting Transportation Asset Management (TAM) procedures and techniques to manage their bridge and pavement assets. As part of this effort, interest has grown in using similar methods to manage geotechnical assets such as rock slopes, soil slopes and embankments, retaining walls, and material sources, all of which are key elements of a functioning transportation system. The Alaska Department of Transportation and Public Facilities (AKDOT&PF) has undertaken a wide-ranging research effort to develop the first-in-the-nation Geotechnical Asset Management (GAM) program, which is already generating significant interest from other agencies and DOTs.

Alaska DOT&PF's geotechnical assets are valued in the billions of dollars. The research conducted for this Final Report demonstrates that GAM, as part of a broader TAM program, provides the information and analysis needed to support decision-making for these assets and to extend their service life, enhancing system performance while optimizing the operating cost of the transportation network.

The research was conducted in three major phases. These phases covered the components required for a TAM-compatible GAM program, including:

- Review of existing programs;
- Inventory and assessment of department assets;
- Construction of an easily accessible database containing asset information using existing AKDOT&PF IT infrastructure;
- Preliminary monetization of risk and estimation of event likelihood based on asset condition;
- Development of preliminary performance measures;
- Development of unit asset improvement costs based on asset condition;
- Initial deterioration, life-cycle cost, and trade-off analysis models; and
- Example utilization of these models in developing performance targets

After an initial review of existing programs is completed, the first step towards a fully functioning asset management program is identifying and inventorying the selected classes of assets. This includes identifying where the assets are located and performing initial condition evaluations. AKDOT&PF identified four geotechnical asset types for inclusion in its initial GAM program: rock slopes, unstable soil slopes and embankments, retaining walls, and material sites. Inventory and assessment work spanned multiple years and several distinct work efforts, as summarized in the following list:

- 2007-2015: Initiation of asset inventory work with the Statewide Material Site Inventory (MSI) project conducted by R&M Consultants (Anchorage, AK).
- 2008-2009: Research initiated for an Unstable Slope Management Program (USMP), conducted by University of Alaska, Fairbanks (UAF) researchers (Huang and Darrow 2009). The research group developed a draft USMP rating system incorporating both risk and hazard elements.
- 2009-2010: Completion of a second of work phase, involving conducting a field program to inventory and assess select rock slopes, unstable soil slopes, and embankments statewide. Initial development of inventory and assessment measures for retaining walls.
- 2013-2017: Implementation of a third phase of work with completion of USMP inventory on National Highway System (NHS) routes, initiation of retaining wall inventory work

statewide with development of the Retaining Wall Inventory (RWI) database and assessment work on NHS and Alaska Highway System (AHS) routes with development of the Retaining Wall Management Program (RWMP).

Research into GAM concepts, principles, and program development aspects spanned multiple projects and multiple phases. This report focuses on what has come to be known as "Phase III" of the GAM project, initiated in 2013. The research team was led by Landslide Technology (LT) of Portland, Oregon, and worked in close cooperation with the Statewide Materials Section in AKDOT&PF.

The purpose of Phase III is completion of tasks identified as necessary to complete the GAM research program for unstable slopes and other geotechnical assets. This final phase built on previous inventory and assessment work to develop TAM-compatible asset management tools.

Research Results

Inventory and assessment work is the foundation of an asset management program, but a successful program also requires that this inventory work be incorporated into performance measures, decision support tools, and other analyses that can be used by department planners, with results shared with the general public. The starting point for all of these tools is the development of condition indices that describe how well each asset contributes to transportation corridor functionality and reliability. During this phase, the research team developed final condition indices and performance measures for the four geotechnical asset classes included in the Department's GAM program. These final 'Condition Indices' and 'Condition States' focus on characteristics that can deteriorate over time. These measures tie an asset's performance with service expectations according to the corridor's Functional Classification, like Levels of Service in other AKDOT&PF management endeavors. The calculations for rock slopes, unstable soil slopes and embankments, and retaining walls use data collected during field ratings. For material sites, asset condition is determined at the maintenance station level, in order to incorporate reasonable haul distances and overall material availability for large construction projects. This required incorporating AKDOT&PF route and service area data in an office environment. For all assets, the Condition Indexes map to a Good/Fair/Poor Condition schema similar to that used in existing TAM programs. Thousands of geotechnical features have been inventoried and assessed as part of AKDOT&PF's many asset management endeavors. Figure ES-1 summarizes the condition of three asset classes.

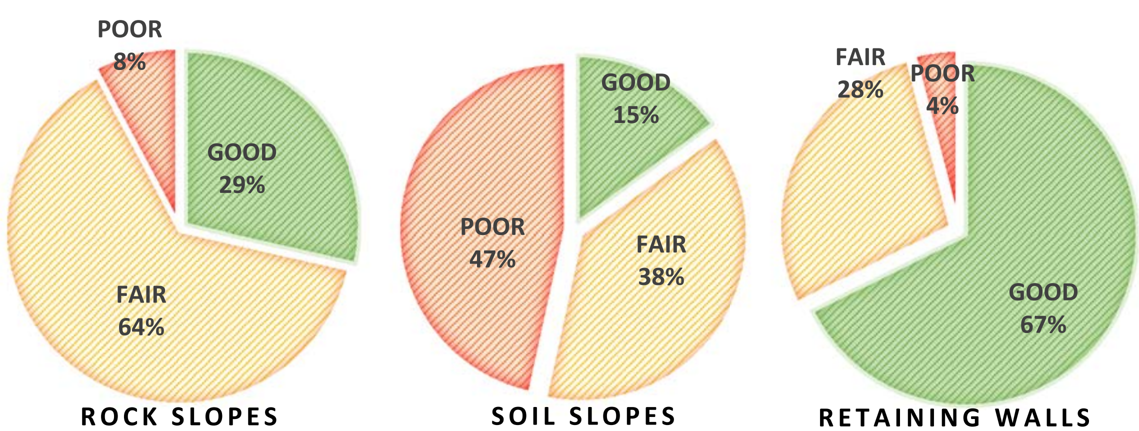

Figure ES-1: Network condition assessment for target geotechnical asset classes.

An integral component of long-term planning goals is the ability to develop reasonable initial cost estimates for a suite of mitigation/rehabilitation activities. To this end, LT used conceptual mitigation cost data from other state DOTs and from AKDOT&PF data sources to develop models correlating asset condition with an average mitigation cost. These models utilize the average mitigation costs associated with a particular Condition State and asset type to provide mitigation cost models applicable at the network level.

The research team conducted a first-ever series of expert elicitation meetings to develop preliminary deterioration models. These models feed into the life-cycle cost analyses and return on investment analyses necessary to understand existing conditions of the state's geotechnical assets.

It is also incorporated into the tradeoff and return on investment analyses used to forecast budget needs. A straightforward goal of many TAM programs is to prevent deteriorating conditions over time, typically a 10-yr period. Comparing the likelihood of assets transitioning to a worse condition and the modeled preservation costs, the sum required to maintain current conditions is significant; over $150 million per year (Figure ES-2). This figure appears large, and it is; AKDOT&PF is however, already investing in corridor improvements triggered, in part, by geotechnical issues. Deformation from deteriorating permafrost is a significant contributor to the Soil Slope and Embankment budget. Corridors such as the Glenn Highway near Long Lake, Richardson Highway through the Alaska Range, and the Seward Highway near Kenai Lake all have concentrations of Poor performing geotechnical assets driving major reinvestments with costs comparable with the figures below.

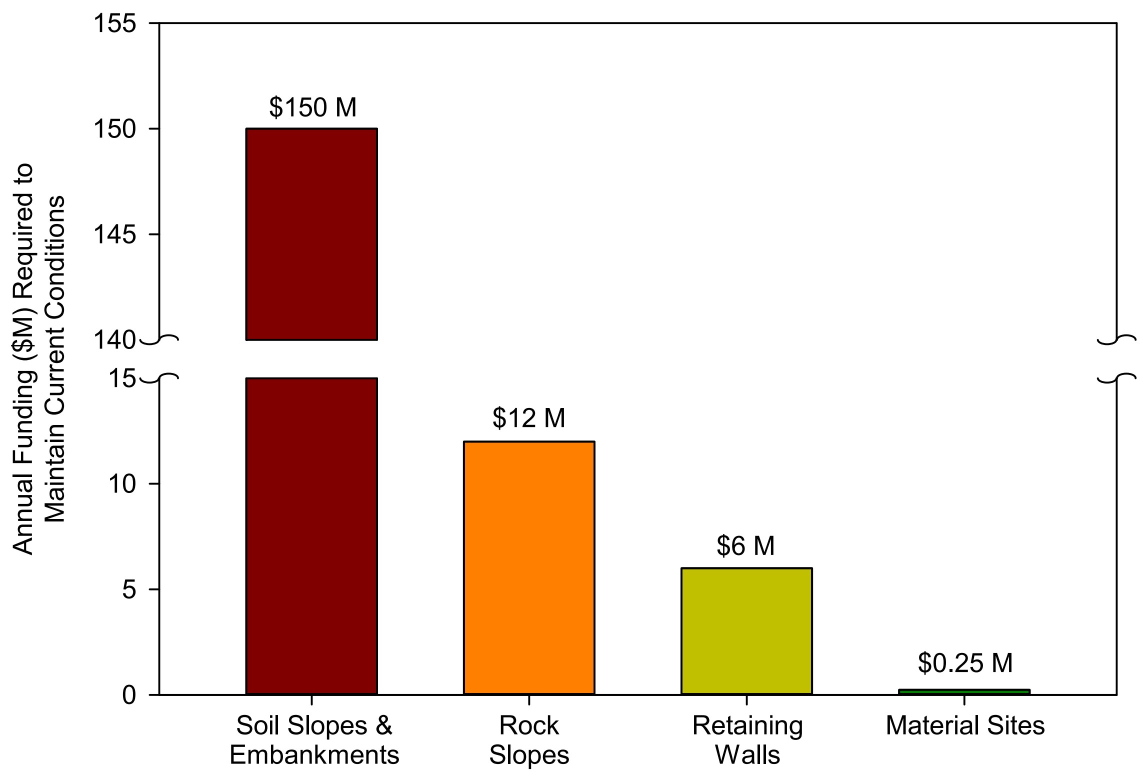

Figure ES-2: Forecast annual costs to maintain existing conditions of inventoried and assessed geotechnical assets.

By incorporating preservation activities into the annual budgets, significant savings could be realized by encouraging preservation activities in addition to more common reconstruction efforts. As an example, Figure ES-3 shows annualized savings lost from not maintaining network conditions. If zero percent of the forecast budget ($167M) is utilized for preservation and replacement of geotechnical assets, then the opportunity to save a forecast $25M annually is lost. If additional funding beyond that required to maintain current network conditions is set aside, network conditions will improve over time and savings will increase.

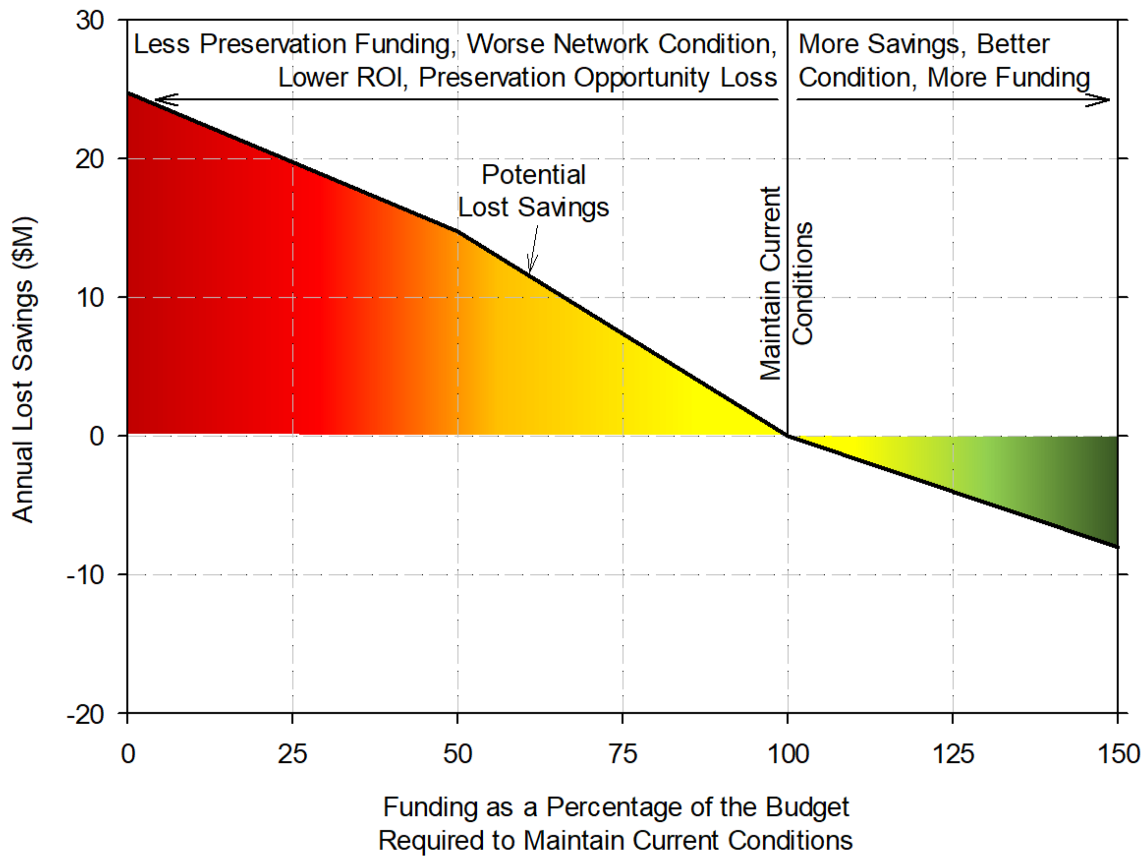

Figure ES-3: Funding preservation of geotechnical assets preserves network condition as the lowest long-term costs. Funding on a worst-first basis results in lost savings, shown relative to the percent of complete funding.

Based on life cycle cost estimation and investment analysis, this research has estimated that $1 spent on preserving slope and wall conditions today not only pays for itself, but also returns an additional $1.17 (117% ROI) to the Department and road users. Adoption of GAM as part of formal asset management policy at AKDOT&PF will *Keep Alaska Moving through service and infrastructure* at the lowest long term costs.

1 INTRODUCTION

1.1 Introduction to Geotechnical Asset Management (GAM)

Transportation agencies around the world, and particularly U.S. Departments of Transportation (DOTs), are increasingly turning to transportation asset management (TAM) as a framework for maximizing the performance and service life of their valuable infrastructure.

> *The term 'asset management' means a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost. (23 USC 101(a)(2))*

A demand for accountability for efficient use of scarce resources motivates the movement toward management of transportation assets. In fact, based on federal law, a TAM program is mandatory for pavements and bridges, and a similar, but more flexible management strategy is encouraged for other asset classes within the right-of-way corridor (23 USC 119(b)(3)). Integration of TAM into transportation agency business models is also motivated by a desire within the professional community to adopt the same rigorous standards of quality for program decision-making as already exist for many design and engineering activities. This includes the formation of a performance-oriented culture to build on the existing safety-oriented culture (Gordon, et al. 2011). Facilitating the growth of TAM is a rapid improvement in technology for collection, storage, analysis, and communication of information useful for making decisions and tracking progress.

Risk plays a central role in federal and state asset management practices, but to date it is an area where agencies are just beginning to adopt data-driven practices for managing the infrastructure as a whole. According to the Federal Highway Administration:

> *The goal is better decision-making that is based upon quality information and well-defined objectives, and considers risks to the assets and system performance as part of the decision-making process…*
>
> *All State DOTs currently manage their transportation network along with its assets; however, few apply risk-based asset management principles in their investment decision-making processes. For example, although most States conduct risk analyses at the project level, risk assessment and management at the program level is often a missing component of current management practices. Congress has recognized the importance of risk analysis in asset management by expressly requiring the State asset management plan to be risk-based (23 USC 119(e)(1)). (FHWA 2015b)*

In Alaska, as in many states, broad risk factors such as climate change, seismic events, and flooding make their initial impact on **geotechnical assets** such as slopes, embankments, and retaining walls. Damages to these assets then affect the condition, safety, mobility, and maintenance costs of a roadway corridor. Therefore, even though geotechnical assets are not explicitly referenced in the federal legislation, they nonetheless form a critical link in a comprehensive risk-based and data-driven transportation asset management plan. This explains why state DOTs are evaluating adoption of geotechnical asset management practices that include an inventory, periodic condition survey, deterioration models, and life cycle cost analysis.

Geotechnical assets represent a significant investment by the Department to enhance the function and performance of the transportation system. They are expensive to build and maintain, and they represent a major component of the state's transportation infrastructure. Managing these assets to reduce the hazards and risks posed by failures and to contain the demands these interruptions place on Department resources and the public is clearly in the best interest of the Department. Applying Asset Management principles to this effort can greatly assist with documenting progress and planning for future investments.

1.2 Overview of Development of AKDOT&PF's GAM Program

Work on AKDOT&PF's innovative GAM program was conducted under multiple tasks, commonly referred to as Phase I, Phase II, Phase III, and the Tongass Corridor Study. The Phase III work is the subject of this current report, but it incorporates inventory and analysis decisions made in the other research studies.

Phase I initiated the Unstable Slopes Management Program (USMP) in 2008-2009. The research was conducted by Scott Huang, et. al. at the University of Alaska, Fairbanks. It consisted of a review of existing unstable slope management systems, and provided guidance on how these systems could be adjusted to meet Alaska's unique needs.

Phase II refined the recommendations made in Phase I, testing the proposed inventory and rating methods on approximately 100 rock slopes, unstable soil slopes, and embankments that presented frequent maintenance concerns. This phase also included the development of initial service life and performance measures for rock slopes, unstable soil slopes and embankments, and retaining walls.

Among other research tasks, the Tongass Corridor Study tested application of rating and inventory methods used in Phase II on a corridor-scale. This led to the development of acceptance criteria for the various geotechnical assets and finalized rating categories to use with inventoried rock slopes, soil slopes and embankments, and retaining walls statewide.

Phase I and Phase II work is discussed in greater detail in Appendix A. Work on the Tongass Corridor Research Study informed decisions made in the GAM program, but it also included significant independent research work. The final report for the Tongass Corridor Study is projected to be available from the Department in late 2017.

1.3 Goals for Phase III of the AKDOT&PF GAM Program

This final report details what is effectively Phase III of AKDOT&PF's geotechnical asset management program. Phases I and II focused on development of an Unstable Slopes Management Program (USMP), but they laid the groundwork for the current GAM program. Research conducted in these earlier phases is discussed in greater detail in Section 0.

Goals for Phase III in the research and development work for AKDOT&PF's GAM program included the following:

- Expansion of the initial Phase II inventory and rating work to unstable slopes on NHS routes statewide.

- Development of inventory and rating procedures for retaining walls, followed by field tests and implementation.
- Incorporation of data from the Material Site Inventory (MSI) project into AKDOT&PF's GAM program. September 30, 2015 marked the completion of the MSI project, conducted by R&M Consultants of Anchorage. Data collected for the MSI was used to develop asset management measures similar to those for the other inventoried geotechnical assets described in this report.
- Design a road map for maintaining the existing geotechnical asset dataset and expanding it to cover additional transportation corridors where practical.
- Development of Condition State criteria for all geotechnical assets following the Good/Fair/Poor condition groups recommended at the federal level for Transportation Asset Management (TAM) programs.
- Development of Asset Valuation methods for all geotechnical assets for use in department-level planning and budgeting.
- Creation of generalized Action Levels for a given geotechnical asset based on Condition State, which include the mitigation options likely to be most appropriate for treating an asset in a particular Condition State.
- Derivation of first-generation Deterioration Models for all geotechnical assets that can be used to project worsening conditions and increased maintenance costs posed by aging geotechnical assets.
- Development of Life Cycle costs for all geotechnical assets, for use in developing department budgets at the multi-year level.

These goals are addressed in the various sections of this report, as broadly summarized in Table 1-1 below. This final phase built on previous inventory and assessment work to develop TAM-compatible asset management tools. The previous projects are discussed to a limited extent in Section 0 of this report, and some project-specific reports are also available from the Department or included as appendices to this report.

Table 1-1: Report Sections for the research goals identified for finalization of AKDOT&PF's Geotechnical Asset Management Program.

GAM Project Phase III Goals	Report Section
Expansion of inventory and rating work for rock slopes, unstable soil slopes, and retaining walls to NHS routes statewide.	Section 2
Development of inventory and rating procedures for retaining walls, followed by field tests and implementation.	Section 2
Incorporation of data from the Material Site Inventory (MSI) project.	Sections 2 - 11
Development of Condition State criteria for all geotechnical assets following the Good/Fair/Poor condition groups recommended at the federal level for Transportation Asset Management (TAM) programs.	Section 3
Demonstrate example applications of the geospatial asset database in cost-effective department workflow.	Section 4, Section 8
Derivation of first-generation event likelihoods based on asset condition, and initial risk monetization.	Section 5

Development of Asset Valuation methods for all geotechnical assets for use in department-level planning and budgeting.	Section 6
Derivation of first-generation Deterioration Models for all geotechnical assets.	Section 7
Development of Life Cycle costs for all geotechnical assets, for use in developing department budgets at the multi-year level.	Section 8
Creation of generalized Action Levels for a given geotechnical asset based on Condition State, including generalized mitigation options.	Section 9
Design a road map for maintaining the existing geotechnical asset dataset and expanding it where practical.	Section 10

This project is the first of its kind and therefore should be reexamined in the future, comparing costs and deterioration rates against repeat condition assessments. Ideally, repeat inventory and assessment work visiting many sites in a single summer work period will be conducted approximately every decade network-wide and at five years on NHS highways. As the AKDOT&PF GAM program matures and a more extensive dataset becomes available, it is recommended that the data and preliminary correlations developed for asset valuation, deterioration, and life cycle cost be revisited.

1.4 Assets in the Alaska Geotechnical Asset Management Program

Four geotechnical asset types are included for inventory and evaluation in AKDOT&PF's Geotechnical Asset Management (GAM) program:

- Rock Slopes (1,001 assets inventoried),
- Unstable Soil Slopes and Embankments (631 assets inventoried),
- Retaining Walls (411 assets inventoried),
- Material Sites (2,919 assets inventoried).

Rock slopes are unstable slopes which are capable to producing rockfall. Rockfall events can vary in size and failure type and can consist of many rocks or one larger block. Along roads, these slopes may be naturally occurring, but typically, they have been cut in the past as part of road construction. Based on when the road was built, ditch and slope geometry may differ considerably from modern construction standards. In the GAM project, all rock slopes are assumed to be inherently unstable, but only those likely to impact the roadway in the event of failure were inventoried.

Unstable soil slopes and embankments include natural and/or constructed soil cut or fill slopes with landslides, debris flows, and/or exhibiting instability related to permafrost melt. It is a broad asset category that covers both slopes and debris flow channels that deposit material on the road and settlement displacement caused by failures in thawing ground. As with rock slopes, soil slopes may be naturally occurring, but have often been cut or loaded as part of roadway construction. By definition, all embankments have been built. Because well engineered and constructed embankments and soil slopes can remain stable indefinitely, only those assets already exhibiting signs of instability were inventoried. Note that rock slopes and unstable soil slopes and embankments were initially assessed as part of the Unstable Slope Management Program (USMP). Due to this history, the term *unstable slopes* is often used to refer to all rock slope and unstable soil slope and embankment assets. A more detailed discussion of inclusion and rating criteria for unstable slopes are provided in Section 2.1.

Retaining wall is synonymous with "earth retaining system," which is defined as "any structure intended to stabilize an otherwise unstable soil mass by means of lateral support or reinforcement" (Sabatini 1997). The retaining wall types in AKDOT&PF's asset management program include:

- Anchored
- Bin
- Cantilever
- Crib
- Gravity
- Mechanically stabilized earth
- Pile
- Rockery
- Soil Nail

In general, all of the assessed walls have the ability to negatively impact the roadway in the event of failure. This is determined by professional judgement, but is generally based on wall height and proximity to the roadway. Walls which are related to bridges are already inventoried and inspected by the department's Bridge Group, and therefore were not added to the GAM program dataset. A more detailed discussion of inclusion and rating criteria for retaining walls are provided in Section 2.3.

Material sites in the GAM program are operated by AKDOT&PF or they are sites in which the Department has an interest. These sites produce a range of products; from high-quality aggregates to lower-quality borrow materials. Over 2,000 material sites are included in the current Material Site Inventory (MSI) developed by R&M consultants between 2007 and 2015. Not all of these sites are currently open or available for department use. Because material sites are a source of construction material, they are generally located near the transportation corridor, but rarely pose a threat to continued corridor function should any adverse incidents take place at the actual material site. Instead, these assets are evaluated in terms of identifying potential material scarcity within a given area, since a lack of quality material can affect maintenance operations, increase construction project costs, or force the use of substandard materials. The work on rating and valuing material sites is discussed in Section 2.4 and 3.5 of this report.

1.5 Literature Review

As part of the initial scope of work for this project, Landslide Technology personnel and subconsultants Paul Thompson and PanGEO conducted an updated literature review to gain an overview of the current state of the practice for asset management and performance measures. This review built on an initial review that was part of earlier project phases and focused on the development and test implementation of the Unstable Slopes Management Program (USMP). A compiled bibliography of the updated literature review is included as Appendix B.

1.6 Additional Research on Integrating GAM Assets with Corridor-Level Performance

A central, logical goal of the information gained from the GAM projects is development of a performance index than can be used to evaluate a segment of the transportation system, referred to as a transportation corridor. This index is based on a combination of the conditions of all assets, including both GAM and TAM assets, located within that part of the corridor. The Corridor Health Index, based on work done as part of the GAM research study for the Tongass Highway Corridor, was developed to meet this goal. In essence, the health index uses the minimum acceptable Condition State of an asset and then computes the proportion of assets in the evaluated segment that meet this minimum standard. By weighting the individual asset types, an overall health index is developed that measures how well the corridor and the state's investment strategies are serving to meet the department goals, which likely would vary depending on the highway class, i.e., major arterial, minor arterial, or local collector.

The Tongass GAM Research Project – Final Report (Report Number STP4000(126)(B)) presents the Corridor Health Index and associated models and formulas in detail.

1.7 Report Authorship

This research report is the product of collaboration between many authors. All contributors reviewed the work of others, and provided guidance and feedback in the various sections. However, various sections had different lead authors, as noted below:

Landslide Technology:

- Executive Summary
- Section 1: Introduction
- Section 2: Summary of Asset Inventory Work
- Section 3: Development of Asset Condition Index and Condition State
- Section 4: Utilizing Rating Data for Geospatial Analysis
- Section 6: Cost Estimation for Improvement of Department Geotechnical Assets
- Section 9: Alternative Actions Based on Condition State
- Section 10: Effective Utilization of the GAM Database
- Section 11: Recommendations

Paul D Thompson:

- Section 5: Risk Aspects for Geotechnical Assets
- Section 7: Development of Asset Deterioration Measures and Risk Analysis Methods
- Section 8: Incorporation of the GAM into Long-Term Planning, with select sections with LT as lead author.

2 SUMMARY OF ASSET INVENTORY WORK

The best way to track how well the Department is managing its geotechnical assets is to gather current performance data and then to track future performance. Conducting an asset inventory and condition survey establishes the performance starting point. Currently, AKDOT&PF's GAM program contains at least partial inventories of the following four asset types:

- Rock Slopes
- Unstable Soil Slopes and Embankments
- Retaining Walls
- Material Sites

Under AKDOT&PF's GAM project, clear, concise, and repeatable field procedures were developed and tested for rating the Department's unstable soil slope, rock slope, and retaining wall assets. The procedures for rating rock slopes, unstable soil slopes, and embankments were developed as part of the Unstable Slope Management Program (USMP). Procedures for rating and assessing retaining wall assets were developed as part of the Tongass Corridor GAM study, and ultimately codified as the Retaining Wall Management Program (RWMP). Inventory work on AKDOT&PF's Material Sites was performed as part of the Material Site Inventory (MSI) project by R&M consultants.

Asset inventory work completed to date is briefly summarized in this section. Field rating guides providing more detailed instruction on field procedures for assessing/inventorying rock slopes, unstable soil slopes/embankments, and retaining walls are enclosed with this report as Appendices C, D, and E, respectively. Reference to these guides in future fieldwork will enable quick assessment of asset performance over time, and assist the agency in tracking its progress towards department goals. The information obtained through these field ratings are applicable for ongoing progress reports to remind the public of the importance of continued monitoring in strategic planning.

2.1 Rock Slope Assets

In 2008, AKDOT&PF initiated work on its Unstable Slope Management Program (USMP) which inventoried and assessed rock slopes and unstable soil slopes/embankments. The USMP has since been fully incorporated into the GAM Program, but due to this history, is still common to find the term *unstable slopes* used to describe rock slopes, unstable soil slopes, or embankments, particularly in older documents. Because the USMP included all of these asset types, inventory work for rock slopes, unstable soil slopes, and embankments was all conducted at the same time. Therefore, there is significant overlap between Section 2.1 and Section 2.2 when discussing asset inventory development.

2.1.1 Summary of Work on Rock Slope Assets

Work on an inventory and assessment program for AKDOT&PF's unstable slopes began in 2009. To date, it has consisted of three distinct phases:

- Unstable Slope Management Program (USMP) Phase 1
- Unstable Slope Management Program (USMP) Phase 2
- As a component of the current GAM program

A brief summary of the work, focusing on the inventorying and rating of rock slope assets is provided in this section. A more detailed summary can be found in Appendix C. The USMP

Phase 1 resulted in a formal report, which is available from the Department. More detailed information on the Phase 2 work is also available from the Department upon request.

2.1.1.1 USMP Phase I

Phase I of the USMP project was a research project conducted by Scott Huang, et.al. at University of Alaska, Fairbanks, under contract with AKDOT&PF, in 2009. The project surveyed nine rock/soil slope asset management programs developed by other states and countries and provided recommendations to AKDOT&PF as it began development of its own USMP program.

The Phase I study recommended a multi-phase rating process for sites inventoried under the USMP. An initial rating by Maintenance and Operations (M&O) personnel to identify critical slopes would be followed by a detailed assessment conducted by a geotechnical engineer or engineering geologist.

The initial M&O rating was broken into two separate forms, the M&O Unstable Slope Incident Report and the M&O Preliminary Rating form. The Slope Incident Report was intended for routine use by M&O personnel to better capture slope performance data. The Preliminary Rating Form was to be filled out by M&O supervisors once for each unstable slope site. It would collect site information and historical performance (e.g., event size, frequency, required maintenance). Collecting this data from M&O would help field inspectors eliminate low hazard slopes, economizing the more time intensive detailed slope rating process.

After reviewing the M&O data, a geotechnical engineer or engineering geologist would perform a detailed unstable slope assessment rating. Slopes would be scored in a variety of hazard and risk rating categories. The individual scores from the hazard and risk categories would then be added together to obtain the total site score. A major addition in the hazard rating section was the incorporation of criteria for rating frozen ground and the potential impact of freeze-thaw cycles on the mechanical weathering of slopes.

Completion of the Phase I study laid the groundwork for subsequent phases of the AKDOT&PF USMP development. For example, the proposed M&O Unstable Slope Incident Report proved too cumbersome to adopt by often busy M&O personnel at the time, but thanks to advances in online data collection and the growth of AKDOT&PF's Transportation GIS service, it is very similar to the service now provided by the Geotechnical Event Tracker, which is discussed in Section 10.

2.1.1.2 USMP Phase II

Applying the Phase I research, AKDOT&PF, with technical support from Landslide Technology and R&M Consultants, started work on Phase II. This portion of the project included both field inventory work and initial work on developing service life classifications, probable mitigation/intervention based on asset condition, and benefit / cost indices for unstable slopes.

In this section summarizing asset inventory work, only the portion of Phase II research related to finalizing rating criteria and conducting field work is discussed. Other components of the Phase II research are touched on in Section 9 and discussed in greater detail in Appendix A.

2.1.1.2.1 Final Rock Slope Rating Categories

The rating forms proposed in the Phase I report were finalized, along with the cutoffs, descriptions, and scoring of the proposed categories. The proposed M&O Incident Report was incorporated into the M&O Preliminary Report, which now consisted of seven rating categories. The total number of evaluated categories for soil and rock slopes was also equalized, so that each slope type had the same possible maximum point value, and comparison of slopes across the state was simplified.

For all categories, the allowable scores range from 1 to 100, where 1 is the best possible score and 100 is the worst. For those rating categories which are not directly scored through equations, the field rater estimates the most reasonable score based on professional judgement, input from maintenance personnel, and past performance history. The maximum possible Hazard Rating score for a rock slope is 800 points from eight categories. The maximum possible Risk Rating score for an unstable slope is 900 points (nine categories). Scores from the Risk Rating and Hazard Rating categories are summed to calculate the total USMP score for a site.

Collectively, the hazard ratings seek to quantify the likelihood that a rockfall event will occur at a site and affect the roadway, requiring some level of maintenance response. The risk ratings assess the consequences and inconvenience which an event will pose to the travelling public and the potential costs of this event, resulting from maintenance involvement, slope or roadway repairs, or right of way purchase should the failure extend beyond current ROW boundaries. The various rating categories are summarized in Table 2-1. The Hazard and Risk Rating categories are described in detail in the Rock Slope Field Rating Guide in Appendix C.

Table 2-1: Rock slope asset rating categories with Preliminary rating categories and hazard and risk detailed rating categories.

Preliminary Rating Categories	**Hazard Rating Categories**		**Risk Rating Categories**
Frequency Roadway is Affected – Historic Activity	Geologic Condition - Case 1	Structural Condition	Roadway Width
		Rock Friction	
Maintenance Action Required – Historic Activity	Geologic Condition - Case 2	Structural Condition	Annual Average Daily Traffic (AADT)
		Difference in Erosion Rates	
Event Volume/Size or Length of Roadway Affected – Historic Activity	Ditch Effectiveness		Average Annual Vehicle Risk (AVR)
Potential for Event to Affect Roadway – Historic Activity	Maintenance Frequency		Percent Decision Sight Distance
Roadway Impacts	Rockfall History		Potential Impact on Traffic
Traffic Impacts	Block Size/Event Volume		Right of Way Impacts
Decision Sight Distance	Slope Height		Environmental Impacts
	Water on Slope	Annual Precipitation	Maintenance Complexity
		Slope Drainage	Event Cost

2.1.1.2.2 Initial Inventory and Assessment Work

After finalizing the rating categories, researchers field-tested them by inventorying the "Top 100" unstable slopes on AKDOT&PF-maintained roads in 2010 and 2011. Working with the superintendents of the Department's three maintenance regions and geotechnical personnel familiar with the highway system, they compiled a list of unstable slopes regularly required maintenance effort or were a source of maintenance concern. This was then winnowed down to a final list of 105 critical sites, consisting of both soil and rock.

However, some of the indicated sites covered several highway miles. For example, the Anchorage maintenance district provided one rock slope "site" along the Seward Highway that spanned Milepost 104 to Milepost 115. During the field ratings, it was divided into smaller individual rock cuts to improve rating clarity and make slope activity easier to monitor in the future.

During the Phase II field work, 123 rock slopes received detailed ratings and were added to the asset database and to a publicly accessible online map.

2.1.1.3 Expanded Inventory and Assessment Work in the GAM Program

The GAM Program absorbed the Phase I and II USMP research and expanded it to the rest of Alaska's NHS routes. Starting in November 2013, Landslide Technology conducted rock slope evaluations in the Tongass Corridor, as part of the Tongass GAM Research Project. The M&O Preliminary Maintenance Rating was eliminated from the rating process because of the time it required from Maintenance personnel if inventory work was expanded statewide. The research group also developed basic acceptance criteria for the rock slope asset database that used a three-tier rock slope classification system.

- *Class A*: Capable of producing rockfall that reaches the roadway, have a history of doing so, require regular unscheduled maintenance attention, or could have impacts beyond the right-of-way (Figure 2-1)
- *Class B*: Unlikely to produce rockfall that reaches the roadway, but have an infrequent history of producing rockfall or of requiring unscheduled maintenance attention (Figure 2-2)
- *Class C*: Highly unlikely to produce rockfall that will affect the roadway or private property (Figure 2-3)

A more detailed discussion of the difference between *Class A, Class B,* and *Class C* rock slopes with more examples is provided in the Rock Slope Field Rating Guide in Appendix C.

Figure 2-1: Class A rock slope due to adverse geologic character, activity levels, and insufficient ditch catchment. Klondike Hwy MP 3.9.

Figure 2-2: Class B rock slope. The slope does not pose a safety concern, but the consequence of rockfall events blocking the ditch and culverts, leading to sheet flow over the road, warrants inclusion into the database. Steese Hwy MP 86.5.

Figure 2-3: Class C rocky slope. Excluded from database due to stable configuration and short height. Either criteria would be sufficient. This could also be reasonably judged a soil slope due to the small rock size. Parks Hwy, approximately MP 340.

After finishing assessment work on the Tongass Corridor, the research team started inventory and assessment work on NHS routes statewide in August 2014. Routes were divided between

R&M and LT to conducting as many field ratings as possible during the summer months. Rezanof Drive on Kodiak Island and the Dalton Highway were the only NHS routes not evaluated in 2014. On Kodiak, the Pillar Mountain rock slope, the major rock slope on Rezanof Drive, was in the design phase for rockfall mitigation. Final inventory work on the Dalton Highway concluded in August 2015.

In total, field inspectors from LT and R&M added 874 rock slopes to the rock slope asset database. Of these, 601 were identified as *Class A* rock slopes and received detailed ratings. The remaining 273 sites were *Class B* rock slopes that were entered into the database, but did not receive a detailed rating.

In addition to the sites collected during periods of organized inventory expansion, other sites were added occasionally to the database between 2010 and 2015. Typically, these were sites that either were mitigated, and M&O requested that the site be reevaluated to reflect the positive effect of the mitigation work, or they were sites that became increasingly active and M&O requested they be reevaluated to capture the ongoing deterioration. As of September 1 2015, the rock slope asset database contained 1,003 sites, of which 274 are *Class B* slopes. Figure 2-4 shows the location of *Class* A rock slope assets inventoried along NHS routes.

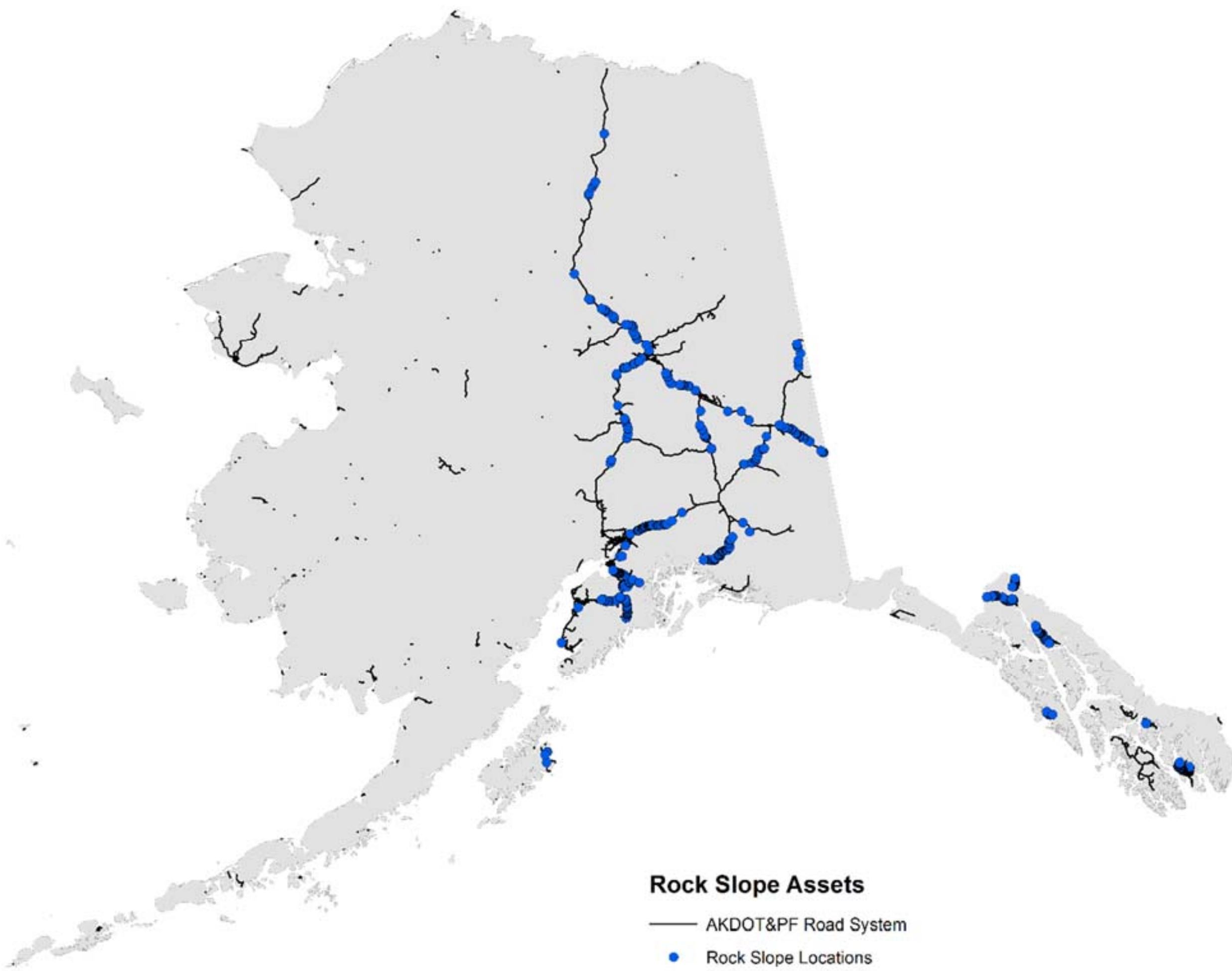

Figure 2-4: Locations of rock slope assets inventoried and given a detailed evaluation as part of the Unstable Slope Management Program.

2.1.2 Rock Slopes - Total Unstable Slope Management Program (USMP) Scores and Correlation with Condition States

The goal of the USMP project was to create a system for AKDOT&PF to inventory and assess unstable slopes affecting the state transportation system using uniform practices, for integration into the statewide GAM program. Under this framework, both soil and rock slopes have the same total possible score, and site score correlates to the level of combined hazard and risk posed to the department by these unstable slopes. The total site score is calculated by summing the individual category scores in the detailed Hazard and Risk rating categories. Since the maximum possible Hazard score is 800 points and the maximum possible Risk Score is 900 points, the maximum possible score for an unstable slope under AKDOT&PF's USMP rating system is 1700 points. To date, the highest total score recorded for a rock slope in the USMP database is 890.

As described in Section 3, select rock slope Hazard Rating categories are used to calculate the Condition State of a rock slope and to group the sites into one of three broad categories: Good, Fair, or Poor. This Condition State is consistent with established TAM terminology and can be more easily used in statewide planning. The three Condition State classifications describe how well a slope is meeting agency expectations. Rock slope Condition State is derived from scores in the "Rockfall Activity" and "Ditch Effectiveness" Hazard Rating categories. Slope condition is link to aspects that deteriorate rather that to the risk posed by a slope failure. Therefore, categories from the Risk Rating are not used in Condition State calculations.

Based on a histogram analysis of Hazard and Risk scores, approximate detailed rating score ranges for both rock slope assets in each of the three Condition States were developed. The results of these analyses are summarized in Table 2-2. The histogram analysis displayed good correlation between hazard scores and Condition State, but because no risk category scores are used in calculating slope Condition State, correlations with the Risk Rating scores are less clear. Still, there is a general trend toward higher risk scores correlating to poorer Condition State sites since maintenance costs and traffic impacts rise for larger, more disruptive events. The score ranges extracted from the USMP database and presented in the table below are provided for general reference. They do not replace the calculations used to determine site-specific Condition States, which are described in Section 3.

Table 2-2: Rough correlation between Hazard, Risk, and Total USMP scores and rock slope Condition States, based on histogram review.

Condition State	Hazard Score Range	Risk Score Range	Total Score Range
Good	0-174	0-74	0-249
Fair	175-349	75-124	225-474
Poor	350+	125+	475+

2.2 Unstable Soil Slope and Embankment Assets

As mentioned in the previous section, there is significant overlap between Section 2.1 and Section 2.2 when discussing the development of rock slope, unstable soil slope, and embankment asset inventory procedures. All of these asset types were originally all inventoried under the Unstable Slope Management Program (USMP). Inventory work is therefore summarized more briefly in this section. For a more detailed description of various phases of USMP development, particularly to the research components of Phase I and Phase II, please refer to the previous section or to the USMP development history document in Appendix A.

The USMP has since been fully incorporated into the GAM Program, but due to this history, is still common to find the term *unstable slopes* used to describe rock slopes, unstable soil slopes, or embankments, particularly in older documents.

2.2.1 Summary of Work on Unstable Soil Slope and Embankment Assets

The USMP survey inventoried rock slopes and unstable soil slopes and embankments using similar metrics. However, differences between the asset types are reflected in the different database acceptance criteria for the two asset types, and unique rating categories in the hazard component of the total USMP score.

2.2.1.1 USMP Phase I

Phase I of the USMP project was a research project conducted by Scott Huang, et.al. at University of Alaska, Fairbanks, under contract with AKDOT&PF, in 2009. The study noted that none of the surveyed nine rock/soil slope asset management programs developed by other states and countries included metrics to assess instabilities related to frozen ground, and very few of them provided a way to assess failures in soil slopes or embankments.

As discussed in the previous section, the researchers recommended a multi-phase rating process for sites inventoried under the USMP. An initial rating by Maintenance and Operations (M&O) personnel to identify critical slopes would be followed by a detailed assessment conducted by a geotechnical engineer or engineering geologist. In order to capture the potential impacts of Alaska’s extreme environment on slope instability, the team made initial recommendations for rating categories that would incorporate frozen ground and the potential impact of freeze-thaw cycles on the mechanical weathering of slopes. Detailed information on the development of these rating categories can be found in the Phase I report (Huang and Darrow 2009).

Completion of the Phase I study laid the groundwork for subsequent phases of the AKDOT USMP development. The new hazard rating categories for frozen ground impacts were refined prior to field work in Phase II, and are presented in the Unstable Soil Slope and Embankment Field Rating Guide in Appendix D.

2.2.1.2 USMP Phase II

Applying the Phase I research, AKDOT&PF, with technical support from Landslide Technology and R&M Consultants, started work on Phase II. This portion of the project included both field inventory work and initial work on developing service life classifications, probable mitigation/intervention based on asset condition, and benefit cost indices for unstable slopes.

In this section summarizing asset inventory work, only the portion of Phase II research related to finalizing rating criteria and conducting field work is discussed. Other components of the Phase II research are touched on in Section 9 and discussed in greater detail in Appendix A.

2.2.1.2.1 Final Unstable Soil Slope and Embankment Rating Categories

The rating forms proposed in the Phase I report were finalized, along with the cutoffs, descriptions, and scoring of the proposed categories. The M&O Preliminary Report, which incorporated the M&O Slope Incident Report, had the same categories for both rock slope and unstable soil slope and embankment assets. The total number of evaluated categories is identical for both rock slope and unstable soil slope and embankment assets, so that each slope type had the same possible maximum point value, and comparison of slopes with the USMP program was simplified.

As with rock slopes, the allowable category scores range from 1 to 100, where 1 was the best possible score and 100 was the worst. For those rating categories which are not directly scored through equations, the field rater estimates the most reasonable score based on professional judgement, input from maintenance personnel, and past performance history. Like for rock slopes, the maximum possible Hazard Rating score for an unstable soil slope or embankment is 800 points and the maximum possible Risk Rating score is 900 points. Scores from the Risk Rating and Hazard Rating categories are summed to calculate the total score for a site.

The various rating categories are summarized in Table 2-3. The Hazard and Risk Rating categories are described in detail in the Unstable Soil Slope and Embankment Field Rating Guide in Appendix D.

Table 2-3: Unstable soil slope and embankment asset rating categories with M&O preliminary rating categories and hazard and risk detailed rating categories.

<table>
<tr><th>M&O Preliminary Rating Categories</th><th colspan="2">Hazard Rating Categories</th><th>Risk Rating Categories</th></tr>
<tr><td rowspan="2">Frequency Roadway is Affected – Historic Activity</td><td colspan="2">Length of Roadway Affected</td><td rowspan="2">Roadway Width</td></tr>
<tr><td colspan="2">Thaw Stability</td></tr>
<tr><td rowspan="2">Maintenance Action Required – Historic Activity</td><td colspan="2">Roadway Impedance</td><td rowspan="2">Annual Average Daily Traffic (AADT)</td></tr>
<tr><td colspan="2">Maintenance Frequency</td></tr>
<tr><td>Event Volume/Size or Length of Roadway Affected – Historic Activity</td><td colspan="2">Roadway Displacement or Slide Deposit</td><td>Average Annual Vehicle Risk (AVR)</td></tr>
<tr><td>Potential for Event to Affect Roadway – Historic Activity</td><td colspan="2">Movement History</td><td>Percent Decision Sight Distance</td></tr>
<tr><td>Roadway Impacts</td><td colspan="2">Axial Length of Slide</td><td>Potential Impact on Traffic</td></tr>
<tr><td>Traffic Impacts</td><td rowspan="4">Water on Slope</td><td rowspan="4">Average of Annual Precipitation and Slope Drainage</td><td>Right of Way Impacts</td></tr>
<tr><td rowspan="3">Decision Sight Distance</td><td>Environmental Impacts</td></tr>
<tr><td>Maintenance Complexity</td></tr>
<tr><td>Event Cost</td></tr>
</table>

2.2.1.2.2 Initial Inventory and Assessment Work

After finalizing the rating categories, researchers worked with the superintendents of AKDOT&PF's three maintenance regions and geotechnical personnel familiar with the highway system to compile a list of unstable slopes regularly requiring maintenance effort or a source of maintenance concern. These "Top 100" (technically 105) unstable slopes were used to field-test the proposed rating categories.

As with the rock slopes, some of these "Top 100" sites covered several highway miles, particularly in permafrost-impacted terrain. For example, the Tok maintenance district provided one unstable embankment site along the Taylor Highway that was 19 miles long. During the field ratings, these types of sites were divided into smaller unstable roadway segments, particularly if they were separated by soil slopes or embankments that exhibited good performance. This improves rating clarity and makes slope activity easier to monitor in the future.

During the Phase II field work, 69 unstable soil slopes or embankments received detailed ratings and were added to the asset database and to a publicly accessible online map.

2.2.1.3 Expanded Inventory and Assessment Work in the GAM Program

The GAM Program absorbed the Phase I and II USMP research and expanded it to the rest of Alaska's NHS routes. Starting in November 2013, Landslide Technology conducted unstable soil slope and embankment evaluations in the Tongass Corridor, as part of the Tongass GAM Research Project. Unlike rock slopes, soil slopes cut or constructed to a stable angle can remain stable indefinitely, unless impacted by external threats, such as river erosion. This is true for both cut slopes and well-constructed earthen embankments. In order to keep the inventory fieldwork within reasonable bounds of time and budget, and hold the database to a reasonable size, soil slopes deemed to be stable were not entered into the USMP database. In the case of debris flows and river erosion, all sites that exhibit these types of instabilities with the capacity to affect the roadway and/or that require maintenance action to protect or preserve the roadway were rated and entered into the USMP database.

As discussed previously, the M&O Preliminary Maintenance Rating was eliminated from the rating process because of the time it required from Maintenance personnel if inventory work was expanded statewide. The research group also developed basic acceptance criteria for the unstable soil slope and embankment asset database that used a three-tier classification system.

- *Class A*: Slopes exhibiting signs of instability that could affect public safety, require regular maintenance action, or threaten the functionality of the surrounding infrastructure in the event of a failure. In addition to the classic slope failure types, segments exhibiting clear signs of settlement or instability due to freeze-thaw processes are also treated as *Class A* soil slope sites. (Figure 2-5)
- *Class B*: Slopes exhibiting signs of minor instability but which are relatively short with a wide ditch, have required little or no unscheduled maintenance attention in the past, or that are deemed unlikely to require maintenance attention in the future. Slopes that can be reasonably assumed to be threatened by future erosion were also included in the *Class B* category. (Figure 2-6)
- *Class C*: Slopes exhibiting no signs of instability and/or are highly unlikely to affect the roadway in the event of failure (Figure 2-7)

A more detailed discussion of the difference between *Class A, Class B,* and *Class C* sites with more examples is provided in the Unstable Soil Slope and Embankment Field Rating Guide in Appendix D.

After finishing assessment work on the Tongass Corridor, the research team started inventory and assessment work on NHS routes statewide in August 2014. Routes were divided between R&M and LT to conducting as many field ratings as possible during the summer months. Final inventory work on the Dalton Highway concluded in August 2015.

Between November 2013 and August 2015, field inspectors from LT and R&M added 534 sites to the unstable soil slope and embankment asset database. Of these, 456 were identified as *Class A* unstable soil slopes or embankments and received detailed ratings. The remaining 78 sites were *Class B* sites that were entered into the database, but did not receive a detailed rating.

In addition to the sites collected during periods of organized inventory expansion, other sites were added occasionally to the database between 2010 and 2015. Typically, these were sites that either were mitigated, and M&O requested that the site be reevaluated to reflect the positive effect of the mitigation work, or they were sites that became increasingly active and M&O

requested they be reevaluated to capture the ongoing deterioration. As of September 1, 2015, the unstable soil slope and embankment asset database contained a total of 633 sites, of which 62 are *Class B* slopes. Figure 2-8 shows the location of *Class* A unstable soil slope and embankment assets inventoried along NHS routes.

Figure 2-5: Class A soil embankment. Roadway surface exhibiting thaw-unstable settlement with an uneven pavement surface. Alaska Hwy MP 1361.9.

Figure 2-6: Class B soil slope. Short soil cut exhibiting thawing permafrost. Site poses minimal safety risks, but appears to require ongoing minor maintenance attention to maintain the roadside ditch. Steese Hwy MP 68.4.

Figure 2-7: Class C soil slope: New soil cut is performing well and is not unstable at this time. Add to database only if instability develops. Parks Hwy MP 257.2

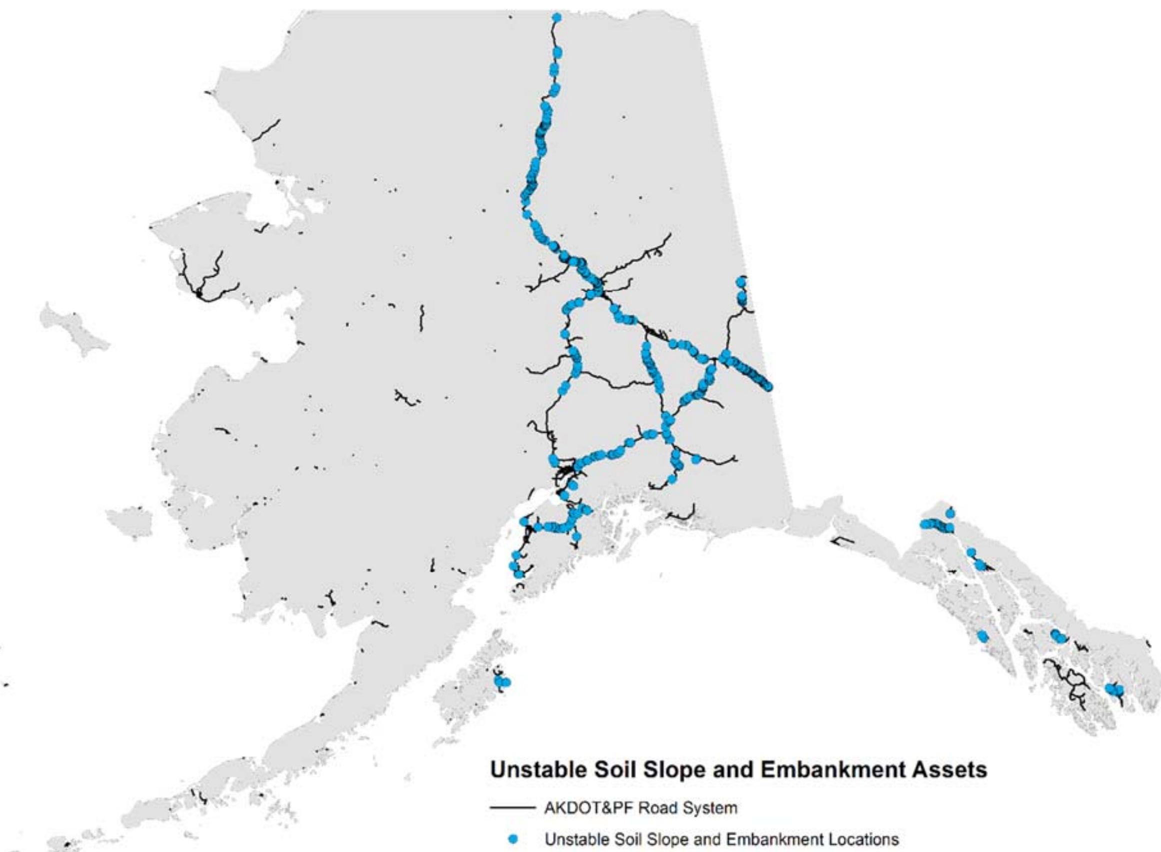

Figure 2-8: Locations of unstable soil slope and embankment assets inventoried and given a detailed evaluation as part of the Unstable Slope Management Program.

2.2.2 Soil Slope and Embankment Assets - Total Unstable Slope Management Program (USMP) Scores and Correlation with Condition States

Assessment work for both rock and soil slope/embankment assets initiated under the USMP project. Researchers intentionally developed the same total possible score for both rock and soil slopes. The total site score is calculated by summing the individual category scores in the detailed Hazard and Risk rating categories. The maximum possible score for an unstable slope under AKDOT&PF's USMP rating system is 1,700 points. To date, the highest total score recorded for an unstable soil slope or embankment is 1,064.

As described in Section 3, select USMP rating categories are used to calculate an asset's Condition State and assign it to one of three broad categories: Good, Fair, or Poor. This Condition State is consistent with established TAM terminology and is applicable in statewide planning. The three Condition State classifications describe how well a slope is meeting agency expectations. Soil slope and embankment Condition State is derived from scores in four of the Hazard Rating categories:

- Length of Affected Roadway
- Roadway Impedance
- Roadway Displacement, and
- Movement History

Slope instability is not linked to the risk posed by a slope failure; so, categories from the Risk Rating are not used in Condition State calculations.

Based on a histogram analysis of Hazard and Risk scores, researchers develop approximate detailed rating score ranges for soil slope assets in each of the three Condition States. The results of these analyses are summarized in Table 2-4. The histogram analysis displayed good correlation between hazard scores and Condition State. Since no risk category scores are used in calculating slope Condition State, correlations with the Risk Rating scores are less clear. Still, there is a general trend toward higher risk scores correlating to poorer Condition State sites since maintenance costs and traffic impacts rise for larger, more disruptive events. The score ranges extracted from the GAM database and presented in the table below are provided as guidelines for general reference. They do not replace the calculations used to determine site-specific Condition States, which are described in Section 3.

Table 2-4: Rough correlation between Hazard, Risk, and Total USMP scores and unstable soil slope/embankment Condition States based on histogram review.

Condition State	Hazard Score Range	Risk Score Range	Total Score Range
Good	0-149	0-49	0-199
Fair	150-299	50-99	200-399
Poor	300+	100+	400+

2.3 Retaining Wall Assets

Work on cataloguing the Department's retaining wall assets began with the development of the *Retaining Wall Inventory (RWI)*, a system-wide baseline inventory compiled by the Statewide Materials Section. The RWI captures general information into data fields describing location, classification (category, type, function), and dimension characteristics. Acceptance criteria, data field definitions, and process methodology are described in detail in the *Retaining Wall Inventory Procedures Manual* (last revised in February 2017), available from AKDOT&PF.

The RWI will be maintained by the Department as a baseline inventory, but it does not address condition assessment. In order to integrate retaining walls into the GAM program, Landslide Technology built on the RWI and developed the *Retaining Wall Management Program (RWMP)*. The RWMP assesses retaining walls by scoring them across a range of hazard, risk, and appearance categories. It will ultimately contain all retaining walls deemed capable of affecting the roadway in the event of failure, with the exception of those retaining walls related to bridge construction and already regularly inspected by the Bridge Group.

2.3.1 Summary of Work on the Retaining Wall Inventory (RWI)

Starting in 2012, AKDOT&PF began work internally on a Retaining Wall Inventory (RWI). Most of the work on the RWI desk study was completed between June and August 2014. An accompanying Retaining Wall Inventory Procedures Manual was also developed by AKDOT&PF (last revised February 2017).

The RWI is available on AKDOT's TGIS service as a geodatabase containing retaining wall locations, project history, construction data, and other information. It contains a point location for each wall, with various wall information in an associated attribute table. Data in the geodatabase originated from a desk study of AKDOT&PF As-Built Information located on the Department's Electronic Document Management System (Edocs), AKDOT&PF Construction Bid Tabs and the AKDOT&PF Bridge and Culvert Inventory. The location information in these various data sources was refined where possible by reference to Google Street View and the AKDOT&PF Digital Roadway Viewer. Information about the retaining wall in the geodatabase attribute table is drawn from AKDOT&PF As-Builts. A data dictionary (Appendix G) summarizes the information categories in the geodatabase.

As of May 2017, the RWI includes 1,318 walls, shown in Figure 2-9. The desk study has been field checked in select areas as part of work on the Retaining Wall Management Program (RWMP) described in the following section.

2.3.2 Summary of Work on the Retaining Wall Management Program (RWMP)

The Retaining Wall Management Program (RWMP) contains field assessment data necessary to develop TAM-compatible Condition States for the Department's retaining wall assets. It grew out of work on the Tongass Corridor GAM Test Project. The research team used the exponential scoring methods already applied in the USMP, but the majority of the rating categories were heavily altered or entirely new.

In addition to changes made in the Hazard and Risk Rating categories, a third sub-rating of Appearance was added. Because retaining walls are constructed typically of manmade materials, they follow a more uniform pattern than other geotechnical assets. This enables both inspectors with technical expertise and members of the general public with limited engineering experience to quickly form an opinion on wall condition based solely on its physical appearance. The new rating sub-score captures the general sense of how wall appearance reflects wall performance. The final rating categories are presented in Table 2-5.

The field rating procedures and category descriptions are described in detail in the Retaining Wall Management Program Field Rating Guide, presented in Appendix E.

Table 2-5: RWMP detailing rating categories for the hazard, risk, and appearance scores.

Hazard Rating Category	Risk Rating Category	Appearance Rating Category
Wall Height	Annual Probability of Complete Failure	Technical Appearance
Vertical and/or Horizontal Alignment	Potential Impact on Traffic	Public Perception
Roadway Displacement due to Wall Movement	Roadway Width	
Length of Roadway Affected	Average Annual Daily Traffic (AADT)	
Maintenance Frequency	Failure Impact on Roadway	
Wall Drainage System	Average Vehicle Risk within 100 feet of Wall Length	
Annual Precipitation	Percent Decision Sight Distance	
Critical Component Health	Right of Way Impacts	
Movement History	Environmental Impacts	
	Maintenance Complexity	
	Wall Failure Cost	

The LT research team conducted initial retaining wall inventory work in Ketchikan in June 2014, following development of the rating categories. Rated walls included all those owned by the Department that were greater than two feet tall, and all those whose ownership was unclear but whose failure could affect the roadway. In all, 97 retaining walls received detailed ratings as part of the Tongass Corridor GAM Study.

Based on the time and effort expended rating retaining walls in Ketchikan Borough, several changes were made to inventory and rating procedures going forward. Retaining walls assessed in the RWMP now generally meet the RWI's criteria for a *highway retaining wall* or *culvert headwall.* Assessed walls are:

- Not inside a bridge zone
- For highway walls: at least 4 feet tall at the point of maximum wall height
- For culvert walls: at least 6 feet tall at the point of maximum wall height
- Regardless of height or setback, if a wall showed evidence of developing problems that could impact the road, it was assessed in the RWMP

The bridge zone is defined in the Retaining Wall Inventory Procedures Manual. Retaining walls supporting bridges are evaluated by the Bridge Group, which conducts routine inspections under the Department's Bridge Management System. In general, bridge-related retaining walls whose length was less than twice the height of the bridge structure were not included in the condition rating campaign.

In 2015, the retaining wall inventory and assessment work was expanded to select NHS routes in the Central and Southcoast Regions, using the RWI database described in the previous section. A total of 113 retaining walls in Central and Southcoast Regions were added to the RWMP database during this field work. While inventorying and assessing retaining walls, the inspectors also field-verified the RWI and made a tracking sheet for walls that were not captured in the desk study, existed but did not meet inventory criteria, or that did not exist in the field.

As of May 2017, 210 retaining walls on NHS routes –and about 200 on non-NHS routes– have been field inventoried and assessed in Alaska, as is shown in Figure 2-9. Additional work remains to expand inventory coverage of this asset to the remaining NHS routes. Based on the RWI, AKDOT&PF owns/operates approximately 1,300 walls in the state. The inventory to date represents approximately 32% of AKDOT&PF's total walls.

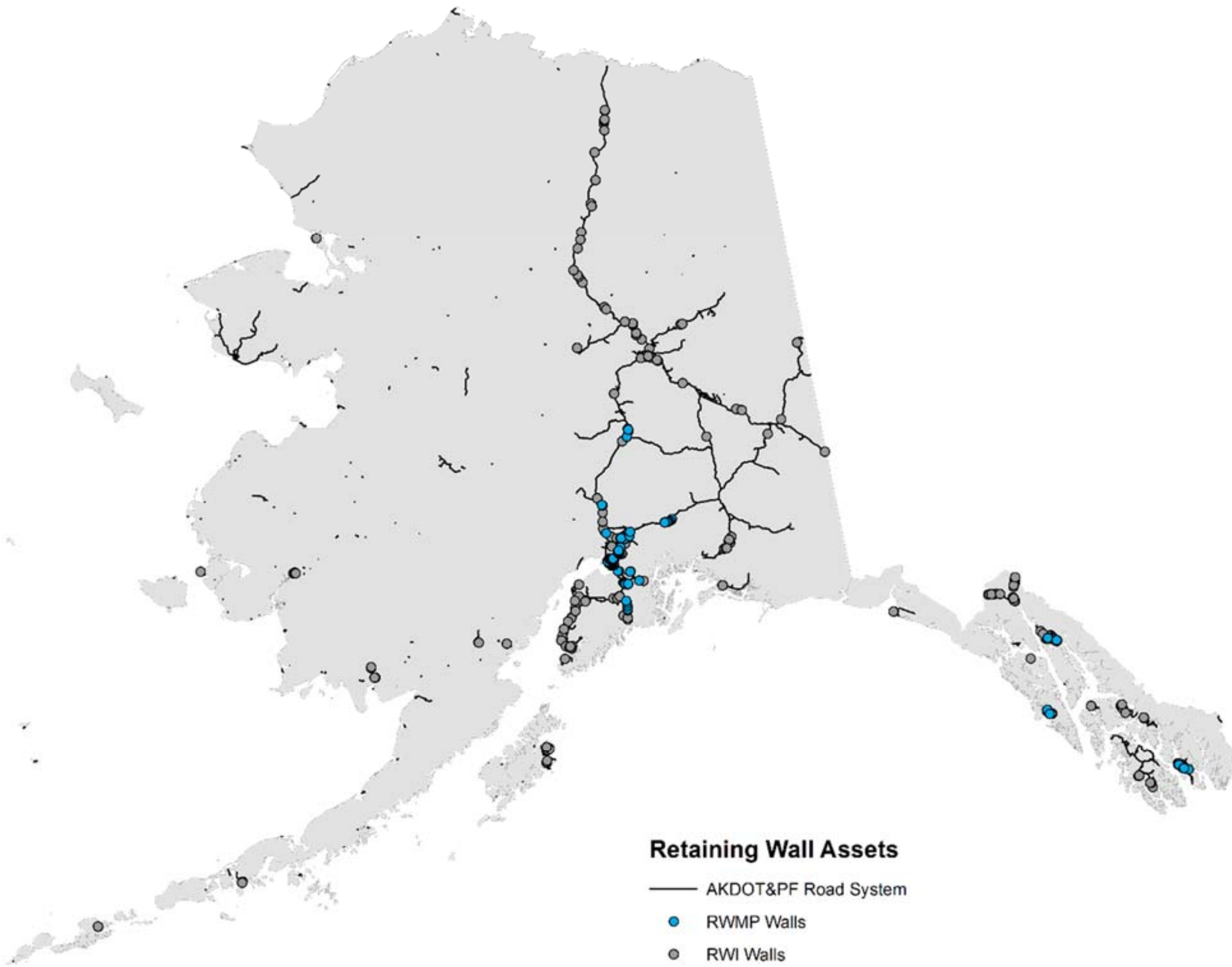

Figure 2-9: Statewide map showing retaining walls contained in the Retaining Wall Inventory (RWI) and retaining walls that have been evaluated as part of the Retaining Wall Management Program (RWMP).

2.3.3 Total Retaining Wall Management Program (RWMP) Scores and Correlation with Condition States

The goal of the RWMP is to create a process within the GAM Program for AKDOT&PF to inventory and assess retaining walls affecting the state transportation system using a uniform framework. Under this convention, each site has the same total possible score, and site score roughly correlates with level of hazard and risk posed to the Department by each retaining structure. The total score for a site is calculated by summing up the individual category scores in the detailed Hazard, Risk, and Perception rating categories. Since the maximum possible Hazard score is 900 points, the maximum possible Risk score is 1,100 points, and the maximum possible Perception score is 200, the maximum possible score for a retaining wall under AKDOT&PF's

RWMP rating system is 2,200 points. To date, the highest total score recorded for a retaining wall in the RWMP database is 1,074.

As described in Section 3.4, select RWMP hazard rating categories are used to classify the Condition State of a retaining wall into one of three groups: Good, Fair, or Poor. These Condition States are more easily applied to statewide planning tasks than the raw RWI scores. For retaining walls, Condition State is a derived from scores in three Hazard Rating categories:

- Vertical and Horizontal Wall Alignment
- Roadway Displacement Due to Wall Movement
- Critical Component Health

Based on a histogram analysis of Hazard, Risk, and Perception criteria scores for retaining walls in Good, Fair, or Poor Condition States, approximate detailed rating score ranges of wall assets in each Condition State were developed. These ranges for each criteria type are summarized in Table 2-6. These ranges are intended only as guides, and do not replace the calculations used to derive retaining wall Condition State, which are described in detail in Section 3.

Table 2-6: General correlation between the Hazard, Risk, and Perception criteria scores and the total RWI scores with the retaining wall Condition State, based on histogram analysis.

Condition State	Hazard Score Range	Risk Score Range	Perception Score Range	Total RWI Score Range
Good	0-149	0-149	0-49	0-349
Fair	150-224	150-299	50-149	350-674
Poor	225+	+300	150+	675+

2.4 Material Site Assets

R&M Consultants, Inc., conducted the Statewide Material Site Inventory (MSI), under AKSAS 76174/fed project number STP-000S(530) and AKSAS 76149/federal project number STP-000S(823). As part of the MSI, R&M collated pre-existing Material Site data collected and scanned from the extensive agency paper files and gathered new information through an on-site inspection process. The field procedures for inventorying and assessing Material Sites are documented as part of the MSI project, as described in the *Statewide Material Site Inventory Methodology Manual* (R&M Consultants, 2015).

Completed in September 2015, the MSI catalogued 2,919 unique material site locations documented on the road system, of which 920 are "active." **Active** sites are defined as currently used by DOT&PF and/or considered to have potential for use on future maintenance or construction projects. **Inactive** sites are those in which DOT&PF no longer has an interest and/or are no longer available for material extraction. Separated by region:

- Northern Region has over 680 active sites spread around approximately 3,400 road miles
- Central Region has over 190 active sites spread around approximately 1,700 road miles.
- Southcoast Region has over 40 active sites captured within this inventory over approximately 500 road miles. Note the Southcoast Region material needs are largely met with private sources.

The final documentation for the MSI is represented by a collection of reports, plus a geodatabase. The reports are accessed through a web-based interface[1], which also features an

[1] http://www.dot.state.ak.us/stwddes/desmaterials/matsiteportal/materialsitemap.cfm. Accessed August 2017.

interactive location map. A methodology manual, also available through the webpage[2], describes the desk study procedures, field methods, and inspection categories used to build the MSI.

In addition to the web-based interface, R&M also provided a geospatially-referenced database compiling site location information and site inspection data for all material sites in the MSI. This geodatabase was integrated into the GAM program and used to assess the availability of valuable material to Department maintenance stations, a process described in detail in Section 3.5. For the GAM program, *valuable material sites* are described as **active** and **open** material sites capable of producing at least 250,000 cubic yards of Type A and B material, crushed products, or aggregates. The 136 *valuable material sites* currently operated by AKDOT&PF are shown in Figure 2-10.

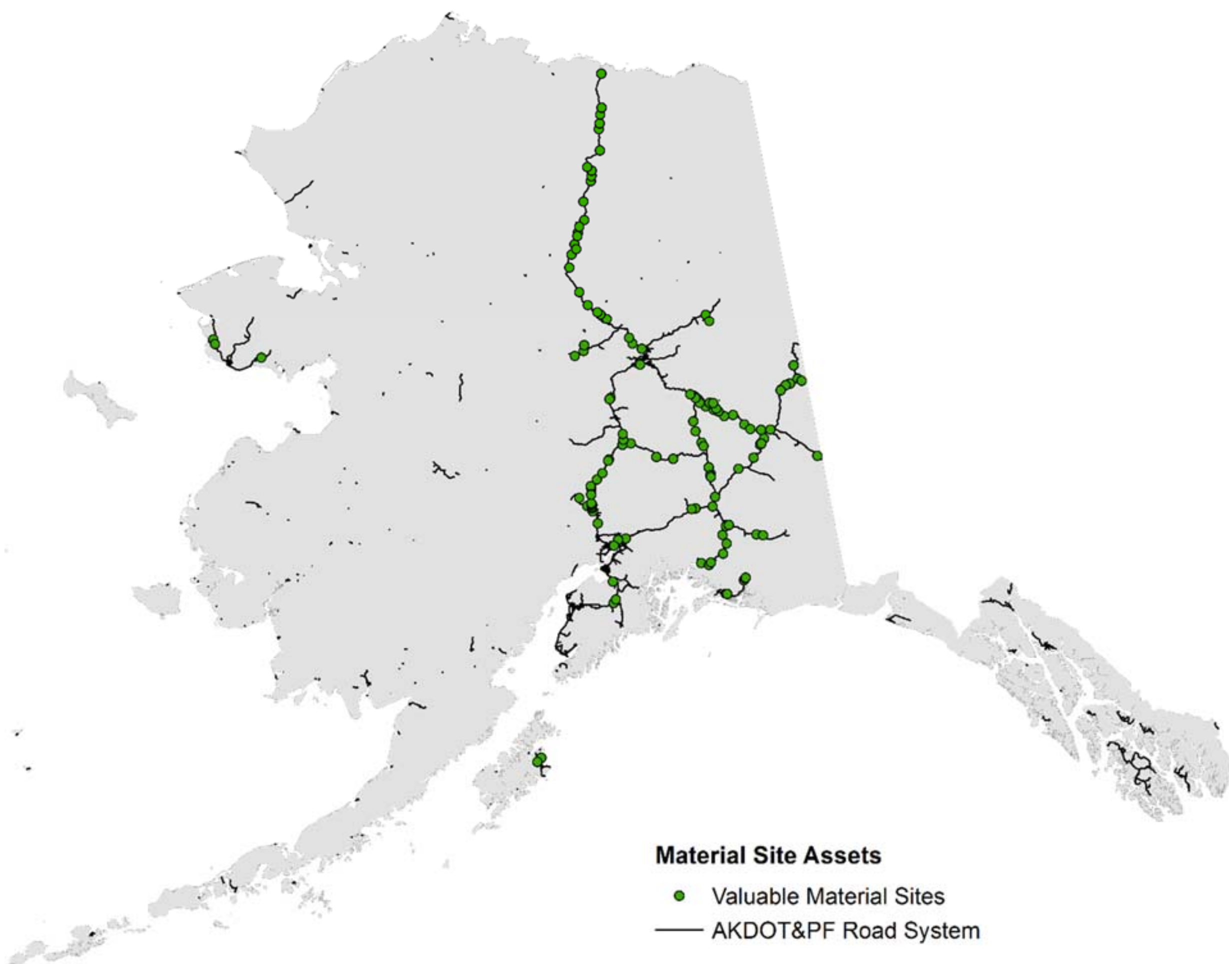

Figure 2-10: Valuable Material Sites operated by AKDOT&PF as of August 2015.

[2] http://www.dot.state.ak.us/edocs_code/edocs_document_relay_nativefile_bydocname.cfm?ddocname=dot-anc_110599&inline=1. Accessed August 2017.

3 DEVELOPMENT OF ASSET CONDITION INDEX AND CONDITION STATE

3.1 Context of Condition State Development and Good/Fair/Poor Criteria

A desired outcome of asset management programs is to maintain or achieve acceptable asset condition for acceptable life cycle cost within defined transportation corridors. To meet this goal, preservation or reconstruction actions are carried out to reverse or prevent asset deterioration. Recent Federal guidance proposes a three-category system to describe bridge or pavement assets as Good, Fair or Poor. These relatively broad categories are used at the programmatic-planning level to help identify both those assets that are currently performing poorly and those that would most benefit from preservation actions to prevent deterioration from, for example, a Fair to a Poor Condition State. AKDOT&PF's GAM program follows the same Good/Fair/Poor protocol for tracking the condition of geotechnical assets.

The Good/Fair/Poor Condition States that have been advanced at the federal level in recent research (Guerre, et al. 2012) and in recent rulemaking (FHWA 2017) are intended to improve FHWA's ability to assess the health of the nation's highway infrastructure and serve two primary objectives:

- Define a consistent and reliable method of assessing infrastructure health with a focus on bridges and pavements on the Interstate Highway System; and
- Develop tools to provide FHWA and Department of Transportation personnel with key information for a better and more complete view of infrastructure health, nationally.

To meet these objectives, the federal work focused on the development of a consistent methodology for categorizing assets as in Good, Fair or Poor condition, which can be used consistently across the country. Asset performance in this context is based on condition criteria. Guerre (2012) recommended the following criteria to determine a Good, Fair or Poor condition for bridges and pavements:

> ***Good condition*** *– Bridge and pavement infrastructure that is free of significant defects, and has a condition that does not adversely affect its performance. This level of condition typically only requires preventive maintenance activities.*
>
> ***Fair condition*** *– Bridge and pavement infrastructure that has minor deterioration of bridge elements; or isolated surface defects or functional deficiencies on pavements. This level of condition typically could be addressed through minor rehabilitation, such as crack sealing, patching of spalls, and corrosion mitigation on bridges; and overlays and patching of pavements that do not require full depth structural improvements.*
>
> ***Poor condition*** *– Bridge and pavement infrastructure that is exhibiting advanced deterioration and conditions that impact structural capacity. This level of condition typically requires structural repair, rehabilitation, reconstruction or replacement.*

For those geotechnical assets monitored under the GAM program, the definitions and required level of action would be similar for Good, Fair or Poor condition sites to that outlined above.

3.1.1 Integration of Good/Fair/Poor Criteria into AKDOT&PF's GAM Program

Within AKDOT&PF's GAM Program, the research team developed a method to convert asset rating data collected during field inventory work into a set of simple and broadly applicable classifications, termed Condition States, which coincide with those advocated under TAM guidance. The GAM program provides for uniform statewide application of these Condition State categories to all assets in a given class, such as retaining walls. Application of Condition States also provides a consistent vocabulary for making comparisons between asset classes. The consistent vocabulary allows use of the Condition States in asset cost valuations, development of corridor health indices, deterioration models, and other programmatic asset management tools.

During the initial research discussions for the AKDOT&PF GAM project, the research team determined that five numerical Condition States was the ideal number for selecting applicable categories of preservation, while remaining clearly identifiable in a routine visual inspection. These five divisions can be directly mapped to a Good/Fair/Poor Condition State as follows: Conditions State (CS) 1 is *Good*, CS 2 or 3 is *Fair*, and CS 4 or 5 is *Poor*. This ensured that AKDOT&PF's GAM program followed the methods advocated under the current TAM program, but also helped make Condition State – Mitigation Cost correlations (Section 6) for geotechnical assets more robust by allowing for greater resolution of asset performance. The Condition State score is derived from the Condition Index, which is calculated from selected rating categories evaluated during asset rating and inventory work. It is generally presented as a whole integer (1, 2, 3, etc.) or as a category (Good, Fair, or Poor).

The Condition State score does not seek to assess the risk posed to the travelling public in the event of failure, being instead concerned solely with the physical performance of the geotechnical asset, regardless of its location or the adjacent highway. Because the Condition State is based on asset performance and activity, it is integral in developing the programmatic-level planning and asset management tools described in the following Sections of this report.

3.1.2 Background on Condition State Element Score Development

The rating categories in Rockfall Hazard Rating System (RHRS)-based programs, such as the USMP and the RWMP utilize an exponential scoring function, with "1" being an excellent score and "100" being a failed condition or worst-case scenario. This exponential scoring approach produces significantly higher scores and greater score separation, which is useful for identifying the most hazardous sites within a corridor. However, it differs from the traditional TAM scoring methodology, where a linear function is used. Within TAM, a score of 100 represents an excellent condition and a score of 0 represents a failed condition or worst-case scenario. This linear scoring system is more useful for presenting information in a manner similar to the grading practices that the public is already accustomed to using in school settings. To avoid possible confusion that could arise by using different scoring methods, equations were developed to allow certain USMP category scores to also be presented as Condition State Element Scores (CSES) using a TAM scoring format. See Table 3-1 below. The conversion equations differ slightly between the different asset types, and are discussed in detail in the individual Condition State development subsections.

Material Sites were not assessed using an RHRS-based rating system, so there were no score conversions to undertake. The development of Condition States for material sites differs significantly from other geotechnical assets, and is discussed in detail in Section 3.5.

Table 3-1: Rock Slope, Unstable Soil Slope and Embankment, and Retaining Wall Assets — Summary of the relationships between USMP category scores, Condition State Element Scores (CSES), Condition Index, and asset Condition State.

USMP Score		USMP Exponent ('x' in 3^x)			Condition Index Range		
Rock/ Wall	**Soil Slope/ Embankment**	**Rock/ Wall**	**Soil Slope/ Embankment**	**CSES Score**	**High**	**Low**	**Condition State**
3	Slope not rated	1	--	100	100	80	1, Good
9	3	2	1	75	79	60	2, Fair
27	9	3	2	50	59	40	3, Fair
81	27	4	3	25	39	20	4, Poor
100	81	NA	4	0	19	0	5, Poor

3.2 Condition Index and Condition State Development – Rock Slopes Assets

During planning meetings, the GAM team developed the following five Condition States for rock slopes that describe how well the slope is supporting the smooth functioning of the transportation system. The descriptions of the numerical Condition States for rock slope assets and how these five Condition States align with a Good, Fair or Poor condition are summarized in Table 3-2. These written descriptions incorporate rockfall activity, maintenance requirements, and the condition of any existing mitigation measures, but the numerical Condition State used in tracking assets and asset performance is mathematically derived from the site's field rating. This section summarizes the development of these rock slope Condition States, including all relevant mathematical methods.

Table 3-2: Condition States for Rock Slope Geotechnical Assets

Condition State, Condition Index and Action Level	Description
CS: 1- Good **CI: 100-80** **No action needed**	Rock slope produces little to no rockfall and no history of rock reaching the road. Little to no maintenance needs to be performed due to rockfall activity. Rockfall mitigation measures, if present, are in new or like new condition.
CS: 2 – Fair **CI: 80-60** **Review status at 5-year intervals**	Rock slope produces occasional rockfall that may rarely reach the road. Some maintenance needs to be performed on a scheduled basis due to rockfall activity to address safety. Mitigation measures, if present, are in generally good condition, with only surficial rust or minor apparent damage.
CS: 3 – Fair **CI: 60-40** **Inspect at bi-annual intervals. Consider mitigation efforts.**	Rock slope produces many rockfalls with rock occasionally reaching the road. Maintenance is required bi-annually or annually to maintain safety. Mitigation measures, if present, appear to have more significant corrosion or damage to minor elements. Preventative maintenance or replacement of minor mitigation components is warranted.
CS: 4 – Poor **CI: 40-20** **Inspect annually. Perform major rehab and repair efforts.**	Rock slope produces constant rockfall with rocks frequently reaching the road. Maintenance is required annually or more often to maintain ditch performance. Much of the required maintenance response is unscheduled. Mitigation measures, if present, are generally ineffective due to significant damage to major components or apparent deep corrosion.
CS: 5 – Poor **CI: 20-0** **Perform major mitigation or reconstruction efforts**	Rock slope produces constant rockfall and nearly all rockfall reaches the road. Virtually no rockfall catchment exists or is effective. Maintenance must respond to rockfalls regularly, possibly daily during adverse weather. If present, nearly all mitigation measures are ineffectual due to deferred maintenance, significant damage, or obvious deep corrosion.

3.2.1 Field Rating Categories used in Condition Index/Condition State Development for Rock Slope Assets

When a rock slope is inventoried and rated in the GAM slope database, it is evaluated across a variety of categories that capture hazard (rate of activity, slope geometry, etc.) and risk (AADT, traffic impacts, etc.). For the AKDOT&PF GAM project, the Condition State for a rock slope is defined a combination of the rockfall history and the ability for the roadside ditch to prevent falling rock from entering the roadway. These two components are captured by the "Ditch Effectiveness" and "Rockfall History" categories in the detailed Hazard Rating. Table 3-3 summarizes the linear Condition State Element scores for these two categories.

Table 3-3: Condition State Elements used in calculating Condition Index and Condition State for Rock Slope Geotechnical Assets

Ditch Effectiveness Condition State Element	
100 points	Good Catchment. All or nearly all falling rocks are arrested before reaching the roadway. No additional action required to improve ditch.
75 points	Moderate Catchment. Falling rocks occasionally reach the roadway.
50 points	Limited Catchment. Falling rocks frequently reach the roadway.
25 points	Ineffective Catchment. No roadside ditch or ditch is totally ineffective.
0 points	No Catchment. Slope overhangs roadway or no roadside catchment is provided. All rockfalls reach the roadway.
Rockfall Activity Condition State Element	
100 points	Few Falls. Rockfalls occur only a few times a year (or less), or only during severe storms. This category is also used if no rockfall history data is available.
75 points	Occasional Falls. Rockfall occurs regularly. Rockfall can be expected several times per year and during most storms.
50 points	Many Falls. Typically, rockfall occurs frequently during a certain season, such as the winter or spring wet period, or the winter freeze/thaw, etc. This category is for sites where frequent rockfalls occur during a certain season but are not a significant problem during the rest of the year. This category may also be used where severe rockfall events have occurred.
25 points	Constant Falls. Rockfalls occur frequently throughout the year. This rating is also applied to sites where severe rockfall events are common.
0 points	Daily or Weekly Falls. Rocks are on the roadway on a daily or weekly basis regardless of weather. Very large, severe events are common.

3.2.2 Condition State Derivation – Rock Slope Assets

The Condition States used by AKDOT&PF to categorize how well an asset is performing (Good/Fair/Poor) are obtained mathematically.

The relationships between Rock Slope Asset USMP category scores, CSES scores, Condition Index, and Condition State are derived in the following subsections.

3.2.2.1 Conversion of Rating Category Scores to Condition State Element Scores

To convert between exponential USMP scoring system and the linear TAM scoring system, algorithms were derived to extract the exponent from the 3^x formula used in the USMP scorings. The formulas used are presented in the equations (Equation 3-1 and Equation 3-2) shown below. Table 3-1 summarizes the relationship between the USMP scores and CSES values.

Equation 3-1: Algorithm for USMP category score to CSES conversion given that 0 < USMP Category Score ≤ 81

$$\text{CSES} = 100 - \left(25 \times (USMP\ exponent - 1)\right)\ where$$

$$USMP\ exponent = \frac{\ln(USMP\ Score)}{(\ln 3)}$$

Equation 3-2: Algorithm for USMP category score to CSES conversion when USMP Category Score > 81.

$$CSES = (USMP\ Score\ \times -1.3158) + 131.58$$

In cases where a low hazard slope has been entered into the database but not rated (i.e., a Class B slope), all Condition State Element scores are considered to be 100 until a deterioration in performance or a full evaluation indicates otherwise.

3.2.2.2 Condition Index Calculation

The CSES values derived using the equations in Subsection 3.2.2 are averaged together to calculate the Condition Index, as presented in Equation 3-3.

Equation 3-3: Condition Index Equation for Rock Slope Geotechnical Assets

$$Condition\ Index = \frac{(Ditch\ Effectiveness\ CSES + Rockfall\ History\ CSES)}{2}$$

The Condition Index follows the previously established TAM scoring conventions, as it covers a linear range from 0 to 100, with 0 being the worst possible Condition Index score, and 100 being the best. The Condition Index is used to calculate the asset Condition State.

3.2.2.3 Condition State Derivation

The Condition Index is converted to the Condition State using Equation 3-4. Scores range from 1 to 5, with 1 (Good) describing the best condition an asset attain and 5 (Poor) being a failed condition. Asset Condition State scores are generally presented as whole integers, although decimal Condition States are occasionally used, as in the development of asset condition – asset mitigation costs described in Section 6.

Equation 3-4: Condition State Equation for Rock Slope Geotechnical Assets

$$Condition\ State\ (round\ up, integer\ only) = \frac{\left(100 - (Condition\ Index)\right)}{20}$$

As an example, inventoried *Class A* rock slopes on the Turnagain Arm south of Anchorage are shown in Figure 3-1. Although none of the rock slopes along this stretch of the Seward Highway are in Poor condition, the high concentration of Fair condition rock slopes in this segment of the transportation corridor raises maintenance costs for the Department and increases risks for roadway users.

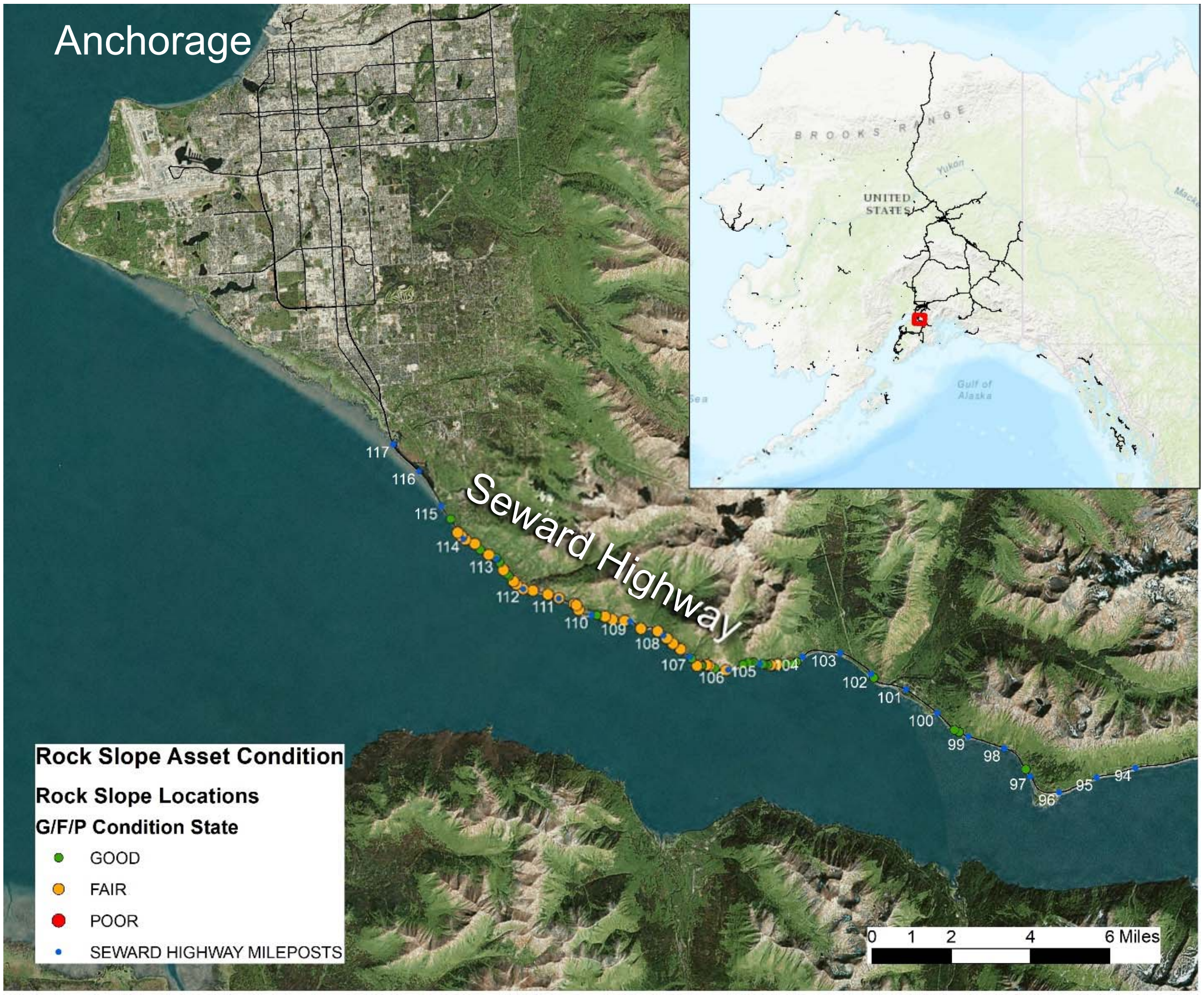

Figure 3-1: Seward Highway along the Turnagain Arm south of Anchorage, with the location and condition of inventoried rock slopes.

3.3 Condition Index and Condition State Development – Soil Slope and Embankment Assets

Development of Condition States for unstable soil slopes and embankments was particularly challenging, as not all soil slopes in the transportation system are inherently unstable, nor will all soil slopes in a transportation corridor necessarily become unstable or deteriorate significantly over time. However, the condition of many soil slopes and embankments does deteriorate over time and slopes that were not inventoried in earlier rounds of field work may be added to the inventory. Hidden conditions also create instabilities that may make themselves evident decades following construction. Currently, soil slopes and embankments which show no signs of instability are not included in the geotechnical asset inventory because the time required to inventory and assess every stable soil slope or embankment in the state would not significantly improve the quality or usability of data in the GAM inventory.

The GAM team developed the following five Condition States for unstable soil slopes and embankments, which describe how well the slope is performing. Table 3-4 summarizes the descriptions of the numerical Condition States for these assets and how these five Condition

States align with a Good, Fair or Poor condition. These written descriptions incorporate slope activity, maintenance requirements, and the condition of any existing mitigation measures, but the numerical Condition State used in tracking assets and asset performance was mathematically derived from the site's field rating. The development of these unstable soil slope and embankment Condition States, including all relevant mathematical methods, are summarized in this section.

Table 3-4: Condition States for Soil Slope and Embankment Geotechnical Assets

Condition State, Condition Index and Action Level	Description
CS: 1 – Good **CI: 100-80** **No action needed**	Soil slope or embankment is stable. Stable slopes will not be entered into the USMP database. Sites that have been successfully mitigated for many years are also be included in this category.
CS: 2 – Fair **CI: 80-60** **Review status at 5-year intervals**	Instability is slow moving and is impacting a short width and length of the roadway surface or shoulder. Maintenance efforts are routine and not accelerated by the instability. If present, mitigation measures are functioning properly and in new or like-new condition.
CS: 3 – Fair **CI: 60-40** **Inspect at bi-annual intervals. Consider mitigation efforts.**	Instability moves at a moderate rate and could be impacting up to half of the roadway and up to 225 feet of roadway. Maintenance efforts have been increased in response to the instability. Mitigation measures, if present, appear to moderately damaged and/or of limited effectiveness.
CS: 4 – Poor **CI: 40-20** **Inspect annually. Perform minor rehab and repair efforts.**	Slope or embankment is in a degraded condition and moves or degrades at a relatively fast rate that may be impacting up to the full roadway width and a significant length (400 feet or greater) of the roadway. Maintenance requirements may be much higher than routine efforts with some emergency responses required. Mitigation measures, if present, are largely ineffective due to deferred maintenance or significant damage to major components.
CS: 5 – Poor **CI: 20-0** **Perform major mitigation efforts**	Fast moving failures occur multiple times per year that impact the full roadway width. Road closures may occur multiple times per year. Maintenance requirements are extraordinary to maintain corridor function and these efforts interfere with other normal but critical maintenance operations. Mitigation measures, if present, are ineffectual due either to deferred maintenance or significant damage.

3.3.1 Field Rating Categories used in Condition Index/Condition State Development for Soil Slope and Embankment Assets

As with rock slopes, unstable soil slopes and embankments inventoried and rated under the USMP are evaluated across a variety of categories that capture hazard (rate of movement, slope geometry, etc.) and risk (AADT, traffic impacts, etc.). For the AKDOT&PF GAM project, the Condition State for an unstable soil slope or embankment is a combination of the likelihood that landslide movement will occur at a given site and the probable extent to which this event will impact the roadway. It's calculated using four categories from the detailed hazard rating:

- Length of Affected Roadway
- Roadway Impedance
- Roadway Displacement/Slide Deposit
- Movement History

The linear Condition State Element scores for these categories are summarized in Table 4-5.

Table 3-5: Condition State Elements used in calculating Condition Index and Condition State for Unstable Soil Slope and Embankment Geotechnical Assets

Length of Affected Roadway Condition State Element	
100	None
75	25’
50	100’
25	225’
0	400’ or greater
Roadway Impedance Condition State Element	
100	None
75	Shoulder only. The travel lanes are not affected by the landslide event or embankment deformation, but the available paved surface is reduced. A detour or traffic control is typically not required except during maintenance activities. For thaw unstable slopes, normal highway speed and driving behavior is maintained and little effect to the inspection vehicle is felt while maintaining the speed limit.
50	Half Roadway. Events affect 50% of the travel lanes but adequate paved surface is available to maneuver around the event. A detour is typically not required but traffic control would be needed during maintenance/repair activities. For thaw unstable slopes, tire marks are observed and a notable vertical movement to the inspection vehicle is felt while traversing the section at the speed limit.
25	3/4 Roadway. Events affect 75% of the surface dedicated to travel lanes. Maneuvering actions may still be possible by using paved or unpaved shoulders, if available. A detour or complete vehicle stoppage may be required. For thaw unstable slopes, breaking or evasive maneuvering is required when travelling at the speed limit.
0	Full Roadway. Events or deformation affect the entire road with no opportunity to maneuver around the event. A detour or halted traffic flow is required. For thaw unstable slopes, this subcategory is reserved for those sites that have already been marked by maintenance crews with warning signs, cones, or a temporary reduction of the speed limit.
Roadway Displacement or Slide Deposit Condition State Element	
100	No Crack or Deposit
75	Visible crack, slight settlement, or small deposit of material on road. Minor pavement cracking or heaving, or a thin deposit of slide debris has occurred but they are small enough not to disrupt traffic flow or require evasive maneuvers. Scheduled roadway maintenance is required. Slight (0 to 6 inches) untreated pavement settlement is observed within the thaw unstable embankment section.
50	1-inch offset or 2 inches of material on road surface or moderate settlement. A noticeable drop or heave in the pavement or a deposit of slide debris has occurred requiring lower speeds to traverse. Untreated pavement settlement is 6 to 12-inches over a 450-foot section. Maintenance attention may be required.
25	2-inch offset, 6 inches of material on road, or significant settlement. A large drop or heave in the pavement or a deposit of slide debris has occurred that requires significantly lower speeds to traverse and may elicit unsafe driver reactions. Untreated pavement settlement is 12 to 36-inches over a 450-foot long section.
0	4-inch offset, 12 inches of material on road, or extreme settlement. A major drop or heave in the pavement or deposit of slide debris has occurred that cannot be traversed. Unsafe driver reactions are likely and immediate maintenance attention is required to reestablish safe traffic flow. Untreated settlement is 24-inches or greater over a 300-foot or shorter section.
Movement History Condition State Element	
100	None
75	Minor movement, sporadic creep, or very slow settlement. The rate of movement is low and non-continuous. Pavement disturbance is minor on an annual basis and maintenance requirements are minimal and carried out as a scheduled activity. Settlement rate is very slow (inch-scale movement over 10 years).
50	Up to 6 inches annually, steady annual creep, or moderate settlement rate. The rate of movement is low but continuous. Roadway maintenance is routinely required to avoid road closures but maintenance action can generally be on a scheduled basis. Settlement rate is slow to moderate (inches per 5 year scale) and steady.
25	Up to 6 inches per event, more than two events per year or fast settlement. The rate of movement is moderately high. Events occurring more than twice a year that require immediate and unscheduled maintenance are a persistent maintenance problem. Settlement rate is fast (inches per year) and may be steady or accelerating.
0	>1 ft. displacement in hours (includes all debris flows) or rapid, continuous settlement. The rate of movement is high. Significant roadway disturbance develops quickly. Emergency unscheduled maintenance intervention is required to maintain traffic flow and correct unsafe conditions. Settlement is rapid and continuous (feet per month).

3.3.2 Condition State Derivation – Soil Slope and Embankment Assets

Stable soil slopes and embankments are not rated and added to the Unstable Soil Slope and Embankment database. In contrast, all rock slopes and retaining walls that could affect the roadway in the event of failure were inventoried. The assumed default state for all non-inventoried soil slopes and embankments is 1/Good. To account for this, the relationships between USMP category scores, CSES scores, Condition Index, and Condition State for unstable soil slopes and embankments are slightly different than outlined in the previous section for rock slopes.

The relationships between USMP category scores, CSES scores, Condition Index, and Condition State for unstable soil slopes and embankments are derived in the following subsections. Note that because stable soil slope and embankments are not inventoried, the highest possible Condition State for a rated, unmitigated unstable soil slope or embankment is 2/Fair. Mitigated slopes, slopes that have not affected the roadway but are likely to in the future (e.g. bank erosion), or those that the rater judged that they should be in the database may be in a 'Good' condition and still be in the database.

3.3.2.1 Conversion of Rating Category Scores to Condition State Element Scores

Within transportation parlance, there is no such thing as a "Good" landslide, and therefore there are two significant differences between the CSES algorithms used for unstable soil slopes and embankments and those used for rock slopes and retaining walls. Within the inventoried rock slopes and retaining walls, there were some assets which are performing very well, so 1 was subtracted from the USMP exponent in the CSES conversion equation for these assets. This was not done for unstable soil slopes and embankments. Also, all soil slope scores greater than 81 were translated to a CSES score of 0, eliminating the linear conversion between 81 and 100 used when converting rock slope and retaining wall rating scores. This reflects the greater rates of movement and roadway impedance described in the landslide rating elements used to calculate the soil slope Condition Index. The worst-case category descriptions are more extreme for soil slopes than for rock slopes, to the point where scores above 81 provide very little additional hazard information. It is possible for a maintenance department to work around a rock slope that generates a large-volume event on an infrequent basis, but there is no way to work around a slide that moves greater than 1-foot per hour or an embankment that is moving multiple feet per month.

The equation used to convert from USMP category scores to CSES is presented in Equation 3-5.

Equation 3-5: Algorithm for USMP category score to CSES conversion

$$\text{CSES} = 100 - \left(25 \times (USMP\ exponent)\right)\ where$$

$$USMP\ exponent = \frac{\ln(USMP\ Score)}{(\ln 3)}$$

3.3.2.2 Condition Index Calculation

The CSES values derived using the equations in Subsection 3.3.2.1 are averaged together to calculate the Condition Index, as presented in Equation 3-6.

Equation 3-6: Condition Index Equation for Unstable Soil Slope and Embankment Geotechnical Assets, with rating category names abbreviated due to space constraints.

$$Condition\ Index = \frac{(Length\ CSES +\ Impedance\ CSES + Displacement\ CSES + History\ CSES)}{4}$$

The Condition Index follows the previously established TAM scoring conventions, covering a linear range from 0 to 100, with 0 being the worst possible Condition Index score, and 100 being the best. The Condition Index is used to calculate the asset Condition State that is discussed in Subsection 3.3.2.3.

3.3.2.3 Condition State Derivation

Although the USMP to CSES conversion and the CSES components differs between rock slopes and unstable soil slopes/embankments, the Condition State Integer is calculated using the same equation for both asset types, Equation 3-4.

As an example, inventoried unstable soil slopes and embankments along a segment of the Glenn Highway east of Palmer and Wasilla are shown in

Figure 3-2 below. The location markers are coded based on asset condition, helping zones of poorly performing assets stand out.

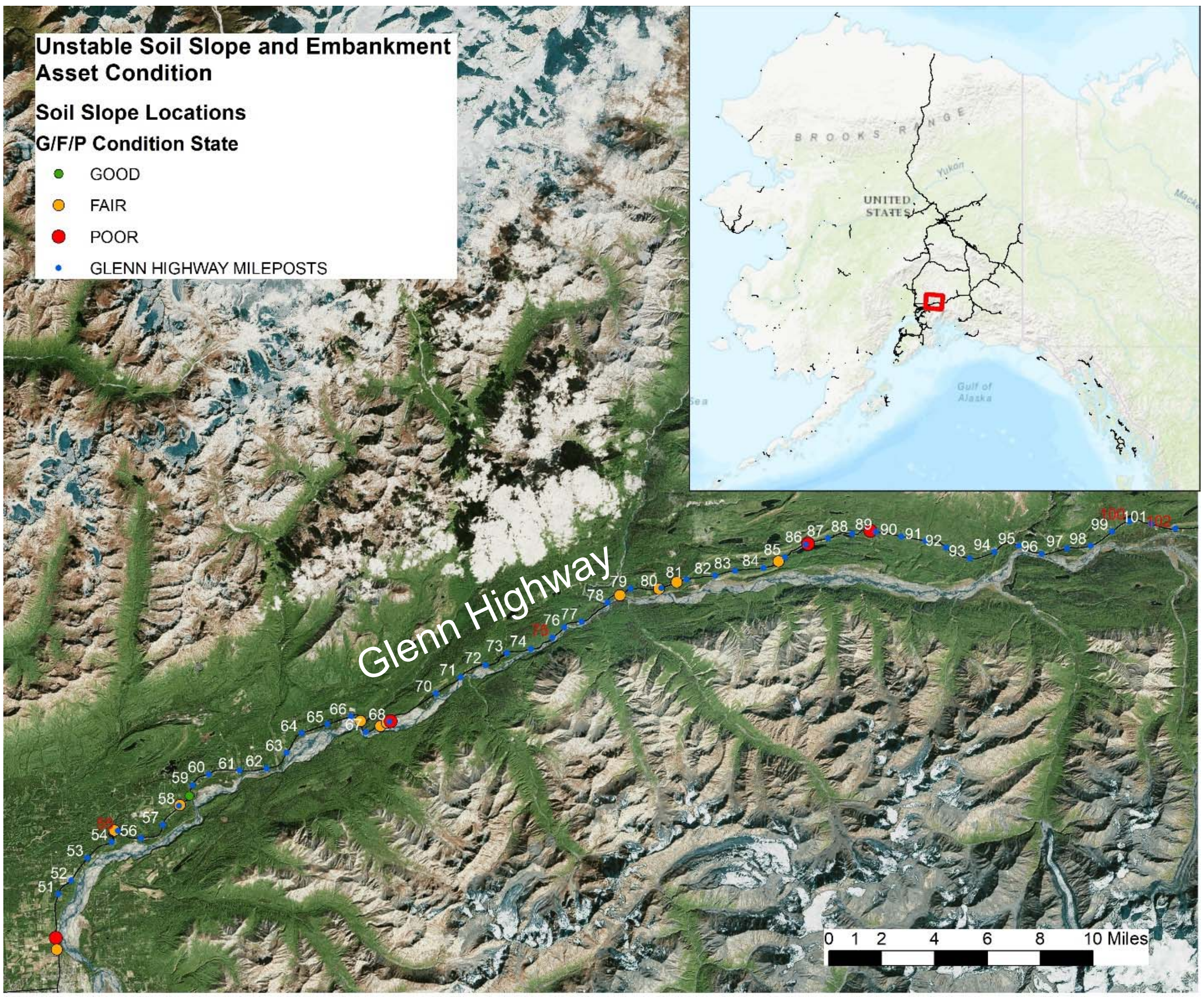

Figure 3-2: Glenn Highway east of Palmer with point locations and condition of inventoried unstable soil slopes and embankments.

3.4 Condition Index and Condition State Development – Retaining Wall Assets

Incorporating the data collected as part of the Tongass Corridor GAM Test Project, the GAM team developed the following five Condition States to describe how well a given retaining wall asset is performing based upon observable physical characteristics. Ultimately, an investigation into the condition of the buried components would be the most comprehensive way evaluate wall condition, but would require a much more time and cost intensive program. Because many critical components of a retaining wall are hidden from view, only those which were visible to field inspectors were rated, and overall wall behavior, such as alignment, was used as a proxy for the condition of those hidden or otherwise obscured wall elements. General horizontal and vertical consistency and curvature at the time of original construction is assumed. The descriptions of the numerical Condition States for assets in this class and how these five Condition States align with a Good, Fair, or Poor condition are summarized in Table 3-6. The written descriptions incorporate retaining wall alignment, condition of wall components, impacts to the adjacent roadway or road-related assets due to wall performance, history of past wall movement, and the general appearance of the wall. The numerical Condition State used in tracking retaining wall assets and their performance is calculated from the field inventory rating.

As with rock slopes, all retaining walls, even those which are performing well, are assumed to deteriorate and to decay over time as the asset ages. For this reason, many inventoried and rated retaining walls are in Good condition. Because the basic assumptions underlying definition of a Good Condition State are the same for both rock slopes and retaining walls, the mathematical formulas used to convert exponential scores to Condition State Element Scores are identical between both asset types. This section summarizes the mathematical methods used to develop retaining wall Condition States.

Table 3-6: Condition States for Retaining Wall Geotechnical Assets

Condition State, Condition Index and Action Level	Description
CS: 1 – Good **CI: 100-80** **No action needed**	Wall alignment is good both vertically and horizontally. No structural cracks in wall surfaces, though cosmetic cracking and superficial corrosion of elements may be apparent. No apparent translated impacts to adjacent roadway or road related assets due to wall displacement. No evidence of distortion or lost/missing bearing elements are apparent. Surface coatings (if present) are fully protective. No history of movement/deformation.
CS: 2 – Fair **CI: 80-60** **Review status at 5-year intervals**	Wall alignment is fair with only very minor deviations vertically and horizontally. Visible structural hairline cracks on wall or road may be present. Evidence of efflorescence in cracks for concrete walls. Only minor distortion is present with no lost/missing bearing elements. Movement history is non-existent or minor.
CS: 3 - Fair **CI: 60-40** **Inspect at biannual intervals. Consider mitigation efforts.**	Wall alignment is variable with some areas noticeably out of alignment. Cracks with open apertures are apparent on the pavement and/or wall surface. Corrosion of visible metallic elements or lost bearing elements may have occurred. The wall has or is developing a history of movement.
CS: 4 – Poor **CI: 40-20** **Inspect annually. Perform minor rehab and repair efforts.**	Wall alignment is poor with some areas exhibiting clear signs of significant distortion. Some significant cracks are developing in wall or wall-supported road features. Corrosion may be extensive and bearing elements may have been lost. The wall has a history of measureable annual or seasonable movement. Effects on the roadway may still be minor, but the wall meets original design goals only to a limited extent.
CS: 5 – Poor **CI: 20-0** **Perform major mitigation efforts**	Entire wall exhibits significant distortion. Cracks with open and/or patched apertures are apparent in the pavement or wall surface. The wall may be undermined and/or corrosion may have significantly degraded metallic elements. The wall has a history of measurable seasonable movement or may be at risk of imminent failure. Although the roadway may be showing no to minor displacement, the wall no longer provides significant support to transportation corridor function.

3.4.1 Field Rating Categories used in Condition Index/Condition State Development for Retaining Wall Assets

Inventoried retaining wall assets are evaluated across three categories – hazard, risk, and appearance – which are designed to fully capture retaining wall performance, but only select rating categories are used to define asset Condition State. It is calculated using the following three categories from the detailed Hazard Rating:

- Vertical and Horizontal Wall Alignment
- Roadway Displacement Due to Wall Movement
- Critical Component Health

The linear Condition State Element scores for these three categories are summarized in Table 3-7 below.

Table 3-7: Condition State Elements used in Calculating Retaining Wall Asset Condition Index and Condition State

Vertical and Horizontal Wall Alignment Condition State Element	
100	Good wall alignment. No visible distortion in the wall.
75	Fair wall alignment. Minor wall distortion is visible.
50	Portion of wall showing poor alignment. Portions of the wall exhibit clear distortion.
25	Poor alignment entire wall. The entire wall exhibits poor alignment.
0	Failed, unrepaired sections. A portion of the wall or the entire wall has failed.
Roadway Displacement Due to Wall Movement Condition State Element	
100	No visible crack in wall or roadway. No deposit on the road.
75	Small crack in wall or roadway. Minimal displacement or threat of deposition on road.
50	Minor crack in wall or roadway with visible displacement. Some traffic impacts possible.
25	Crack in wall or roadway with measureable displacement. Deposition on road likely with short term (hours to days) traffic impacts likely.
0	Significant wall or roadway cracking and displacement impeding traffic with long term (days to weeks) mobility impacts likely.
Critical Component Health Condition State Element	
100	No evidence of corrosion, lost bearing, or missing components
75	Evidence of minor corrosion, lost bearing, or missing components
50	Evidence of moderate corrosion, lost bearing, or missing components
25	Evidence of major corrosion, lost bearing, or missing components
0	Evidence of complete corrosion and/or loss of critical components

3.4.2 Condition State Derivation – Retaining Wall Assets

The relationships between RWMP category scores, CSES scores, Condition Index, and Condition State are identical for both retaining wall and rock slope assets. The summary table found in Section 3.2 is repeated here for reference as Table 3-8.

Table 3-8: Retaining Wall Assets — Summary of the relationships between USMP category scores, Condition State Element Scores (CSES), Condition Index, and asset Condition State.

USMP Score	USMP Exponent	CSES Score	Condition Index Range		Condition State
			High	Low	
3	1	100	100	80	1, Good
9	2	75	79.99	60	2, Fair
27	3	50	59.99	40	3, Fair
81	4	25	39.99	20	4, Poor
100	NA	0	19.99	0	5, Poor

3.4.2.1 Conversion of Rating Category Scores to Condition State Element Scores

The algorithms used to convert the exponential scoring systems applied in the Retaining Wall Management Program (RWMP) to the linear scoring system found in TAM are identical to those used to convert the exponential scores applied to rock slopes in the USMP. This is because both rock slopes and retaining walls are assumed to be inherently unstable. Just as weathering tends to cause rock fall frequency to increase over time, weathering will gradually impact the components critical to retaining wall performance.

To convert between the exponential RWMP scoring system and the linear TAM scoring system, algorithms were derived to extract the exponent from the 3^x formula used in the RWSMP scorings. The formulas used are presented in the equations shown below. Table 3-1 summarizes the relationship between the RWMP scores and CSES values.

Equation 3-7: Algorithm for RWMP category score to CSES conversion given that 0 < RWMP Category Score ≤ 81

CSES = $100 - \left(25 \times (USMP\ exponent - 1)\right)\ where$

$$USMP\ exponent = \frac{\ln(USMP\ Score)}{(\ln 3)}$$

Equation 3-8: Algorithm for USMP category score to CSES conversion given that 81 < USMP Category Score

$$CSES = (USMP\ Score\ \times -1.3158) + 131.58$$

3.4.2.2 Condition Index Calculation

As for unstable rock slope and unstable soil slope and embankment assets, a retaining wall's Condition Index is calculated by averaging its CSES values, as shown in Equation 3-9 below.

Equation 3-9: Condition Index Equation for Retaining Wall Geotechnical Assets

$$Condition\ Index = \frac{(Alignment\ CSES + Road\ Displacement\ CSES + Component\ Health\ CSES)}{3}$$

This linear Condition Index follows established TAM scoring conventions, where zero is the worst possible score and 100 is the best. It is used to calculate retaining wall Condition State, as described in the following section.

3.4.2.3 Condition State Derivation

The retaining wall Condition Index is converted to retaining wall Condition State using Equation 3-10. Scores range from 1 to 5, with 1 (Good) describing the best condition a retaining wall can attain and 5 (Poor) being a failed condition. Asset Condition State scores are generally presented as whole integers.

Equation 3-10: Condition State Equation for Retaining Wall Geotechnical Assets

$$Condition\ State\ Integer = roundup\left(\frac{\left(100 - (Retaining\ Wall\ Condition\ Index)\right)}{20}\right)$$

The point locations of inventoried retaining walls are replotted in Figure 2-4 below, with the legend based on asset Condition State, instead of total RWMP Score.

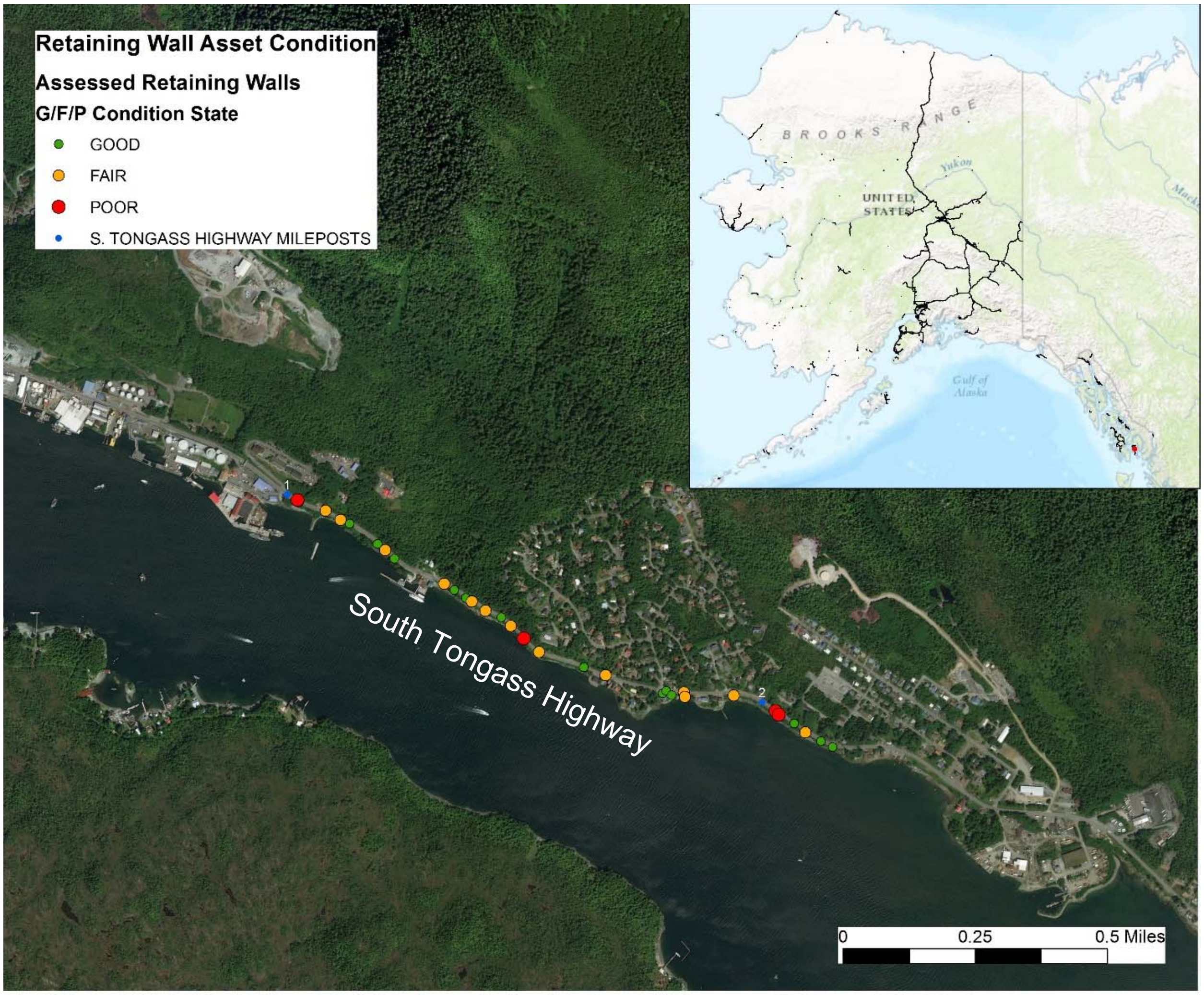

Figure 3-3: Inventoried and assessed retaining walls along South Tongass Highway between Ketchikan and Saxman. The numerous fair and poor condition retaining walls in this area are starting to affect roadway performance, and a project to address these failing walls as part of a larger corridor improvement project is currently underway.

3.5 Condition Index and Condition State Development – Material Sites

A primary goal of a successful GAM program is to maintain or achieve acceptable asset condition and life cycle cost along the roadway corridor, in order to assure that the transportation system functions smoothly and cost-effectively. Material sites are a non-standard geotechnical asset, in that they do not impact the roadway through failure in the way that rock slopes or retaining walls can. The material site may be mined and depleted by human action, but it will rarely degrade independent of human influence. Furthermore, because they are accessible from the roadway but generally not supporting it, poor performance of a material site means something different to the travelling public than poor performance of an unstable soil slope. Instead of noticing an immediate effect from deposition of debris on the roadway, public impacts from poor quality material sites are seen in higher construction costs and generally reduced roadway performance, such as deformation of an embankment early in its life cycle due to the use of inferior materials during construction.

With these differences in mind, the GAM team developed a way to integrate material sites into the asset management program by evaluating material scarcity at a regional level. A two-pronged approach was applied to Condition State development that combined both the ability of a given material site to supply desirable material for construction projects and the availability of these sites in a potential project area. Material sites are used to generate borrow, aggregate, and other valuable products for use in roadway maintenance and construction. However, all of these materials are rarely available from a single site. Instead, it is necessary to look at the amount of material available from several sites in the area of a proposed project in order to get a true sense of material availability. The research team determined that the two-pronged method described in the following subsections better captures availability of materials over multiple potential project areas, since there is a limited economically feasible haul distance from each site.

Incorporating the data collected during the Material Site Inventory (MSI) Project, the GAM team developed the following five Condition States to describe high quality material scarcity in a given maintenance station's geographic boundaries. The descriptions of the numerical Condition States for these geotechnical assets and how these five Condition States align with a Good, Fair, or Poor condition are summarized in Table 3-9.

Table 3-9: Condition States for Material Site Geotechnical Assets

Condition State, Condition Index, and Action Level	Description
CS: 1 – Good **CI: 100-80** **Access to valuable materials throughout maintenance station service area. No action required.**	More than 80% of road miles in the maintenance station service area are within a 5-mile radius of a valuable material site, defined as an active and open site capable of providing Type A and B or better material, with an available quantity of at least 250,000 cubic yards. Maintain usage rights of valuable material sites in maintenance station boundaries and protect from competing land uses.
CS: 2 – Fair **CI: 80-60** **Access to valuable materials throughout most of maintenance service area. Consider options to address coverage gaps.**	60 – 79% of road miles in the maintenance station service area are within a 5-mile radius of a valuable material site. Maintain usage rights of material sites in maintenance station boundaries and protect from competing land uses. Consider expanding an existing material site capable of producing Type A and B materials or better, developing a new site, or stockpiling material at a strategic location in the station service area.
CS: 3 - Fair **CI: 60-40** **Limited access to materials throughout most of maintenance service area. Invest in options to address coverage gaps in critical areas.**	40 – 59% of road miles in the maintenance station service area are within a 5-mile radius of a valuable material site. Maintain usage rights of valuable material sites in maintenance station boundaries and protect from competing land uses. Consider expanding an existing material site capable of producing Type A and B materials or better, developing a new site, or stockpiling material at a strategic location(s) in the station service area.
CS: 4 – Poor **CI: 40-20** **Highly limited access to materials. Investment in improvements in material availability in most of service area.**	20 – 39% of road miles in the maintenance station service area are within a 5-mile radius of a valuable material site. Maintain usage rights of valuable material sites in maintenance station boundaries and protect from competing land uses. Department investment required to obtain sufficient materials, either by expanding or proving up existing sites, developing or reopening new sites, or stockpiling material at strategic locations in the station service area.
CS: 5 – Poor **CI: 20-0** **No access to materials. Investment required to improve material supply throughout service area.**	Less than 20% of road miles in the maintenance station service area are within a 5-mile radius of a valuable material site. Maintain usage rights of valuable material sites (if any) in maintenance station boundaries and protect from competing land uses. Investment required to expand or prove up existing sites (if available), develop a new site, or stockpile material throughout the station service area.

3.5.1 Material Site Index Report Categories used in Condition Index/Condition State Development for Material Site Assets

Because material sites are significantly different from other geotechnical assets physically affecting or supporting the roadway, the development of useful Condition States for these assets posed several challenges. Landslide Technology worked with other experts and department personnel to develop a definition for a *valuable material site* to which AKDOT&PF would wish to maintain access, and to define a reasonable maximum distance material could be hauled for a project before haul costs became prohibitive.

AKDOT&PF's Material Site Inventory (MSI) currently contains 2,919 material sites. Of these, 920 were "Active" sites and received a complete Site Inspection Report. Not all material sites are active and open, nor did all Active sites provide access to valuable materials, much less provide desirable materials in sufficient quantities for a significant construction project in the transportation corridor. The definition of a *Valuable Material Site* (VMS) ultimately incorporated three categories from the MSI Site Inspection Report form:

- Field 15, "Category," which contained site classification (15.a) and site status (15.b),
- Field 21, "Est_Quan_Avail" which described the estimated material quantity available at a site in cubic yards,
- Field 41, "Potential_Usability," which described the best-known potential use of the available material.

To be a valuable material site, Field 15 had to classify the site as both "Active" and "Open," Field 21 had to report a quantity of available material greater than 250,000 c.y., and Field 41 had to classify produced material as Type A and B or better (Type A and B, crushed products, and aggregates). It was judged that haul costs can generally be considered prohibitive in cases where haul distance exceeds approximately five miles. This distance is supported by AKDOT&PF experience and material source spacing during the construction of the Trans-Alaska Pipeline (maximum 10-mile distance between material sites). Certain materials are hauled greater distances, but since the majority of valuable material sites under the current rating schema produce Type A and B material, a 5-mile radius (not road miles) from the material site was determined to be a good average haul distance for material sites for application at the programmatic planning level.

3.5.2 Condition State Derivation – Combining Maintenance Station Service Area and Valuable Material Sites

All materials required for a roadway project are rarely available from a single site. Instead, it is necessary to look at the amount of material that could be supplied by several sites in an area in order to get a more robust sense of material availability. Evaluating material scarcity at the district level was considered, but this level of analysis was too broad, and did not help focus attention on specific areas of scarcity, particularly in light of the fact that the maximum economically feasible haul distance for valuable material is modeled as 5 miles. Also, analysis at the district level made it difficult to highlight particular areas within the district where access to materials is limited and could impact planned projects. Instead, maintenance station service areas, which typically cover 50 to 150 road miles, were used for the analytical basis. These service areas are already well-defined geographically. Using a smaller area in Condition State calculations gave a better geographical picture of where VMSs and their materials are scarce.

The group measured material scarcity as a function of the percentage of NHS and AHS road miles in a maintenance station service area within a radius of five mile-linear buffer of a VMS. AKDOT&PF-administered routes not on the AHS or NHS were eliminated from the analysis.

Finally, unlike the inventory work completed to date for other assets, the MSI program looked at all material sites managed by the DOT statewide. Because this level of data was available, the Condition States for the maintenance station service areas were evaluated based on the total number of road miles for which the maintenance station was responsible on both the Alaska Highway System and the National Highway System (AHS and NHS), instead of only NHS road miles. AKDOT&PF-administered routes not on the AHS or NHS were still eliminated from the analysis because those routes are seldom the focus of large construction or mitigation projects. The percentage of maintenance station service area NHS/AHS road miles within a five-mile radius of a valuable material site was then calculated for each maintenance station service area.

The higher the proportion of maintenance station road miles outside the 5-mile radius of a valuable material site, the higher project costs are likely to be, as materials will likely be provided by a private contractor, or sub-standard materials will be used in a project, resulting in lowered performance or a claim. Districts with a Condition State of Good/1 had over 80% of their road miles within 5 miles of a valuable material site. Districts with a Condition State of Poor/5 had less than 20% of their road miles within 5 miles of a valuable material site (see Table 4-10). Figure 4-4 shows maintenance station service area boundaries, determined Condition States, and locations of valuable material sites. The VMSs and the maintenance station service area Condition States are also shown in Figure 3-4.

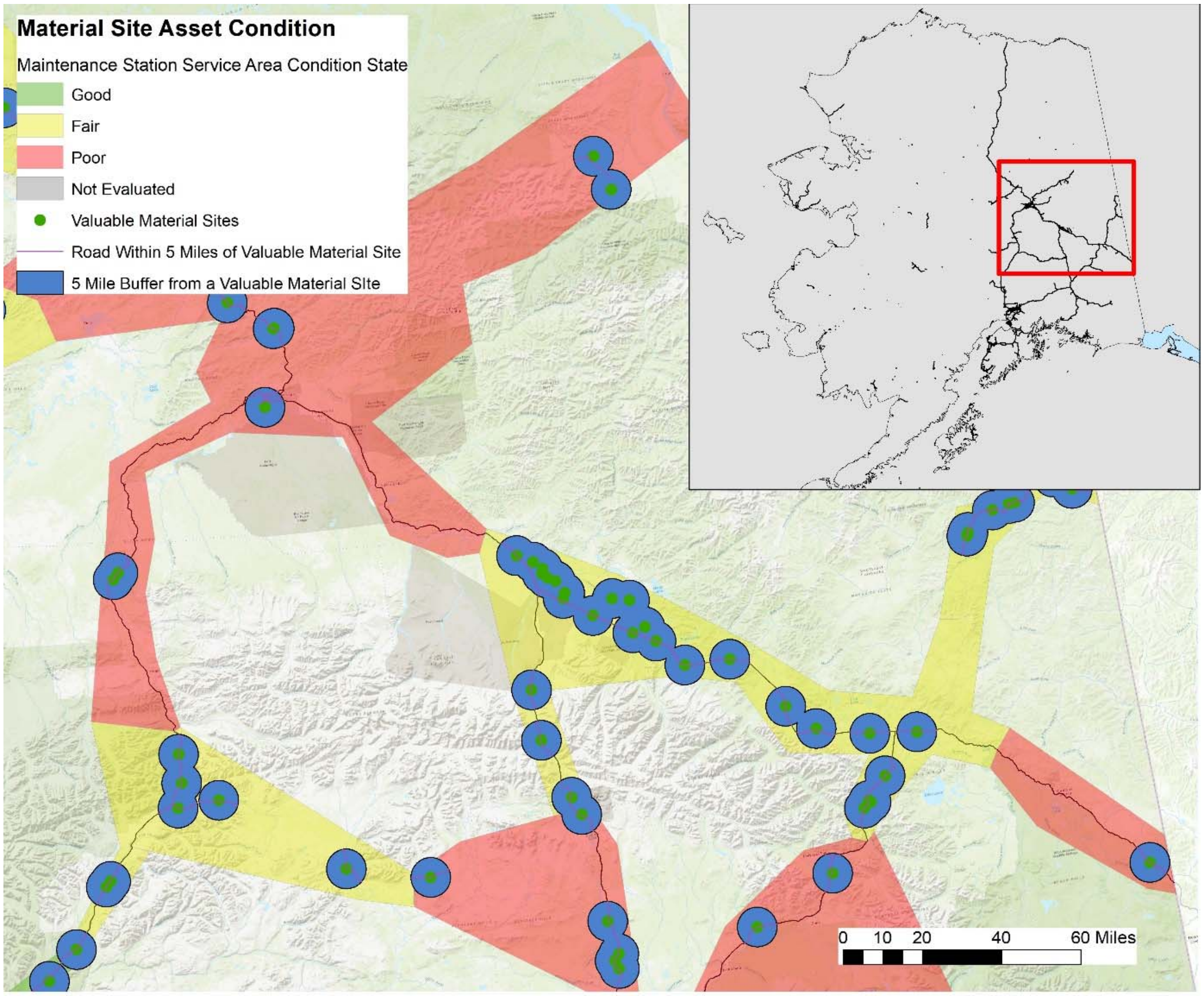

Figure 3-4: Maintenance Station Service Areas along the Alaska Highway showing valuable material sites (green) and service area Condition States as of August 2015.

4 UTILIZING RATING DATA FOR GEOSPATIAL ANALYSIS

Once geotechnical assets have been inventoried, the geospatial location and site evaluation information can be joined in a GIS-environment and incorporated into geographic analyses. These analyses can, for example, help determine where deteriorated conditions are concentrated in a given transportation corridor. In the following example, a cluster analysis of rock slope Condition States is conducted on NHS routes. Similar analyses could be conducted using AKDOT&PF's other geotechnical assets to help identify corridor segments most in need of attention or areas where multiple sites could be mitigated as part of a single project.

4.1 Analysis Example - Cluster Analysis of Rock Slope Condition State

Using the rock slope geodatabase, which includes site midpoints, basic site information, and rating information for all inventoried rock slopes, a geographic analysis was conducted to help determine where concentrations of less optimal and deteriorated conditions are present. For this example, the automated analytical tools readily available under the basic software license were used to perform a cluster analysis, examining the spatial distribution of statistically significant clusters of assets with Condition State values greater than that expected under random chance. Those clusters with assets in Fair/Poor condition than expected are referred to as "hot spots" in the analysis, while those clusters with assets in Good condition than expected are referred to as "cold spots." Sites where assets are in Good/Fair condition are "neutral" or "not significant" in the cluster analysis tool. Using the 5 (Poor) to 1 (Good) Condition State values, the 'Optimized Hot Spot Analysis' tool was utilized to generate a hot spot map of the inventoried rock slopes throughout the NHS system (Figure 4-1). At this statewide scale, the cluster analysis exhibits a few select areas with high concentrations of Fair/Poor Condition State rock slopes, most notably along the Seward and Glenn highways in Central Region.

When zooming in on a specific region, more complex patterns become apparent. Taking Central Region as an example in Figure 4-2, variation within the hot spots stands out. For instance, the slopes nearest Anchorage (i.e. MP 110-115) on the Seward Highway were constructed much earlier than those built to the south (i.e. MP 104-110) and did not benefit from wider ditches and controlled blasting techniques, resulting in the relative 'heat' in this portion. Also on the Seward Highway, the rock slopes between the city of Seward and the Sterling Wye are built to older standards and have relatively low ditch effectiveness, resulting in the corresponding hot spot. Note that portions of the Seward along Kenai Lake are currently scheduled to be upgraded in the coming years. Hot spots around the Long Lake area near Chickaloon on the Glenn Highway are also notable. In contrast, rock slopes around Thompson Pass in the Northern Region are mostly low activity slopes with good ditch effectiveness, resulting in the 'Cold Spot' in this vicinity.

The existing areas mapped as a mix of good and fair slopes should not be ignored. Rock slopes will deteriorate with age, and rockfall issues may arise in these areas over time, particularly for those slopes where current rockfall activity has a greater influence on the slope condition than ditch effectiveness. For instance, since the Turnagain Arm rock slopes were rated in the "Top 100" 2010 survey, there has been a marked increase in rockfall activity recorded in the Maintenance Management System (Figure 4-3). This increase in rockfall activity highlights the need for regular re-rating activities and corresponding slope maintenance and repair.

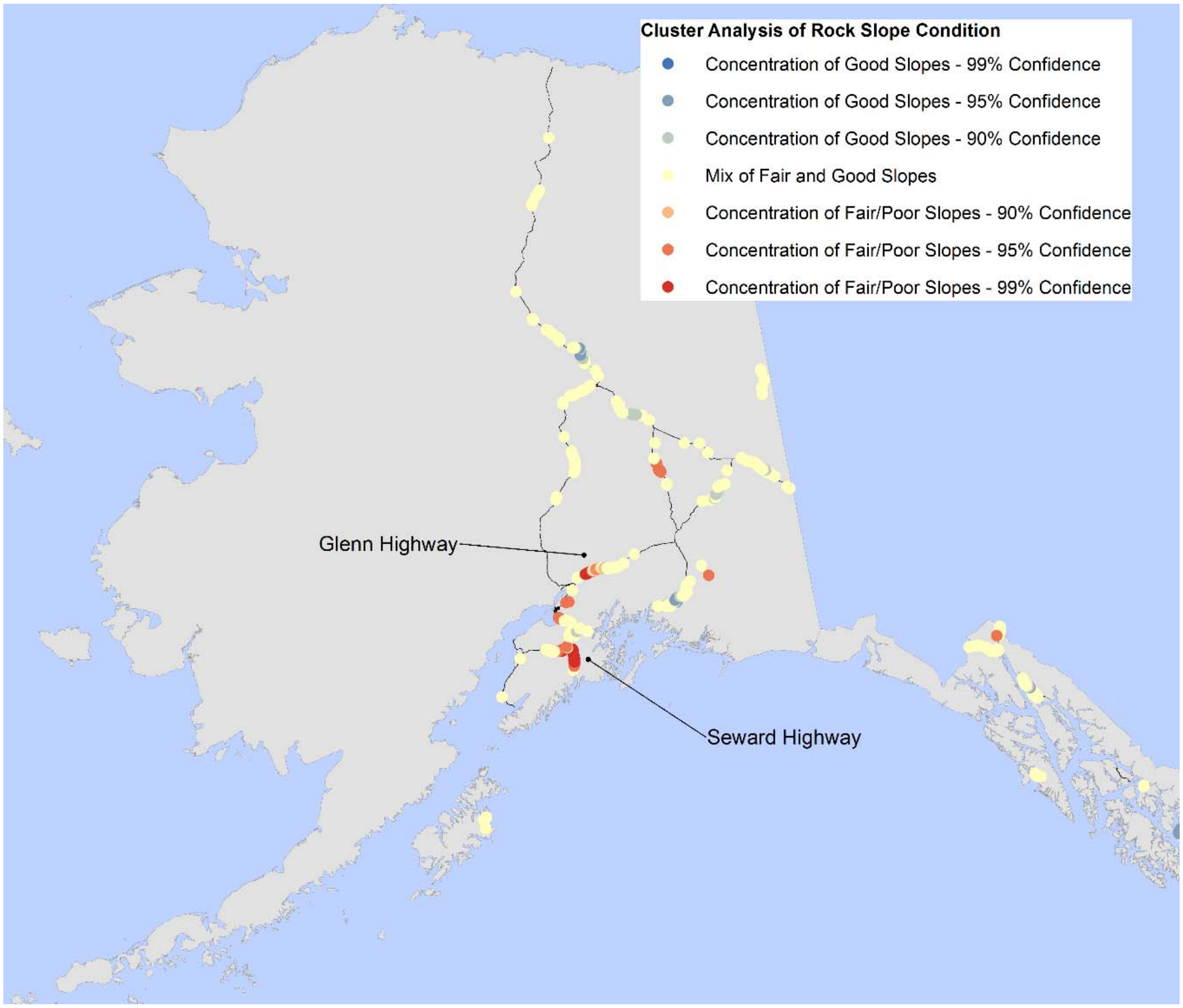

Figure 4-1: Cluster Analysis of Rock Slope Condition State on statewide NHS routes. Note that while most rock slope corridors have assets in Good or Fair condition, Fair and Poor slopes are concentrated in certain segments of the Seward and Glenn Highways.

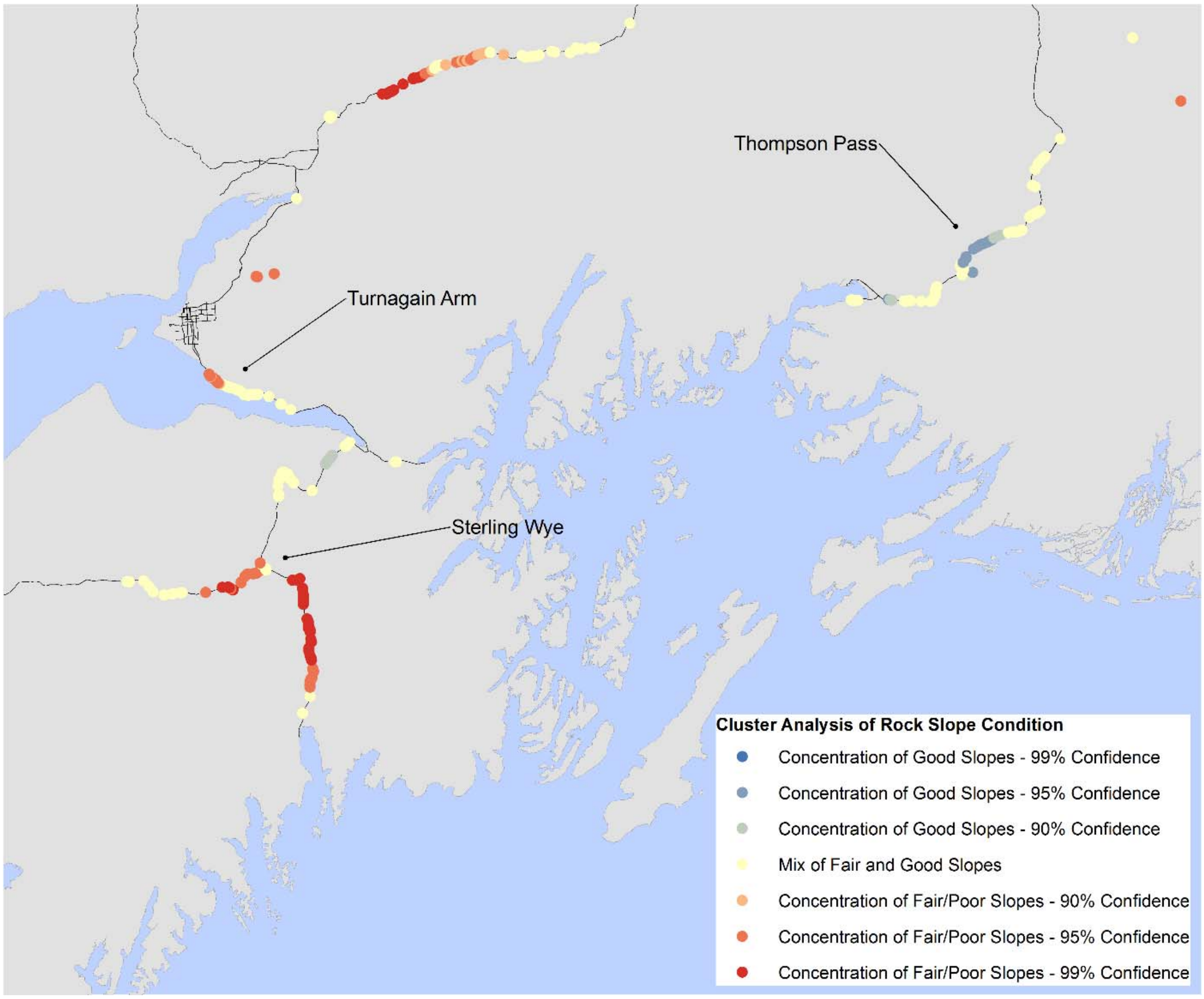

Figure 4-2: Cluster analysis map showing rock slopes in portions of Central and Northern regions. Areas with particular concentrations of Fair/Poor and Good slopes are called out.

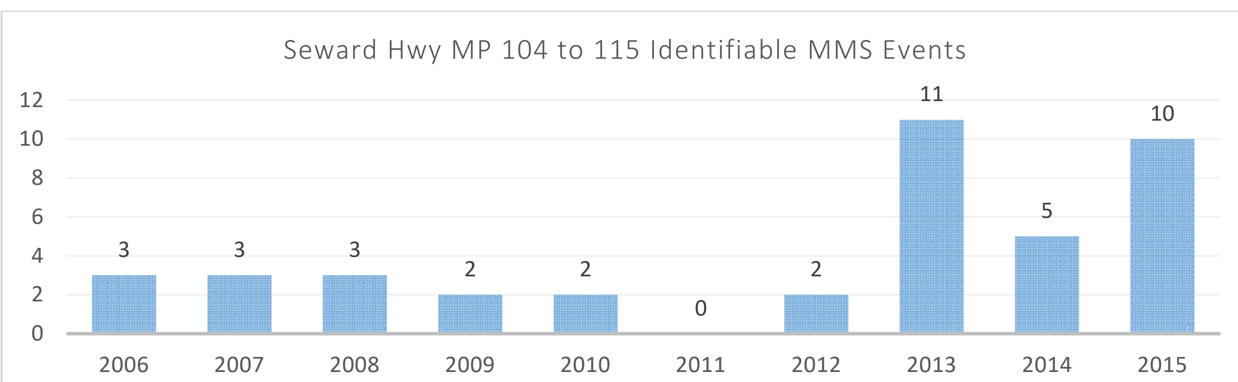

Figure 4-3: Annual count of location-identifiable rockfall cleanup activities in the MMS on the Seward Highway between MP 104 and 115. These counts do not include regularly scheduled maintenance work, such as daily rockfall patrols.

5 RISK ASPECTS FOR GEOTECHNICAL ASSETS

5.1 Estimating Event Likelihood

Within the AKDOT&PF GAM research project, Shannon and Wilson is currently conducting a GAM Risk Management Study that, among other tasks, seeks to establish a preliminary relationship between asset condition and the likelihood of a service disruption. These estimates will cover rock slopes, unstable soil slopes and embankments, and retaining walls and are meant to incorporate both routine adverse events (e.g. rockfall) and extreme events (e.g. earthquakes). These likelihoods will not be accurate at the site-specific level, but at the corridor or regional level, they can help the department in decision-making processes, and help forecast monetary consequences of these adverse events. The preliminary likelihood estimates from the GAM Risk Management Study are shown summarized in the tables below. More detailed discussion of the methods and final results can be found in that final report.

Table 5-1: Preliminary correlation between condition state and likelihood of service disruption for the various geotechnical asset types from the GAM Risk Management Study.

Asset Type	Annual Probability of Service Disruption by Condition State				
	1 – Good	2 – Fair	3 – Fair	4 – Poor	5 – Poor
Rock Slopes	4%	10%	18%	63%	86%
Soil Slopes and Embankments	2%	10%	39%	63%	86%
Retaining walls	1%	4%	10%	18%	63%
Material Sites	1%	1%	1%	10%	63%

5.2 Monetizing the Consequences of Adverse Events

The GAM priority-setting process aims to minimize life cycle agency cost at the same time that it maximizes safety and mobility. These are competing objectives: when the funding level is fixed, adding money to safety-related improvements means taking money away from preservation, and vice versa. The framework requires a fair way to balance these objectives. One common way to do this is to monetize safety and mobility in the form of social cost. The models for this kind of analysis are well established (AASHTO 2010). Bridge and pavement management systems use these models for the same purpose. A good description with example application to risk analysis can be found in a recent Florida DOT research report (Sobanjo and Thompson 2013).

Social cost models can convert estimates of accident count and road closure duration in hours per year into consistent estimates of social cost as long as traffic volume and detour route or alternative mode information is available. For the present application, AASHTO's Red Book (AASHTO 2010) has a very detailed presentation of alternative methods, including quantitative parameters derived from dozens of studies. Given the relative scarcity of data available for this analysis, a relatively simple adaptation of the Red Book Models provides the necessary computations.

5.2.1 Mobility Impacts

If the Threat to Mobility is less than one hour, travellers will likely wait for the road to be cleared unless the detour route is shorter. In this case, the impact of a service disruption will be a closure of up to an hour; so, the mean closure would be 30 minutes. The mobility disruption cost in this scenario is presented in Equation 5-1.

Equation 5-1: Mobility Disruption Cost for a closure lasting up to one hour.

$$M\$ = \frac{ADT}{48} \times 0.25 \ \times TT\$ \times VO$$

Where *ADT*/48 is the number of vehicles to arrive at the site in one half hour
0.25 is the average delay in hours per vehicle if vehicles arrive randomly over the half hour
TT$ is travel time cost, the value per hour of a vehicle occupant's time ($30.50 in 2015$[3])
VO is the average vehicle occupancy rate (1.3[4])

If the Threat to Mobility is greater than one hour, the impact is likely to be travellers using an alternate route if one is available. In this case the mobility disruption cost is calculated using Equation 5-2.

Equation 5-2: Mobility Disruption Cost for a closure lasting more than one hour with a detour available.

$$M\$ = ADT \times DD \times (DL \times VOC\$ + DL/DS \times TT\$ \times VO)$$

Where *ADT* is the number of vehicles per day which normally use the route
DD is the number of days that traffic is detoured
DL is the detour length in miles (found in Pontis or the Department's GIS)
VOC$ is the average vehicle operating cost per mile ($0.207 in 2015$[5])
DS is the detour speed in mph
TT$ is travel time cost, the value per hour of a vehicle occupant's time ($30.50 in 2015$)
VO is the average vehicle occupancy rate (1.3)

Detour day ranges are provided in the Threat to Mobility definitions shown above. Midpoints of these ranges can be used in this equation. Detour length is available for most bridges in the Department's Pontis bridge management system. Many geotechnical assets are located near bridges and these sites can use the Pontis estimate. For sites that are more isolated, the Department's Geographic Information System is able to compute appropriate estimates. Detour speed should be assessed in the field, and, if unknown, it can be assumed to be identical to that at the asset site.

In cases where the Threat to Mobility is greater than one hour and no detour route is available, the computation can assume a shift to a different mode of transportation. In this case, mobility disruption cost is calculated using Equation 5-3.

Equation 5-3: Mobility Disruption Cost in cases where closure is greater than 1 hour and no detour is available

$$M\$ = ADT \times DD \times VO \times AM\$$$

Where *ADT* is the number of vehicles per day which normally use the route
DD is the number of days that traffic is detoured
VO is the average vehicle occupancy rate (1.3)
AM$ is the alternate mode cost

[3] AASHTO Red Book, page 5-4. This figure uses the average over all occupations, computed as an opportunity cost. It is updated to 2015 dollars using the Consumer Price Index.
[4] This value was suggested in the Red Book, but the Department Planning Office might use a different estimate.
[5] AASHTO Red Book, page 5-10. This is based on the "large car" column and includes fuel, oil, maintenance, and tires. It is updated to 2015 dollars using the Consumer Price Index.

The alternate mode cost can be assessed in the office using published marine or air fares, and is only needed for sites that lack a detour route.

5.2.2 Safety Impacts

As defined above, Threat to Safety is an estimate made by an inspector of the number of vehicle crashes likely to be caused by a service disruption event. These can entail vehicles being struck by falling debris, vehicles striking debris that is already lying in the road, or vehicles that lose control or are damaged due to debris avoidance or pavement damage. For this analysis, these incidents are assumed to be single-vehicle crashes. The Red Book has procedures and research-based metrics that take into account typical crash injury severity rates and property damage. The safety disruption cost is presented in Equation 5-4.

Equation 5-4: Safety Disruption Cost

$$S\$ = AC \times ACC\$$$

Where AC is estimated accident count, taken as the middle of the selected Threat to Safety range.
$ACC\$$ is the average cost per crash ($43,525 in 2015$[6]).

5.2.3 Recovery Costs

The GAM risk framework included evaluation of potential maintenance or recovery costs based on asset performance, as shown in Table 5-2 below.

Table 5-2: Summary of Risk-Based Recovery Costs

Performance Level	Descriptor	Performance Factor Options
0	Acceptable	Costs are less than $10,000
25	Low	Costs range from $10,000 to $50,000,
50	Minimal	Costs range from $50,000 to $100,000
75	Major	Costs range between $100,000 to $250,000
100	Catastrophic	Cost exceeds $250,000

The cost ranges provided above can be assessed in the field and used to develop the Recovery Cost Estimate (Equation 5-5).

Equation 5-5: Recovery Cost Estimate (from table)

$$R\$ = midpoint\ of\ applicable\ cost\ range$$

5.2.4 Consequence Costs

The total cost of a transportation service disruption is estimated as the sum of mobility cost, safety cost, and recovery cost (Equation 5-6).

Equation 5-6: Consequence Cost

$$Consequence = M\$ + S\$ + R\$$$

[6] AASHTO Red Book, page 5-24. This figure is an average over all vehicle classes and accident types. It excludes insurance reimbursement to avoid double-counting of costs. It is updated to 2015 dollars using the Consumer Price Index.

5.2.5 Likelihood of Disruption

The table presented earlier in this section provides estimates of the return period of adverse events, which are defined in part within the Condition State definitions in Section 3. The total expected value risk cost component is calculated from Equation 5-7, where the annual event likelihood is obtained from Equation 5-8.

Equation 5-7: Risk component of life cycle social cost

$$Value\ of\ Risk\ Component = Likelihood \times Consequence$$

Equation 5-8: Annual Event Likelihood

$$Likelihood = 365/RP$$

Where RP is the return period in days

5.3 Consequences of Poor Performance of Material Sites

The material sites managed by AKDOT&PF do not directly support the roadway, and failures within the material sites are unlikely to pose direct risks to the travelling public. However, material scarcity influences overall corridor performance. Poor access to valuable materials within a reasonable distance of a construction project increases the risk of incurring excess haul costs, or increases the risk that embankments will be constructed using substandard materials, resulting in poor embankment performance and a shortened pavement and embankment life cycle. Finally, poor access to materials hampers the Department's ability to respond quickly to emergency situations requiring corridor repair. All of these risks impose monetary costs on the public by requiring expenditures that could be used to fund other projects if better access to valuable materials were available.

Unfortunately, these additional costs are not well constrained at this time. Future research is required to monetize the consequences of material scarcity in AKDOT&PF's maintenance station service area.

5.4 Risk Costs

In order to account for Department and user costs to determine consequences to the public, cost estimates for recovery and consequences and likelihood of disruption are required. These risk cost estimates are also being developed in the GAM Risk Management Study. This report is being completed by Shannon and Wilson under separate contract to AKDOT&PF and is expected to be finalized in 2017.

6 COST ESTIMATION FOR IMPROVEMENT OF DEPARTMENT GEOTECHNICAL ASSETS

Inventorying and rating geotechnical assets, thereby identifying corridors with a concentration of high risk/hazard sites, is only one facet of a successful GAM program. GAM research also assists in the development of programmatic, high level cost estimates for mitigation of a suite of sites based on calculated site Condition States. These estimates are not for use at any one specific site due to the large variety of potential problems, choices of mitigation measures, and site improvement goals. However, these estimates are intended to accurately reflect the average cost of mitigation for a set of assets with known Condition States.

Since the state of Alaska is still in the beginning stages of asset monitoring, the GAM research implementation was designed to utilize existing, large-scale datasets from other state DOTs where available. For rock slope and unstable soil slope/embankment assets, a mitigation cost estimate – Condition State correlation was developed using data from the Montana Department of Transportation (MDT) and the Washington Department of Transportation (WSDOT), which already have fully implemented unstable slope rating systems with conceptual mitigation costs for slopes meeting certain criteria. No similar large-scale dataset was available for retaining walls or material sites, since AKDOT&PF is one of the first DOTs to integrate its geotechnical assets into an asset management program. Projected costs for retaining walls are based on data extracted from department bid tabs. Projected costs for material sites are based on Department records of permitting and development costs as well as input from key personnel. The development of cost estimates for the various geotechnical asset classes is the subject of the following subsections.

6.1 Development of Mitigation Cost Models Based on Asset Condition States for Rock Slopes

The mitigation cost model incorporates rating and conceptual mitigation cost data obtained from MDT's Rockfall Hazard Rating System (RHRS) (Pierson, Beckstrand and Black, Rockfall Hazard Classficaton and Mitigaton System 2005, D. L. Beckstrand, et al. 2017) and overhead rate data obtained from WSDOT's Unstable Slope Management System (USMS) (D. Beckstrand, et al. 2016). As part of MDT's RHRS program, conceptual mitigation design work was performed for the 100 highest-rated slopes in the state, information that was not part of AKDOT&PF's initial USMP research in Phase II or part of the current GAM implementation. Within WSDOT's USMS program, slopes which score above a certain benchmark are automatically referred for a conceptual design, which is passed on to a regional engineer who develops a total project cost for use in a cost-benefit analysis. This additional data allowed average overhead costs (PS&E, mobilization, traffic control, construction engineering, etc.) for unstable slope mitigation work to be estimated and checked against the smaller set of overhead costs available for rockfall mitigation projects in Montana.

6.1.1 Incorporation of the Montana Department of Transportation Dataset

For the MDT RHRS, detailed ratings using the RHRS were conducted at 869 locations. Conceptual mitigation designs and cost estimates were developed for the 100 sites with the highest scores, hereafter referred to as the top 100 sites. Preliminary Rating Data, Detailed Rating Data, and Preliminary Mitigation Design and Cost Estimates for the top 100 sites were presented to MDT in a final report in September 2005 (Pierson, Beckstrand and Black, Rockfall Hazard Classficaton and Mitigaton System 2005). The mitigation element unit prices and calculated Condition States, areas, and cost estimates used to perform this analysis are available upon request. When developing the mitigation cost – Condition State correlation described in this report, the 2005 average unit prices were updated to 2014 average unit prices based on experience working with specialty Pacific Northwest rockfall contractors routinely using difficult access construction techniques, such as wagon drills, rope access, and helicopter-supported mitigation construction, and etcetera.

6.1.1.1 Development of Square Footage Estimate for Average Rock Slope Face

Development of an estimated mitigation cost per square foot of slope face required development of a basic formula that could be used to estimate the slope face square footage at every site, based on the measurements available in the MDT dataset. Initial concept work assumed that all slopes were vertical and slope face area was reasonably well approximated by the area of a triangle. Site photographs for a random sample of the rated sites in Montana were then used to refine these equations. Following examination of the photographs for the selected sites, a refined estimate of slope face area was produced using sixty percent of slope length times the greatest slope height within the section, and that a more representative slope layback was 0.5H:1V. This contributed an additional 5% to the area, resulting in the 65% multiplier in Equation 6-1.

Equation 6-1: General Estimate of Rock Slope Face Square Footage

$$Area = 0.65 * (height\ of\ slope)(length\ of\ slope\ along\ roadway)$$

6.1.2 Development of Rock Slope Condition State – Mitigation Cost per Square Foot Correlation

Because MDT’s RHRS system and AKDOT&PF’s USMP system both used the same exponential rating format and shared many of the same categories, it was possible to calculate the Condition State for each rockfall site using the equations outlined in Subsection 3.2.

Condition States are generally reported as whole integers, 1, 2, 3, etc. However, for the purpose of developing a more robust Condition State – Mitigation Cost correlation, decimal Condition States were used to achieve additional separation. This method allowed for better capture of the distribution of RHRS/USMP scores within each Condition State Group for MDT’s Top 100 sites.

The Top 100 sites were then plotted in mitigation cost per square foot versus square footage of rock face, as shown in Figure 6-1 below, with the sites color-coded based on Condition State. A general trend toward an economy of scale is apparent, but Poor Condition State sites are shown to dominate the high ends of both the mitigation cost and total square footage spectrums.

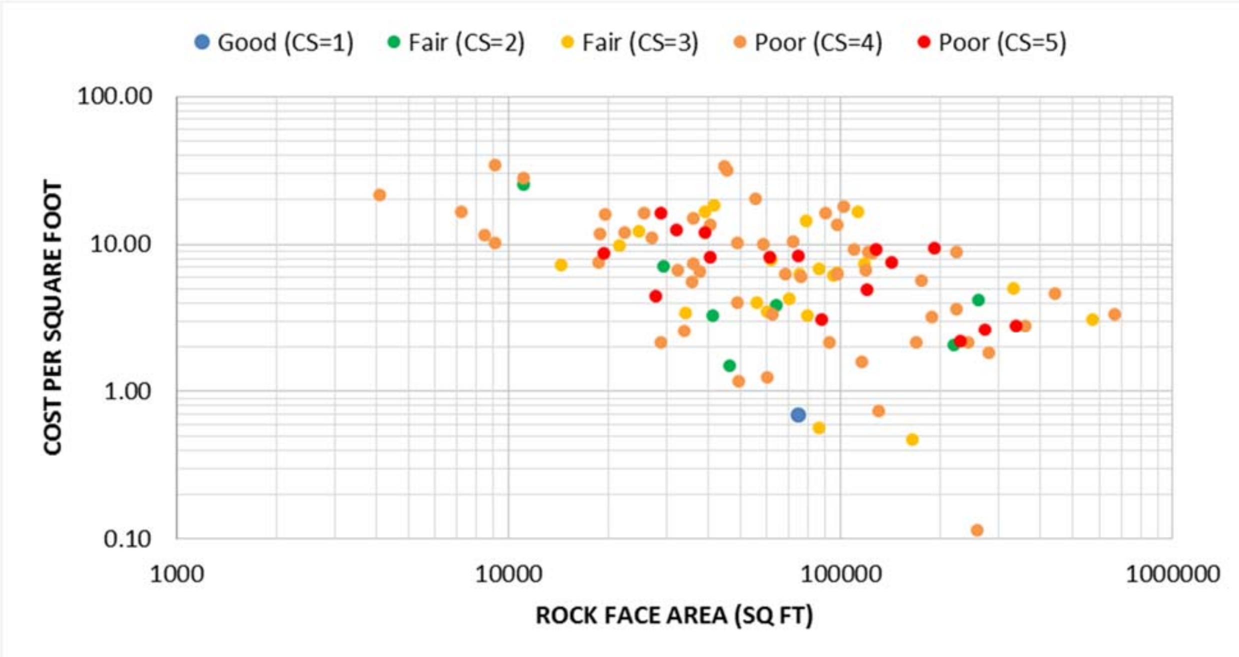

Figure 6-1: Scatter plot of square footage of rock slope face vs. mitigation cost per square foot. Dot color indicates slope Condition State.

To draw out a possible relationship between Condition State and mitigation costs, a new plot was created showing slope Condition State versus mitigation cost per square foot, Figure 6-2. There is still appreciable scatter in mitigation cost per square foot within each Condition State group. However, the plot indicates that the Good sites cost less to improve than the Poor sites.

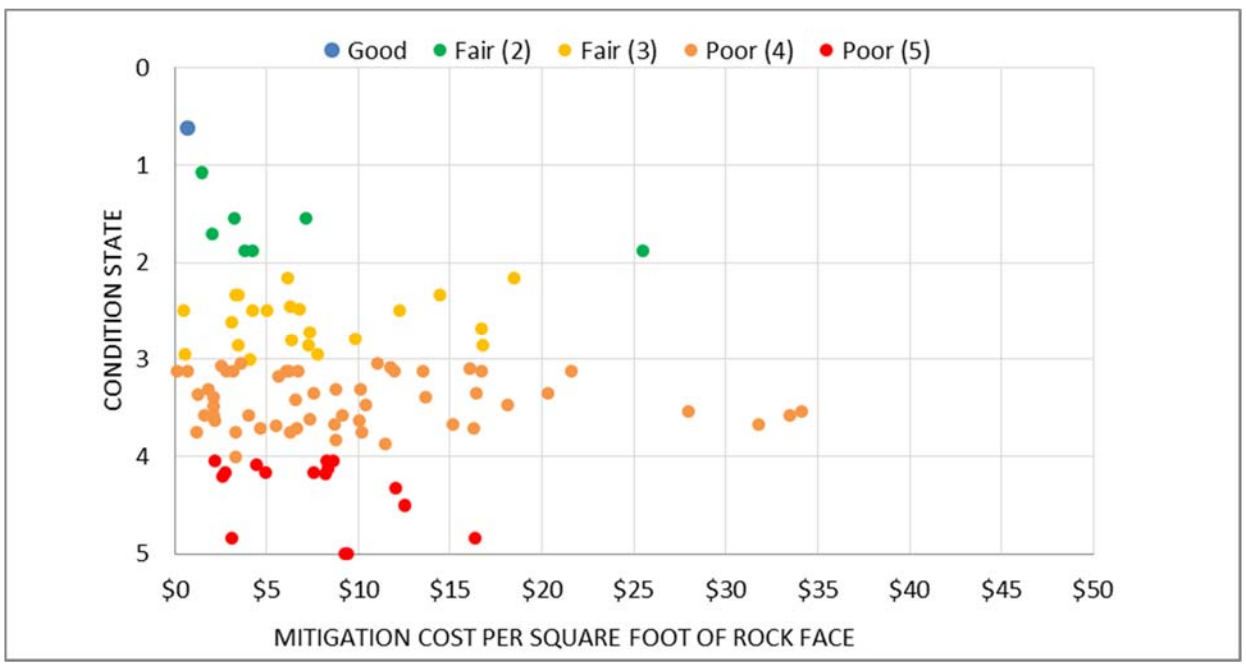

Figure 6-2: Scatter plot of mitigation cost per square foot of rock face vs calculated rock slope Condition State for the top 100 sites identified for MDT.

The small sample size of Condition State 5 sites is probably due to a combination of factors, including construction practices and the speed with which these sites are repaired or mitigated relative to Condition State 3 or 4 sites due to risk and hazard concerns. The relatively small number of Condition State 1 and 2 slopes in the top 100 sites is also more readily apparent, which is to be expected since low scoring sites were largely eliminated from the detailed ratings and other contributing factors resulted in the high RHRS score (e.g. slope height, geometry, AADT, etc.). In MDT's conceptual mitigation design work, total RHRS score, not slope Condition State, was used to determine the Top 100 sites. Therefore, the Good and Fair category sites mitigated in this survey were likely outliers within their Condition State group.

To try to generate a more representative sample pool, the MDT Detailed Ratings were used to identify 6 additional Condition State 1 sites and 29 additional Condition State 2 sites. In order to develop an estimate that reflected more realistic mitigation costs for Condition State 1 and 2 slopes, a simple, cost effective mitigation strategy was developed for these additional sites. It was assumed that the main contributor to hazard in Condition State 2 slopes is limited or insufficient catchment on a relatively inactive slope, which could be addressed by the installation of a simple roadside concrete barrier. Therefore, to develop mitigation costs for the additional rock slopes with Condition State 2, mitigation was assumed to be solely the cost of installing concrete barriers along the length of the slope. This investment would raise the Condition State from a 2 to a 1. These additional sites were added to the seven Condition State 2 rock slopes already included in the Top 100 sites. Unlike the original seven sites, the 29 new sites did not take individual site conditions into account. However, the original sites likely represented outlier cases in that Condition State group, and if evaluated alone would have skewed the trend.

Slopes in Condition State 1 are Good, with rocks rarely affecting the roadway, and generally not requiring any unscheduled or emergency mitigation activities. However, these sites do require routine maintenance, generally in the form of ditch cleaning, to prevent the site from degrading to a less desirable Condition State. AKDOT&PF maintenance was very helpful in providing average ditch maintenance costs used in general planning and budgeting. The average daily cost used in the Southcoast Region is approximately $6,000/day, including the cost of all equipment and personnel. The standard planning factor for linear feet of ditch line cleaned 2,000 feet[7] per day. This results in a maintenance cost of $3.00/day/linear foot of roadside ditch. However, this 2,000-foot standard planning factor covers both rock slope ditch cleaning activities and simple trimming and mowing along stable slopes. Because of this, it is an unrealistically high achievement when applied to rock slopes alone, and would result in maintenance cost estimates that were lower than reality.

Instead, an average daily rockfall ditching of 500 linear feet was applied, which increased the average cost for this activity fourfold. This is based on a scenario where the roadside ditch is adequate to prevent rockfall from reaching the road, but the rock slope is sufficiently active that significant rockfall debris accumulate in the roadside ditch between regularly scheduled maintenance activities. The 500 linear feet used in Condition State 1 maintenance cost estimation also attempts to account for the extra time and effort required to remove larger blocks or debris piles from the base of the rock slope.

An updated scatter plot showing both the original top 100 sites and the additional Condition State 1 and 2 sites is shown in Figure 6-3. Costs shown for Condition State 1 (Good) sites only

[7] Patz, Greg. Maintenance Superintendent – Southcoast Region. Personal Communication. January 29, 2015.

reflect the cost for ongoing maintenance costs since it is not possible to improve a site beyond a Good condition.

Using this final dataset, a set of average Condition States and average mitigation costs was developed for each Condition State and plotted in Figure 6-3. Individual point values are presented in Table 6-1. As shown in the table and plot, the average mitigation cost per square foot of Condition State 5 rock slopes is actually lower than the average mitigation costs for Condition State 4 sites and nearly equal to the average mitigation cost for Condition State 3 sites. Because it is not reasonable for an agency to save money by allowing a slope to deteriorate to a worse Condition State, the Condition State 5 data point was eliminated when calculating the linear trend line.

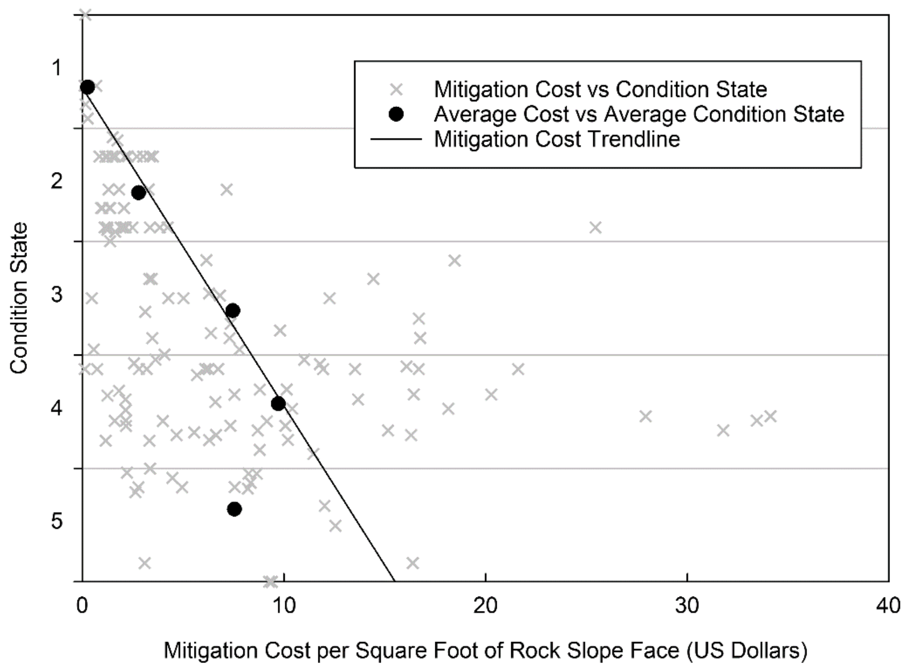

Figure 6-3: Scatter plot and trend line of mitigation cost per square foot of rock slope face vs rock slope Condition State.

Table 6-1: Average Condition State and Average Mitigation costs including MDT Top 100 sites and additional Condition State 1 and 2 sites.

Condition State Category	Average Condition State	Average Mitigation/Improvement Cost per ft² Without Overhead
1-Good	0.64	$0.26
2-Fair	1.57	$2.79
3-Fair	2.61	$7.46
4-Poor	3.43	$9.72
5-Poor	4.36	$7.54

The conceptual designs included only the cost of the actual mitigation components, which are only a portion of the total project cost for a given slope. Additional costs, such as mobilization, traffic control, and other overhead costs, are significant components of the total budget. In order to make the projected rock slope mitigation costs more applicable in planning-level evaluations, average overhead costs were incorporated into the geotechnical mitigation costs derived to develop a total average mitigation cost using data obtained from WSDOT's USMS program, which is also discussed in greater detail in Subsection 6.2.1.3.

The mitigation cost data obtained from WSDOT was specifically for unstable soil slopes and embankments. However, there are many similarities between project parameters for unstable soil and rock slopes, such as difficult access and limited work space, which would result in similar average overhead costs for both asset classes. As described in Subsection 6.2, 88 unstable soil slopes and embankments with conceptual mitigation cost estimates was narrowed down to a list of 50 that contained useable overhead costs. Based on this final list, the average overhead cost for mitigation work at a given site was 123%, and the median overhead cost was 106%. Although average costs were used in developing the Condition State – mitigation cost correlations, the median value for overhead was applicable due to few outliers skewing the result, rounded to a final average overhead cost of 105%.

As a quality check, this number was compared against calculated overhead costs for a rockfall mitigation project currently underway in Montana, with which Landslide Technology is also involved. This project addresses rockfall hazards at 15 sites along the I-15 corridor north of Helena, Montana. Each of the sites received 3-4 pricing options based on the selected rockfall mitigation work and the traffic control option. For these sites, the average overhead cost was 124% and the median overhead cost was 109%. The winning bid for the project, which was awarded in April 2015, was 14.1% below the engineer's cost estimate and resulted in a 70% average overhead cost, not including MDT's internal costs during construction. Based on this, the overhead cost derived from WSDOT's USMS data, which covers a much more diverse set of sites, appears to be a reasonable match for average rockfall mitigation overhead costs. Applying an overhead rate of 105%, the final numerical equation for the average Condition State versus average mitigation cost per square foot is presented in Equation 6-2.

Equation 6-2: Estimated mitigation (with overhead rates) cost per sq. ft. of slope face based on Condition State.

$$Mitigation\ Cost\ per\ ft^2 (in\ 2014\ dollars) = 7.30\ (Condition\ State) - 4.70$$

This equation establishes that, on average, the total cost to improve any site one Condition State will be $\$7.30/ft^2$, regardless of whether the site is going from Condition State 5 to 4 (both Poor Condition States) or Condition State 2 to 1 (Fair to Good). Because the average overhead rate is a constant value, the equation is still linear and thus, the average cost to improve a site more than one Condition State will also increase linearly, as shown in Table 6-2.

Table 6-2: Approximate Total Costs, with both mitigation components and average overhead rates incorporated, for Improving a Rock Slope by a given number of Condition States

Number of Condition States Improved by Mitigation Activities	Average Mitigation Cost per ft^2 Without Overhead	Average Mitigation Cost per ft^2 Incorporating Overhead
1	$3.56	$7.30
2	$7.12	$14.60
3	$10.68	$21.90
4	$14.24	$29.20

It is important to bear in mind that these estimates are likely to be inaccurate when applied on a site-specific basis. However, when generating network-level cost estimates for mitigation of dozens of unstable rock slopes, the average costs produced by this approximation technique should be close, except in the cases where exceptionally adverse factors well outside average conditions require an extraordinary solution.

The costs used in this report may differ slightly from current average mitigation rates in Alaska. It has been Landslide Technology's experience that many Alaskan slopes are significantly improved during construction efforts, such as installing rock bolts while the new cut slope is being excavated, and that stand-alone rock slope mitigation projects are relatively uncommon. In fact, few rock slopes statewide have been addressed as stand-alone rockfall mitigation projects where difficult access construction techniques, such as installation of rock bolts using rope or crane access, or helicopter-supported mesh placement, are used. The costs developed in this portion of the GAM project should be updated as Alaska's rock slope dataset is developed.

Additionally, the average costs presented in this report are currently accurate for 2015 and will become inaccurate over time. It would be good practice to regularly re-evaluate the trend line in light of changing construction costs. Alternatively, indexing the cost estimates to the Historical Construction Cost Index or the National Highway Construction Cost Index (NHCCI)[8], with a factor for specialized slope construction efforts, could estimate cost increases for system-wide inflationary factors. A recent escalation of unit costs for a similar project in Montana found that the unit cost increased to $8.01 per condition state improved for 2017, up about 10% from the $7.30 found in this research (D. L. Beckstrand, et al. 2017).

6.2 Development of Mitigation Cost Models Based on Asset Condition for Unstable Soil Slopes and Embankments

The Washington Department of Transportation (WSDOT) has maintained its Unstable Slope Management System (USMS) since the mid-1990s, and they generously allowed Landslide Technology access to it for use in developing a dataset to use in asset valuation work. The mitigation cost model described in this section incorporates ratings, conceptual mitigation costs, and overhead costs obtained from the USMS program.

Currently, all landslides reported to the WSDOT are entered into the USMS and rated by an engineering geologist or geotechnical engineer. Sites with total score greater than 350 and an average daily traffic (ADT) of greater than 5,000 vehicles also receive a conceptual mitigation design. These conceptual designs are then used in calculating total mitigation costs and the probable cost-benefit ratio of repair vs. continuing maintenance[9]. The site ratings and conceptual mitigation designs conducted within WSDOT's USMS were coupled with the Condition State calculation techniques developed under AKDOT&PF's GAM project, so that average unit prices to improve a site based on site Condition State could be developed without consideration of specific site conditions and mitigation techniques.

It is LT's opinion that the general occurrences of weak materials and occasional poor fill placement have created comparable unstable slope conditions in both states. However, the impact of permafrost on slope stability is unique to Alaska and has not been captured in conceptual mitigation work conducted by any other American state department of transportation. Developing robust mitigation cost estimates for permafrost-impacted embankments and soil slopes will require additional research incorporating asset ratings within AKDOT&PF's GAM program, input from AKDOT&PF's maintenance districts, and project cost data from AKDOT&PF Bid Tabs.

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[8] https://www.fhwa.dot.gov/policyinformation/nhcci.cfm
[9] Johnston, Samuel. WSDOT Geotechnical Specialist. Personal Communication. March 10, 2015.

6.2.1 Incorporation of Washington Department of Transportation (WSDOT) Dataset

With the assistance of WSDOT, 99 unstable soil slopes with ratings and conceptual designs were obtained from the WSDOT USMS database. These unstable slopes were classified as either a landslide, settlement, or debris flow slope failure. Of this initial group, 10 sites were eliminated either because the conceptual data was incomplete (i.e., only the cost of additional investigations), the slide did not yet directly impact the roadway, or because multiple smaller landslides were combined as one site, something that was not done in the AKDOT&PF GAM program. For the three sites with multiple conceptual design options, the lowest-cost option was selected, although a more expensive option might better meet agency needs in terms of right-of-way impacts or length of road closures. The work done to translate category ratings for these final 89 sites from WSDOT's USMS rating system to AKDOT&PF's USMP rating system is described in Subsection 6.2.1.1.

Of the 89 sites used in developing Condition State – mitigation cost correlations, 54 contained total construction cost estimates, which included overhead costs. This information was used to develop overhead costs as a percentage of total project costs, described in Section 6.2.2.

6.2.1.1 Conversion of WSDOT Category Scores to AKDOT&PF Category Scores

WSDOT's USMS hazard ratings are based on information from four categories, as opposed to the nine hazard categories evaluated in the AKDOT&PF USMP ratings[10]. However, these four categories were felt to align closely with the four categories used by AKDOT&PF's GAM program to calculate asset Condition State. The applicable rating categories for the two programs are compared in Table 6-3. Converting WSDOT category ratings to AKDOT&PF category ratings was needed to obtain data that could best be integrated with AKDOT&PF's planning goals. The site evaluation and history write-ups facilitated the re-rating process.

Since the slide length was routinely recorded as part of the site visit, the score for AKDOT&PF's "Length of Affected Roadway" category was recalculated from WSDOT's site information data. The "Roadway Impedance" categories were identical for both agencies, so no conversion was required. The criteria for AKDOT&PF's "Roadway Displacement/Slide Deposit" and WSDOT's "Pavement Damage" are similar but not identical. Where relevant, the "Pavement Damage" scores were adjusted based on the written site history in order to score the site along the guidelines in AKDOT&PF's "Roadway Displacement/Slide Deposit" category. Finally, AKDOT&PF's "Movement History" and WSDOT's "Failure Frequency" were more difficult to reconcile than initially anticipated. While movement rate and maintenance frequency are closely related for unstable slopes moving at a constant annual rate, they diverge for less regularly occurring events, such as a debris flow occurring every 3 to 5 years at a site. When developing the AKDOT&PF USMP rating criteria, the research team decided that debris flows should be treated as extremely rapidly moving landslides because unplanned emergency maintenance work is the general outcome of a debris flow at an unmitigated site. Under AKDOT&PF's USMP program, debris flows sites typically received much higher scores than they did under WSDOT's USMS program. Where relevant, the USMS category score was adjusted based on the written site information to reflect USMP scoring procedures.

[10] WSDOT. WSDOT's Unstable Slope Management System. 2005.

Table 6-3: Comparison of Rating Category definitions for AKDOT&PF and WSDOT unstable slope ratings. Wording that is similar or identical between the Alaska and Washington systems is italicized.

AKDOT&PF Landslide Rating Categories. See Table 3-4 for additional detail.		WSDOT Landslide Rating Categories	
Length of Affected Roadway Element		**Impact of Failure on Roadway**	
100	None	100	--
75	25’	75	<50’
50	100’	50	50’-200’
25	225’	25	200’-500’
0	400’ or greater	0	>500’
Roadway Impedance Element		**Roadway Impedance**	
100	None	100	--
75	Shoulder only.	75	Shoulder Only
50	Half Roadway.	50	Half Roadway
25	3/4 Roadway.	25	¾ Roadway
0	Full Roadway.	0	Full Roadway
Roadway Displacement or Slide Deposit Element		**Pavement Damage**	
100	No Crack or Deposit	100	--
75	Visible crack, slight settlement, or small deposit of material on road.	75	Minor. Not Noticeable
50	1-inch offset, or 2 inches of material on road surface or moderate settlement	50	Moderate. Driver must slow.
25	2-inch offset, 6 inches of material on road, or significant settlement.	25	Severe. Driver must stop.
0	4-inch or greater offset or greater or 12 inches of material on road, or extreme settlement.	0	Extreme. Not traversable.
Movement History Element		**Failure Frequency**	
100	None	100	--
75	Minor movement, sporadic creep, or very slow settlement	75	0/5 YR. Maintenance required less than once every 5 years.
50	Up to 6 inches annually, steady annual creep, or moderate settlement rate.	50	1/5 YR. Maintenance required more often than once every 5 years.
25	Up to 6 inches per event, more than two events per year or fast settlement.	25	1/YR. Maintenance required about once a year.
0	>1 ft. displacement in hours (includes all debris flows) or rapid, continuous settlement.	0	1+/YR. Maintenance required more than once a year.

6.2.1.2 Adjustment of WSDOT Conceptual Mitigation Costs for Inflation

The conceptual mitigation designs used in mitigation cost correlation work were developed between 2000 and 2014. Since the design work covered a significant time span, it was necessary to adjust the conceptual mitigation costs for inflation before a mathematical relationship between soil slope Condition State and mitigation cost could be developed.

WSDOT explained that the conceptual slope mitigation designs are forwarded to the appropriate regional office, where a scoping engineer incorporates all other costs, such as traffic control and construction engineering. Approximately 1 -2 years before a project goes out to bid, an inflationary rate is applied to update the estimated costs. Generally, the Federal Highway Administration (FHWA) National Highway Construction Cost Index (NHCCI)[11] is used. In WSDOT's experience, final bid prices can still fluctuate greatly based on the number of bidders for a project, how aggressive bidding is, and price fluctuations of materials within the larger market.[12] In general keeping with this methodology, Landslide Technology used the FHWA NHCCI to adjust estimated mitigation costs to 2014 prices, enabling direct comparison of mitigation costs per linear foot of slide many years apart.

6.2.1.3 Development of Average Overhead Rates from USMS Dataset

The cost of the actual mitigation components are only a portion of the total mitigation project cost for a given slope. In order to make the projected unstable soil slope mitigation costs more useful in planning-level evaluations, average overhead costs were incorporated into the conceptual geotechnical mitigation costs to develop a total average mitigation cost.

Of the 89 conceptually mitigated sites obtained from the USMS, 54 also contained construction cost estimates. These construction cost estimates were developed by a scoping engineer at a regional office based on the conceptual design provided by the geotechnical engineer and included costs for mobilization, traffic control, construction engineering, etc. Six of the sites also included Right of Way (ROW) costs, but these ROW costs were removed from the overhead cost calculations because they can vary greatly between sites and are typically independent of site condition. ROW costs are more reasonably assessed on a project-by-project basis instead of as some set percentage of total project cost that would be applied statewide.

Upon further examination of the 54 sites used for overhead cost calculations, one was eliminated because the construction cost estimate was based on an outdated mitigation design. Three additional estimates were eliminated because the overhead costs were more than 500% of the conceptual mitigation costs, and these were judged to be extreme situations. For the remaining 50 sites, the overhead cost was calculated as a percentage of the mitigation cost estimate. The average overhead cost for mitigation work at a site was 124%, while the median cost was 106%. Based on this data set, 105% was selected as a reasonable estimate of overhead costs for mitigation work on unstable soil slopes.

Mitigation work for both unstable rock slopes and unstable soil slopes meet many similar criteria, such as difficult access, impacts to the existing roadway during mitigation activities, and limited bid quantities. These similarities indicate that comparing overhead costs for mitigation work for rock and soil slopes was a reasonable check on the validity of the estimated average overhead percentages obtained from WSDOT's USMS program.

A final overhead cost of 105% was applied to all Condition State mitigation costs, and used in the site condition – conceptual mitigation cost correlations developed in Section 6.2.2.

6.2.2 Development of Unstable Soil Slope and Embankment Condition State – Mitigation Cost per Linear Foot Correlation

Following completion of the score conversion work described in Section 6.2.1.1, site Condition States are calculated for each of the 89 sites following the procedure outlined in Section 3.3. It is

[11] http://www.fhwa.dot.gov/policyinformation/nhcci.cfm
[12] Fish, Marc. WSDOT Engineering Geologist. Personal Communication. June 4, 2015.

general practice in the AKDOT&PF GAM Program is to report Condition States as whole integers: 1, 2, 3, etc. However, for the purpose of developing a Condition State – Mitigation Cost correlation, decimal Condition States were used to obtain additional separation between sites and make correlation equations more robust.

A log-log scatter plot of slope Condition State versus mitigation cost per linear foot is shown in Figure 6-4. Average linear footage and average mitigation cost per linear foot of each Condition State category are also shown. Poor condition slopes (Condition States 4 and 5) dominate the upper end of the mitigation cost spectrum, while Fair condition slopes (Condition State 2) tend to be both smaller and less expensive to address. There are no "Good" (Condition State 1) soil slopes shown on the plot because stable slopes are not the focus of conceptual mitigation design efforts.

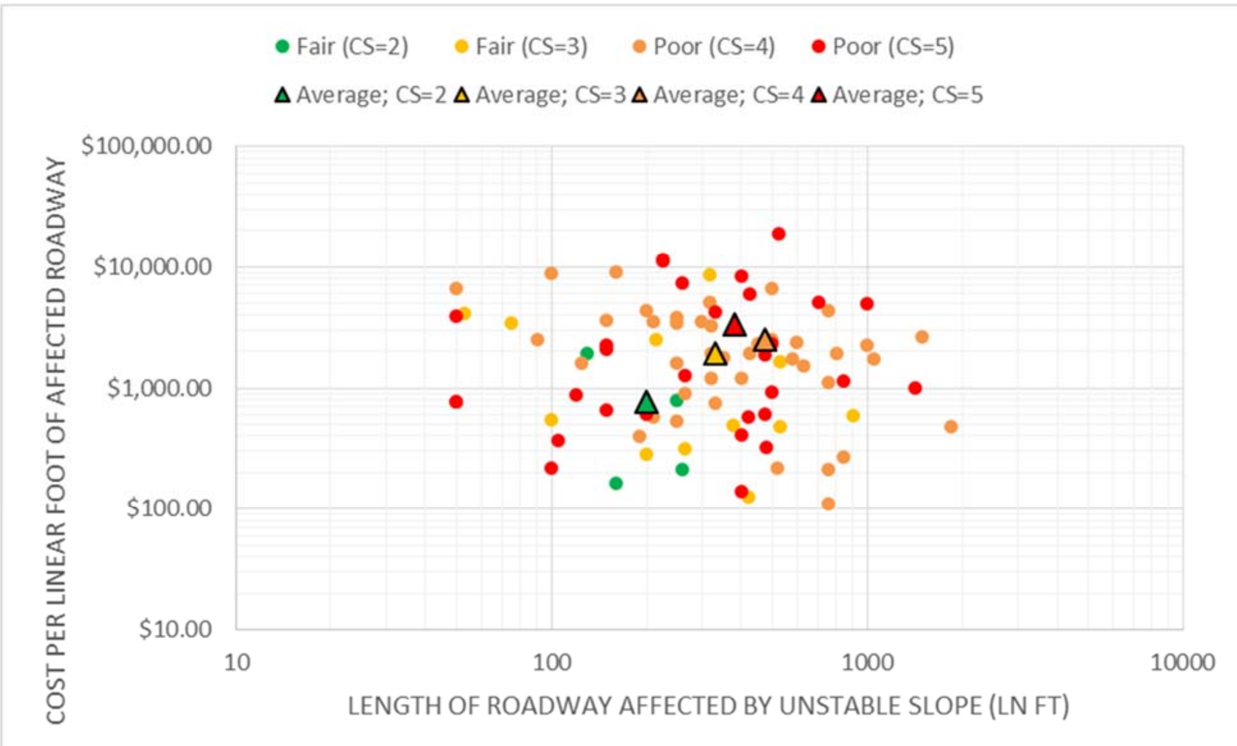

Figure 6-4: Scatter plot showing linear footage of roadway impacted by an unstable soil slope vs. conceptual mitigation costs per linear foot. Dot color indicates slope Condition State. Triangles show the average length and cost per linear foot for each Condition State. Triangles show the average length and cost per linear foot for each Condition State group.

To draw out a possible relationship between Condition State and mitigation costs, a new plot was created showing slope Condition State versus mitigation cost per square foot, Figure 6-5. Appreciable scatter in mitigation cost per square foot remains within each Condition State group, but the general trend is towards increasing mitigation cost with worsening site condition.

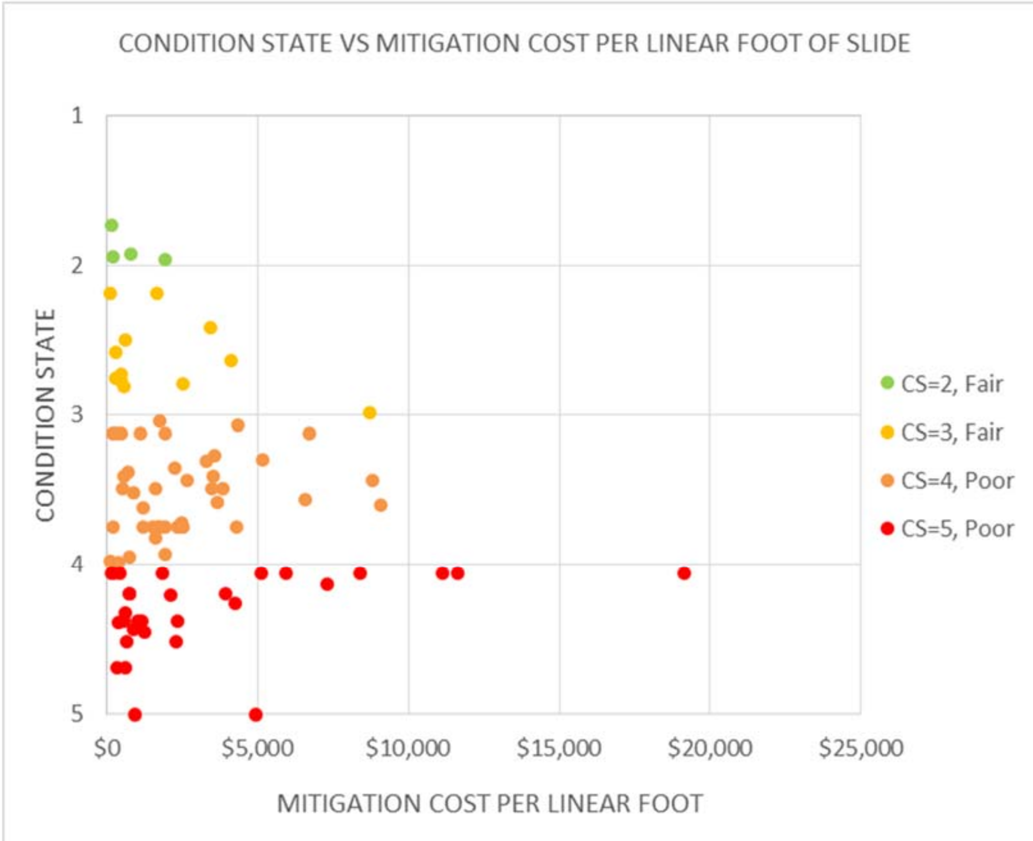

Figure 6-5: Scatter plot of mitigation cost per linear foot of unstable soil slope impacting the roadway vs calculated soil slope Condition State for sites identified for conceptual mitigation by WSDOT.

Also apparent in Figure 6-5 is the low number of Condition State 2 sites, most of which are borderline Condition State 3 sites. As discussed previously, WSDOT develops conceptual designs only for slopes that have a total slope score greater than 350 points. Given that scoring requirement, most sites receiving a conceptual design will be assigned to Condition States 3, 4, or 5 (Fair to Poor), and the included Condition State 2 slopes likely reached the point cutoff through high scores in the risk, as opposed to the hazard, categories.

To partially counteract the bias towards higher Condition State sites, maintenance data obtained from Jason Sakalaskas at AKDOT&PF's Northern Region was incorporated into the data set. This data source is a tracking sheet used since approximately 2009 to track regional maintenance work on pavements by type, quantity, and milepost. The goal behind this spreadsheet was to enable the regional M&O department to determine which sections of the transportation corridor regularly required work and would benefit from mitigation/remediation efforts at a long-term planning level. It does not track any mitigation work that attempts to stop long-term unstable soil slope deformation. However, for those Condition State 2 unstable slopes, which exhibit little movement at a very slow movement rate, it was determined that maintenance work closely approximated any planned mitigation work that would be done at the site. Comparing the rated unstable soil slopes and embankments in the Northern Region with the M&O data, 5 additional Condition State 2 sites were identified. These additional sites were incorporated into the correlation data set, as shown in Figure 6-6. Mitigation costs for these sites were calculated from the average costs used for maintenance planning purposes, which were also provided by Mr. Sakalaskas[13].

Additionally, following the rescoring of WSDOT USMS sites to match AKDOT&PF rating criteria, 40% of Condition State 5 sites were debris flows. Since the typical conceptual design method for debris flow mitigation in the USMS is construction of a dissipation fence, the average mitigation cost for Condition State 5 may be skewed to reflect the cost of this item. A single soil slope failure type similarly dominated no other Condition State group.

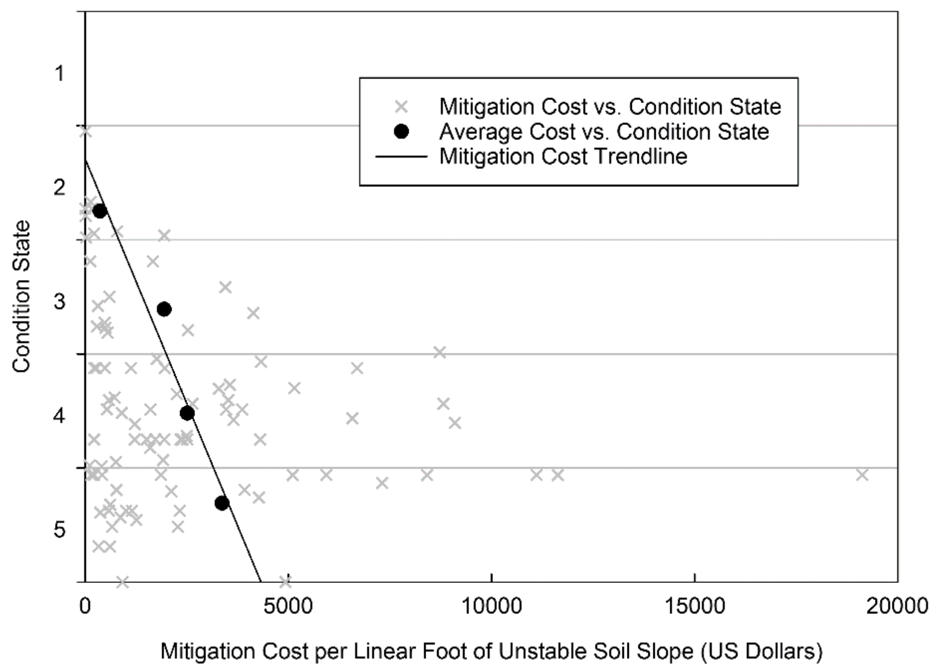

Figure 6-6: Scatter plot of mitigation cost per linear foot of unstable soil slope impacting roadway vs slope Condition State, with the average mitigation cost vs average Condition State point and trend line superimposed. Additional Condition State 2 sites obtained from AKDOT&PF have been added to the 89 WSDOT USMS sites.

Table 6-4: Average Condition State and Average Mitigation cost by Condition State category, using site rating and mitigation cost data from WSDOT and AKDOT&PF's Northern Region.

Condition State Category	Average Condition State	Average Mitigation/Improvement Cost per ft2
1, Good	NA	NA
2, Fair	1.75	$363.41
3, Fair	2.61	$1,943.74
4, Poor	3.52	$2,509.19
5, Poor	4.31	$3,366.31

As shown in Figure 6-6, sites were sorted by Condition State, and a set of average Condition States and average mitigation costs was developed for each group, as presented in Table 6-4. Once average Condition States and average mitigation costs were determined for each group, it was determined that a linear regression best described the correlation between site Condition State and estimated mitigation cost. The equation describing this relationship, which also incorporated average overhead rates, in presented below (Equation 6-3).

[13] Sakalaskas, Jason. Regional Maintenance Engineer – Northern Region. Personal Communication. January 30, 2015.

Equation 6-3: Calculated Mitigation Cost per linear ft. of Unstable Soil Slope based on Condition State, with average overhead rates incorporated.

$$Mitigation\ Cost\ per\ linear\ ft\ (in\ 2014\ dollars) = 2392.34\ (Condition\ State) - 3095.94$$

Because the cost correlation equation is linear, this average cost of improvement per Condition State is unchanged regardless of whether the site is going from Condition State 5 to Condition State 4 (both Poor Condition States) or Condition State 2 to Condition State 1 (Fair to Good). Average costs to improve a site more than one Condition State will also increase linearly, as shown in Table 6-5. As averages, these estimates will be inaccurate when used on a site-specific basis, but total cost estimates will become more accurate when applied to a larger suite of sites.

Table 6-5: Approximate Total Costs, with both mitigation components and average overhead rates incorporated, for Improving an unstable soil slope or embankment by a given number of Condition States.

Number of Condition States Improved by Mitigation Activities	Average Mitigation Cost per ft^2 Without Overhead	Average Mitigation Cost per ft^2 Incorporating Overhead
1	$1,166.86	$2,392.34
2	$2,333.72	$4,784.68
3	$3,500.58	$7,177.02
4	$4,667.44	$9,569.36

The average costs presented here will become inaccurate over time and should be regularly re-evaluated to capture changing construction costs. Alternatively, indexing the cost estimates to the Historical Construction Cost Index or the National Highway Construction Cost Index (NHCCI), with a factor for specialized slope construction efforts, could estimate cost increases for system-wide inflationary factors.

A data gap in this mitigation cost research is the lack of data on permafrost-related costs. A dataset including freeze-thaw susceptible embankments cannot be obtained from other transportation agencies in the United States. Developing a cost correlation model that incorporates these freeze-thaw susceptible slopes will require ongoing research and monitoring within Alaska. This could be done by using the GAM program to help monitor mitigation/rehabilitation of freeze-thaw susceptible slopes inventoried as part of the current USMP program, and by working with AKDOT&PF Northern Region personnel to identify thaw-unstable embankments that have been successfully mitigated, along with associated costs for those successful mitigation projects.

6.3 Development of Mitigation Cost Models Based on Asset Condition for Retaining Walls

AKDOT&PF's work on valuing its retaining wall assets is the first of its kind. Although other organizations, such as the National Park Service and the Colorado Department of Transportation, have developed methods for inventorying and rating this geotechnical asset, there has been no extensive conceptual mitigation design work conducted on inventoried walls. Similar large-scale datasets like those described in Sections 6.1 and 6.2 to determine a monetary value for retaining walls were not available. Instead, construction cost information obtained from AKDOT&PF's bid tabs was used as a basis for developing retaining wall replacement costs, which were incorporated into the mitigation cost models as a "worst-case" scenario. Throughout the process, the mitigation cost models developed for unstable slope assets provided guidance on the mathematical methods used, and on the final overhead costs applied.

Because the cost information obtained from AKDOT&PF's bid tabs was for the construction of new walls only, there are more inherent assumptions in the mitigation cost development work for retaining walls than there are for unstable rock or soil slopes. This reflects a difference in the amount of research time that state agencies have put into inventorying and rating different geotechnical asset types. Developing a more robust cost estimate trend-line for retaining walls will require additional research work and long-term cost tracking of partial mitigations, with mitigation design and cost estimates for specific walls in the various Condition State categories.

6.3.1 Incorporation of AKDOT&PF Retaining Wall Construction Costs

Because no dataset of conceptual mitigation designs was available for retaining walls, Landslide Technology utilized bid tabs from AKDOT&PF's Central Region to evaluate retaining wall costs. These bid tabs spanned the years 2002 to 2012. A significant advantage of this data source over the data sources used in developing unstable slope mitigation costs was that these bid tabs contained costs for work performed in Alaska. However, the bid tab items were only for construction of new walls, so the costs obtained represent wall replacement costs only.

The data obtained from the AKDOT&PF bid tabs was sorted by wall type, pay item measurement unit, unit cost, and year of construction. Unit costs were obtained from the engineer's estimate, the overall low bidder on the project, and the low bidder on the wall item. The wall types obtained from the bid tabs were anchored solider pile, cast-in-place concrete, stacked gabions, modular block, mechanically stabilized earth (MSE), sidewalk retaining, soldier pile, stub, and timber retaining walls. Walls included in the project bid as "lump-sum" costs were not included in the analysis data set. Sidewalk retaining and stub walls, a total of 5 bid tab items, were also not included in the data analysis because they were bid by the linear foot, and no height estimates for these walls were available. It is also more likely that, as a "sidewalk retaining wall," these walls would not meet the minimum 4-foot wall height acceptance criteria for the RWMP. The majority of retaining walls had pay item measurement in terms of square feet or square meters, but gabions were measured by the cubic yard. Because gabion walls are common in the bid tabs and were frequently observed during the field inventory ratings, an attempt was made to incorporate these walls into the analysis data set. It was assumed that the typical gabion wall is not more than 3 bins tall, and that the bottom baskets are therefore not turned 90 degrees into the slope. Based on this, the cubic yardage was converted to a square footage with resulting costs per square foot that appeared low, but reasonable. The edited bid tab data was shared with PanGEO Inc., for further analysis.

PanGEO ultimately judged that the lowest bid for the wall item provided the most reasonable estimate for the in-place cost of the wall if the project had been bid only for replacement of the wall. Ultimately, there were not enough retaining walls of any one type to generate a reliable wall type-specific replacement cost. Instead, an average replacement cost for a retaining wall in Alaska of any type was developed, and average annual inflation was incorporated. A total of 42 walls were used in the final analysis data set and are shown in the scatter plot (Figure 6-7). A line of best fit was developed relating the average wall cost per square foot of wall face in a given year, and the resulting average annual inflation rate was calculated to be approximately 1% per year.

6.3.2 Development of Retaining Wall Condition State – Mitigation Cost per Square Foot Correlation

Using the trend line developed in Section 6.3.1, the average cost of a retaining wall per square foot of wall face was determined to be $45.72 in 2014 dollars. Because no data is available for repair or mitigation of retaining walls, conceptual or otherwise, several additional assumptions were required to develop a Condition State – mitigation cost relationship for retaining walls that could be used in planning and life cycle cost development. It was assumed that retaining walls in Condition State 1/Good do not require any maintenance work, so the mitigation cost for these walls is zero. At the other end of the spectrum, walls in Condition State 5/Poor were assumed to be so deteriorated that replacement was the only viable option, and the mitigation cost for these walls would therefore be $45.72 per square foot of wall face. Similar to the other mitigation cost estimates, linear correlations between Condition State improvements were developed. Figure 6-8 and Table 6-6 summarize these relationships.

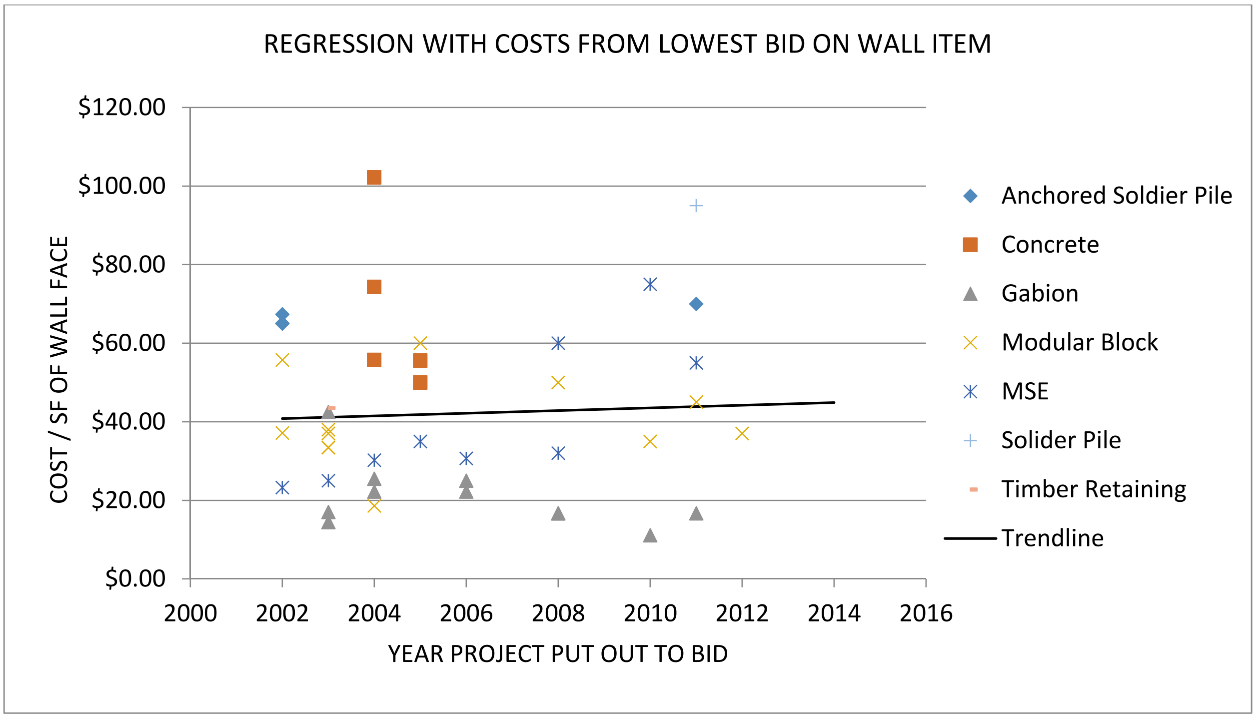

Figure 6-7: Linear Regression relating average wall construction cost per square foot of wall face and year project was bid.

Table 6-6: Linear interpolation plot showing average mitigation cost per square foot of wall face vs Condition State group based on retaining wall construction cost data obtained from AKDOT&PF bid tabs.

Condition State Category	Average Wall Mitigation Cost per ft^2
Good/1	$0.00
Fair/2	$11.43
Fair/3	$22.86
Poor/4	$34.29
Poor/5	$45.72

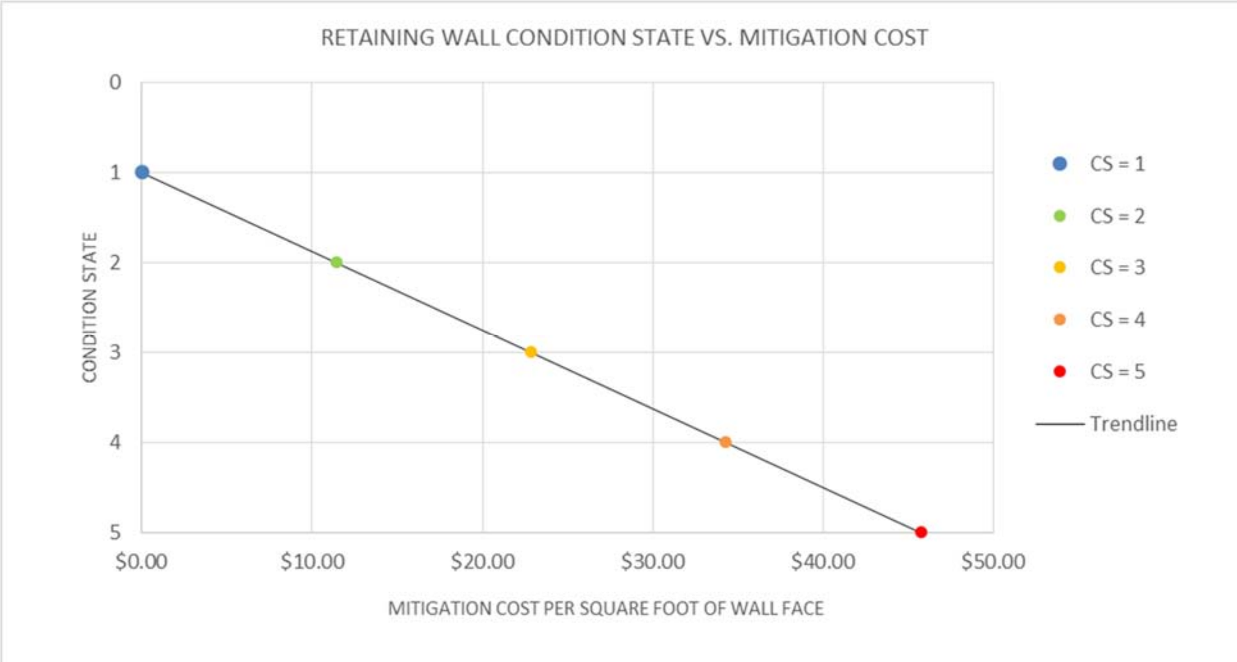

Figure 6-8: Linear interpolation plot showing average mitigation cost per square foot of wall face vs Condition State group based on retaining wall construction cost data obtained from AKDOT&PF bid tabs.

However, the Condition State – mitigation cost correlation developed from the bid tabs only returned the price of wall replacement. Because the retaining walls in the bid tabs were components of much larger projects, it was not possible to discern what portion of the project overhead costs were related to retaining wall work. However, these additional costs, such as mobilization, traffic control, and other overhead costs, are crucial components of the total budget. In order to make the projected retaining wall mitigation costs more applicable in planning-level budgeting, average overhead costs developed for unstable slopes (as described in Section 6.2.1.3) were incorporated into the retaining wall mitigation costs to generate a total average mitigation cost. The underlying assumption is that mitigation work for both asset types generally involves difficult access and potentially hazardous work areas, with work that must frequently be completed within the existing roadway area, requiring traffic control. Also, mitigation of both geotechnical asset types may be addressed on an emergency basis under a single-item project, which would increase mobilization costs. As was done for rock slopes and unstable soil slopes and embankments a standard overhead rate of 105% was applied to the calculated mitigation costs. The resulting numerical relationship between retaining wall Condition State and average mitigation cost per square foot of wall face is presented in Equation 6-4.

Equation 6-4: Average Mitigation Cost of a retaining wall based on calculated Condition State of the asset, with average overhead rates incorporated.

$$Mitigation\ Cost\ per\ ft^2\ of\ wall\ face (in\ 2014\ dollars) = 23.42\ (Condition\ State) - 23.42$$

This equation establishes that, on average, the total cost to improve any wall asset one Condition State will be $23.42/ft^2 of wall face, regardless of both wall type and whether the wall is going from Condition State 5 to 4 (both Poor Condition States) or Condition State 2 to 1 (Fair to

Good). Because the average overhead rate is a constant value, the equation is still linear. Average costs to improve an asset more than a given number of Condition States are shown in Table 6-7, both with and without overhead costs.

Table 6-7: Approximate average Retaining Wall Mitigation Costs for improving a wall by a given number of Condition States.

Number of Condition States Improved by Mitigation Activities	Average Mitigation Cost per ft^2 Without Overhead	Average Mitigation Cost per ft^2 Incorporating Overhead
1	$11.43	$23.42
2	$22.86	$46.84
3	$34.29	$70.26
4	$45.72	$93.68

The costs above are not derived from a dataset that includes mitigation measures or repairs to an existing retaining wall, but this gap could be filled as work on existing retaining walls are tracked. Also not included is ROW acquisition or the temporary shoring that is often part of retaining wall construction. Due to its extreme variability, the incorporation of ROW costs is best addressed on a site-specific basis, once planning attention has been focused on a specific asset or suite of assets.

Note that when using these approximate costs on a wall-specific basis, the estimates are likely to be inaccurate due to the unique conditions, wall types, and constraints present at any one wall location. However, when generating network-level cost estimates for mitigation of multiple retaining walls, the average costs produced by this approximation technique should be close except in the cases where exceptionally adverse factors require an extraordinary solution.

It would also be good practice to regularly re-evaluate the trend line in light of changing construction costs, as the above rates are only valid for 2015 data. Alternatively, indexing the cost estimates to the Historical Construction Cost Index or the National Highway Construction Cost Index (NHCCI), with a factor for specialized mitigation efforts, could estimate cost increases for system-wide inflationary factors.

6.4 Development of Excess Cost Models based on Material Site Availability

As previously discussed in Section 3.5, the Condition State developed using material site data is summarized at the maintenance station level. The performance of each maintenance station's material site inventory was rated according to the percent of the road network centerline mileage classified as being within a reasonable haul distance of a valuable material site. This characterization of performance assumes that, over the long term, each mile of road is equally likely to require aggregate for construction work.

Excess haul costs are assumed required for roadwork on portions of the road network more than five miles from a Valuable Material Site (VMS). The excess haulage would be from the nearest VMS, whether or not it is within the same maintenance station. If a construction site is not close to a material site, the Department generally does have other alternatives. For example, it can bring in aggregate by barge, purchase materials from a private-sector supplier in some areas, gather material from multiple smaller sites, or use lower-quality materials. Therefore, this excess haul cost represents an upper bound, and that lower-cost alternatives might be available or become an acceptable alternative.

In some parts of the state, fewer alternatives are available and the market pricing assumption might not be accurate. As a result, that isolated maintenance stations – those that do not have the possibility of hauling material from a neighboring station – were excluded from the model dataset. This assumption was made as a way of consistently identifying areas of the state where haul cost might not be a reliable indicator of the benefits of opening new state-owned material sites. Based on this assumption, maintenance stations in the Southcoast Region were eliminated, except for those on Kodiak Island.

The final analysis set covered 47 Department Maintenance Stations that are connected by road to at least one other maintenance station. These maintenance stations cover 3,095 centerline miles of road, of which 1,098 miles are within a 5-mile buffer of a significant material site. The 47 stations have a total of 136 significant material sites. For each maintenance station, the research team calculated the percentage of the AHS and NHS network served by VMSs. Each maintenance station service area received a Condition State based on this percentage. Material availability along the entire NHS network was characterized as the percent of centerline miles in maintenance stations classified in each Condition State, as summarized in Table 6-8 below.

Table 6-8: Summary of maintenance station service area Condition State based on material site availability

Condition state	Percent served	Station Count	Total Road Miles	Percent of total road miles
1	>80%	3	177	5.7%
2	>60%	8	439	14.2%
3	>40%	8	559	18.1%
4	>20%	11	1,125	36.3%
5	<=20%	17	795	25.7%
Total		**47**	**3,095**	**100.0%**

Over time, the maintenance station service areas will tend to degrade to worse Condition States as construction projects deplete existing material sites. To counteract this depletion, the Department may opt to develop new sites. Such development is frequently done in advance of specific construction needs, because the process of exploration, permitting, and acquisition can be difficult to justify without identified, large-scale project needs. There is no consistent source of data to determine the exact locations of future sites or to predict what construction needs will occur in the long term; however, knowledge of past depletion rates and typical construction needs can help in determining the rate at which new sites will need to be developed.

6.4.1 Cost and effectiveness of Material Site Development

Based on information obtained from Department maintenance personnel, the average cost of developing a significant new material site is approximately $81,250 per site, not counting real estate costs or the market value of the materials contained in the site. The impact of this investment can vary, because each maintenance station typically has a need for multiple sites to serve its annual construction needs. In order to standardize the units of investment for the analysis, Equation 6-5 was developed to compute the unit cost per mile of road to improve a maintenance station by one Condition State.

Equation 6-5: Cost per mile of road served to improve a maintenance station service area by one Condition State

$$UC_s = \frac{DC}{RM_s(s-1)} \sum_{m \in s} AS_{sm}$$

where

DC = Development cost per material site

RM_s = Total number of road miles in maintenance stations categorized as Condition State s

AS_{sm} = Number of material sites to bring maintenance station m to full coverage, which is summed over maintenance stations in state s

The value of AS_{sm} was determined from a geographic analysis of the road miles in each maintenance station that were more than 5 miles from a VMS (also referred to as unserved road). This cost is zero for maintenance stations already in Condition State 1. The results are reported in Table 6-9. Results indicate that the maintenance stations with the worse coverage (i.e., the lowest Condition State) tended to have lower unit costs to improve the coverage.

AKDOT&PF maintenance personnel indicated that approximately three new material sites are developed each year at current rates. Doubtlessly, this rate would vary in the future depending on the amount of resources devoted to site development. An implication of this observation is that conditions are likely to change slowly, and no maintenance station is likely to change by more than one state in any one year. In order to estimate the relative long-term level of investment in each Condition State, it was assumed that each mile of unserved road is equally likely to require a new material site, so the rate of 3 sites per year was allocated among the various Condition State groups according to the number of unserved road miles, excluding Condition State 1. This is converted to an application rate, the fraction of road miles that receive new service each year, for each Condition State, presented in Equation 6-6 below.

Equation 6-6: Application rate for new material sites based on maintenance station service area Condition State

$$AR_s = \frac{URM_s}{\sum_s URM_s} \times \frac{DC \times ANS}{RM_s \times UC_s}$$

where

URM_s = Number of unserved road miles in maintenance stations classified in state s

ANS = Annual number of new material sites (3 sites per year)

The final costs and application rates are shown in Table 6-9. On average, improving a maintenance station service area's material site condition rating by one Condition State increases its material site coverage by ¼ of the total road mileage assigned to the station. Multiplying this by the application rate and total road mileage, and summing over Condition States, gives an estimate of the total number of road-miles currently gaining new coverage each year because of the development of new material sites. This total is 27.2 road miles.

Table 6-9: Cost per mile of improving one Condition State, and application rate

Condition State	Cost per mile (dollars)	Application rate
1	0	0.000%
2	4,447	0.839%
3	3,123	2.031%
4	2,071	4.237%
5	2,020	5.809%

6.4.2 Development of Excess Haul Cost Estimates

When construction projects take place at locations which are distant from material sites, the Department may incur significant costs for long-distance haulage of aggregate. In order to estimate these costs, the following typical project metrics were used:

50,000 Modeled cubic yards of aggregate needed per project
125 Density of aggregate in lb./cu.ft
$1.00 Haul cost in dollars per ton per truck mile

Under these metrics, the typical project haulage cost is $168,750 per route mile.

The Department's most recent Statewide Transportation Improvement Program (STIP) was analyzed in the geographic information system to estimate the number of projects that take place each year and determine the fraction of those which occur outside the 5-mile buffers around material sites (unserved projects). The average distance from STIP sites to the valuable material site buffer, as an estimate of the excess route-miles, was also visually estimated. These statistics can be uneven from one maintenance station to another, because the locations of projects are not uniformly distributed in any given year. To smooth out the computations of excess distance and unserved projects, two linear regression models were developed for maintenance stations.

In the first model, an estimate of excess road miles was developed as a function of the ratio of road miles outside the 5-mile buffer, to road miles within the 5-mile buffer, as presented in Equation 6-7.

Equation 6-7: Linear regression model for maintenance station service area miles more than 5 miles from a valuable material site

$$Excess\ road\ miles = 3.7895 \times \frac{Miles\ outside\ the\ 5-mile\ buffer}{Miles\ within\ the\ 5-mile\ buffer}$$

In the second model, an estimate of the number of unserved projects was a function of unserved miles, as presented in Equation 6-8.

Equation 6-8: Linear regression model for STIP projects more than 5 miles from a valuable material site

$$Number\ of\ unserved\ projects = 0.354 \times (Miles\ outside\ the\ 5-mile\ buffer)$$

These calculations were performed for each maintenance station and then summarized to estimate an average excess haulage cost per road mile. The denominator of this excess cost per mile is the total number of centerline road miles assigned to the maintenance stations classified in the indicated Condition State. The results are reported in Table 6-10.

Table 6-10: Average excess haul cost by Condition State

Condition state	Avg. excess road miles	Avg. unserved STIP projects	Excess haul cost per road-mile (dollars)
1	0.8	0.5	412
2	1.7	0.7	1,546
3	4.0	1.7	6,200
4	9.7	3.2	21,706
5	7.4	2.0	18,904

6.4.3 Estimated Maintenance Costs per Maintenance Station Based on Material Availability

Existing material sites require ongoing attention to prevent applicable permits from lapsing and ensure access routes, etc., are maintained in good condition. Interviewed AKDOT&PF personnel estimated an average cost of $1,900 per year for each department-managed material site. Researchers averaged the average number of valuable material sites in maintenance station service areas in each Condition State. Combining this with the average maintenance cost for a valuable material site, they estimated an annual per-mile maintenance cost for each maintenance station based on Condition State. The results are shown in Table 6-11. As expected, maintenance stations in a better Condition State will have higher maintenance costs because they have more material sites to manage.

Table 6-11: Annual maintenance costs per maintenance station service area based on road miles served and station Condition State

Condition state	Annual cost per mile (dollars)
1	237
2	199
3	122
4	61
5	17

7 DEVELOPMENT OF ASSET DETERIORATION MEASURES AND RISK ANALYSIS METHODS

The Department spends money constructing or acquiring geotechnical assets, and spends additional money over the lifespans of these assets to keep them functioning as intended. In general, the function of geotechnical assets is to perform as long as possible and refrain from disrupting the desired levels of safety, mobility, and economic efficiency of the state's transportation service. Through its maintenance forces and contractors, the Department implements treatments that maintain or enhance the characteristics of its geotechnical assets to minimize the frequency of disruptions.

Over time, geotechnical assets, like other physical elements, tend to deteriorate. The effect of deterioration is to increase the likelihood of service interruptions and the frequency and cost of routine, reactive maintenance, such as cleaning of catchment ditches and patching of asphalt damaged by rockfall.

Preservation and risk mitigation treatments for geotechnical assets have important inter-temporal tradeoffs analogous to preservation of pavements and bridges. In many cases, a small timely investment in mitigation can extend the life of a rock slope and postpone the day when a major reconstruction might be necessary. If such a treatment is feasible but not accomplished in a timely manner, further deterioration may render it infeasible or increase the rehabilitation cost substantially. Life cycle cost analysis is used to analyze these tradeoffs.

In GAM life cycle cost analysis, all costs are expressed in dollars and combined in a framework where tradeoffs in scope and timing of work can be evaluated. Figure 7-1 shows this as a flow diagram where:

- A treatment model forecasts the costs and outcomes of mitigation and preservation activities in each Condition State. The amount of each treatment is guided by a treatment policy and constrained by available funding. Section 6 describes the methods that have been developed in this study to estimate treatment costs.
- A deterioration model forecasts the change in condition from year to year in the case where no treatment is applied, starting with current conditions from the most recent inspection. Since this is a network-level model, the conditions are expressed as the fraction of the inventory in each Condition State. There is a cause-and-effect relationship between funding and policy on the one hand and 10-year condition outcomes on the other hand. When funding is set at a proposed level, the outcome is a fiscally-constrained condition target in the same sense as in the federal regulations (FHWA 2015).
- The risk model uses a site assessment along with data on traffic and detour routes, as discussed in Section 3.3, though additional risk information may be forthcoming in a separate study currently being conducted by Shannon and Wilson. The condition of each asset affects the likelihood of service disruptions, thus affecting the expected value of disruption costs. For material sites, which do not directly affect roadway function, the risk is instead linked to compromises the Department may be forced to make because quality materials are not readily available to complete a project.
- Risk costs are included in life cycle cost so that the appropriate balance between agency and user costs can be determined, and the total can be minimized. All costs are discounted, based on the year in which the costs are incurred, to reflect the time value of money. By comparing

different policy and funding alternatives, the Department can compute economic metrics such as life cycle social cost savings and returns on investment.

The primary forecasting models (deterioration, treatment cost and effect, and disruption likelihood) are research-based. The best models used in pavement and bridge management rely on many years of quality-assured data, which the Department does not yet have for geotechnical assets. As was the case for pavements and bridges initially, the Department may need to start with research and data maintained by other agencies, along with the best available expert judgment. In a bootstrapping process, it will gradually use these initial models over time to build a sustainable GAM program, while at the same time maintaining good records of the conditions observed, treatments accomplished, and adverse events, so it can improve its forecasting models. In time, it will be able to optimize its program, particularly its policies on mitigation and preservation, resource allocation, and selection of projects to minimize life cycle costs.

An Excel spreadsheet file providing all of the computations described in this section is available upon request. The discussion in the following subsections describes the calculations of each part of the model.

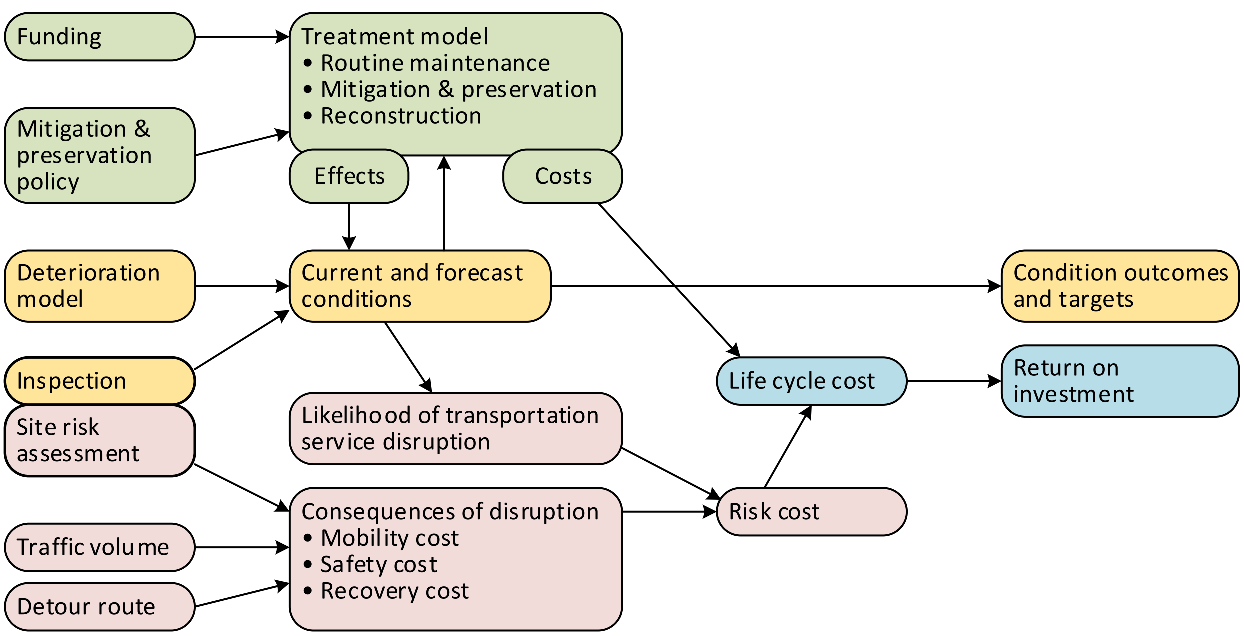

Figure 7-1: Analytical framework for deterioration and life cycle costs

7.1 An Overview of Markov Models

The Markov model is a powerful tool for the development of deterioration measures necessary for the programmatic-level budget discussions that are one of the main targets of a successfully implemented GAM program. A Markov model is based on the median transition time for an asset to deteriorate from the current Condition State to the next one. Initially these transition times can be elicited from expert judgment, as is described in this report. Eventually transition times should be developed using a statistical analysis of historical inspection data, once such data are compiled, to ensure that they agree with the agency's actual deterioration experience (Sobanjo and Thompson 2011).

If it is assumed that individual incidents of deterioration from one Condition State to the next-worse state occur randomly, and are distributed according to a uniform probability distribution over time, then the probability of such a transition can be calculated using Equation 7-1, below.

Equation 7-1: Markov Model Equations

$$p_{jj} = 0.5^{(1/t)} \text{ and } p_{jk} = 1 - p_{jj}$$

Where p_{jj} is the probability of remaining in the same Condition State *j* one year later,
t is the median transition time from the initial Condition State *j* to the next-worse state *k, and*
p_{jk} is the probability in one year of transitioning from state *j* to state *k*

The matrix of probabilities of all Condition States *j* and *k* forms the transition probability matrix.

If an inspector characterizes a single asset by assigning it to one Condition State at a given time, then over a population of assets the percentage in each Condition State forms a condition vector. For example, if there are 100 assets in the population, then perhaps 50 are in state 1, 30 in state 2, 15 in state 3, and 5 in state 4. This condition vector can be multiplied by the transition probability matrix to yield a new vector which is an estimate of the condition of the population one year later. This calculation can be repeated for each additional year for which a forecast is desired. In this way, forecasts useful for life cycle cost analysis can be made as far into the future as needed.

Obviously, a forecast made in this way is not reliable enough for project design purposes. Nevertheless, for the purpose of considering long-term future costs in a way that is simple, reasonable, and consistent, and potentially grounded in actual inspection data, the method is highly suitable. This is why it is often used in pavement management and is universally used in bridge management (Gordon, et al. 2011).

7.2 Expert Elicitation for Markov Model Development

A very simple method of expert judgment elicitation has been developed to estimate reasonable transition times in the absence of inspection data (Cambridge Systematics, Inc 2003) (Thompson, et al. 2012). Almost every state transportation agency used this method when first getting started with their bridge management system, in order to gain experience in using the system early on, and many states have used this method more recently for developing life cycle cost analyses for all their Transportation Asset Management Plans[14].

The method entails dividing the inventory into relatively uniform groups of assets with similar characteristics, which are expected to have similar deterioration rates. For each group, the Condition States are considered separately by asking the following question:

> *Imagine there are 100 assets in the indicated Condition State. After how many years will 50 of them have deteriorated to the next Condition State or worse, if no maintenance or corrective action is taken?*

[14] Transportation Asset Management Plans under development in Minnesota, Ohio, Nevada and Texas.

This question is asked of a group of 3 to 6 experienced experts, who record their answers individually and then discuss them as a group. After discussion, a final estimate of the median transition time is decided upon.

Since AKDOT&PF does not yet have the geotechnical asset condition history required to develop deterioration models using statistical methods, an expert judgment elicitation process was used. Each panelist was asked to answer the questions independently; then the results were tabulated and discussed. Panelists were then allowed to change their answers, which helped to improve the level of common understanding and consensus. For each question, the mean response was used as the transition time. The initial expert elicitation work conducted as part of AKDOT&PF's GAM program is described below. Transition probabilities were then computed from this information as further discussed in Subsection 0.

An expert elicitation method was applied to AKDOT&PF's GAM program during a multi-day meeting in Seattle, Washington, in April 2015. Over the course of the meeting, a group of six experts with experience in geotechnical assets or the expert elicitation process discussed deterioration rates for rock slope, unstable soil slopes and embankment, retaining wall assets, and material source scarcity to be managed under AKDOT&PF's GAM program. The average rates developed in this meeting were used in the models and cost analyses presented in this Section.

Because Condition States based on materials sites were still being developed at the Seattle meeting, and the related deterioration model was extremely preliminary, additional time was devoted to discussion of this geotechnical asset at a larger meeting in Anchorage in July 2015. Department experts from within AKDOT&PF and representatives from R&M Consultants were invited to attend a day-long meeting with the core group present at the Seattle expert elicitation meeting. Those who were too far to conveniently attend the meeting in person, such as the AKDOT&PF personnel in Fairbanks, were able to call in and participate remotely. The expert elicitation format was identical to that used in the Seattle meeting, though several of the experts were reluctant to venture a firm estimate of deterioration time for a given material site. The revised deterioration model was used in the models and cost analyses for material sites presented in this section. It is assumed that over time, as the GAM program ages and supplies AKDOT&PF with quantitative asset deterioration rate data, the initial deterioration models for all of the Department's geotechnical assets will be refined.

7.3 Modeling of Treatment Selection and Cost

For the initial cost analysis, a single generic treatment was defined for each Condition State, to represent the combined effect of all feasible mitigation and preservation activities that may be applicable to a given asset. Each generic treatment was associated with an improvement by an integral number of Condition States. An analysis was performed to estimate a unit cost for each of these generic treatments, as described in Section 6. In the life cycle cost analysis, three types of treatments are represented in different ways:

- Routine maintenance, such as managing channels and culverts to control debris flows, occurs potentially every year on a reactive basis. A fixed unit cost is assumed for each maintenance effort, whose frequency depends on the Condition State of the asset. No budget constraint is applied to these costs in the life cycle cost analysis.
- Corrective action, which includes preservation and risk mitigation, such as installation of rockfall barriers, is programmed work whose scope is determined by site condition in the most recent inspection and site characteristics. This category of work occurs infrequently,

typically once every 20-65 years at a given site. The total amount of such work is constrained by annual budgets.

- Reconstruction may entail complete removal or reconstruction of the asset (i.e., re-cutting of a rock slope, or realignment of the road away from a stability threat). This takes place typically at the end of the asset's service life or as part of other highway reconstruction work. Reconstruction shares the same budget constraint as corrective action, and uses the remaining funding available after all corrective action needs have been met.

Table 7-1 summarizes the unit costs and application rates used in the life cycle cost analysis, using rock slope assets as an example. Application rates indicate the fraction of sites, in a given Condition State, receiving each treatment each year. A rate less than 1 indicates that a site may remain in the indicated Condition State for more than a year before corrective action is taken, or that some sites may never receive corrective action. A rate greater than 1 indicates that some sites receive more than one application in a year.

The application rates depend on the deterioration model discussed in Subsection 0. The same panel that developed the deterioration model, based on an estimation of an application rate required to sustain a stable, long-range, acceptable condition level, thereby offsetting the expected deterioration rates, determined application rates. These initial rates were then adjusted to maximize the likelihood that current conditions are sustainable over the long term. The application rates actually used in AKDOT&PF's life cycle cost analysis may be further reduced if constrained by funding availability. The analysis spreadsheet, available upon request, also includes a parameter, "Corrective emphasis," which can raise or lower all of the application rates proportionally. For most purposes, the default value of this parameter is 100%.

The rightmost column of Table 7-1 is a calculation of the total cost that would be incurred this year, based on current conditions, for rock slope asset work if the indicated unit costs and application rates are applied.

The treatment models developed for AKDOT&PF's unstable soil slope/embankment and retaining wall assets are presented in Table 7-2 and Table 7-3, below. The derivation and format is identical to that shown in Table 7-1.

The treatment model developed for AKDOT&PF's material sites (Table 7-4) is based on the estimated site development cost per mile of unserved road, with a new material site being developed within five miles of the road.

Table 7-1: Treatment unit costs and application rates for rock slope assets.

Treatment model	**Percent acted upon each year, starting in each state**					**Unit cost**	**Total cost**
	State 1	State 2	State 3	State 4	State 5	$/sq.	$k/year
Routine maintenance	0.00%	10.00%	100.00%	150.00%	1000.00%	0.26	4,415
Corrective action							
Improve by 1 state		0.11%	3.19%	1.54%	5.00%	7.30	2,529
Improve by 2 states			3.47%	0.84%	0.27%	14.60	4,487
Improve by 3 states				3.86%	0.25%	21.90	3,491
Improve by 4 states					0.98%	29.20	0
Total percent improved	0.00%	0.11%	6.66%	6.24%	6.50%		10,507

Reconstruct/relocate $ 58.40/sq.ft

Table 7-2: Treatment unit costs and application rates for unstable soil slope and embankment assets.

Treatment model	**Percent acted upon each year, starting in each state**					**Unit cost**	**Total cost**
	State 1	State 2	State 3	State 4	State 5	$/ln.ft	$k/year
Routine maintenance	0.00%	0.00%	10.00%	100.00%	1000.00%	10.00	19,348
Corrective action							
Improve by 1 state		0.20%	0.61%	0.12%	3.63%	2392.34	20,393
Improve by 2 states			0.33%	0.67%	5.00%	4784.68	56,789
Improve by 3 states				1.24%	3.09%	7177.02	76,464
Improve by 4 states					2.14%	9569.36	28,094
Total percent improved	0.00%	0.20%	0.94%	2.03%	13.86%		181,739

Reconstruct/relocate $ 11,483.23/ln.ft

Table 7-3: Treatment unit costs and application rates for retaining wall assets.

Treatment model	**Percent acted upon each year, starting in each state**					**Unit cost**	**Total cost**
	State 1	State 2	State 3	State 4	State 5	$/sq.ft	$k/year
Routine maintenance	0.00%	0.00%	0.00%	0.00%	0.00%	0	0
Corrective action							
Improve by 1 state		4.05%	1.29%	1.19%	0.00%	23.42	1,141
Improve by 2 states			0.00%	2.08%	0.00%	46.84	78
Improve by 3 states				2.10%	0.00%	70.26	119
Improve by 4 states					1.00%	93.68	0
Total percent improved	0.00%	4.05%	1.29%	5.37%	1.00%		1,337

Reconstruct/relocate $ 93.68/sq.ft

Table 7-4: Treatment unit costs and application rates for material assets.

Condition state	**Cost per mile**	**Application rate**
1	$0	0.000%
2	$4,447	0.839%
3	$3,123	2.031%
4	$2,071	4.237%
5	$2,020	5.809%

7.4 Deterioration

The simplest possible deterioration model using Condition State data, as described in Subsection 7.2, is a Markov model, which expresses deterioration rates as probabilities of transitions among the possible Condition States each year. This type of model is used in nearly all bridge management systems, and some pavement management systems as well. Table 7-5, Table 7-6, Table 7-7, and Table 7-8 show the models that were developed for AKDOT&PF's various geotechnical assets using the methods described in Subsection 7.2 and in this section.

Table 7-5: Markov deterioration model developed for rock slopes under the AKDOT&PF GAM program.

Deterioration model	**Markov model - starting Condition State**				
	State 1	State 2	State 3	State 4	State 5
Transition time (years)	38.3	32.5	21.2	13.7	--
Same-state probability	0.9821	0.9789	0.9678	0.9507	1.0000
Next-state probability	0.0179	0.0211	0.0322	0.0493	0.0000

Table 7-6: Markov deterioration model developed for unstable soil slopes and embankments under the AKDOT&PF GAM program.

Deterioration model	**Markov model - starting Condition State**				
	State 1	State 2	State 3	State 4	State 5
Transition time (years)	55.0	23.1	12.6	7.6	--
Same-state probability	0.9875	0.9704	0.9465	0.9128	1.0000
Next-state probability	0.0125	0.0296	0.0535	0.0872	0.0000

Table 7-7: Markov deterioration model developed for retaining walls under the AKDOT&PF GAM program.

Deterioration model	**Markov model - starting Condition State**				
	State 1	State 2	State 3	State 4	State 5
Transition time (years)	25.2	20.8	8.3	7.2	--
Same-state probability	0.9729	0.9672	0.9199	0.9082	1.0000
Next-state probability	0.0271	0.0328	0.0801	0.0918	0.0000

Table 7-8: Markov deterioration model developed for materials sites under the AKDOT&PF GAM program

Deterioration model	**Markov model - starting Condition State**				
	State 1	State 2	State 3	State 4	State 5
Transition time (years)	16.4	13.9	16.6	18	--
Same-state probability	0.9587	0.9514	0.9592	0.9622	1.0000
Next-state probability	0.0413	0.0486	0.0408	0.0378	0.0000

Using Table 7-5 as an example, the transition time is the number of years that it takes for 50% of a representative population of assets to deteriorate from a given Condition State to the next-worse one; for example, from state 1 to state 2. The same-state probability is the statistical probability in any one year that a given asset will remain in the same Condition State one year later. The next-state probability is the probability that a given asset will deteriorate to the next-worse Condition State one year later. In the models presented here, the sum of the same-state probability and next-state probability is always 1.0000.

If the transition time is known or estimated, the same-state probability can be computed using Equation 7-2, below.

Equation 7-2: Same-state probability for Markov models

$$p_{jj} = 0.5^{(\frac{1}{t})}$$

Where j is the Condition state (before and after 1 year)
t is the transition time in years

The forecast condition of the inventory in any given year is expressed as the fraction in each Condition State. These fractions must sum to 1.0000 over the five Condition States. For any given Condition State k, the fraction in that state after one year is computed from Equation 7-3 below.

Equation 7-3: Forecast of the fraction of assets in a given Condition State after one year from a Markov model

$$y_k = \sum_j x_j p_{jk}$$

Where x_j is the starting fraction in state j

p_{jk} is the transition probability from state j to state k

This calculation can be repeated as many times as needed in order to extend the forecast for additional years in the future. The accompanying spreadsheet, available upon request, shows forecasts for 200 years.

The Condition State data being collected for geotechnical assets are very similar to data sets that are maintained by most state DOTs for their bridge elements. These data sets are ideal for statistical modeling of deterioration. Florida DOT has documented a complete example of the development of such models (Sobanjo and Thompson 2011).

For communication using simple graphs, it is common with Condition State data to compute a condition index as a normalized, weighted average of the distribution of the inventory among Condition States. The following figures show the combined effect of the deterioration and treatment models for AKDOT&PF's various geotechnical assets, expressed as a condition index where 100 is a new asset and 0 is the worst possible condition. This example reconstructs the asset when the probability of Condition State 5 reaches 50%, and has periodic mid-life corrective actions. This graph and the calculations behind it may be found on the LCAP tab of the Life Cycle cost spreadsheet, which is available upon request. Models for unstable soil slopes and embankments, and retaining walls were all developed using the same methods, and are presented in Figure 7-2, Figure 7-3, and Figure 7-4, respectively.

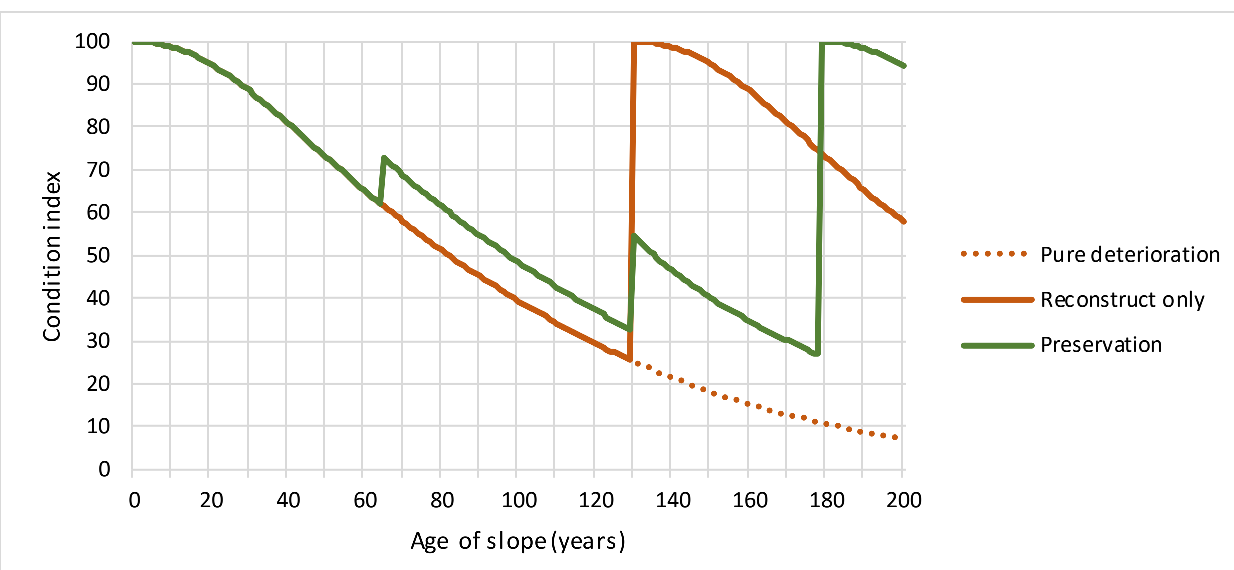

Figure 7-2: Model of deterioration, reconstruction, and preservation for rock slope assets.

Figure 7-3: Model of deterioration, reconstruction, and preservation for unstable soil slope and embankment assets.

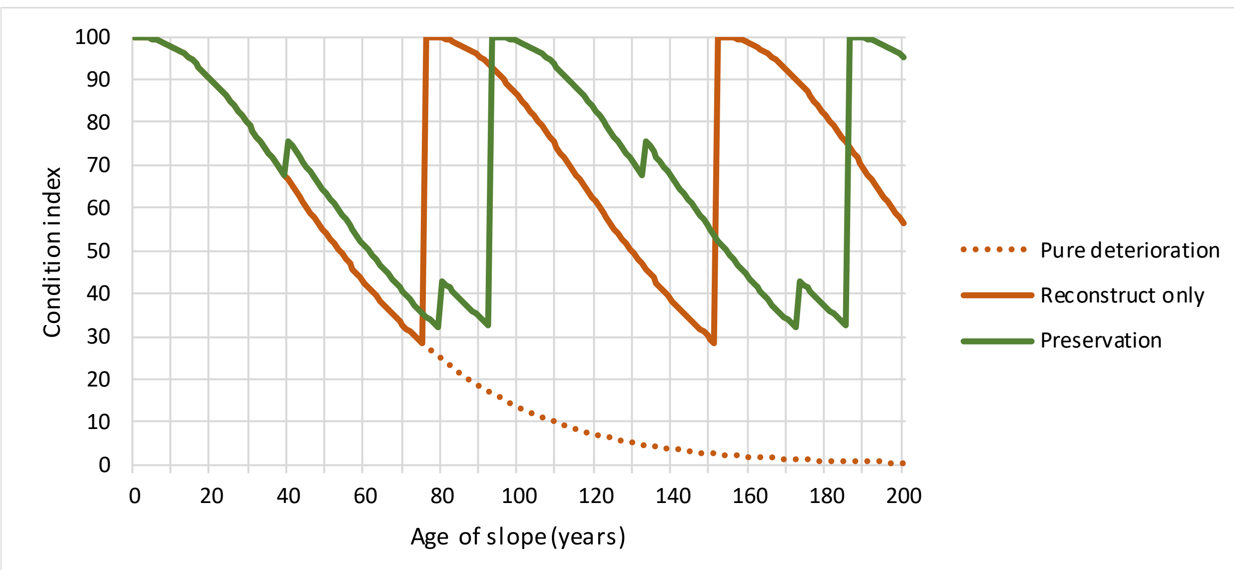

Figure 7-4: Model of deterioration, reconstruction, and preservation for retaining wall assets.

For material site assets, no such periodic reconstruction or preservation costs were incorporated into the deterioration model. Figure 7-5 shows the long-term progression of the condition index, expressed as a condition index where 100 is full coverage of a maintenance station and zero is a complete lack of significant material sites.

Figure 7-5: Deterioration of a typical maintenance station material site inventory due to material depletion

Each downward transition of a maintenance station by one Condition State means 25% of the NHS road mileage has lost its coverage because of depletion. Multiplying this by the next-state probability and the total road mileage, and summing over all Condition States, yields an estimate of lost road-miles of coverage each year. This total is 23.5 miles. This number is slightly less than the annual gain in coverage computed above, based on the estimate of three new sites developed each year. The conclusion is that the current rate should lead to a slow improvement in material supply over time.

It is important to note, however, that this balance of supply and demand does not necessarily mean that the new supply is in locations where the demand exists, although many sites are opened or improved due to the need of nearby construction projects. Despite this, there is a continuing need to improve the forecasting of future road construction locations, at a greater distance into the future than the normal STIP timeframe, to help in making better material site development location decisions.

7.5 Risk Analysis

The Department's risk-based GAM approach is focused on safety, mobility, and condition (maintenance) performance areas. At this time, environmental performance is not incorporated due to lack of data, but this is viewed as a desirable later step. To enable wider adoption with limited funds, the framework can also use a multi-tier process to develop risk registers from the statewide to the corridor level and look at risk for each asset separately or combined. A cursory assessment can be made to help delineate corridors of concern across the state (e.g., Tier 1), and the corridors with the highest initial risk assessment are then investigated with a more detailed survey (e.g., Tier 2). The detailed assessment and inventory work already completed for unstable slopes along the NHS would fall into this Tier 2 category, and could easily be integrated with the event likelihood currently under development in the GAM Risk Management Study.

Each of the geotechnical assets may present a different level of risk to these performance measures. For example, rockfall will typically have a higher risk to safety as compared with landslides. When considering mobility performance measures, large rockfall events may have a higher risk to mobility than other assets based on closure history. The financial consequences will typically be higher for large events, which indicates a relatively high risk to maintenance or condition measures. By using risk analysis in the asset management process, the Department can direct limited funds to assets and corridors based on the desired reduction in risk with respect to TAM program performance measures.

The site-specific visit should be combined with the inventory and detailed assessment visit, and gathers a set of data items which aid in conceptual mitigation design and costing, in addition to the assessment of Condition State. For network level investment analysis, the most significant assessments, in addition to condition, are:

- Threat to safety, a classification of the site according to the number of accidents that would typically result from an adverse event such as rockfall. Currently four threat classes are defined, with the possibility of a more precise measure in the future, if the quality of safety data can be improved to identify crashes caused (in part) by rock slope activity.
- Threat to mobility, a classification of the site according to the duration (in hours or days) of road closure that would typically result from adverse events. Currently five threat classes are defined.
- Recovery cost, a classification of the likely costs to the Department of restoring transportation service after an adverse event. This may include removal of debris, restoration of road geometry, repair of the pavement, and restoration of any damaged protective features or other assets. Currently five classes are defined.

In all cases, these assessments are made based on judgment of the most likely adverse event scenarios at the given site, taking into account the geometrics of the slope and of the road. Contributing factors such as speed limit and sight distance are considered.

As previewed in Section 5.1, the likelihood of an adverse event scenario is determined from the assigned Condition State, also assessed by the inspector, and expressed as a return period (in years) or as a statistical probability per year.

Safety and mobility consequences are expressed in dollars using established research-based methods documented in the AASHTO 'Red Book' (AASHTO 2010).

7.6 Life Cycle Cost Analysis

The deterioration model forecasts conditions from year to year over a long time period. In each year, the forecast conditions determine routine maintenance, corrective action, and reconstruction treatments with their costs and effects. Forecast condition also determines the likelihood of service disruption and the expected value of economic consequences.

Costs that are assigned to future years are discounted according to accepted net present value methods. The discount rate reflects the value to the Department of postponing these costs, thereby making the funding available for other, higher-priority needs. Reconstruction costs are especially large, so there is particular value in postponing these costs as long as possible. The formula for computing life cycle social costs is presented in Equation 7-4.

Equation 7-4: Life-cycle social cost of rock slope, unstable soil slope/embankment, and retaining wall assets

$$LCSC = \sum_{y=0}^{N} df_y\, Q \sum_j x_{jy} \left(mc_j + \sum_a ce \times ca_{jay} cc_a + ra_{jy} rc + lhd_j csq \right)$$

Where df_y is the discount factor for year *y*, computed from

$$df_y = \frac{1}{(1+d)^y}$$

- N is the analysis period, 200 years
- d is the discount rate, currently 2.1% as discussed below
- Q is the quantity of asset in the inventory (rock slopes and retaining walls: sq.ft; unstable soil slopes and embankments: ln. ft.)
- x_{jy} is the fraction of the inventory forecast to be in state *j* in year *y*
- mc_j is the unit cost of routine maintenance in state *j* (rock slopes and retaining walls: $/sq.ft; unstable soil slopes and embankments: $/ln. ft.)
- ce is corrective emphasis, a parameter for what-if analysis of application rate
- ca_{jay} is the treatment application rate for state *j*, action *a*, and year *y*, adjusted for budget constraint as described below
- cc_a is the unit cost of corrective action *a* (rock slopes and retaining walls: $/sq.ft; unstable soil slopes and embankments: $/ln. ft.)
- ra_{jy} is the application rate for reconstruction in state *j* and year *y*, described below
- rc is the unit cost of reconstruction (rock slopes and retaining walls: $/sq.ft; unstable soil slopes and embankments: $/ln. ft.)
- lhd_j is the likelihood (probability) of service disruption for Condition State *j*
- csq is the consequence of service disruption (rock slopes and retaining walls: $/sq.ft; unstable soil slopes and embankments: $/ln. ft.)

When computing this formula in a given year, the spreadsheet model first computes the full value of corrective action needs using a portion of the formula presented in Equation 7-5.

Equation 7-5: Full value of corrective action under life cycle cost analysis

$$Need = Q \sum_j x_{jy} \sum_a ce \times ca_{jay} cc_a$$

It is possible that this result might be more than the budget constraint. To test and adjust for this, the model computes a Financial Sustainability Index (Equation 7-6) from

Equation 7-6: Financial Sustainability Index

$$FSI = if\ Budget \geq Need\ then\ 1.0\ else\ Budget/Need$$

Then if FSI<1 the application rate is reduced by following Equation 7-7.

Equation 7-7: Treatment application rate reduction

$$ca'_{jay} = FSI \times ca_{jay}$$

Using this method, all Condition States are adjusted for cost and effectiveness by the same proportion. After this adjusted corrective action cost, all money remaining in the budget, if any, is applied to reconstruction activities by setting the application rate for reconstruction to be in keeping with Equation 7-8.

Equation 7-8: Application rate for asset reconstruction

$$ra_{jy} = \frac{Budget - FSI \times Need}{Q \times rc}$$

Reconstruction is applied first to Condition State 5. If there is enough reconstruction money to address all of state 5, then the remainder is applied to state 4, then state 3, and so on. All reconstructed quantities are moved to state 1. The sum of corrective action and reconstruction cost is always equal to the annual capital budget.

The calculation of the average consequence of service disruption uses the methods described in Section 5. Since the life cycle cost analysis is at the network level, the consequence formulas use a network average value of each of the input variables including duration of service disruption, number of accidents, traffic volume, and detour length/time. These are expressed as an incident cost per asset, so they must also be converted to a cost per unit quantity by dividing by the average quantity per asset.

NCHRP Report 483 (Hawk 2003) has a thorough discussion of how discount rates are determined. In short, they are determined by agency policy, which should be consistent across all types of assets and all investments of similar lifespan. A common source of guidance is The White House Office of Management and Budget (OMB) Circular A-94[15]. Typically, inflation is omitted from life cycle cost analyses because this practice simplifies the computations. A riskless and inflationless cost of capital for long-lived investments may use 30-year US Treasury bonds for guidance, with a 2015 real interest rate of 1.4%[16]. Transportation agencies usually specify higher discount rates than this, in the 2 to 5 percent range, because of uncertainties in long-term future travel demand and infrastructure requirements.

Currently, the GAM analysis is using a discount rate of 2.1 percent per year, which is within the typical range of state DOT TAM Plans. While this choice of rate has been discussed with Department asset management officials, the Department has not yet selected a discount rate for its TAM Plan.

In net present value analysis, it is necessary to establish an analysis period long enough that subsequent discounted costs are too small to affect near-term decision making. Figure 7-6 shows cost over a 180 year period, encompassing a single replacement cycle for a geotechnical asset. An approximately 200 year analysis period was selected for GAM analysis in order to ensure that these discounted costs are sufficiently small.

[15] http://www.whitehouse.gov/omb/circulars_a094/
[16] http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c/

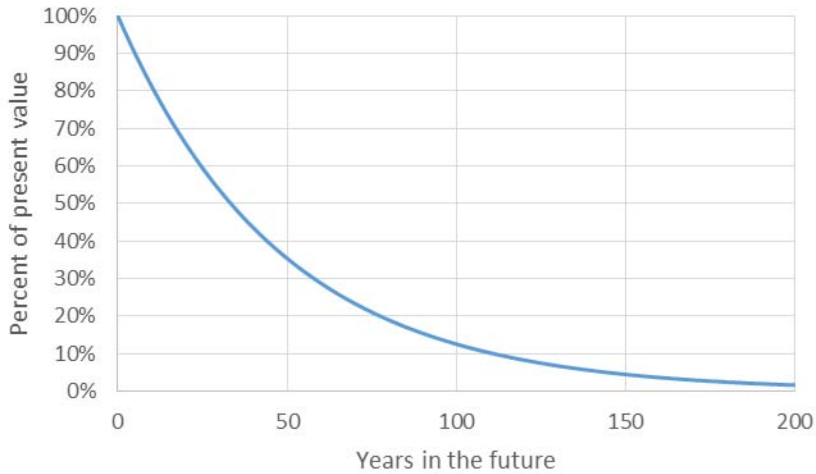

Figure 7-6: Discounted costs over a 180 year period.

7.6.1 Return on Investment Cost Analysis

In the accompanying spreadsheet models, available upon request, the Return on Investment (ROI) worksheets for various geotechnical assets compare life cycle costs between a worst-first reconstruction-only policy, and a policy featuring timely corrective action as described above. The annual budget for both scenarios is set at a level that maintains current conditions over ten years.

The models presented in this section are based on the entire inventory, and do not differentiate between roads with low traffic volumes and/or short detour lengths. Since the life-cycle costs related to mobility benefits are proportional to traffic volume and detour length, social cost savings and return on investment will be significantly higher for certain corridors than the average presented here.

Rock slopes: From the model, annual funding of $9.52 million annually is sufficient to maintain the current statewide condition index of 70.3 after ten years. At this funding level, preservation and risk mitigation work make up 93% of the budget, with reconstruction comprising the rest. Compared to a strategy where no preservation work is done, which has a projected annual cost of $25.49 million, the desired preservation investment reduces life cycle costs by 5%. Every dollar invested in preservation saves $0.38 in long-term costs over the analysis period.

Soil slopes: From the model, a funding level of $154.28 million is required to maintain the current statewide condition index of 48.4 after ten years. At this funding level, preservation and risk mitigation work make up 58% of the budget, with reconstruction making up the rest. Compared to a strategy where no preservation work is done, the desired preservation investment reduces life cycle costs by 5%. Every dollar invested in preservation saves $0.15 in long-term costs over the analysis period.

The high cost to maintain soil slopes is likely tied to the impacts of thawing permafrost on Alaska roadways, something that is expected to continue or accelerate with ongoing climate change. Since this cost to maintain current unstable soil slope and embankment conditions is clearly much greater than what can be made available, AKDOT&PF should expect conditions to continue to decline over the coming decade, with continued high costs for pavement reconstruction. However, AKDOT&PF can still use this model and the asset geodatabase to help focus any available mitigation funds on those corridors where the projected benefit will be greatest.

Further, the low return on investment for preservation of soil slopes and embankments relative to other assets reflects a dearth of attractive methods and technologies for reducing ongoing deterioration or effectively mitigating deteriorated slopes. This makes future research in this area very attractive, particularly considering how the large number of Poor condition unstable soil slopes and embankments is expected to grow in the coming years.

Retaining walls: From the model, a funding level of $3.73 million is sufficient to maintain the current statewide condition index of 79.8 after ten years. At this funding level, preservation and risk mitigation work make up 35% of the budget, with reconstruction making up the rest. Compared to a strategy where no preservation work is done, the desired preservation investment reduces life cycle costs by 7%. Every dollar invested in preservation saves $1.48 in long-term costs over the analysis period. Because a proportionately smaller number of retaining walls have been assessed than any other geotechnical asset, this model is the most likely to change significantly as assessment work expands to other part of the state.

Material sites: The demands placed on material site assets differ significantly from the other inventoried asset types. To develop the cost analysis, the research team combined average site development costs supplied by the department and estimated annual excess haul costs related to lack of valuable materials. Annual funding of $244,000 for new material site development is sufficient to maintain the current statewide average material site availability, with 5% of maintenance station service areas in Good condition (optimal material availability) and 57% in Poor condition.

Assuming supply and demand can be kept roughly in balance, a simple return on investment analysis was developed comparing projected excess haul costs to development/maintenance costs for materials sites. Excess haul costs were calculated using regression models developed from the existing distribution of served and unserved STIP projects. The model assumed that the same level of STIP projects would occur for the entire 10 year analysis period, though project locations would change. With annual excess haul costs estimated at $43.6 million, it is evident that the return on investment in material sites must be high. In this model, the analysis assumed that each maintenance station performs enough new development each year to remain a going concern in perpetuity. The rate of return is then the annual savings in haul costs for the maintenance stations receiving new coverage, less maintenance costs for those new sites, divided by the new site development cost, all of which are discussed in Section 6.4. This estimated rate of return is 882%, or, put differently, every dollar invested in material site preservation saves $8.82 in long-term costs over the analysis period.

8 INCORPORATION OF THE GAM PROGRAM INTO LONG-TERM PLANNING

Within AKDOT&PF's Statewide Designs and Engineering Services Division, the Geotechnical Services group is considering how best to implement a quantitative performance analysis for its geotechnical assets using the same methods now required for bridges and pavements (FHWA 2017). Since geotechnical assets impact safety and mobility primarily by means of the risk of adverse events, the quantitative framework is, in part, a risk analysis focusing on the likelihood and consequence of transportation service disruption.

The Department does not yet have a management system, akin to its pavement and bridge management systems, which can quantify these matters at the asset level. However, there is enough information in the inventory and condition surveys completed thus far, and in research performed by the Department and by other agencies, to develop reasonable network level models at a level of detail comparable to a TAM Plan. These models can answer important questions such as:

- What level of investment in corrective actions and reconstruction is necessary, over a ten-year period, to maintain these assets in their current condition?
- How should this investment be allocated between corrective action and reconstruction, to keep overall costs low and to sustain the desired function of these assets?
- For a given level of funding, what system-wide conditions can be expected after ten years?
- How should the funding be allocated among classes of geotechnical assets to equalize and minimize the risk to the safety, mobility, and economic performance of the transportation network?

The preliminary answers to these questions can be of great value to the Department in applying modern management tools to geotechnical assets. Currently, the federal government does not require formal Geotechnical Asset Management (GAM) programs, but incorporating the results of AKDOT&PF's first-in-the-nation GAM research program into the Department's TAM plan would improve its ability to anticipate and control asset expenditures, and to work proactively to reduce the risk of service disrupting events.

Because current federal regulations require only bridge and pavement assets be included in TAM plans, AKDOT&PF has significant flexibility in how best to incorporate the results of the GAM research program in order to best serve the Department. This section provides example of target setting and performance measures in a situation where the Department chooses to fully integrate GAM into the TAM program. The actual degree to which these modern Best Management Practice tools are applied to geotechnical assets may of course vary based on current Department needs. Even if GAM is not incorporated at this time, the preliminary analysis performed in this research project helps the Department to identify gaps in data and analysis tools, enabling it to improve its management capability over time.

8.1 Development of Aspirational Condition Targets

Condition Performance Measures (PMs) have been developed for unstable slopes, retaining walls, and material sites. In asset management, an agency attempts to maximize the performance of the transportation system at minimum cost, by means of a decision making process based on performance measures and analysis. Asset management models are used to forecast the future outcomes that result from these decisions. In the federal framework described in the October 2016 Final Rule regarding asset management plans (23 CFR Part 515), state DOTs are held accountable for developing and implementing a risk-based management plan for bridges and pavements covering at least a 10-year period (FHWA 2016).

If any additional asset classes, such as geotechnical assets, are included in the Transportation Asset Management Plan, setting and working towards condition targets for these optional assets will provide the maximum benefit to agency management. Flexibility has been built into the Final Rule, so States have options for how they implement TAM principles for these optional asset classes. This adds data collection and analysis effort, but many states are deciding to incorporate ancillary assets in their TAM Plans because of the strong linkage between TAM Plans, the Statewide Transportation Improvement Plan (STIP), and smart management for reducing long-term costs. Because of this linkage, the preservation and improvement needs on ancillary assets are made more visible and are more readily included in agency and federal processes for programming and funding.

Performance measures are used in decision making at the asset level and network level. At the asset level, they take the form of Minimum Tolerable Conditions, a threshold below which a single asset's performance is considered unacceptable and corrective action is warranted. At the network level, performance measures are used to express a desired future outcome for the inventory as a whole, or for a subset of the inventory, in terms of target percentages of the inventory in specific Condition States or performance levels of service. There are two kinds of network level performance targets commonly used in asset management:

- *Aspirational targets:* Performance targets that are set as a matter of judgment or policy, without regard to cost or fiscal constraints, which the agency believes it should work toward and may be able to achieve at a long-run, unspecified future time.
- *Fiscally-constrained targets:* Performance targets that the agency believes it can attain within a specified time frame (usually 10 years) based on the level of funding it reasonably expects to have available. These are products of an investment analysis considering funding forecasts, models of deterioration, cost, and effectiveness, risk analysis, and consideration of uncertainty in planning metrics.

In the Final Rule, the TAM Plan begins with a performance gap analysis, which is a comparison between existing conditions and either the aspirational performance targets or pre-existing fiscally-constrained targets (e.g., if they existed from the previous edition of the plan). Almost by definition, current conditions are worse than the aspirational targets in most agencies. The TAM Plan ends with an investment analysis which determines fiscally-constrained performance targets for the future. These are the targets that the agency wishes to be accountable for, within a set time frame. Generally, fiscally-constrained targets are lower (worse) than aspirational targets, and may be better or worse (usually better) than current conditions.

Performance targets in the federal regulations are expressed as a percentage of the inventory in Good or Poor condition, where the terms Good and Poor are given precise definitions. Any ancillary assets included in the TAM Plan should use the same types of targets.

Performance targets can focus on condition, safety, mobility, or any other agency goal. The mandatory federal targets focus only on condition, but they also require agencies to show how the decision making process incorporates other federal goals including safety and mobility. As described in the Alaska GAM Plan Study, resilience is the performance measure which incorporates the effect of geotechnical assets on safety and mobility. As a result, performance targets for resilience may also be appropriate at some point.

For stakeholders and the public, performance expectations for geotechnical assets depend on functional classifications, in order to reflect the importance of routes to the State and to the Region. A route's Functional Classification as well as its System classification (e.g. NHS or AHS) should adequately capture the route's significance to Alaska. Minimum Geotechnical Performance Measures can be matched to the NHS/AHS Systems or to Functional Classifications. A conceptual example developed during the research project is shown in Figure 8-1 and explained in Table 8-1 and Table 8-2.

When one roadway segment is classified into two Geotechnical Performance domains, the route should be based on the higher performance category. For example, the Richardson Highway between the Tok Cutoff Highway and the Alaska Highway is classified as both a Minor Arterial (High Performance Category) and is on the NHS (Highest Performance Category). In instances such as this, the Performance Measures of the *Highest Performance* Category should be followed. A map of the target Minimum Geotechnical Performance Categories is shown on Figure 8-1.

The performance measures approach is based on condition assessment and periodic re-rating of unstable slopes and adjusts goals and target conditions based on Functional Classification or National versus Alaska Highway System. At the current stage of program development, the targets can be applied just to those roads that have had inventory and condition assessments performed, but AKDOT&PF could eventually implement these assessments and targets across AKDOT&PF's area of responsibility.

Table 8-1: Conceptual example of GAM Performance Targets based on AKDOT&PF's existing Highway System Classification.

AKDOT&PF Highway System	Minimum Geotechnical Performance Target Category	Examples
National Highway System	Highest Performance	Dalton Hwy, Seward Hwy, Haines Hwy
Alaska Highway System	High Performance	North Prince Of Wales Rd, Taylor Hwy

Table 8-2: Conceptual example of GAM Performance Targets based on AKDOT&PF's existing Highway Functional Classification.

AKDOT&PF Functional Classification	Minimum Geotechnical Performance Target Category	Examples
Interstate	Highest Performance	Parks Hwy, Glenn Hwy
Principal Arterial – Other	Highest Performance	Dalton Hwy, Haines Hwy
Minor Arterial	High Performance	Glacier Hwy, Portage Glacier Rd
Major Collector	High Performance	Denali Hwy, Edgerton Hwy, Mitkof Hwy
Minor Collector	Maintain Performance	Old Sterling Hwy, Old Edgerton Loop Rd, North Prince Of Wales Rd
Local	Maintain Performance	Swanson R. Rd (Kenai), Knik R. Rd. (Palmer)

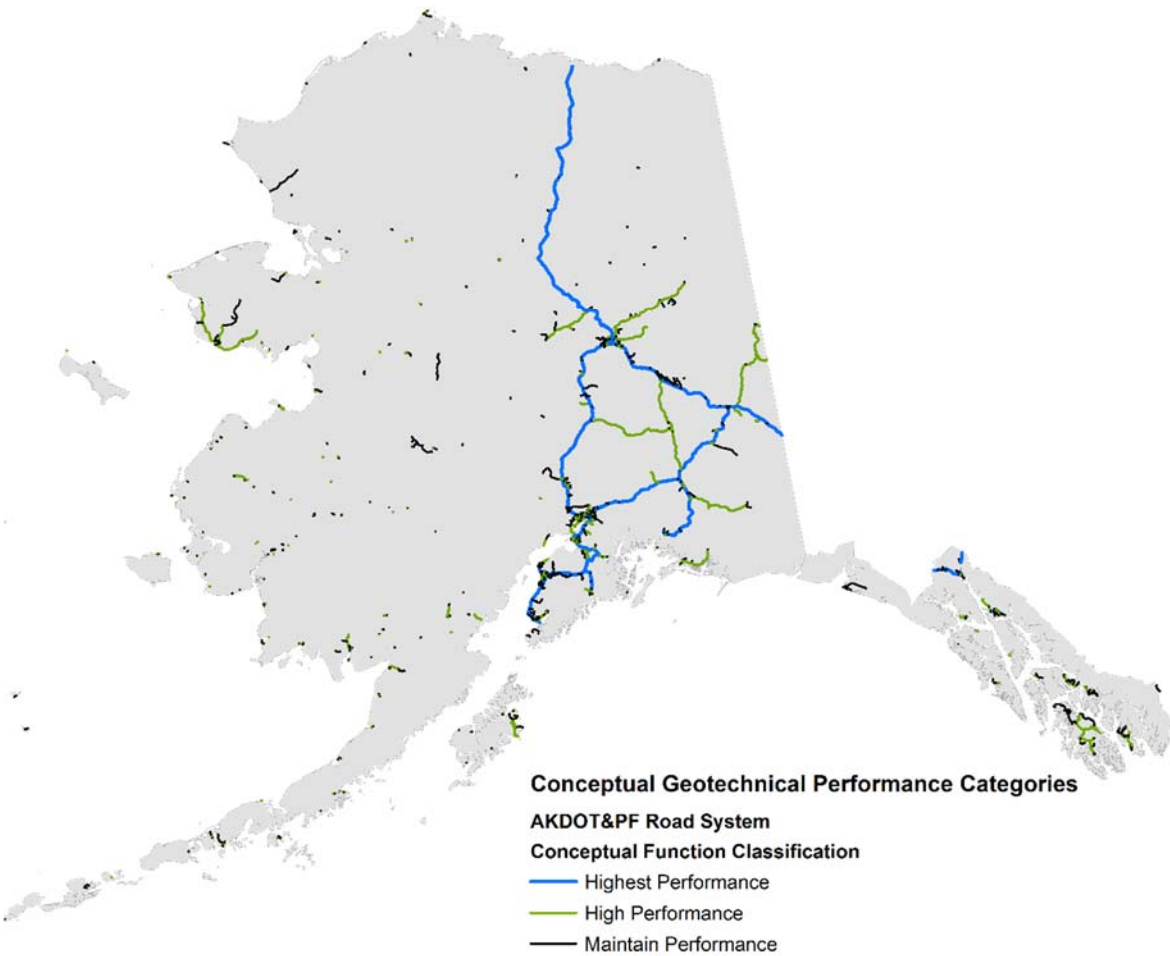

Figure 8-1: Map of the Alaska road system showing example Geotechnical Performance Targets.

8.1.1 Good/Fair/Poor Conditions and Performance Measure Classification

As described in this section, an approach has been developed to use the individual asset Condition States, as defined in Section 3, and the relative proportions of assets in Good/Fair/Poor Condition States to set aspirational condition targets. Performance Measures have been developed using the Good/Fair/Poor descriptors for transportation assets for roadway classifications (Guerre, et al. 2012, FHWA 2017).

Each subsection contains an overview targeted at a specific geotechnical asset, with a table showing the recommended Performance targets for Routes and Regions relative to geotechnical asset type. Further subdivisions identifying particularly problematic areas, such as the Long Lake area or Glitter Gulch may also be advanced. "Fair" is the conceptual minimum tolerable condition for *Maintain Performance* Routes and "Good" for *High* and *Highest Performance* Routes.

Note that these Performance targets have been formulated using relative performance standards that would be used today. For instance, many of the rock slopes in Alaska were designed and constructed without the considerations for ditch effectiveness or rock block support that would be used in a modern setting. Today, roadside ditches would be designed much wider and rock slopes designed with slope angles appropriate for the geologic structure and/or supported with rock reinforcement (rock bolts, dowels, shotcrete, etc.) or rockfall control measures (draped mesh, attenuator, barriers, etc.) and would result in much better performance. Due to this time of construction factor, a larger-than-anticipated percentage of the unstable slope assets will be judged ‘Fair’ or ‘Poor’ and this is not necessarily the result of inadequate maintenance practices.

Note that these Performance Targets below are *aspirational* and would require more funding than the Department has available to even *maintain* current conditions. Rather, these aspirational targets should serve more as design guidelines when performing a corridor realignment or major reconstruction efforts. Additionally, the example targets below can be considered as tools to support decision-making when evaluating which projects or sites to advance to the conceptual or final design phase. These do not replace the targets advanced in AKDOT&PF’s GAM Plan Technical Report, Chapter 6 (P. D. Thompson, 2017 Alaska DOT&PF Geotechnical Asset Management Plan: Technical Report 2017). Alternatively, aspirational condition targets can simply be a percentage Condition Index improvement over the network (i.e 5% improvement over the current conditions), neglecting that performance can be tied to the functional classification or highway systems, as outlined in the following section.

8.1.2 Example Condition Targets for Rock Slopes

As shown in Table 8-3, rock slope performance targets compare the total area of rock slopes evaluated to those assessed in a particular condition. For example, Southcoast Region has about 6.4 million square feet of rock slopes evaluated. Of that, nearly 25% of its rock slope area is in Good Condition, 70% in Fair Condition, and 5% in Poor Condition. There is a heavy reliance on Fair Condition rock slopes due to the variability of geologic structure common in rock slopes. This variability may lead to a ditch with limited effectiveness providing fair performance for a rock slope that exhibits very little adverse structure and correspondingly little rockfall activity.

Table 8-3: Sample Route or Regional Aspirational Condition Targets for Rock Slopes. These can also serve as Design Goals or guidelines for new corridors or major rehabilitations.

Performance Category	Minimum Tolerable Condition State	Minimum Percent ‘GOOD’ (sq ft)	Maximum Percent ‘POOR’ (sq ft)
Highest Performance	Good	80%	5%
High Performance	Fair	70%	10%
Maintain Performance	Fair	50%	15%

8.1.3 Example Condition Targets for Unstable Soil Slopes and Embankments

Recommended aspirational targets for unstable soil slopes and embankments are presented in Table 8-4 below. Unlike Performance Measures for rock slopes, unstable soil slope performance targets are compared to the total road miles inventoried, since stable embankments and soil cuts (i.e. assets in Good condition) are not added to the USMP database. For example, Northern Region has about 520,000 linear feet of evaluated unstable soil slopes. Of the evaluated slopes, 42% are in Fair condition and 52% are in Poor condition. However, when this is compared to the approximately 7.9 million total linear feet of NHS routes administered by the district (all on some sort of constructed fill, even ballast sections in cut areas), 95% of those slopes or embankments are in Good condition, 3% are in Fair condition, and a further 2% are in Poor condition. These numbers compare well with pavement management systems, with regard to their actual, overall performance. Because all slopes or embankments not inventoried are assumed to be in Good condition, the percentage of soil slopes and embankments in Good condition is much higher than for other asset types.

Table 8-4: Sample Route or Region Aspirational Condition Targets for Unstable Soil Slopes and Embankments.

Performance Category	Minimum Tolerable Condition State	Minimum Percent 'GOOD' (ln ft)	Maximum Percent 'POOR' (ln ft)
Highest Performance	CS – 2 Fair	95%	1%
High Performance	Fair	92%	2%
Maintain Performance	Fair	90%	2%

8.1.4 Example Condition Targets for Retaining Walls

All walls that are not part of a bridge structure should be added to the GAM Inventory through the Retaining Wall database. Acceptance criteria for entry into the Retaining Wall Inventory (RWI) are outlined in AKDOT&PF's Retaining Wall Inventory Procedures Manual (AKDOT&PF 2017). The RWI then forms the backbone of the field inventory and detailed assessments of retaining walls for the Retaining Wall Management Program (RWMP).

As with rock slopes, current conditions are compared to aspirational targets based on the condition of the approximate exposed wall face square footage. Unlike rock slopes however, the Performance Standards for retaining walls are higher due to the less forgiving nature, typically more rigorous engineering design, and high costs of replacing of a failing retaining wall.

Proposed retaining wall aspirational targets are shown in Table 8-5. Inventory work has not yet been completed in any region, and these targets may be adjusted once inventory work is finished. At the time of this report, 38% of NHS/AHS road miles in Central Region have been surveyed, the greatest percentage of any of Alaska's three regions. Of that, approximately 65% of the wall face area is in Good Condition, 34% is in Fair Condition, and 1% is in Poor Condition. Walls in Fair or Poor condition are likely due to flaws in wall design or construction, or to the decay of a wall over its life cycle.

Table 8-5: Sample Route or Region Aspirational Condition Targets for Retaining Walls.

Performance Category	Minimum Tolerable Condition State	Minimum Percent 'GOOD' (sq ft)	Maximum Percent 'POOR' (sq ft)
Highest Performance	CS – 2 Fair	95%	2%
High Performance	CS – 2 Fair	90%	3%
Maintain Performance	Fair	85%	10%

8.1.5 Example Condition Targets for Material Sites

Unlike unstable slopes and retaining walls, asset evaluation of material sites incorporated material scarcity metrics, which were determined on the maintenance station service area level. Since a typical maintenance station covers multiple route types, the route-type breakdown employed in setting aspirational targets for the other asset types does not apply here. Instead, targets were developed only for maintenance stations with potential STIP projects. STIP projects typically require significant material quantities. Routine maintenance material requirements, in contrast, are typically small. Maintenance stations with poor access to the significant quantities required by STIP projects may still be able to easily obtain sufficient material quantities to meet routine needs.

Recommended condition targets for maintenance service stations with STIP projects are presented in Table 8-6. Currently, there are 57 maintenance stations with inventoried material sites. Of these, 5% are in Good Condition, 28% are in Fair Condition, and 67% are in Poor Condition.

Table 8-6: Aspirational Condition Targets for material availability in Maintenance Station service areas.

Performance Category	Minimum Tolerable Condition State	Minimum Percent 'GOOD' (%)	Maximum Percent 'POOR' (%)
High Performance to Maintain Perf.	Good	60%	10%

8.2 Development of Fiscally-Constrained Condition Targets

A by-product of the life cycle cost analyses described in Section 7.6 is a yearly forecast of Condition States. These conditions will vary depending on the budget constraint that is selected, since the budget affects the amount of corrective action and reconstruction that can be done.

TAM plans require the establishment of fiscally-constrained targets for asset condition after ten years. If the Section 7.6 equations are used, the models can provide a reasonable estimate of ten-year condition outcomes at any feasible budget level, which may form the basis for condition targets. This kind of parametric analysis is often called a Tradeoff Analysis. The Tradeoff worksheet used to generate the following models is contained in an Excel spreadsheet file, which is available upon request.

For the purpose of these models, the funding necessary to maintain current conditions, developed in the return-on-investment analysis described in Section 7.6, was assumed to correspond to the desired long-term condition level. A range of round-number budget constraints was selected above and below this desired level.

8.2.1 How to Read a Tradeoff Analysis Plot

The final plot associated with a tradeoff analysis is very data dense. The graph shows the 10-year forecast average asset condition index, 10-year forecast percentage of assets in Good condition, and 10-year forecast percentage of assets in Poor condition, all based on varying initial annual funding levels. This section presents a brief walk-through of how users can interpret data out of the analysis plot to meet various planning needs. The Tradeoff Analysis developed for rock slope assets is used as an example, but the specific rock slope asset tradeoff analysis is discussed in Section 8.2.2.

As a starting point, take the blue dots and the solid blue line highlighted in Figure 8-2. Each blue dot represents the forecast average asset condition index in 10 years based on a specific initial annual funding level. Due to the complexity of the model, the solid blue line connecting these dots is not a free-standing line derived from an equation. Rather, it is a line of best fit from point to point that approximates the average condition index outcomes for the various non-modeled annual funding options. Note that since the tradeoff analysis looks at asset condition for the entire group, the actual condition of individual assets may still degrade, even as average conditions remain constant.

Because the tradeoff analysis is complex, specific condition index – annual funding forecasts are only developed over a certain range. In this example, the analysis was conducted over 10 evenly spaced intervals between zero and $16 million dollars per year. Funding levels are expected to increase annually based on a set rate of inflation. For this model, inflation was assumed to be 2.5% per year.

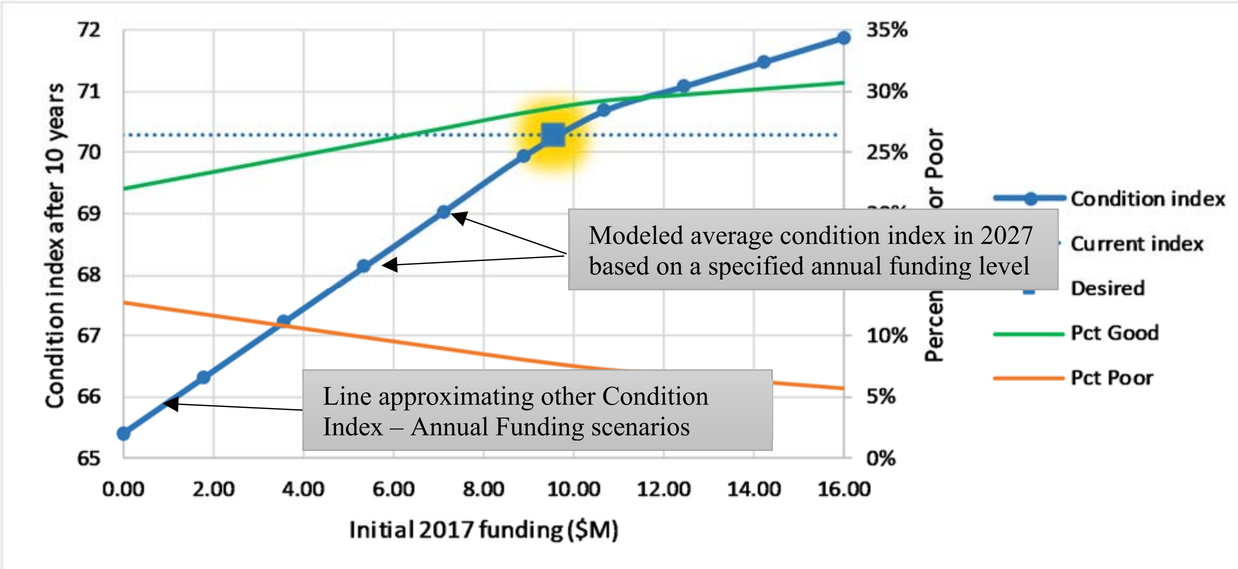

Figure 8-2: Reading a Tradeoff Analysis Plot, Part 1: various modeled funding scenarios and resulting average condition index in 10 years.

Next, the blue dashed line represents the current (2017) average asset condition index. For rock slope assets, the current average Condition Index is 70.3. The point of intersection between the dashed line and the solid blue line is the annual funding required to maintain average current conditions over the 10-year period between 2017 and 2027. In Figure 8-3 is called out using a blue square circled with a yellow halo. The initial estimate can be refined by solving the tradeoff analysis model for funding levels around the estimated point of intersection.

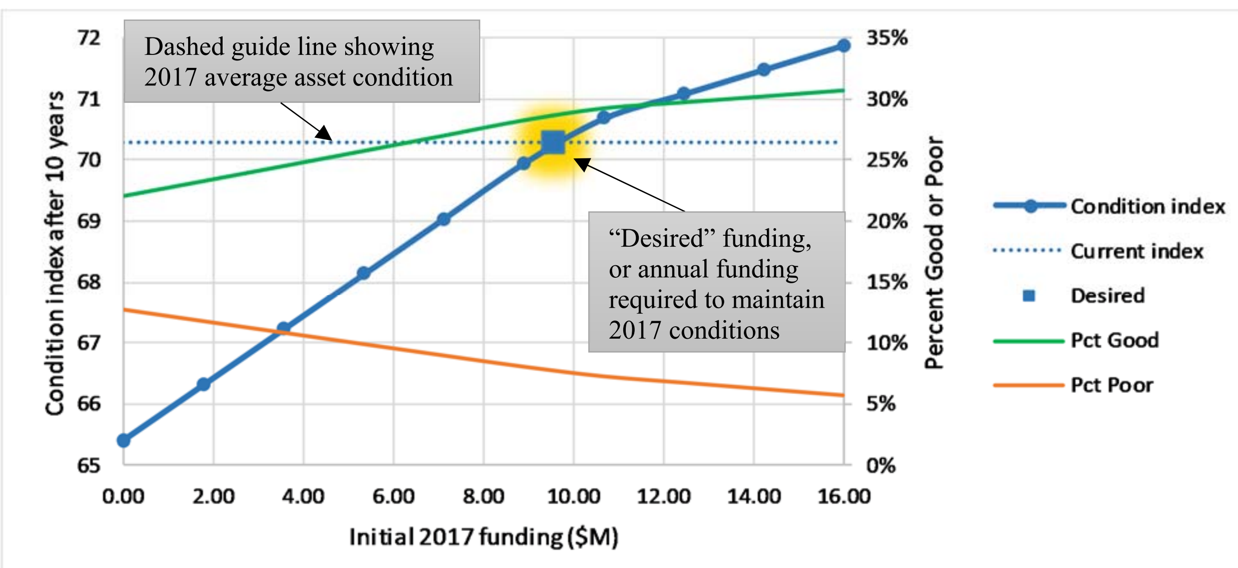

Figure 8-3: Reading a Tradeoff Analysis Plot, Part 2: determining the estimated annual budget required to maintain current average asset conditions.

Finally, in addition to average condition index, the tradeoff analysis also incorporates the deterioration model to forecast the percentage of assets that will be in Good or Poor condition based on funding level, as shown in Figure 8-4. These add nuance to the average condition index information, and equate to the performance targets that would be found in a standard asset management plan. The forecast pair of various performance targets also helps planners visualize how increased funding for mitigation and preservation work will decrease the number of assets in Poor condition, while increasing the number of assets in Good condition. This pair of forecasts could also be removed from the tradeoff analysis plot and presented as free-standing information, if the Department is trying to succinctly share GAM performance targets with the general public.

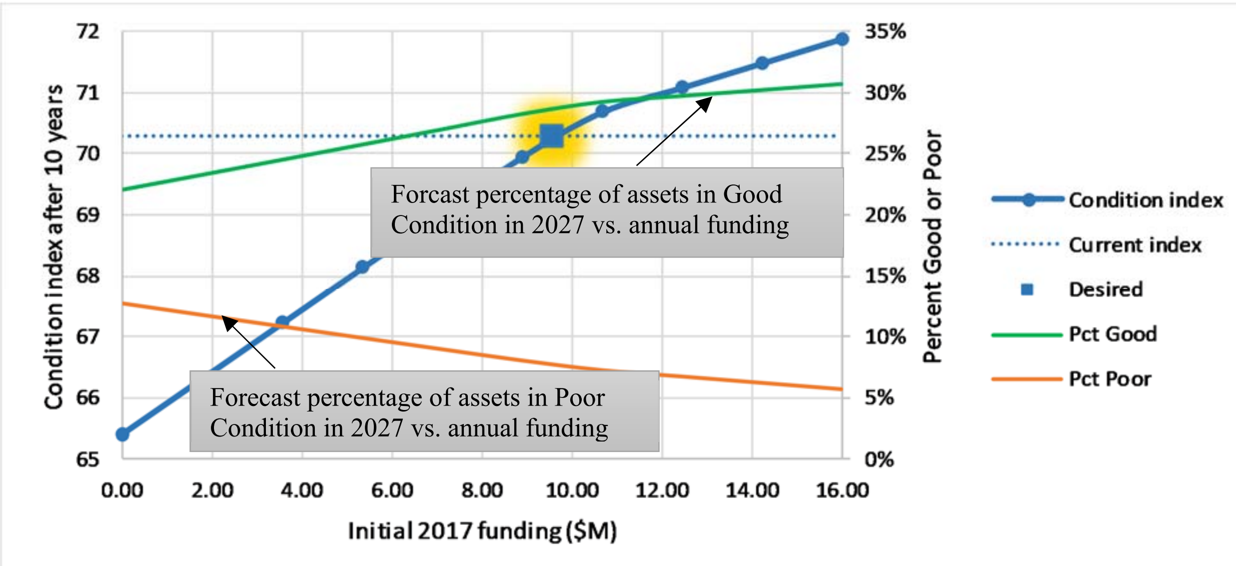

Figure 8-4: Reading a Tradeoff Analysis Plot, Part 3: Estimating the future percentage of assets in Good or Poor condition based on funding level.

8.2.2 Example Fiscally Constrained Condition Targets for Rock Slope Assets

The results of applying the equations from Section 7.6 to the current suite of inventoried rock slope assets is shown inFigure 8-5 below. The horizontal axis is a range of fiscal scenarios showing the first-year funding level, which is assumed to increase 2.5% per year due to inflation. The left vertical axis is the statewide condition index forecast after ten years, and the right vertical axis shows the percent Good and percent Poor condition assets after ten years. The percent Good and percent Poor lines represent reasonable GAM performance targets for each level of funding. As expected, higher levels of funding produce better conditions.

Based on this figure, the desired funding level of $9.52 million is sufficient to maintain the current statewide condition index of 70.3 after ten years. At this level, the ten-year performance targets for TAM Plan purposes would be 29% Good and 8% Poor. The total 10-year funding requirement, including inflation of 2.5% per year, is $107 million.

If Department planners determine that this level of funding is not achievable, they may choose to set lower performance targets, accepting future deterioration of this asset type in exchange for a funding level that the Department can reasonably be expected to meet at this time. For example, if a funding level of $2 million is achievable, than AKDOT&PF may reasonably expect rock slope asset condition to deteriorate to 23% Good (a decrease of 6% from 2017) and 13% Poor (an increase of 5% from 2017) over the next 10 years.

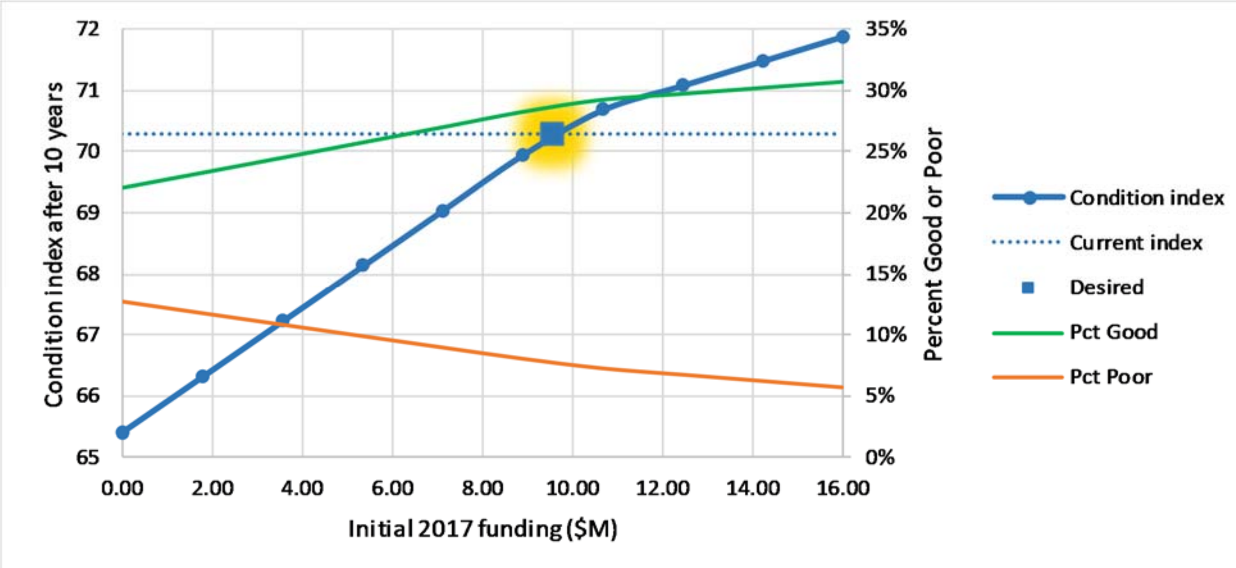

Figure 8-5: Condition vs. annual funding for rock slope assets over a 10-year period.

8.2.3 Example Fiscally Constrained Condition Targets for Unstable Soil Slope and Embankment Assets

The results of applying the equations from Section 7.6 to the current suite of inventoried unstable soil slope and embankment assets is shown in Figure 8-6 below. As in the previous section, the horizontal axis shows a range of fiscal scenarios for the first-year funding level, which is assumed to increase 2.5% per year due to inflation. The left vertical axis is the statewide condition index forecast after ten years, and the right vertical axis shows the percent good and percent poor after ten years. These show reasonable performance targets (% Good and % Poor) for each level of funding.

Based on this model, annual funding of $154.28 million would be required to maintain the current statewide average condition of 48.4 for inventoried unstable soil slope and embankment assets over the next 10 years. At this level, the ten-year performance targets for TAM Plan purposes would be 19% Good and 47% Poor. The total 10-year funding requirement, including inflation, would be $1.728 billion.

This cost is clearly far beyond the Department's current fiscal capabilities, so the average condition for these geotechnical assets can be expected to decline with time. If no funding is allocated for mitigation, reasonable performance targets at the end of the 10-year period will be 14% Good (a decrease of 5% relative to 2017) and 61% Poor (an increase of 14% relative to 2017).

Consequences of this deterioration will be reflected in increased reconstruction costs for pavements on unstable soil slopes and embankments, and in increased vehicle damage on uneven driving surfaces, among other projected impacts. Operations strategies such as speed restrictions and temporary or permanent closures may help AKDOT&PF deal with deteriorating conditions. These operational options are likely to be particularly important in areas of the state experiencing permafrost instability, where slope deterioration rates are fastest. Northern Region in particular is expected to bear the brunt of deteriorating unstable embankment assets.

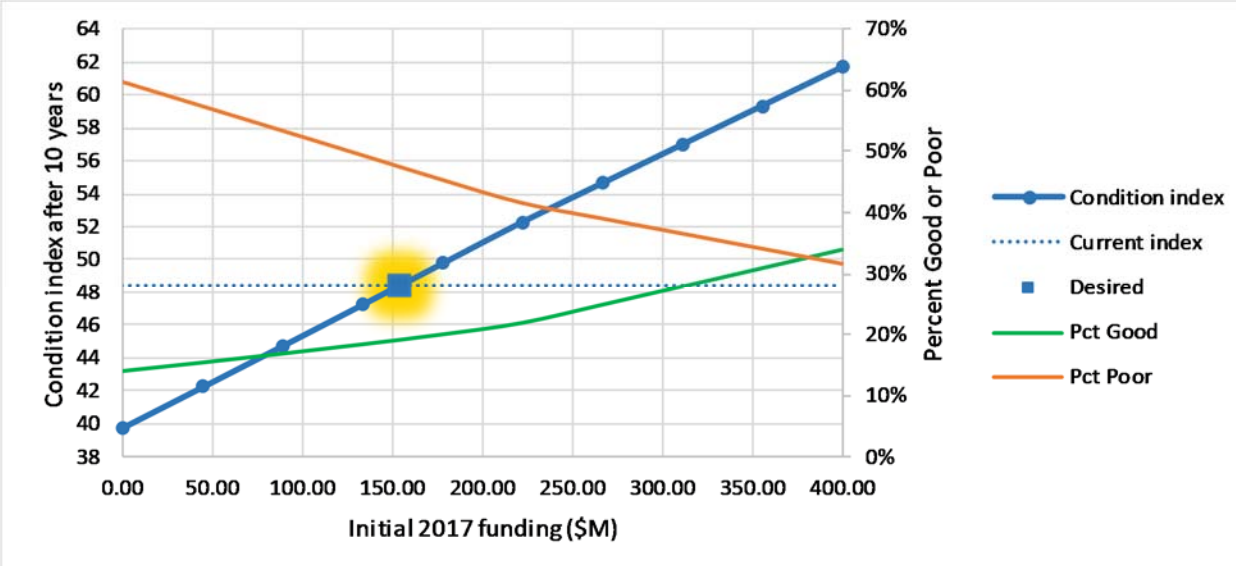

Figure 8-6: Condition vs annual funding for unstable soil slope and embankment assets over a 10-year period.

8.2.4 Example Fiscally Constrained Condition Targets for Retaining Wall Assets

As for rock slope and unstable soil slope and embankment assets, the equations from Section 7.6 to the current suite of inventoried retaining wall assets and used to develop Figure 8-7 below. The first year funding level shown on the horizontal axis is still assumed to increase by 2.5% per year due to inflation. The left vertical axis is the statewide condition index forecast after ten years, and the right vertical axis shows the percent good and percent poor after ten years. These show reasonable performance targets for TAM plan purposes based on each level of funding.

From this model, annual funding of $3.73 million is sufficient to maintain the current statewide average condition index of 79.8 for retaining wall assets over the coming 10-year period. At this level, the performance targets for TAM Plan purposes would be 62% and 2% Poor. The total 10-year funding requirement, including inflation, would be $42 million.

As in the analyses conducted in the previous subsections, Department planners may select different performance targets if a different funding level is selected. Note that because retaining walls as a group are in better average condition that other inventoried geotechnical assets, a slight increase in annual funding above the level desired to maintain conditions results in a rapid decline of the percentage of Poor condition retaining walls to near-zero levels.

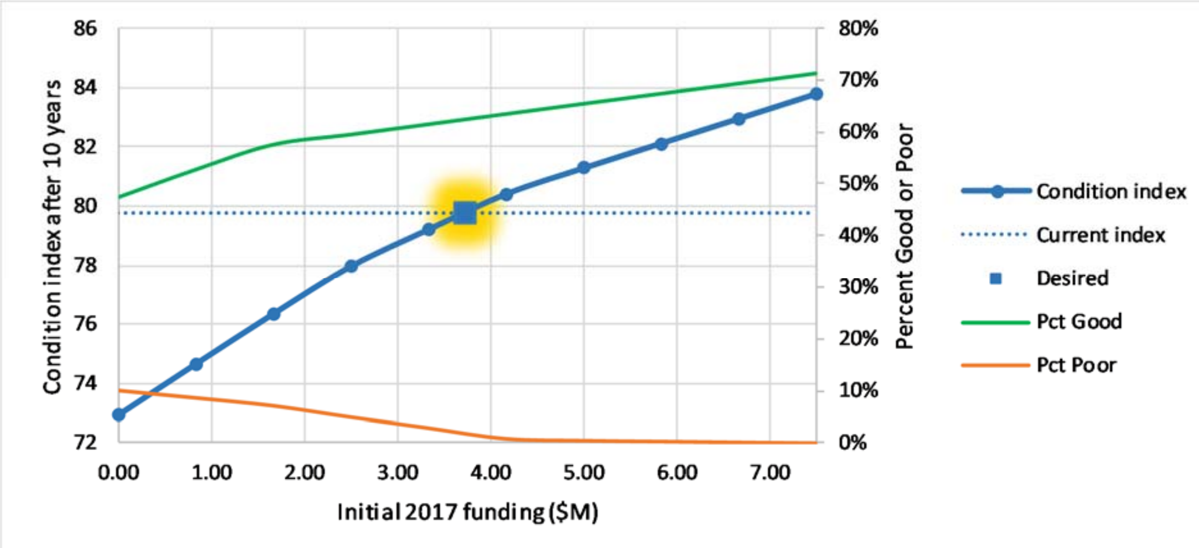

Figure 8-7: Condition vs annual funding for retaining wall assets over a 10-year period.

8.2.5 Example Fiscally Constrained Condition Targets for Material Site Assets

As discussed in Section 6.4, the application rate for material site development is assumed to be proportional to the number of road miles that are currently unserved. As a result, the investment analysis concentrates new development in states 4 and 5. These also happen to be the maintenance stations where new site development is least expensive per new road mile served.

Figure 8-8 below presents an analysis showing the amount of new service that is possible under different levels of funding for new site development. As in the analyses for the other geotechnical assets, initial funding is assumed to increase 2.5% year to reflect inflation.

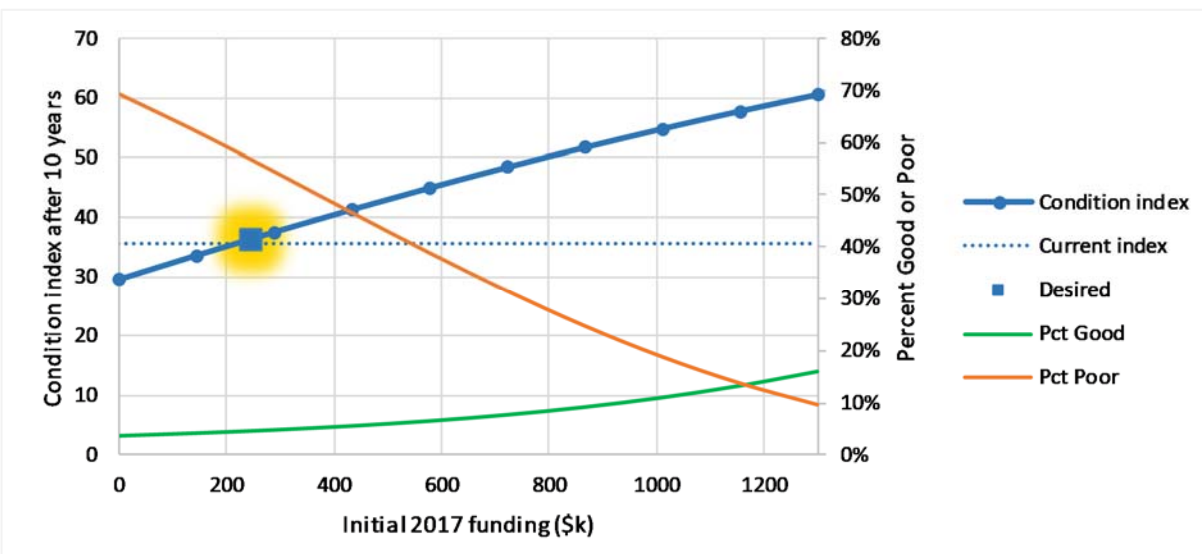

Figure 8-8: Condition vs annual funding for material site-based maintenance station service area condition vs funding over a 10-year period.

In this model, the current annual funding of about $244,000 per year is sufficient to maintain current statewide average material availability. The associated 10-year TAM Plan performance targets would be 5% of maintenance stations in Good condition (optimal material availability) and 57% in Poor condition. The total 10-year funding requirement, including inflations, is $3 million. If the Department were able to allocate more funding for site development, that change, at least in this model, would primarily affect the percent of maintenance stations whose inventories are in Poor condition (states 4 and 5).

8.2.6 Example Application of Aggregating Targets for Use in Budget Decision-Making

The fiscally constrained condition targets above can be mined for data to be used in the planning process. Condition and funding requirements for multiple asset types can be aggregated into a single plot for presentation in a planning meeting. As an example, the research team extracted data from each of the fiscally constrained models based on four budget scenarios:

- The budget required to maintain current conditions is provided.
- The Department budgets 50% more than the amount required to maintain current conditions.
- The Department budgets 50% less than the amount required to maintain current conditions.
- The Department does not budget any money for managing geotechnical assets.

For each asset type, the team looked at the projected net change in average asset condition over 10 years, the initial annual budget required for each scenario, and the initial annual savings if preservation goals were used to allocate the budget dollars, instead of applying only a worst-first project selection process. In order to simplify data presentation, the four asset types were aggregated into a single data series, as shown in Figure 8-9. The plot illustrates the lost savings when not incorporating preservation projects and the accompanying declining conditions.

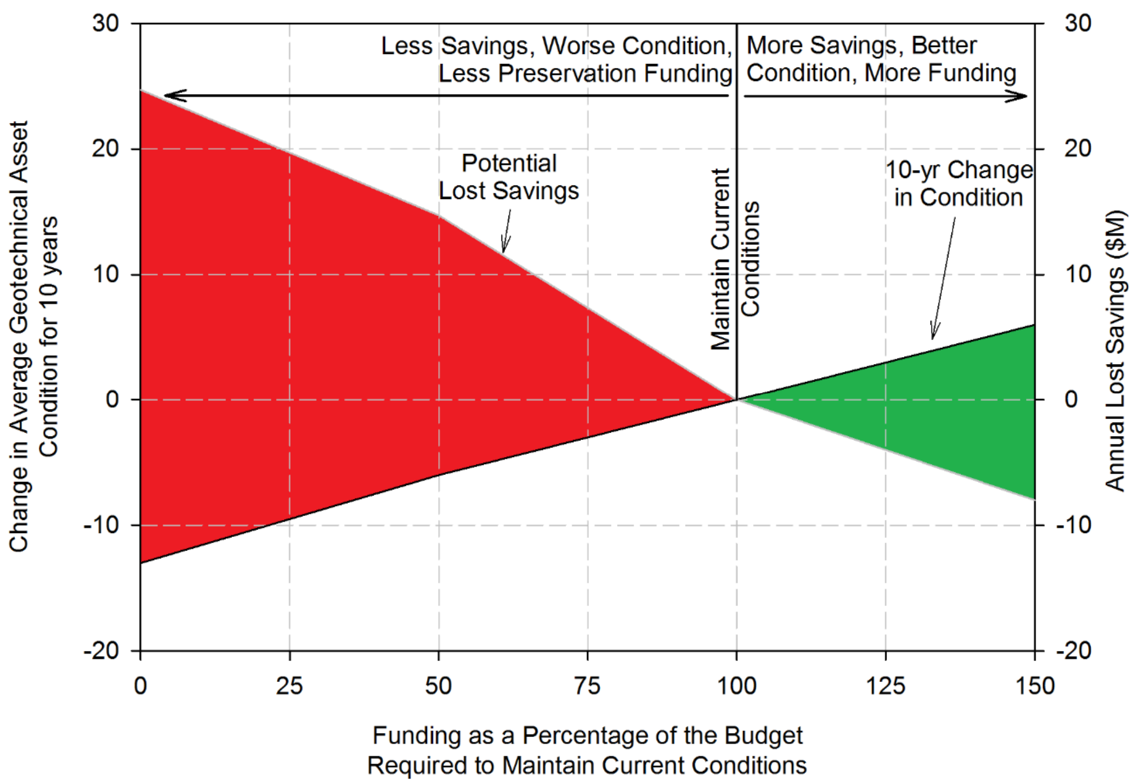

Figure 8-9: Use of current asset condition, deterioration models, and return on investment models to forecast future conditions based on various funding scenarios.

8.3 Applying GAM to Project Prioritization and Design Estimation – Southcoast Region Example

In 2014, AKDOT&PF discussed allocating up to $2 million of construction funds annuals for the repair and rehabilitation of unstable slopes, pavements, and culverts in the Southcoast Region (SR). This provided an opportunity to incorporate ongoing GAM research work into conceptualizing project selection. In December 2014, Landslide Technology delivered a report titled "Prioritization and Design Effort Estimation for Southcoast Region Unstable Slopes," containing a short-list of 10 target projects. The report is summarized in this section and presented in full in Appendix F. It is intended as an example of how the GAM system could be effectively utilized to identify opportunities for hazard and/or risk reduction in the early stages of a multi-year, region-wide planning process.

To demonstrate how the GAM program could help efficiently allocate those funds, the report incorporated data collected during GAM program inventory and assessment work. In the Southcoast Region, the GAM database includes NHS routes with known unstable slopes, as well as the AHS portion of Glacier Highway and North and South Tongass. The evaluated routes, south to north, are:

- South Tongass
- North Tongass
- Mitkof Highway
- Halibut Point Road
- Egan Drive/Glacier Highway
- Haines Highway
- Lutak Road
- Klondike Highway
- Richardson Highway[17]

Candidate sites were selected by incorporating a variety of factors. These factors included asset Condition States, review of asset rating photographs, M&O input, potential economic impacts of road closure, the possibility of combining mitigation work with other upcoming projects, and expert judgment. Researchers also referred to 2013 Pavement Serviceability Ratings (PSR) to identify where poor condition pavements and poor condition slopes overlap. Finally, researchers worked to achieve an economy of scale where possible, grouping multiple sites into a hypothetical construction contract that could be completed in a single season. This would reduce the costs incurred by individual mobilizations, and could potentially allow individual sites to be added or removed in a construction season as budget and rehabilitation progress permits.

Based on the results of this analysis, five rock slope and five unstable soil slope/debris flow sites were identified and given a priority ranking. The priority ranking was closely tied to the risks posed by slope activity, but also took the existence of upcoming nearby projects into account, where that information was available. In order of rank, the prioritized sites were:

1. Haines Highway Debris Flows, MP 17-23
2. Klondike Highway Unstable Slopes
3. Ketchikan ROW Unstable Slopes

[17] The southern portion of Richardson Highway was transferred from Northern Region to Southcoast Region in November, 2014 and was therefore included in this report. As of April, 2015, it has been transferred back to Northern Region.

4. Ketchikan Wolfe Point and South Tongass MP 6.87 Slope
5. Richardson Highway Slopes
6. Lutak Road NHS Slopes and Ferry Terminal Slope
7. Lutak Road Debris Flows
8. Mitkof Highway Debris Flows
9. Glacier Highway Slopes
10. Halibut Point Road Slope

The sites are also shown in Figure 8-10 below.

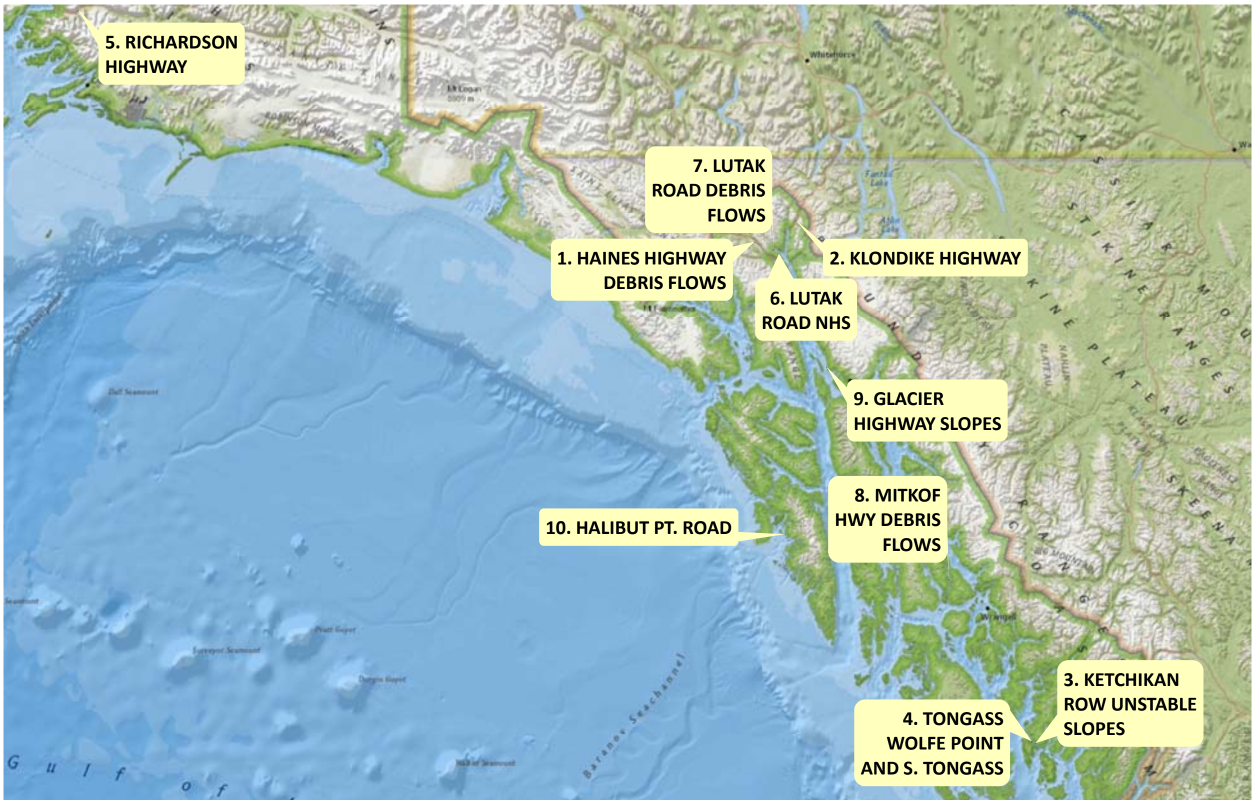

Figure 8-10: Prioritized sites in Southcoast Region identified in December 2014 design effort estimation report.

A brief overview of the safety issues posed by these sites was provided in the report, and additional, more extensive site descriptions and conceptual design effort outlines were included at the end of the planning document. Site-specific conceptual mitigation designs were not developed, but the sites were loosely divided into three level of effort categories, low, moderate, or high, based on projected level of effort:

Low level of design effort ($10,000 - $40,000): No subsurface explorations or difficult access, little to no modelling, and plans that can be developed with minimal effort from site photos.

Moderate level of design effort ($40,000 - $100,000): Possible test-pitting, but no geotechnical drilling. Some rope access and additional photogrammetric data collection may be required. Office analyses required, possibly with additional site information collected by AKDOT&PF survey crews. Some engineering assistance may also be required during construction.

High level of design effort ($100,000+): Drilling or other site investigations are required to assess geotechnically complex problems and/or highly variable geologic conditions. Specialized construction sequencing and traffic control may be required, multiple sites may be grouped into one project, or a variety of mitigation approaches may be required.

Items considered in the design effort cost estimates included the presence of difficult site access, the requirement for subsurface explorations, photogrammetry, and engineering, as well as overall project size and scope.

The goal of this planning document was to initiate a conversation on the best allocation of proposed budget dollars to meet the needs of the Southcoast Region. Starting from the identified priority sites, interviews with district supervisors could provide additional feedback on where rehabilitation efforts would be best directed, and could also help refine the methods used to identify and prioritize sites.

This type of planning document would be one of many benefits in a fully operation GAM system. Similar planning documents could one day become a routine initial step in the early stages of multi-year, region-wide planning efforts. The asset databases and rating-based valuations would make the planning process more efficient by speeding the identification of high-hazard or risk areas.

8.4 Application of GAM to Develop Additional Performance Measures

Successful asset management is essentially successful data management. Performance measures give agencies a way to compile data and share it in an easy-to-digest format, one where changes can quickly be tracked over time. Example performance measures include improvements to average asset Condition States as a way to measure deterioration prevention and measures related to asset risk and/or resiliency. Depending on the type of data collected, measures can also be developed for management performance or incident response. All of the Performance Measures presented in this section are examples of what AKDOT&PF could develop, based on the existing GAM program, as well as options that could be developed if additional data is collected in the coming years. Target performance for each asset is set by the Department, and generally varies based on route classification. Performance measures can be refined based on the results of asset inventory and rating work.

8.4.1 Management Performance Measurement

Management Performance Measurement (MPM) is intended to track how well AKDOT&PF is proactively managing and improving its assets over time. MPM combines data from asset inventory and rating work with maintenance records of road-closing events due to asset failures. Determining the performance of department assets can be performed on a number of scales, such as on a road-mile linear scale (0.25, 1-mile, 5-mile, etc.), on a per route or corridor scale (Alaska Highway, Long Lake area of the Glenn Highway, etc.), or on an Administrative Unit scale (Northern Region, Maintenance District, etc.). Example targets developed based on corridor function classification are shown in Table 8-7.

A successful MPM program will reduce the occurrence of failures, patching, and road closures over time. However, due to the sporadic nature of slope failures and their close relationship to climatic events, as well as Alaska's unique vulnerability to climate change (Chapin, et al. 2014) (US Artic Research Commision Permafrost Task Force Report 2003), multiple years will be required before an obvious decrease in reactionary responses can be observed.

8.4.2 Corridor Health Index

The Condition States of all the different assets types in a transportation corridor can also be combined to measure the overall health of the transportation corridor segment. This Corridor Health Index (CHI) would provide another tool to help the Department measure how well it is meeting long-term performance goals. By integrating all of the Department's assets into one metric, the CHI helps capture interaction between geotechnical and structural assets. For example, poorly performing culverts may to contributing to unstable embankments and poor condition pavements. By looking at all assets early in the design process, the Department can avoid change orders and build a longer-lasting product.

A sample CHI model was developed in the associated GAM research project that featured the Tongass Highway Corridor as a prototypical model. The CHI concept is described in detail in the report for AKDOT&PF Research Project RES-13-007, Ketchikan North/South Tongass Highway Stability Reconnaissance Project/Geotechnical Asset Management Program/Unstable Slope Management Program. Example targets developed based on corridor function classification are shown in Table 8-7.

Table 8-7: Example Performance Measures for management, incident response, and corridor health using rock slope assets as an example

AKDOT&PF Functional Classifications	Example Management Performance Measure Target	Example Corridor Health Index Target, by Corridor Length
Highest Performance: Interstate, Principal Arterials, and National Highway System.	Inventory and assessment work conducted every 5 years. Adverse event information collected annually. Average per-mile condition of rock slopes is Good, with road closures occurring less than once per year.	> 80% of Corridor in Good Condition < 5% of Corridor in Poor Condition
High Performance: Minor Arterial, Major Collector, and Alaska Highway System	Inventory and assessment work conducted every 5-10 years. Adverse event information collected annually. Average per-mile condition of rock slopes is Good/Fair. Road closures occur multiple times per year, concentrated seasonally.	> 70% of Corridor in Good Condition < 10% of Corridor in Poor Condition
Maintain Performance: Minor Collector and Local Routes	Inventory and assessment work conducted every 10 years. Adverse event information collected annually. Average per-mile condition of rock slopes is Fair, with road closures occurring multiple times per year.	> 50% of Corridor in Good Condition < 10% of Corridor in Poor Condition

9 ALTERNATIVE ACTIONS BASED ON CONDITION STATE

The ideal geotechnical asset maintenance and mitigation strategy is to make the appropriate investments at the right time to either extend the time an asset remains in its current Condition State or elevate its Condition State through performance enhancement. In general, standard maintenance or minor contractor activities would be used to extend the time that an asset remains within its current Condition State. Larger investments would typically be made when attempting to improve the Condition State by one or more classes, which would also lengthen the time an asset meets performance requirements.

Ideally, selecting a mitigation approach should balance the level of investment against the cost of ongoing maintenance and the potential social costs related to an unstable slope or retaining wall failure, or material scarcity within a maintenance service area. The asset Condition State – mitigation cost correlations developed in Section 6 can be used to estimate the level of investment required to meet the Department's aspirational goals, as described in Section 0. In applying these broad estimates, likely typical mitigation measures can also be correlated to asset Condition State.

The following sections provide a general review of the types of mitigation options available to the department and how mitigation effectiveness is modeled at the planning level. This is followed by a discussion of typical mitigation actions based on Condition State for the four asset classes currently covered by AKDOT&PF's GAM program: rock slopes, unstable soil slopes and embankments, retaining walls, and material sites. Sections 9.1, 9.2, and 9.3 are focused on unstable slopes and retaining walls, assets which directly support roadway function. Since the condition of material sites has been valued at the service area level in terms of material scarcity, mitigation options for that asset type are discussed separately (Section 9.4).

9.1 Types of Mitigation Options

The purpose of mitigation is to reduce the occurrence or the effect of adverse events. Intervention measures for rock slopes, unstable soil slopes and embankments, and retaining walls fall into three broad categories: protection, stabilization, and avoidance. Intervention measures for material sites center on maintaining or improving access to materials, which is generally accomplished via permitting and investigation work, as opposed to construction projects.

Protection measures are intended to control failures, preventing them from impacting the travel way. For unstable slopes, this would include measures like draped mesh, which directs rockfall debris into the roadside ditch, or channels and culverts designed to manage debris flows. These types of mitigation measures typically rely on continued maintenance attention, but at times that can be regularly scheduled. Stabilization reduces the potential for events to occur. This could include the installation of horizontal drains to reduce movement rates of an unstable soil slope, or the installation of anchors to strengthen a failing retaining wall. Avoidance is typically the mitigation measure of last resort, used to relocate the road facility away from harm's way without addressing the asset's failure potential. This method of mitigation often requires significant investment and the purchase of additional right-of-way. Options include new roadway alignments, tunnels or elevated structures.

9.2 Evaluating Mitigation Effectiveness

The selection of a mitigation design for a particular site is dependent on several criteria that are typically considered during the project development stage. Careful consideration of the goals established for the various assets within the GAM program requires the design effectiveness, durability and cost to be carefully weighed.

For the selected mitigation to be effective, designs need to match the conditions at a site. Quantifying the site conditions requires insight into the anticipated event size, behavior, and recurrence interval. The level of effectiveness required can be a function of the significance and vulnerability of the route. Both stabilization and protection measures are intended to limit the likelihood of impacts to the roadway, but protection measures will likely require more maintenance attention then stabilization measures in order to guarantee their effectiveness. In general, assets that produce large events are more likely to benefit from stabilization measures, while protection measures are applied to sites where activity is dominated by smaller events. Adopting an avoidance approach is less common due to ROW requirements and cost but is quite effective for highly vulnerable sites or where the local site conditions accommodate this type of design and the existing ROW is adequate.

Durability is directly related to anticipated design life and reflects how well a design option will hold up to the rigors of exposure and use. The same site activity metrics used to assess mitigation effectiveness, are major considerations in this evaluation, along with local environmental stressors that could shorten the project's design life. For example, a rockfall event that is too large for a system can cause the mitigation measure to fail after only a few impacts, while use of certain materials, such as steel mesh, may quickly degrade in a corrosive environment. Another factor that affects durability is the quality of construction due to materials used or the experience of the contractor.

From a management perspective, cost of mitigation is a major consideration, especially when some measures employed at lower cost can effectively maintain a site within a Condition State, while others can raise the Condition State from one to four levels. Under GAM, either option could be a design goal for the agency. Life cycle cost analysis should then be performed to compare design options and to guide the choice between intervention and continued maintenance.

9.3 Typical Mitigation Actions Based on Geotechnical Asset Type and Condition State

Good Condition State assets are, by definition, supporting the agency's performance goals and generally require only routine maintenance. However, as asset condition declines due either to poor original design or construction, or to normal deterioration throughout design life, the asset will begin to require a higher level of maintenance in order to continue supporting agency performance goals. Assets that are in Condition State 1 or 2 typically perform well, but may still require some maintenance, periodic evaluation, and recording of unstable slope events. Regardless of the level of maintenance attention, they cannot be improved above a Condition State of Good (1). Fair condition assets in Condition State 2 can be improved to Condition State 1 but the return on investment is generally best realized by simply maintaining their current condition and extending design life at that level as long as possible.

Even when a slope or retaining wall is in Condition State 3, continued maintenance instead of major interventions may be appropriate, especially if the cost of remediation is more than the cost of 30 years of maintenance at the current level and risk costs are similarly low. Alternatively, a Condition State 3 asset may be partially mitigated to a Condition State 2 slope for a similar cost of improving a 2 to a 1. The investment required to maintain a Condition State

3 asset, or to raise it to Condition State 2, is often reasonable enough to make the investment sensible, especially when this offsets further deterioration that would, if unchecked, drop the slope into a Condition State 4 (Poor). If a reconstruction project were planned for a highway segment/corridor that contains multiple Condition State 3 sites, this would present an excellent opportunity to consider making a larger investment in Condition State improvement at that time.

Condition State 4 assets are significantly underperforming, and associated hazards and risks, as well as the maintenance demands, make them good candidates for mitigation interventions. It is likely that the asset can still be maintained in the Condition State 4 class with effort, but an investment similar to that required for 30 years of maintenance could raise it one or two Condition States, leading to significant improvement in maintenance operations and highway safety.

Assets in Condition State 5 are in a failed state. The hazards, risks, and maintenance demands are unacceptable. The deteriorated conditions may lead to regular road closures and other transportation system disruptions. For these assets, there is little to be done short of making a large investment in asset improvement. As has been shown in many other areas, such as pavements, waiting until a feature fails and then repairing or reconstructing it is more expensive than making timely investments to maintain or upgrade it during its design life.

In all these cases, the purpose of mitigation investments is to reduce department operating costs and social impacts related to asset failure or underperformance. Making wise capital expenditures in this area helps satisfy the department's performance goals. As in all design decisions, the effectiveness and the durability of the proposed design must meet the demands created by the asset location.

In the following subsections, typical mitigation actions for AKDOT&PF's various GAM assets are described, based on the asset's Condition State. These mitigation actions range from routine maintenance within the scope and ability of M&O staff using available equipment, to large-scale projects requiring design and construction work by outside contractors.

For all of the following assets, the typical mitigation actions are provided for guidance only. Mitigation design selection criteria as well as detailed description of the types and applications of each design option should be obtained from appropriate sources as a proposed project moves forward.

9.3.1 Rock Slope Assets

Since maintaining existing assets through prudent allocation of scarce budget resources is a component of GAM, typical required maintenance actions can be seen as the base level of rock slope mitigation. All rock slope assets, regardless of Condition State, require some level of maintenance attention. Table 9-1 presents typical levels of maintenance attention for rock slopes based on Condition State. This maintenance is within the scope and ability of M&O staffs using available equipment.

As Table 9-1 indicates, poorly performing rock slopes require ongoing maintenance attention that may quickly become impractical for a maintenance station, both based on time requirements and overall budget demands. At this point, more extensive mitigation work should be discussed. Typical mitigation actions and expected Condition State outcomes are summarized on Table 9-2.

Table 9-1: Typical Maintenance actions for Rock Slopes.

Condition State	Standard Rock Slope Maintenance Activities
1 - Good	Occasional ditch cleaning to maintain catchment and drainage performance.
2 - Fair	Routine seasonal ditch cleaning. Installation of a rockfall warning sign may be advisable. Review performance of any mitigation measures installed and maintain as necessary.
3 - Fair	Occasional rock on road - regular seasonal road patrol and occasional unscheduled road and ditch clearing. Installation of a rockfall warning sign required.
4 - Poor	Rockfall frequently reaches roadway – year round road patrol and unscheduled emergency response required. Installation of a rockfall warning sign required.
5 - Poor	Unacceptable, constant maintenance required to keep road clear/safe

Table 9-2: Typical Example Preservation Actions for Rock Slopes. Site specifics dictate actual actions performed.

Condition State	Protection	Stabilization	Avoidance	Expected Outcome
1 - Good	Ditch Cleaning	Not required	Not required	Maintains current state
2 - Fair	Jersey rail, berm, ditch shape improvements	Slope scaling	Not required	Maintains and/or upgrades current state
3 - Fair	Draped mesh, attenuator fence, enhanced fallout area (see avoidance)	Rock bolts, shotcrete, trim blasting, slope scaling, anchored mesh, cable lashing	Minor alignment adjustment	Maintains and/or upgrades current state
4 - Poor	Draped mesh, attenuator fence, flexible barrier fence, or improve catchment area	Rock bolts, shotcrete, reslope, slope scaling, anchored mesh, cable lashing	Road realignment within R/W. May or may not include changing the slope configuration	Upgrades current state
5 - Poor	Construct new catchment area, flexible barrier fence, rockfall shed	Major slope reinforcement program, anchored mesh, reconstruct slope	Major realignment, elevated structure, tunnel	Creates a New Slope/Upgraded to Condition State 1 or 2

It is common for a rock slope preservation (synonymous with a 'rockfall mitigation project') to contain design elements from more than one category. Preservation projects that require specialized equipment and/or experience are provided by outside contractors. Table 9-2 was developed as a discussion guide or starting point. For mitigation work on a specific project, appropriate additional information sources should be consulted. For example, design selection criteria as well as detailed description of the types and applications of each design option presented in Table 9-2 are thoroughly covered in Transportation Research Board publication "Rockfall Characterization and Control" (K. A. Turner 2012).

9.3.2 Unstable Soil Slope and Embankment Assets

As with rock slopes, typical required maintenance actions can be seen as the base level of mitigation for unstable soil slopes and embankments. Unstable soil slopes and embankments in a Good condition are unlikely to require maintenance attention. A possible exception would be maintenance of installed mitigation components, such as cleaning of horizontal drains. At the other extreme, slopes in a Poor condition frequently require unplanned maintenance attention to keep the roadway passable. Table 9-3 presents typical levels of maintenance attention for soil slopes and embankments based on Condition State. This maintenance is assumed to be within the scope and ability of M&O staff using available equipment.

Table 9-3: Typical Maintenance actions for Unstable Soil Slopes and Embankments.

Condition State	Standard Unstable Soil Slope And Embankment Maintenance Activities
1 - Good	Routine inspection of surface condition. Routine maintenance of existing mitigation measures, if present.
2 - Fair	Annual inspection with crack repair, surface levelling, or debris flow cleanup every five years. Installation of a warning may be advised.
3 - Fair	Regular inspection required with crack repair, surface leveling, or debris flow cleanup required every one to five years. Installation of a warning sign advised.
4 - Poor	Significant movement occurs annually – unscheduled emergency response required. Crack repair, surface levelling, or debris flow cleanup required annually or more often to maintain safe surface. Installation of a warning sign required.
5 - Poor	Major movement or debris flow that closes roadway. Unacceptable, constant maintenance required to keep road clear/safe. Services require a specialty Contractor.

As maintenance attention described in Table 9-3 becomes more extensive for poorly performing slopes, more extensive mitigation work should be discussed. Typical mitigation actions and expected Condition State outcomes are summarized in Table 9-4. Stabilization of the existing slopes is the most common mitigation option for this asset type. The protection measures listed in this table are most applicable to debris flows, but many other unstable slopes can benefit from attention to site drainage, with targeted improvements undertaken where necessary. Whenever a planned unstable soil slope or embankment mitigation project requires specialized equipment and/or experience, these services are provided by outside specialty contractors.

Table 9-4 was developed to guide discussion, not to replace site-specific mitigation work. For that work, appropriate additional information sources should be consulted. For example, design selection criteria as well as detailed description of the types and applications of each design option presented in Table 9-4 are thoroughly covered in Transportation Research Board publication "Landslides: Investigation and Mitigation" (A. K. Turner 1996) and mitigation measures discussed in detail in "Landslides in Practice" (Cornforth 2005).

Table 9-4: Typical Mitigation Actions for Unstable Soil Slopes and Embankments.

Condition State	Protection	Stabilization	Avoidance	Expected Outcome
1 - Good	Not required	Not required	Not required	Maintains current state
2 - Fair	Road drainage system/storage capacity improvements, roadway surface repairs	Excavate small slides, place rock inlay	Minor alignment adjustment	Maintains and/or upgrades current state

3 - Fair	Improve drainage system, install flow barrier, subgrade reinforcement	Reshape slide, install deep patch/rock inlay/shear key/buttress, drain slide	Minor alignment adjustment, reset guardrail as needed	Maintains and/or Upgrades current state
4 - Poor	Excavate storage basin, install barriers	Reshape slide mass, install deep patch, drain slide, place light-weight fill	Road realignment within R/W	Upgrades current state
5 - Poor	Excavate large collection basin, install barriers, reshape source area	Rock inlay/shear key/buttress	Major realignment, elevated structure spanning flow path (debris flow)	Creates a New Slope/Upgraded to Condition State 1 or 2

9.3.3 Retaining Wall Assets

Unlike unstable slopes, maintenance attention is rarely performed for retaining walls in a Good or Fair Condition State. However, all retaining walls should receive some level of inspection or maintenance attention over their design life. Table 9-5 presents typical levels of maintenance attention for retaining walls based on Condition State. This maintenance is believed to be within the scope and ability of M&O staffs using available equipment, but since walls are generally constructed in areas where ROW is limited, even routine retaining wall maintenance, such as clearing vegetation from the face of a welded wire face wall, may require specialized equipment not readily available to M&O personnel.

Table 9-5: Typical Maintenance actions for Retaining Walls.

Condition State	Standard Retaining Wall Maintenance Activities
1 - Good	No action required
2 - Fair	Routine maintenance and monitoring, such as clearing vegetation from the wall face.
3 - Fair	Occasional patching or debris removal required to maintain roadway function. Continue routine maintenance. Repair damaged elements.
4 - Poor	Regular patching or debris removal required as wall ceases to support roadway or retaining the slope above it. Replace damaged elements.
5 - Poor	Unacceptable, constant maintenance required to support roadway function.

As Table 9-5 indicates, poorly performing walls require maintenance attention that may be impractical for a maintenance station, particularly if assistance from outside contractors is required. At this point, more extensive mitigation work should be discussed. Generic mitigation options for retaining walls based on Condition State are presented in Table 9-6. Mitigation options for a retaining wall may vary widely between different wall types and specific mitigation designs should be developed by a qualified geotechnical engineer.

Table 9-6: Typical Mitigation Actions for Retaining Walls.

Condition State	Protection	Stabilization	Expected Outcome
1 - Good	Not required	Not required	Maintains current state
2 - Fair	Reestablish wall drainage	Repair critical elements	Maintains and/or upgrades current state
3 - Fair	Improve wall drainage system, patch roadway cracks	Repair critical elements, replace individual elements as necessary	Maintains and/or Upgrades current state
4 - Poor	Replace damaged roadway components (guardrails, asphalt patch, etc.)	Replace critical element(s)	Upgrades current state
5 - Poor	Repair roadway	Rebuild wall	Creates a New Wall/Upgraded to Condition State 1 or 2

9.4 Mitigation of Material Scarcity – Material Site Assets

Material Sites were evaluated not based on the individual sites characteristics alone, but also on the extent to which material is readily available at the service area level, as discussed in Section 3.5. A maintenance station service area with Good material availability is generally able to support the department’s construction goals by providing easy access to valuable materials. On the other hand, those service areas in Poor condition have such limited access to materials that it is likely necessary to purchase materials from a private source or use lower quality materials in embankment construction.

Maintenance work for material sites is generally limited to maintaining the appropriate permits for continued site operations and ensuring that access roads to the site are cleared and graded when necessary.

Material scarcity at the service area level is tackled either by maintenance, expansion, or material stockpiling. Maintenance generally refers to the work required to keep an existing site in production, while expansion can refer either to expansion of a specific site, or to an increase in the number of total material sites within a service area. Stockpiling refers to the storage of valuable materials at an existing site for future use. Intervention measures for material sites are generally accomplished via permitting and geotechnical investigation work to expand existing sites. In many parts of the state, private sources also supply materials for construction projects. The costs of continuing to use these private sites should be included in any cost-benefit analysis, particularly when discussing development of a completely new site.

Again, the typical mitigation actions suggested here (Table 9-7) are provided for guidance only. Mitigation method selection should be made via discussion with relevant shareholders in the service area, particularly if material is desired for a specific proposed project.

Table 9-7: Typical Actions to maintain or improve material availability at the maintenance station service area level.

Condition State	Maintenance	Expansion	Stockpiling	Expected Outcome
1 - Good	Maintain access to existing sites, filing required permits when necessary	Not required	Not required	Maintains current state
2 - Fair	Maintain access to existing sites, filing required permits when necessary	Prove up existing sites for possible expansion	Not required	Maintains and/or upgrades current state
3 - Fair	Maintain access to existing sites, expedite renewal of existing permits	Prove up existing sites for possible expansion, begin permitting process to reopen a suitable closed site	Stockpile material, such as quality excavation spoils, if an upcoming project indicates a need	Maintains and/or Upgrades current state
4 - Poor	Maintain access to existing sites, expedite renewal of existing permits, restart permitting process for valuable site where permit has lapsed	Expand existing sites, begin permitting process to reopen multiple closed sites, explore permitting and opening a new site near upcoming project locations	Stockpile material as it becomes available	Maintains and/or Upgrades current state
5 - Poor	Maintain access to existing sites, if any, expedite renewal of existing permits, restart permitting process for sites where permit has lapsed	Permit and open new sites, expand existing sites, if any	Purchase material and store for future use	Upgrades current state

10 EFFECTIVE UTILIZATION OF THE GAM DATABASE

The active use of the extensive geotechnical asset database will ensure that the Department can effectively track and manage their assets and properly incorporate the benefits of this system. To facilitate this, all the asset data is housed within AKDOT&PF's Transportation GIS (TGIS) ArcGIS Online (AGOL) website[18]. The maps and applications used in data management are largely developed from templates created by ESRI (originally Earth Systems Resource Institute).

To support the GAM research program, LT made use of AKDOT&PF's existing subscription to ESRI's AGOL system. The Department already uses this platform to share valuable information, like route data and traffic counts, internally and with the general public. The advantages of using this existing system to host the GAM asset databases are many:

- Familiar to AKDOT&PF personnel, with IT support available both from within AKDOT&PF and from ESRI;
- ESRI routinely works to improve and update the AGOL system, so stored data is unlikely to become "trapped" in an obsolete format;
- Data uploaded and curated by other AKDOT&PF sections, such as AADT, is easily incorporated into GAM maps and applications;
- Easily accessed from any computer;
- Authorized users with a Department-affiliated AGOL account can update existing records and create new site records, eliminating requirement for a single gatekeeper to maintain data;
- Online maps and applications are easily incorporated into webpages or other outreach for Department planning purposes or to share with the general public;
- Saves the Department money by using an existing GIS system.

Housing the data on this site permits interactive use of the data online, as well as enabling export to desktop GIS platforms for project-specific use. Department users may need to acquire an AGOL user name and password from the TGIS group to obtain full functionality. Authorized AKDOT&PF users can maintain the asset databases as changing conditions warrant.

TGIS has created a group within AKDOT's AGOL account called the Geotechnical Asset Management Group. Members of this group will be primarily responsible for maintaining the asset geodatabases, as well as the publically available maps, apps, and layers. The GAM group may also provide various decision support maps and analyses as requested by planners. Membership will be managed by Statewide Materials.

This section provides a basic overview of the TGIS AGOL database and provides recommendations for maintaining it. More detailed descriptions and discussion of procedures are provided in Appendix G, "Guide to Use and Maintenance of the GAM Database." Note that the guide is not intended to provide training on general use of the AGOL system, only to provide methods for using and maintaining the current asset geodatabases. Tutorials on using AGOL can be found online[19] and will reflect the latest updates to the AGOL system.

10.1 Overview of the Online Database

Following field inventory work, a master geodatabase was created for each geotechnical asset. These geodatabases, and some reference layers, such as precipitation and AADT, obtained from

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[18] http://akdot.maps.arcgis.com/home/index.html - TGIS AGOL Base Website
[19] http://resources.arcgis.com/en/Tutorials/ - AGOL Tutorials

other sources, were uploaded to the AGOL platform. The final list is provided in Table 10-1 in alphabetical order for easy reference.

Table 10-1: GIS geodatabases and individual layers hosted on AGOL as part of AKDOT&PF's GAM program. Layers maintained by AKDOT&PF's TGIS group, such as Mileposts and AADT, are not included in this table

File Name	Layer Name	Layer Type
Material Site Assets		Geodatabase
	AHD_NHS_Merged	Polylines
	Five_Mile_Buffer	Polygons
	Five_Mile_Intersect	Polylines
	MaintServiceArea	Polygons
	MaterialSiteLocations	Points
	Valuable_Material_Sites	Points
Soil Slopes and Embankment Assets		Geodatabase
	SoilSlopes	Points
	SoilSlopeLines	Polylines
Rated Retaining Walls		Geodatabase
	RetainingWalls	Points
	RetainingWallLines	Polylines
Retaining Wall Inventory		Geodatabase
	RetainingWallInventory	Points
Rock Slope Assets		Geodatabase
	RockSlopes	Points
	RockSlopeLines	Polylines
Precipitation	Precipitation	Polygons
GAM_Event_Service		Geodatabase
	Point_Locations	

These GIS data layers are the primary method for interacting with the database so that all AKDOT&PF users have access to the same, up-to-date data. Currently, these geodatabases, maps, and apps, are all hosted in Landslide Technology's user account in AKDOT&PF's AGOL server space. At the end of this research project, management of these layers will be transferred to an individual or group identified by Statewide Materials that will be responsible for long-term data management and maintenance. The geodatabases will also be backed up on AKDOT&PF's Enterprise system to avoid accidental loss of data.

Extraction of the data in a variety of formats, such as shapefiles or tabular datasets is possible with the AGOL platform. However, standalone datasets, such as one for a particular Region, should be used only for specific projects and analytics, such as regional planning or relative prioritization within a particular highway segment. Other tools within the AGOL platform permit filtering and data analysis. Because certain levels of data analysis in AGOL are tied to a user's "role," users may need to work with the TGIS group if they want to perform a particularly detailed analysis. Basic update and edit capabilities are available to all users with a Department AGOL account, though future Group permissions may limit the editing capability to only a select group of personnel.

10.1.1 Viewing existing data

Currently, the database applications for rock slopes, unstable soil slopes and embankments, retaining walls, and material sites can be found directly through AGOL[20] (Figure 10-1). This interface is designed as the central public access to the AKDOT&PF Geotechnical Asset Management Program. The tabs at the top permit viewers to flip between of the various geotechnical asset types interchangeably over the same geographic extent. An overview tab has also be added, showing all of the assets in a single pane.

The AGOL map interface is interactive, and LT took advantage of this functionality when developing the GAM Program interface. The current interface presents the four inventoried asset classes in separate tabs, with a fifth tab providing a statewide overview of all inventoried assets. As the user changes the map scale using the map controls or the mouse wheel, different datasets and symbols appear. For example, a heat map overview was created for rock slope, unstable soil slope and embankment, and retaining wall assets showing concentrations of Fair or Poor condition assets. As the user zooms in, the heat map is replaced with individual points for asset locations. At even greater zoom levels, asset linear extents, color coded by condition, are also visible. If one of these points is clicked, a pop-up with open with additional asset information. As the user zooms back out, these individual points disappear again. The maps within the AGOL interface are also linked, meaning that the map location stays the same as the user moves between asset tabs. Figure 10-1 and Figure 10-2 below show the GAM Program interface in the zoomed-out default view and a more detailed information view centered on Long Lake on the Glenn Highway. The rock slope asset tab is used in this example.

Additional data on each asset is displayed in a popup window, which is accessed by zooming in and clicking on the point location. Photos are also available for unstable slope and retaining wall assets. Following discussions with TGIS and Statewide Materials site photos will be available as attachments, which can be accessed through the popup window for a specific asset. A hyperlink in the popup window will point to site photos, and ideally also to any press releases, news reports, or site plans associated with geotechnical events or mitigation work at the asset location. Popups for the material site assets would point back to the Material Site Inventory (MSI).

Each of the maps in the GAM Program interface is also available as a stand-alone product, which can be searched for on AKDOT's Transportation GIS website[21]. Users with an AGOL account can save a copy of these maps to their own accounts, and adjust the map's basemap, default view, legend, etc. as needed for individual projects. The layers referenced in the map can also be searched for and added to new maps or downloaded for further analyses.

[20] http://arcg.is/1M73bQ1 - Direct link to Geotechnical Asset Management Program Application. Direct links to the underlying maps (for additional filtering and analysis capabilities) are http://arcg.is/1N4BWHL (rock slopes), http://arcg.is/1N4C4qW (soil slopes), http://arcg.is/1N4BSYz (retaining walls), and http://arcg.is/1N4BXvi (material sites).

[21] http://akdot.maps.arcgis.com/home/index.html

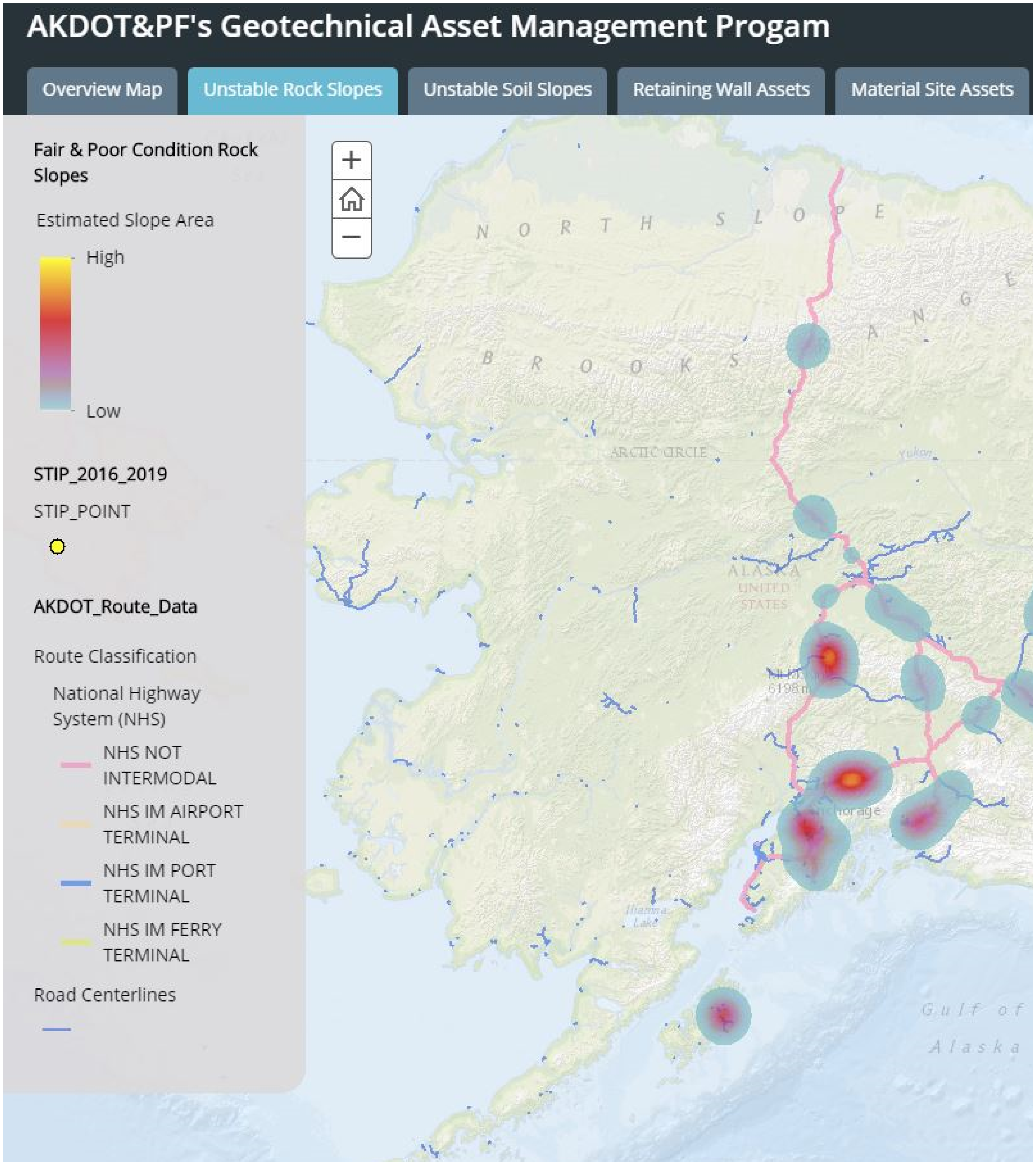


Figure 10-1: Statewide view when the GAM Program interface is opened, showing heat map of Fair/Poor assets.

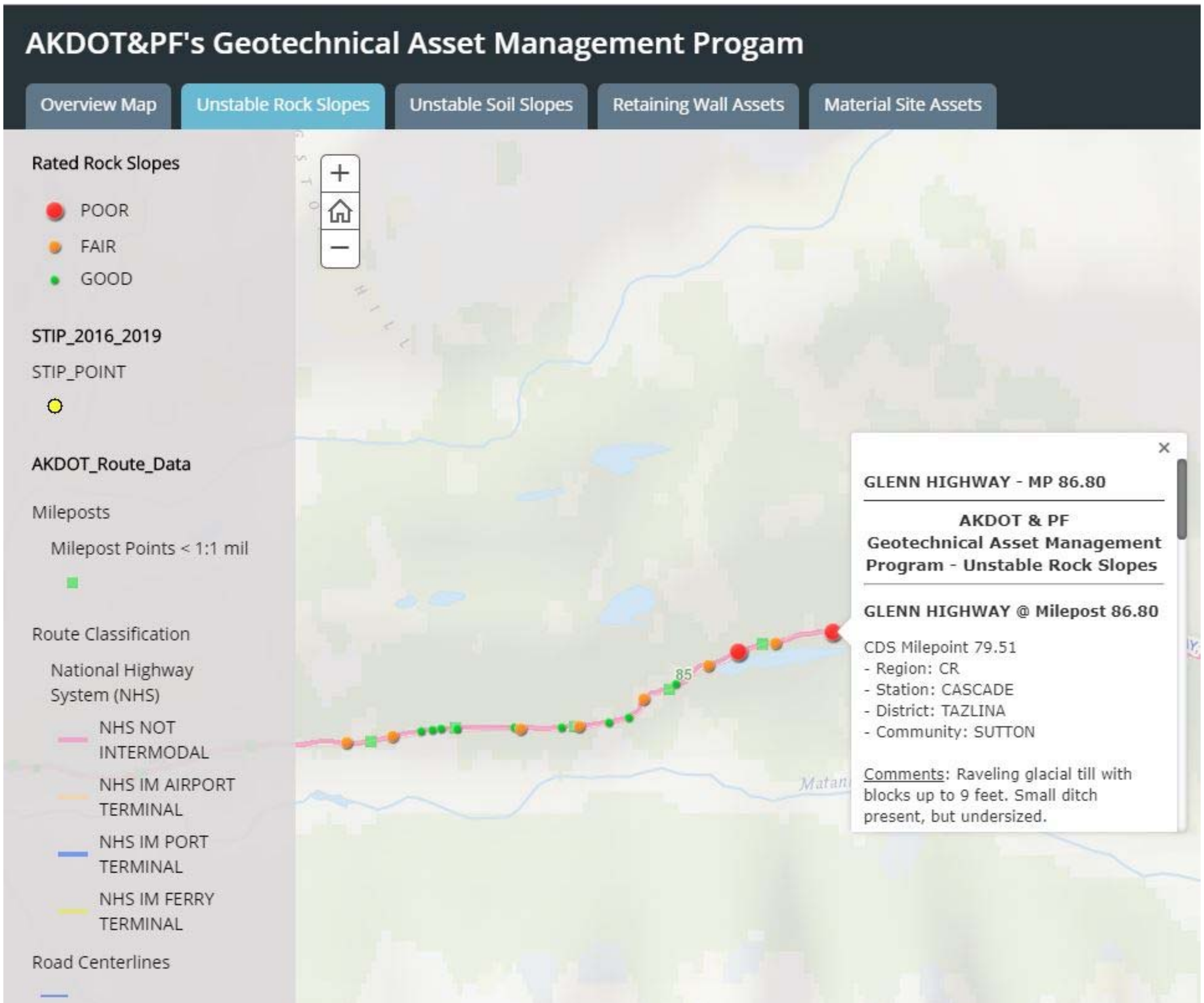


Figure 10-2: Pop up and individual rock slope asset locations, obtained by zooming in from the default view.

10.1.2 AGOL Analyses and Filtering

Within the AGOL platform, filtering and analysis tools are available, though some may require coordinating with the TGIS group to obtain additional privileges. The new maps and layers can be used to provide decision support exhibits for AKDOT&PF planners. By applying ESRI's analysis toolset to the geospatially referenced asset information, data presentation is modern and engaging. New links between the interactions of various Department assets may also be identified. These tools and their potential applications are briefly summarized in this section, and covered in greater detail in Appendix G.

The filtering tools use an SQL query format to select or exclude assets based on criteria selected by the user, such as condition, location, a specific category score, etc. For instance, if working with the rock slope map, adjustments can quickly be made so that the map displays all rock slopes in Condition State 3 (Fair) with Total Scores above 400 points to target a potential priority list of moderate condition sites with a high USMP score to prevent further deterioration to a Poor Condition. This filtering approach results in identification of 26 sites, concentrated on the

Haines, Seward, and Glenn Highways with lesser concentrations on the Klondike and Tongass Highways (Figure 10-3).

Figure 10-3: Example use of AGOL Filtering Tool to identify Condition State 3 Rock Slopes with USMP Scores Greater than 400. 26 identified sites.

Use of the analysis tools require an AKDOT&PF account with Publisher privileges. These online tools include Summarization, Location, Pattern and Proximity Analysis, and Data Management Tools. While many of these tools are of limited use on linear systems such as a highway network, tools which enable buffering around assets and incorporation of other datasets, such as the Material Site Inventory, can serve Department interests. For example, a buffer around STIP Projects involving Realignments, Fair and Poor Condition Rock Slopes, and an absence of good material sources nearby could identify where STIP-related rock excavation or rock cut expansion could improve traveler safety while also generating spoils that can be stockpiled for use in future projects.

10.1.3 Updating Site Information

Any new asset data should be added to the databases as it is obtained. This includes updating existing site information to replace outdated or incorrect data, incorporating additional information, such as new photos or site comments, and adding new sites to the database. If an existing site is re-rated, the old rating should be archived for future reference.

Simplified maps to support field work and information updates have been created in AGOL for rock slopes, unstable soil slopes and embankments, and retaining walls. These maps are shared only with the AGOL Group *Geotechnical Asset Management*, to avoid potential confusion, and to discourage any edits by AGOL users unfamiliar with the inventory and assessment system. The Group was established within AGOL to facilitate sharing of GAM-related data within a GIS environment. All three of these maps share an identical basic format to make the editing process for these assets as easy as possible.

In the desktop environment, site edits can also be made directly in the “Field Work” maps, by logging into AGOL. The maps are also designed to be compatible with ESRI’s existing Collector App, and can be downloaded for use in the field when cell or internet connections are unavailable. Edits made when disconnected from the server can be synced to the database upon returning to the office. The Collector App can be run on cell phones or tablets using the iOS and Android operating systems. Additionally, personnel with the Windows 10 operating system installed on their desktop can run the Collector App on their desktop PC. If available, this option is preferable in the office because the Collector App is specifically designed to collect and edit data. It has several features that improve ease of use over editing directly in the map on the AGOL platform. The Collector App is recommend for editing and updating sites where possible, especially since ESRI regularly updates and improves the app. Technical support can be obtained from either TGIS or ESRI if required.

Unlike the data for unstable slopes and retaining walls, the data for material site assets is not editable in AGOL. The various material site reports and other documentation generated by R&M Consultants, Inc. and hosted on the Material Site Inventory (MSI) website were used to create a geodatabase that could be used in GIS desktop applications or uploaded to AGOL. This geodatabase is now hosted on AKDOT&PF's TGIS site, where it is used to generate the various material site maps. It can also be downloaded for use in desktop analyses. The geodatabase is not live-linked to the pdf reports on the MSI website. Care will need to be taken in the future to ensure that the two data sets remain the same, with updates made to both the MSI and the MSI geodatabase at the same time.

Specific methods for updating site information are discussed in Appendix G.

10.1.4 Adding Geotechnical Events

"Geotechnical events," defined here as adverse events or acute hazardous situations occurring at geotechnical asset sites, occur regularly throughout the AKDOT&PF road system and span a wide array of situations. Tracking these events and the associated traffic delays, accident history, clean-up/repair and subcontracting costs will ensure the most up-to-date information is factored into future evaluations, hazard analyses, budgeting, and project planning. Ensuring a uniform and consistent entry of event information is crucial in providing quality information for utilization in the analyses supporting the GAM program.

In order to meet this goal, a map[22] and associated web-based application[23] were developed in AGOL to track a variety of geotechnical events. The map and app build upon an earlier system (SALLy) that was devised and tested in the Southcoast Region. Within the app, users are requested to fill out a series of fields, most of which are populated through drop-down menus, ensuring uniform responses. After entering event data, the reporter is prompted to place the event on an AGOL-hosted map, either by inputting the Latitude/Longitude information or by dropping a pin in the correct location, as shown in Figure 10-4. Additional electronic files, such as event photos, pdf prints of news reports, or compressed plan sets, can also be attached through the app interface. Once the event is submitted, it is automatically included in the AGOL TGIS system, and appears in both the GAM Event Service geodatabase and on all maps that reference that geodatabase. If necessary, users can edit site location or event information at any time by logging into AGOL as navigating to the GAM event service geodatabase or to the GAM Event Tracker Basemap.

The final field list (Table 10-2) was refined with input from department personnel to find the balance between the data required for future GAM evaluations and the information and time required to input a new event. The range of geotechnical events was made as wide as possible, resulting in a total of nine event categories. The choices include a category named "Other", which could apply to a rock block potentially posing risk to transportation corridor function, for example.

[22] GAM Event Tracker Geoform Basemap
[23] Geotechnical Event Tracker - GeoForm for event tracking and mapping.

Table 10-2: Geotechnical Event Tracker – Fields and options in the AGOL-hosted Geoform

DATA FIELDS	FIELD TYPE	POSSIBLE CHOICES / DATA REQUESTED
Event Date	Entry-Specific	Enter the event date. If available, enter the event time.
Type of Event	Dropdown Menu	Choose from: Rockfall; Debris Flow; Icefall; Retaining Wall Failure; Tree Fall; Flood Damage/Encroachment; Landslide and/or Embankment Failure; Snow Avalanche; Frost Heave; Other
Event Size	Dropdown Menu	Choose from: Minor or routine; Moderate; Major; or a Catastrophic event
Accidents	Dropdown Menu	Choose from: No Accident; Property Damage Only – One Vehicle; Property Damage Only – Two or More Vehicles; Minor or Moderate Injury Accident; Serious to Critical Injury Accident; Fatal Accident
Closure Duration	Dropdown Menu	Choose from: Temporary slowdown under 30 minutes; Temporary slowdown between 30 minutes and 2 hours; Temporary slowdown over 2 hours; Closure under 1 hour; Closure between 1 and 6 hours; Closure between 6 and 24 hours; Closure between 24 and 72 hours; Closure between 72 hours and 1 week; Closure between 1 week and 1 month; Closure longer than 1 month
Resources Applied to Event Response	Dropdown Menu	Choose from: M&O personnel & pickups only; M&O plus M&O heavy equipment; M&O plus other DOT resources; M&O, DOT, and outside resources; Government Emergency Declaration
Cost in Dollars	Entry-Specific	Enter total cost of event, including M&O costs, equipment rentals, and outside contractor/consultant costs
MMS Sequence Number (If Available)	Entry-Specific	MMS Sequence Number(s) associated with the event
Comment	Entry-Specific	Any additional information necessary. 2000 character maximum.
Attach Files	Entry-Specific	Attach photos, PDFs of news articles, or other files related to the event.

When populating the Geotechnical Event database, the research team worked to incorporate as much historical information as possible. Events recorded in Southcoast Region's SALLy program were added, as were Maintenance Management System (MMS) activity entries[24] that could be traced to specific sites. The MMS database houses the day-to-day activities for Department Maintenance and Operations (M&O) personnel and equipment, subdivided into Activity Codes that are associated with direct Department costs. MMS code "58645-ROCK&LANDSLIDE CLNUP", is directly related to unstable slope events that require M&O response. Most or all of the "ROCK&LANDSLIDE CLNUP" entries are associated with a roadway and specific milepost or milepost range. In general, only resource and cost information was available through the MMS, so information on road and traffic impacts or accident information was not included for events mined from the MMS. Impacts for more expensive MMS events could possibly be obtained by contacting the M&O foreman responsible for responding to the event in question.

The geotechnical event application has retained a space for the MMS sequence number, if available. This would allow users to search for the more detailed cost information located in the MMS. However, it is not anticipated that the MMS will be mined for current events once the

[24] https://mmsreports.dot.state.ak.us/moport - MMS dataport, requires direct 'inside the firewall' connection to AKDOT&PF server. Select "Cost by Activity Detail/Summation" from the "Cost Report" section of the site. Choose the Maintenance District of interest, date range, and "58645-ROCK&LANDSLIDE CLNUP" from the Activities list. Copy and paste the results into an Excel sheet for summarization.

Geotechnical Event Tracker application is released within AKDOT&PF. New geotechnical events should be added through the application, so that all relevant information is collected upon entry creation.

In its current form, previewed in Figure 10-4, the Event Tracker App collects the minimum information required to obtain event data that can be used in economic and risk-based valuations for the Department, an integral part of GAM. When collecting data for a specific project, it may be necessary to contact regional personnel for additional information on a specific event.

The GAM Event Service geodatabase can be filtered to show certain trends within AGOL maps or presentations. It can also be downloaded, and the data can be extracted for use in more complex analyses in the ArcGIS desktop environment or in Excel. For example, events on the Seward Highway south of Anchorage were viewed using AGOL's time-history function, showing the accumulation of rockfall events and costs over time. Using this tool, a 30-second video of 2005-2015 rockfall activity on the Seward Highway south of Anchorage was prepared.[25] The video illustrates rock slope deterioration and exhibits the type of visualization and analysis possible when complete data is collected and mined.

The Event Tracker Map and associated Geotechnical Event Tracker application are currently available to the general public, but discussion is ongoing on how to restrict access to department personnel without requiring creation of individual AGOL accounts. Currently, any user can add a geotechnical event, or extract geotechnical event data as required for a specific project.

10.1.5 Feature Data Layer Services for Desktop GIS

All data located on the AGOL servers is also available for direct inclusion into ArcMap for Desktop. It can be used with desktop GIS applications for more advanced mapping and analysis. A user with an AKDOT&PF AGOL account can add AGOL-hosted layers by first signing into ArcGIS using their AKDOT&PF account credentials from the *File: Sign-In* menu from ArcMap. After sign-in, the TGIS AGOL data is available from the standard Add Data Menu item after selecting the "Add Data From ArcGIS Online" menu item (Figure 10-5-A), then utilizing the resulting dialog for finding the relevant data layers (Figure 10-5-B). Data layers created for this research program have been tagged with "GAM" to simplify content searches.

[25] http://www.landslidetechnology.com/rockfall-GAM-DataTracking.htm

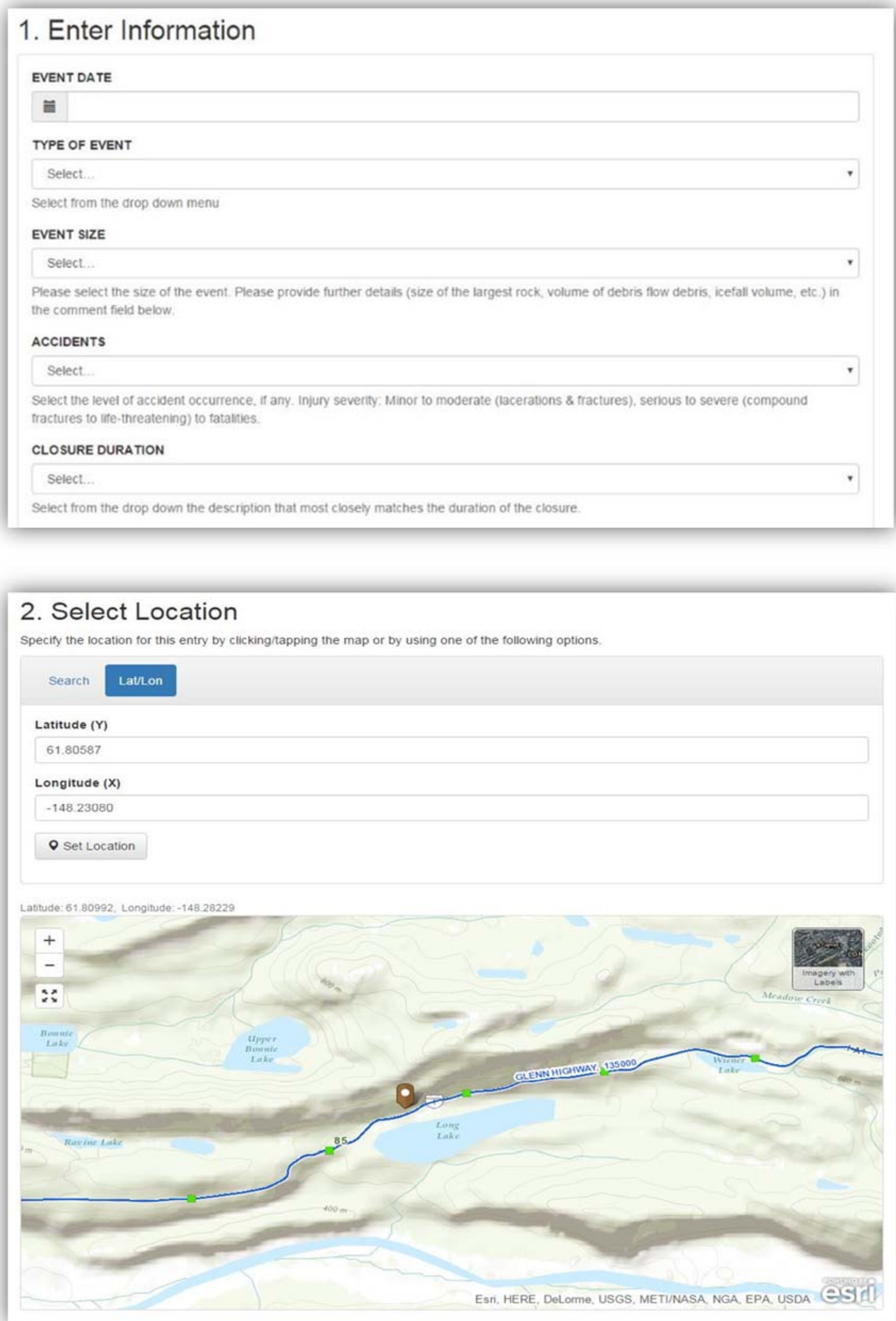
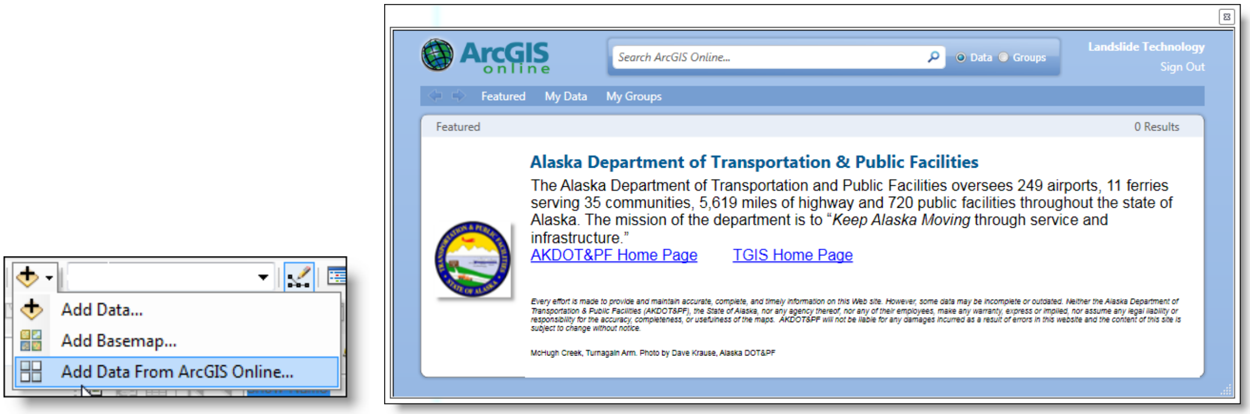


Figure 10-4: View of portions of the Geotechnical Event Tracker Geoform, highlighting the use of menus to collect data and pin-drop functionality to collect event location.



A. B.

Figure 10-5: Example dialogs from ArcMap 10.2 to add hosted data onto Desktop GIS.

10.2 Supporting the Online Database

As discussed in Section 10.1.3, data for unstable slopes and retaining walls can be edited directly within the AGOL environment. Any changes made to the individual asset maps, whether addition of new sites or edits to existing data, are immediately reflected in the GAM interface. However, AGOL and the Collector App are not able to automatically run calculations and populate fields based on values input into other fields. To simplify future rerating and rating of occasional new slopes, Excel-based worksheets were prepared to facilitate data collection and calculation of total Scores, Condition Indices and States, and initial Programmatic Cost Estimates for these asset types. These calculated values should then be added to the asset geodatabase via the Collector App or by making edits in the office.

The Excel workbooks were designed to run on both laptops and tablets that have Windows installed. The sheets prompt the user to enter site-specific information in the orange cells. Values in the gray and blue cells are calculated from measurements or rating values, or filled in from linked reference tables in other workbook sheets.

When using an Excel data collection sheet, the rater fills in only the orange cells. Grey and blue cells are either filled in from the linked reference tables in other workbook sheets or calculated from measurements or rating values put into the orange cells. The sheet "New Site Information" tabulates all of the data from the "Site Rating Calculator" sheet for easy input in AGOL. Except for the Site Rating Calculator, all sheets are locked, so that data cannot accidentally be changed. Within the Site Rating Calculator Excel sheet, all grey and blue cells are locked so that references and equations cannot accidentally be altered. At this time, the programmatic costs applied in the worksheet are identical to those discussed in Section 6. As new project information or inflation rates are incorporated into the asset valuations, the costs referred to in this sheet will also be updated.

The Excel "Site Rating Calculator" sheets for rock slopes, unstable soil slope and embankments, and retaining walls are shown in Figure 10-6 (rock slopes), Figure 10-7 (soil slopes/embankments), and Figure 10-8 (retaining walls) on the following pages. The workbook is discussed in greater detail in Appendix G. The "Site Rating Calculator" sheets and the Excel "New Site Information" sheets for these asset types are also available in Appendix C, D, and E, respectively.

Because material site Condition States incorporate both specific material site data and regional material availability, no re-rating application has been developed for material sites. It is anticipated that any revisions to Material Site data will be made within the MSI interface with later revisions made to the MSI AGOL layers. Changes to existing material site information are anticipated to be occur less often and to require more complex re-rating work when they do occur. Because of this, changes to material site data should be incorporated into specific material site improvement projects.

It is assumed that any new material site evaluations will use the same inventory criteria currently applied in the material site reports developed by R&M. These evaluations will be conducted on a case-by-case basis by an experienced geotechnical engineer or engineering geologist. No Excel-based rating sheets were developed for this asset type.

Alaska DOT&PF Rock Slope Rating Calculator

Fill in orange cells

Ver. 1.00

Rated By	G. Washington
Rating Date	1/1/2016
Site ID	1800000243302016

Site Information

Region	NR	Community		**Rockfall Type**	
Highway Name	PARKS HIGHWAY	Maint. District	Denali	Rock Avalanche	NO
CDS Route Number	180000	Maint. Station	Cantwell	Planar Failure	NO
Hwy MP	200	Common Name		Wedge Failure	YES
CDS Milepoint	243.3	B-Slope	NO	Toppling Failure	NO
Latitude	54.00000	Mitigation Present	NO	Raveling/Undermining	NO
Longitude	-145.00000	Site Rating Status	ACTIVE	Block Failure	YES
Comments	Test Site				

Character Count 9

Site Measurements

Slope Height (ft)	50	Roadway Width (ft)	36	Sight Distance (ft)	850
Slope Length (ft)	200	Speed Limit (mph)	60	AASHTO DSD (ft)	1000
Block Size (ft)	2	Annual Precipitation (in)	17	*GIS Alaska Precipitation Map - http://arcg.is/1kmhCUN*	
Event Volume (cy)	12	AADT (Count)	1450	*GIS 2012/2013 AADT Map - http://arcg.is/1MnAI6W*	

Evaluation Result Summary

Condition Index	75	Total USMP Rating	266	Programmatic Improvement Cost to CS1	$ 47,450
Condition State	2	Hazard Rating	195	*Note calculation is programmatic and does not reflect site-specific needs. Actual costs may differ significantly.*	
Condition State Text	FAIR	Risk Rating	71		

Slope Hazard Rating

		Highest of size or volume scores	81
		Slope Height Score	9
Case 1 Structure Score	27	*Discon. Fav, discon rand, discon adverse, cont. adverse*	
Case 1 Joint Friction Score	27	*Rough irreg, undulating, planar, clay filled/slicks*	
Case 2 Features Score	9	*Few features, Occ, Many, Major*	
Case 2 Diff Erosion Score	3	*Small diff, Mod, Large w/ fave, Large w/un fave*	
		Geologic Character Score (Highest sum of Case 1 or Case 2 Scores)	54
Ditch Effectiveness Score	9	*Good, Moderate, Limited, None*	
		Ditch Effectiveness Score	9
Maintenance Freq. Score	9	*Sched. ditch maint, patrols after storms, daily seasonal patrols, daily patrols*	
		Maintenance Frequency Score	9
Rockfall History Score	9	*Few, Occ, Many, Constant*	
		Rockfall History Score	9
Annual Precipitation Score	27		
Slope Drainage Score	20	*Dry or well drained, intermittent water, usually on slope, always on slope*	
		Water on Slope Score	24
		Hazard Subtotal	195

Slope Risk Rating

		Decision Sight Distance Score	7
		Roadway Width Score	9
		AADT Score	6
% Time Car Within Site	4%		
		Average Vehicle Risk Score	1
Impact on Traffic Score	27	*Minor Delay, One Lane Open, 100 mi or 1 day closure, no detour or 3 days +*	
		Traffic Impacts Score	27
ROW Impacts Score	3	*None, minor, private prop-no structures, structures/roads/RR/util/parks*	
		Right of Way Impacts Score	3
Envir. Impacts Score	0	*Zero points if no environmental impacts are likely, 50 pts if some possible*	
		Environmental Impacts Score	0
Maint. Complexity Score	9	*Routine, Specialized equip, difficult effort/location, complex or dangerous*	
		Maintenance Complexity Score	9
Event Cost Score	9	*$10k, $50k, $100k, $250k in reasonable worst case*	
		Event Cost Score	9
		Risk Subtotal	71

Figure 10-6: Excel worksheet for site-specific rating, calculations, and summarization with sample values entered for an example rock slope site. Available through the AGOL GAM App.

Alaska DOT&PF Soil Slope and Embankment Rating Calculator

Fill in orange cells

Ver. 1.00

Rated By	G. Washington
Rating Date	1/1/2016
Site ID	1900000003702016

Site Information

Region	SR	Community		**Landslide Type**	
Highway Name	REZANOF DRIVE	Maint. District	Kodiak	Above Roadway	YES
CDS Route Number	190000	Maint. Station	Kodiak	Below Roadway	NO
Hwy MP	2	Common Name		Crossing Roadway	NO
CDS Milepoint	3.7	B-Slope	NO	**Landslide Movement Type**	
Latitude	54.00000	Mitigation Present	NO	Translational Slide	NO
Longitude	-145.00000	Site Rating Status	ACTIVE	Rotational Slide	YES
				DebrisFlow	NO
				Slump	NO
				Erosional Failure	NO

Comments: This is a test site.

Character Count 20

Site Measurements

Axial Length of Slide (ft)	35	Sight Distance (ft)	650	
Rdwy Length Affected (ft)	300	AASHTO DSD (ft)	875	
Roadway Width (ft)	28	Annual Precipitation (in)	25	*GIS Alaska Precipitation Map - http://arcg.is/1kmhCUN*
Speed Limit (mph)	55	AADT (Count)	1000	*GIS 2012/2013 AADT Map - http://arcg.is/1MnAI6W*

Evaluation Result Summary

Condition Index	41	Total USMP Rating	244	**Programmatic Improvement Cost to CS1**
Condition State	3	Hazard Rating	107	$ 65,310,882
Condition State Text	FAIR	Risk Rating	137	

Note calculation is programmatic and does not reflect site-specific needs. Actual costs may differ significantly.

Slope Hazard Rating

			Length of Roadway Affected Score	45
			Axial Length of Slide Score	5
Thaw Stability Score	3	*Unfrozen, Slightly thaw unstable, Mod. unstable, Highly unstable*	*Thaw Stability Score*	3
Rdwy Impedence Score	9	*shoulder, 1/2, 3/4, full roadway*	*Roadway Impedence Score*	9
Maintenance Freq. Score	9	*Sched. ditch maint, patrols after storms, daily seasonal patrols, daily patrols*	*Maintenance Frequency Score*	9
Roadway Displacement or Slide Deposit Score	9	*visible crack, 1" offset/2" deposited, 2" offset/6" deposited, 4" offset/ 12" depositied*	*Roadway Displacement/Slide Deposit Score*	9
Movement History Score	9	*sporadic creep, up to 6" annually, more than two 6" events/year, >12" in hours (all debris flows)*	*Movement History Score*	9
Annual Precipitation Score	9			
Slope Drainage Score	27	*Dry or well drained, intermittent water, usually on slope, always on slope*	*Water on Slope Score*	18
			Hazard Subtotal	**107**

Slope Risk Rating

			Decision Sight Distance Score	12
			Roadway Width Score	27
			AADT Score	5
% Time Car Within Site	4%		*Average Vehicle Risk Score*	1
Impact on Traffic Score	20	*Minor Delay, One Lane Open, 100 mi or 1 day closure, no detour or 3 days +*	*Traffic Impacts Score*	20
ROW Impacts Score	3	*None, minor, private prop-no structures, structures/roads/RR/util/parks*	*Right of Way Impacts Score*	3
Envir. Impacts Score	50	*Zero points if none likely, 50 pts if some possible*	*Environmental Impacts Score*	50
Maint. Complexity Score	9	*Routine, Specialized equip, difficult effort/location, complex or dangerous*	*Maintenance Complexity Score*	9
Event Cost Score	9	*$10k, $50k, $100k, $250k in reasonable worst case*	*Event Cost Score*	9
			Risk Subtotal	**137**

Figure 10-7: Excel worksheet for site-specific rating, calculations, and summarization with sample values entered for an example unstable soil slope. Available through the AGOL GAM App.

Alaska DOT&PF Retaining Wall Rating Calculator

Fill in orange cells		Rated By	G. Washington
Ver. 1.00		Rating Date	1/1/2016
Site Information		**Wall ID**	1800000151502016

Region	NR	Community		**Wall Information**	
Highway Name	PARKS HIGHWAY	Maint. District	Denali	Wall Category	Bridge Abutment
CDS Route Number	180000	Maint. Station	Cantwell	Wall Function	Earth Ret., Cut
Hwy MP	150	State/Fed Proj. No.	10001	Wall Type	Anchored
CDS Milepoint	151.5	Construction Date	2000	Offset	LT
Latitude	54.00000	Status	ACTIVE		
Longitude	-145.00000				
Comments	This is a test.				

Character Count 15

Site Measurements

Wall Height (ft)	15	Sight Distance (ft)	850	
Wall Length (ft)	25	AASHTO DSD (ft)	1000	
Roadway Width (ft)	36	Annual Precipitation (in)	15	*GIS Alaska Precipitation Map - http://arcg.is/1kmhCUN*
Speed Limit (mph)	60	AADT (Count)	1450	*GIS 2012/2013 AADT Map - http://arcg.is/1MnAI6W*

Evaluation Result Summary

Condition Index	83	Total USMP Rating	160	Programmatic Improvement Cost to CS1
Condition State	1	Hazard Rating	47	SITE IS GOOD
Condition State Text	GOOD	Risk Rating	101	*Note calculation is programmatic and does not reflect site-specific needs. Actual costs may differ significantly.*
		Perception Rating	12	

Wall Hazard Rating

			Wall Height Score	5
			Length of Roadway Affected Score	3
			Annual Precipitation Score	9
Vertical and Horizontal Alignment Score	9	*Good, fair, poor, failed*		
			Wall Alignment Score	9
Rdwy Displacement due to Wall Movement Score	3	*none, visible crack, minor displacement, measurable displacement*		
			Roadway Displacement Score	3
Maintenance Freq. Score	3	*none, occasional, routine, year-round*		
			Maintenance Frequency Score	3
Drainage System Score	3	*good, fair, damaged/poor, non-functional/not present*		
			Drainage System Score	3
Other Problems	9	*evidence of cracking, corrosion, or damaged elements - none, minor, mod., major*		
			Other Problems Score	9
Movement History	3	*sporadic, minor, measureable annual, and measurable seasonal displacement*		
			Movement History Score	3
			Hazard Subtotal	47

Wall Risk Rating

			Decision Sight Distance Score	7
			Roadway Width Score	9
			AADT Score	6
% Time Car Within Site	0%			
			Average Vehicle Risk Score	1
Impact on Traffic Score	27	*Minor Delay, One Lane Open, 100 mi or 1 day closure, no detour or 3 days +*		
			Failure Impact on Traffic Score	27
Impact on Roadway Score	9	*shoulder, 1/2, 3/4, full roadway*		
			Failure Impact on Roadway Score	9
ROW Impact Score	3	*None, minor, private prop-no structures, structures/roads/RR/util/parks*		
			Right of Way Impacts Score	3
Envir. Impacts Score	0	*Zero points if none likely, 50 pts if some possible*		
			Environmental Impacts Score	0
Likelihood of Failure Score	3	*low, medium, medium-high, high*		
			Estimated Likelihood of Failure Score	3
Maint. Complexity Score	27	*Routine, Specialized equip, difficult effort/location, complex or dangerous*		
			Maint Complexity Score	27
Event Cost Score	9	*<$50k, $250k, $1,000k, >$1,000 in reasonable worst case*		
			Event Cost Score	9
			Risk Subtotal	101

Wall Appearance/Perception Rating

Tech. Appearance Score	3	*exceeds expectations, meets exp., needs improvement, failed*		
			Technical Appearance Score	3
Public Perception Score	9	*well maintained, routine investment, needs work, failed*		
			Public Perception Score	9
			Appearance/Perception Subtotal	12

Figure 10-8: Excel worksheet for site-specific rating, calculations, and summarization with sample data entries for an example retaining wall site. Available through the AGOL GAM App.

11 RECOMMENDATIONS

The research performed and data collected as part of this project represents a significant advancement in the understanding of how geotechnical assets contribute to Alaska's Transportation System and help ensure its continued function. In order to achieve maximum benefit from this research, the research team recommends the following:

a. Integrate the GAM Plan into the TAM Plan currently under development;
b. Maintain access to the data collected during this project;
c. Budget for expansion of existing databases; and
d. Advance additional research that will help improve management of geotechnical assets

These broad recommendations are discussed in the following sections in greater detail.

11.1 Integration of GAM Research into AKDOT&PF Planning Workflow

At the Department planning level, there are multiple steps that can be taken to incorporate the results of this research into AKDOT&PF's workflow, all of which will help the Department save money and better manage these valuable assets. The recommended implementation steps include:

a. Incorporate GAM terminology into policy recommendation language;
b. Maintain budget for routine geotechnical asset inspection;
c. Maintain a STIP line item for geotechnical asset preservation activities;
d. Report geotechnical asset condition to the public as part of the Results-Based Alignment process;
e. Develop an asset-level analysis of risk and life cycle cost to be used in project planning and programming;
f. Biennial update of the GAM Plan, and inclusion in the federal TAM Plan; and
g. Begin development of statistical models of asset deterioration after a second inspection cycle is completed.

Since integration of geotechnical assets into state TAM plans is not currently required, the Department has significant flexibility in how they pursue these recommendations. All these implementation steps are discussed in greater detail in the Geotechnical Asset Management Plan prepared by Paul D. Thompson as a component of this research project (P. D. Thompson, Geotechnical Asset Management Plan: Technical Report 2017).

Policy recommendation language. Particularly in regards to the data standards and decision criteria developed in this research project, prototype language has been developed for several areas that are valuable in asset management. Incorporating this language will help the Department communicate effectively between TAM planners. If the GAM plan is incorporated into Department planning in stages, ensuring that language is consistent between the TAM and GAM plans will help prevent any future confusion.

Budgeting for asset preservation and inspection. AKDOT&PF's GAM program will only be as useful to the Department as data quality allows. The current research has resulted in initial models of various funding scenarios, proposed asset inspection intervals, etc. By incorporating asset preservation and inspection into routine budgeting, the Department will be able to derive maximum benefit from the GAM research, and avoid a worst-first approach to asset preservation, where assets are ignored until they fail. In particular, maintaining a STIP line item will help AKDOT&PF proactively draw on federal funding where appropriate.

Regularly reporting asset condition with the public. Since the Department lacks the financial capability to repair all geotechnical assets at this time, communication with the general public is essential to demonstrate the Department is working to allocate limited funds as efficiently as possible. One of the simplest ways to do this is to make the GAM plan in general and the condition of geotechnical assets specifically readily available to the general public. Currently, the research team has already developed a brief overview of the GAM program that uses AGOL-hosted data and is currently available to the public through the TGIS web portal. This overview or similar interfaces could easily be incorporated into the GAM program webpage planned by the Materials Section.

Applying risk and life cycle cost to project selection. The GAM Plan Technical Report provides guidance on incorporating risk and life cycle costs into a spreadsheet model that could be used in project selection. By incorporating these costs at the asset or corridor-level, the Department can help choose projects that will provide the most benefit to roadway users.

Biennial GAM plan updates. Regularly reviewing and updated the GAM plan will ensure that it continues to meet the Department's needs. This process will also be easier if the GAM plan is incorporated into AKDOT&PF's TAM plan, since this will help the Department ensure that it is getting the maximum benefit from any changes, and that changes are acceptable to all stakeholders. It will also help the Department track changes in asset conditions over time, and how these changes compare to Agency targets.

Develop improved models of asset deterioration. At this time, the deterioration models used to develop the GAM program are based on expert elicitation. Once a second inspection cycle has been scheduled and completed, this initial model can be refined with data collected in the field. Continuing to improve and refine models of deterioration, cost, and preservation effectiveness over time will result in a GAM program provides improved decision-making support to the Department. This work should continue over all future inspection cycles, with the deterioration models improving with the growth of the data set.

11.2 Continued Improvement of Department Data Collecting Capabilities

In order to improve the initial correlations between asset condition and risk, mitigation, and maintenance costs, the Department should continue to improve its ability to collect high-quality data that can be used in future research. As companies like ESRI work to incorporate live-updating into their online programs, data collection in the field is becoming easier, and the instant feedback helps encourage adoption. Some of the recommendations in this section, such as improvements to AKDOT&PF's Maintenance Management Service (MMS) are already underway. If geotechnical assets are also considered when making changes to Department data collection processes, the Department will reap additional benefits.

Improve accident reporting procedures. Improve the existing accident reporting procedures to indicate where asset limitations or failures are contributing factors. This is true for all asset types, but particularly relevant to geotechnical assets. This will help the Department better monetize risk impacts, for both user safety and mobility. The research team has developed an application, the Geotechnical Event Tracker, which can be used to collect basic accident data tied to geotechnical asset failures. This prototype could be refined in the future based on user feedback.

Improve work reporting for maintenance and contract management. Currently, it is difficult to pull specific maintenance locations from the MMS database, and a single job code may cover work on multiple geotechnical asset types. Data on work performed by private contractors is nearly impossible to maintain. By incorporating additional job codes and data fields into the revised MMS system, the Department can improve tracking of specific work location, type of work, quantity, and cost. A similar database could also be developed to summarize work performed by outside contractors for easy reference.

Enhance existing inventory databases. The existing asset databases contain site locations, basic information, and detailed rating data. As these database are used, additional improvements may be identified that could help support the inspection process, including inspection crew and equipment scheduling, quality assurance review, issuance of work requests, and management reports.

11.3 Maintenance of the Asset Databases

As discussed in previous sections, the inventory and assessment data for the individual assets are currently maintained in ESRI's AGOL space, which is an easily accessible online platform. The GAM Plan Executive Summary (P. D. Thompson, Geotechnical Asset Manangement Plan: Executive Summary 2017) summarizes the crucial steps in maintaining the geodatabase as part of GAM Plan implementation:

a. Maintaining the collected data and the platform it is stored in;
b. Utilizing it as part of the planning process;
c. Encouraging use of the GAM geodatabases by the Department's planning, geotechnical and maintenance personnel;
d. Completing the condition assessment process for retaining wall assets on the NHS;
e. Expanding the condition assessment process for slopes and walls to the remainder of AHS;
f. Tracking events and expenses related to unstable slope events; and
g. Updating Condition Assessments at regular intervals or when conditions change.

Recommendations on implementing these steps are expanded upon in the following paragraphs.

Maintain Esri License. The databases for the various geotechnical assets are accessed and interfaced with through the ArcGIS Online (AGOL) portal. Through this portal, Department personnel can view premade maps, configure their own, and access all the data collected as part of the GAM project. This accessibility extends to online browser-based access, desktop GIS access, exportation to GIS or database/Excel compatible formats, and mobile field access to the identical datasets. This is possible through the Department's existing Esri enterprise license. It is critical that the Department maintain and renew this license or to ensure compatibility with future similar products.

Maintain Data Servers. Depending on the specific methods that the AGOL platform uses to store Department data, any Department servers housing data referenced by the AGOL layers need to be maintained.

Require Use of the Event Data Entry Layers. Accurate tracking of unstable slope events and their impacts on Department expenditures, cost to the public, and loss of road use on a site-specific basis will provide critical information for rerating sites, accurately tracking risk and recurrence intervals, revising asset deterioration rates, and tracking user cost. The AGOL-based application, “Geotechnical Event Tracker” is an online form designed to collect basic event data, photos, and news articles for integration into an event map on the department’s AGOL platform.

Data mining of the Maintenance Management System (MMS), as performed for most of the state of the Seward Highway south of Anchorage (see Section 10.1.4), is also encouraged for utilizing existing data in pattern analysis and identification of where conditions may be deteriorating. MMS sequence numbers can also be input into the event tracker application, so that detailed cost breakdowns for an event can be obtained if necessary. Currently, Statewide Materials has mined the MMS for various geotechnical asset-related events through October 2016. It is recommended that data mining of the MMS be performed on an annual basis and compared to the geotechnical events input through the Geotechnical Event Tracker application.

Rerate Sites when Conditions Change. When conditions change for a geotechnical asset, rerate it using the appropriate asset rating spreadsheet. Separate Excel sheets have been developed for rock slopes, unstable soil slopes and embankments, and retaining walls. If an asset is re-rated, enter the new GAM rating into the appropriate AGOL layers, marking the outdated evaluation as an “archive rating.” This will update the associated heat map and all other map layers that reference that data layer. For example, when updating a retaining wall rating, the rater will use the Retaining Wall Rating Excel template, transfer site information and scores to the AGOL-hosted Retaining Wall Layer, and save these changes.

Revisions to Material Site data will be made within the Material Site Inventory interface. Changes to existing material site information are anticipated to be occur less often and to require more complex re-rating work when they do occur. Because of this, changes should be made by a qualified engineering geologist or geotechnical engineer and incorporated into specific material sites improvement projects.

Rerate existing assets at regular intervals. One principle of Asset Management is to prevent or slow future deterioration by maintaining assets before excess deterioration forces major repair or replacement. Much like bridge inspections and pavement serviceability ratings, this requires regular re-inspection. However, due to the generally stable nature of a well-designed geotechnical asset, the rerating interval can be tailored to for each Good/Fair/Poor Condition State. Table 11-1 contains recommended rating intervals for slope and retaining wall assets.

Table 11-1: Recommended rating interval for unstable slope and retaining wall geotechnical assets based on roadway functional classification.

AKDOT&PF Functional Classification	Recommended Rating Interval
Highest Performance: Interstate, Principal Arterials, and National Highway System.	Reevaluate assets on a 5-year interval
High Performance: Minor Arterial, Major Collector, and Alaska Highway System	Reevaluate assets on a 10-year interval
Maintain Performance: Minor Collector and Local Routes	Reevaluate assets on a 15-year interval or as activity/safety dictates
All	Reevaluate when a change in activity dictates, slope is reconfigured, or retaining wall is reconstructed

For material sites, full rerating of assets at regular intervals is not anticipated. Maintaining data quality for this layer is based on ensuring the proper permits are in place for all sites of interest, monitoring the change in available material after large construction projects, and incorporating any new data from material site investigations. However, the level of attention given to specific maintenance service areas can still be tailored for Good/Fair/Poor Condition States, as shown in Table 11-2 below.

Table 11-2: Recommended rating attention for material site geotechnical assets based on material availability in the maintenance station service area.

Condition State	Recommended Attention
Good	Review state of permitting for valuable material sites on a 5-year period, review state of projected material reserves at valuable sites on a 10-year period or after significant extraction has occurred
Fair	Review state of permitting for valuable material sites on a 2-year period, review state of projected material reserves at valuable sites on a 5-year period
Poor	Review state of permitting annually and projected material reserves for valuable material sites in the service area on a 2-year period
All	Reevaluate site reserves following large-scale construction projects that may have depleted local material sites, when new geotechnical work has proved up an existing site, when a new site has been permitted and opened, or when an existing site has been closed

11.4 Additional Data Coverage

The primary focus of this research work has been on the NHS system, with occasional inventory of AHS routes. No routes below the AHS category level were comprehensively evaluated in the same systematic fashion. Opportunities exist to cover the remaining portions of the AHS and select high traffic Collector routes. This would also assist Department assessment, planning, and budgeting in communities not served by NHS roads. Culverts and subsurface data could also be included in this field work/data gathering portion.

11.5 Additional Research Opportunities

Collection and integration of actual asset activity. As unstable slope and retaining wall work activities and adverse events are recorded and costs are tracked, models to estimate probabilistic activity based on Condition State or other USMP-tracked items can be formulated. For example, the probabilistic risk of rocks entering the road along with causing accidents or delays can be used to generate data-based risk costs for delaying rock slope improvements. The Montana Department of Transportation (MDT) is currently conducting research correlating rock slope condition with event likelihood as part of a larger research project to update its existing rock slope management program (Landslide Technology 2017). If AKDOT&PF were to expand asset activity correlations beyond rock slopes, this would also be a first-of-its-kind research effort, like the GAM research projects. This work could be tied to the data collection improvements discussed in Section 11.2.

Collection and integration of material-scarcity related costs. The data used to estimate costs for developing new material sites, maintaining existing sites, reasonable haul distances, typical project requirements, and excess haul costs were all developed using institutional knowledge and expert elicitation. AKDOT&PF does not currently maintain the information required for a quantitative analysis in a central location that could easily be accessed. Development of a more robust data set and improvement of the cost model proposed in this report would also be a first-of-its-kind research effort.

Improved preservation strategies for soil slopes. The research conducted for this study identified a low return-on-investment for existing methods of soil slope and embankment preservation, particularly in relation to the other geotechnical assets in the study. Conversely, the Department's inventoried unstable soil slopes and embankments are on average in worse condition than any other asset group. This indicates that the potential benefits for new preservation and mitigation methods is large. It is recommended that AKDOT&PF promote research in this area to the extent that is feasible, particularly for permafrost-impacted slopes. Permafrost is rare in the rest of the United States, and it is therefore unlikely that another DOT will fund research that would help meet Alaska's needs in this area.

Use of emerging remote sensing techniques. There are a number of emerging techniques that permit precise measurement of large swaths of terrain with minor vegetative cover. These techniques have the potential to be particularly useful for collecting rock slope and retaining wall data, but they could also be applied to unstable soil slopes and embankments. A relatively new methodology for rapidly collecting and assessing hazardous slopes and walls above highways has been the release of professional-grade photogrammetric software. These newer software packages are intended for a wider user base, thus making the software more affordable. However, their application to less accessible slopes and walls below the roadway is still limited without the benefit of aircraft to photograph the slope and the common presence of heavy vegetation.

Agisoft's PhotoScan photogrammetric software has recently been used to monitor rockfall activity above rail and transportation corridors in Canada and for a pilot program for the Colorado Department of Transportation (Lato, Gauthier and Hutchinson 2015) as well as pilot studies in Alaska (Dunham, et al. 2017). This software permits the rapid creation of surface models from photos collected via aerial oblique photos or from the ground surface. Photos collected from a helicopter with doors removed offers the most rapid data collection technique while still producing reliable and accurate results. Using this method, an entire corridor can be photographed from a helicopter or a unmanned aerial vehicle (UAV) in an afternoon with corresponding surface models generated and georeferenced soon thereafter. Figure 11-1 illustrates a surface model generated at the Nenana Canyon Site on the Parks Highway.

Figure 11-1: Parks Highway PhotoScan surface model. Blue squares indicate helicopter positions. This low density surface consists of 1.6 million points and 323,000 TIN faces.

Repeated surveys can be used to detect changes resulting from rockfall activity or mass movement. This was recently tested at an active slope in Nenana Canyon on the Parks Highway by comparing a 2011 ALS LiDAR surface to the surface model generated by PhotoScan. Following a georeferencing process in another software package (CloudCompare), the surfaces were compared with absolute differences shown in Figure 11-2. This comparison revealed potential landslide movement generating rockfall activity from the weak rocks on the slope as well as more active rockfall chutes on the southern (right) edge of the slope. Note the debris accumulation indicated in the ditch, signifying a concentration of rockfall activity.

These datasets illustrate a key advantage of this photogrammetric technique: the nearly normal incidence angle of the photograph to the slope face results in an even point density that stays consistent to the top of the slope. This preserves details that would otherwise be lost from road-based survey techniques and also permits observation of overhangs that would not be seen from other techniques.

A test consisting of repeated surveys to determine activity rates and volumes involved at a few select corridors could serve the GAM program well.

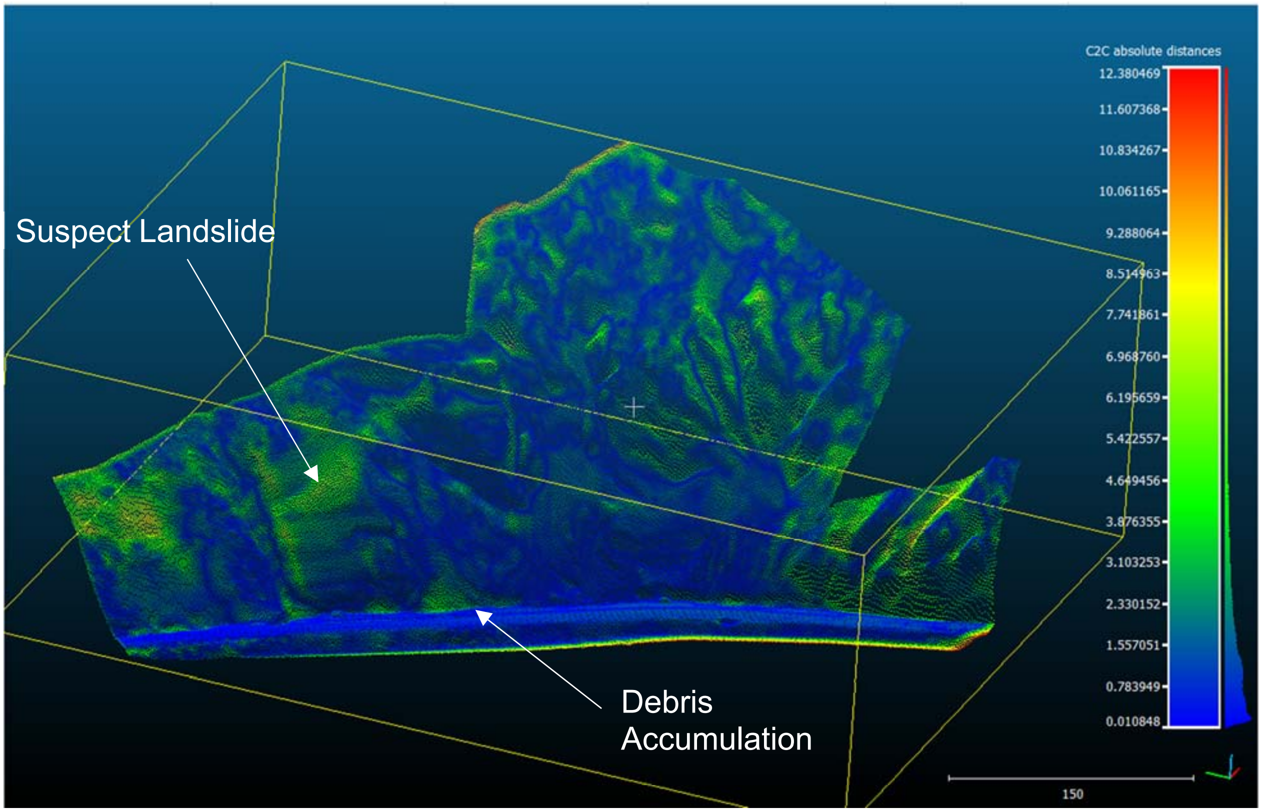


Figure 11-2: Surface comparison between 2011 LiDAR and 2015 PhotoScan surface model generated by CloudCompare. Greens indicate surface changes.

<u>Integration of DGGS LiDAR Data.</u> The Alaska Division of Geological & Geophysical Surveys (DGGS) has prepared and published LiDAR datasets of significant portions of the interconnected highway system north and east of Anchorage (Hubbard, Koehler and Combellick 2011). The extent of this data is shown in Figure 11-4 and covers where most of the unstable soil slopes in the Northern Region are present. This data was recently used in Nenana Canyon to assist with reconnaissance of rockfall problems and, along with site reconnaissance, revealed a number of landslides that are increasing rockfall activity, reducing ditch effectiveness, and delaying construction projects.

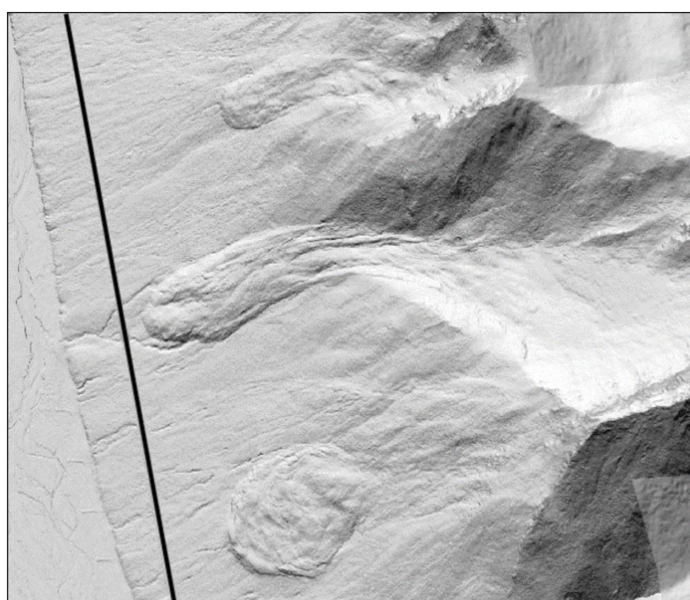


Figure 11-3: Frozen Debris Lobes on the Dalton Highway (black line), MP 219.

Other features, such as the frozen debris lobe encroaching the Dalton Highway near MP 219 (Figure 11-3), could be mapped and included as areas with future significant impact to the highway system.

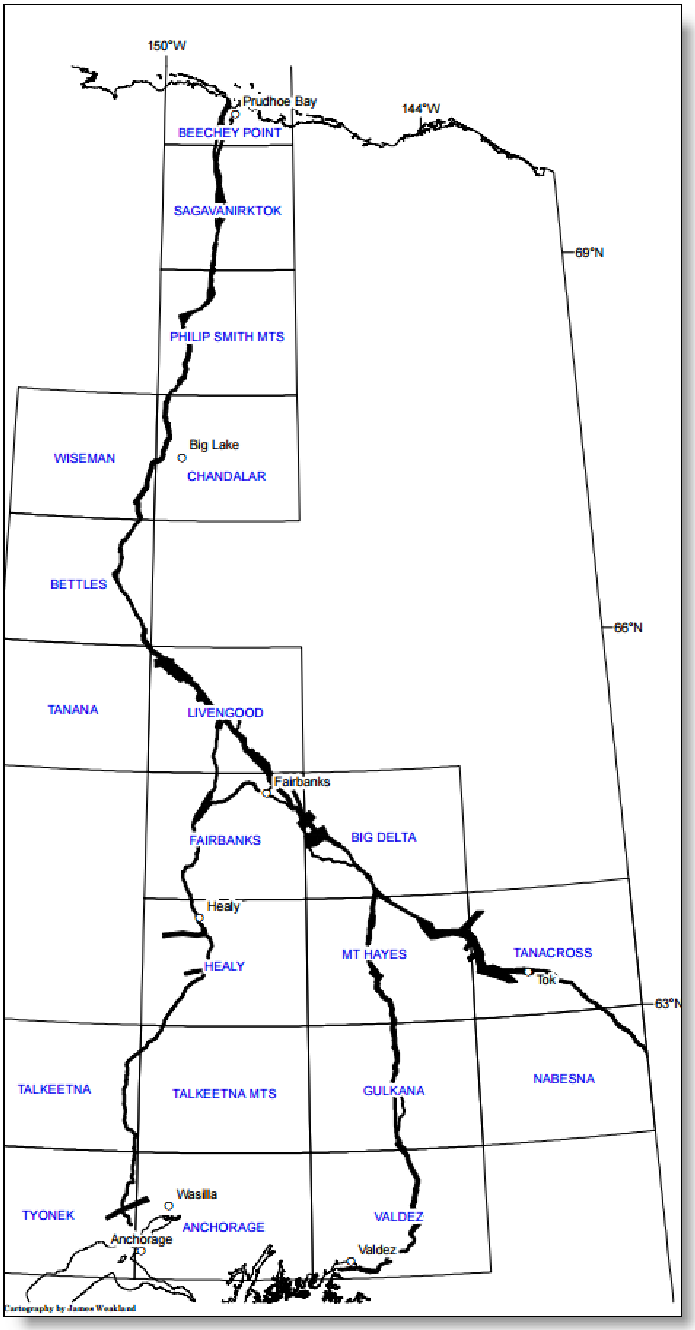


Figure 11-4: Extent of DGGS LiDAR data in 2012.

Promotion of further research. Since AKDOT&PF has developed the first-in-the-nation GAM program, there is sizable interest from other state DOTs seeking to apply modern management principles to their geotechnical assets. The Department can use this interest to promote national or pooled-fund research where possible to further improve its deterioration, cost effectiveness, and risk models.

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Appendix A

DEVELOPMENTAL HISTORY OF THE UNSTABLE SLOPE MANAGEMENT PROGRAM

CONTENTS

A-1. INTRODUCTION

Transportation corridors throughout Alaska include poorly performing slopes, generally divided into unstable rock slopes and unstable soil slopes. Failures within this class of assets range in severity, from those that cause injury or block traffic to those that are generally unnoticed by the general public. However, in all cases these unstable slopes place a strain on the functionality of the transportation corridor as a whole, and require regular repair and maintenance costs. With approximately 5,600 miles of roadway within the state system, the Alaska Department of Transportation and Public Facilities (AKDOT&PF), is responsible for maintaining a functional, reliable, and efficient transportation system over a wide range of environments that are subject to challenging geologic conditions. Like many state transportation agencies, AKDOT&PF is moving towards more proactive risk management of unstable slopes throughout the state. An integral part of this proactive risk management has been the development of a Geotechnical Asset Management (GAM) Program.

The state of Alaska began funding research into the development of an Unstable Slopes Management Program (USMP) in 2009. The USMP would allow unstable slopes across the state to be identified and assessed under uniform criteria. The USMP has since been incorporated into the GAM program, along with retaining walls and material sites. The goal of this document is to provide a brief chronology of the development of the USMP and summary of the relevant research work, prior to the program's incorporation into the current GAM program.

A-2. USMP PHASE I – RESEARCH AND PROGRAM INCEPTION

In 2009, under contract with AKDOT&PF, background research on USMPs was conducted by Scott Huang, et.al. at University of Alaska, Fairbanks. The goal of this research was to survey USMPs developed by other states and countries and, drawing from the results of this survey, to provide guidance to AKDOT&PF as it began development of its own USMP program.

The nine programs surveyed drew heavily on the Rockfall Hazard Rating System (RHRS) assessment categories developed in the late 1980s, but they often expanded on, altered, or replaced these initial RHRS evaluation categories to cover unstable soil slopes or to meet department-specific needs. In general, the surveyed USMPs utilized a two-stage implementation, with preliminary ratings followed by more detailed evaluations. The unstable slopes management systems surveyed and evaluated in the Phase 1 study included:

- Oregon DOT-I, 1985; an RHRS system developed to assess rock slopes across the state.
- Oregon DOT-II, 2001; a new rating system applicable to rock slopes, landslides, and debris flows, unlike the rock slope-specific 1985 program.
- Ohio DOT, 2007; a Geologic Hazards Management System (GHMS) designed to manage landslides across the state, as well as potential hazards posed by abandoned mines, karst, and shoreline erosion.
- New York DOT, 1988 and 1993; a Federal Highways Administration (FHWA) – based system for evaluating rockfall sites across the state.
- Utah DOT, 2001; a multi-phase rockfall rating system, with the rockfall hazard inventory in Phase I followed by rockfall hazard rating for select sites in Phase II. Applied Oregon DOT-I in Phase I and drew from Oregon DOT-I, Oregon DOT-II, and New York DOT to develop suitable parameters in Phase II.

- Washington DOT, 1993; a matrix-based rating system designed to rate rock slopes, landslides, erosion, and settlement.
- Tennessee DOT, 2000; a two-phase rockfall hazard rating system, using the standard RHRS in Phase I, and a detailed RHRS rating system slightly altered to meet state-specific needs.
- Missouri DOT, 2004; a two-phase rating system which organized parameters into “risk of failure” and “consequence of failure” categories, instead of the “hazard” and “risk” categories used by other DOTs.
- British Columbia Ministry of Transportation, 2000; adopted the RHRS system developed in Oregon DOT-I, but converted units to metric and Transportation of Canada (TAC) standards.

None of the programs surveyed included instabilities related to frozen ground, and very few of them provided a way to assess soil slopes or fill failures. However, they offered general guidance on ways to balance hazard and risk assessment in the development of a scoring system for AKDOT&PF’s planned USMP.

Drawing on these older programs, the Phase I study recommended a multi-phase rating process for sites inventoried under the USMP. An initial rating by Maintenance and Operations (M&O) personnel to identify critical slopes would be followed by a detailed assessment conducted by a geotechnical engineer or engineering geologist. The initial M&O rating was further broken into two separate forms. First, a simple four category preliminary rating form was developed for routine use by M&O personnel, who are generally the first responders to a slope failure and therefore best able to assess the roadside ditch performance and roadway impacts immediately after an event. In its original conception, this form was to be filled out after every failure event, to prevent important slope performance data from being lost or forgotten. It was referred to as the M&O Unstable Slope Incident Report. A second, more comprehensive preliminary rating form was developed, to be filled out by M&O foremen once for each unstable slope site. It would collect basic location and dimension data, as well as document precise data on historic slope performance based on the important M&O perspective. A major benefit of these preliminary ratings would be the elimination of low hazard slopes, economizing the more time intensive detailed slope rating process.

In the second phase, the detailed unstable slope assessment rating, slopes were assessed on both hazard and risk criteria. The individual scores from the hazard and risk categories were added together to obtain the total site score. A major addition in the hazard rating section was the incorporation of criteria for rating frozen ground and the potential impact of freeze-thaw cycles on the mechanical weathering of slopes. Detailed information on the development of the rating categories created during Phase I research can be found in the Phase I report (Huang, et al., 2009). Over the course of subsequent phases, these rating forms and categories were refined to meet the demands placed on them during field implementation and based on the knowledge gained during system testing.

Completion of the Phase I study laid the groundwork for subsequent phases of the AKDOT&PF USMP development. In addition to the previously described slope hazard and risk assessment ratings, the Phase 1 study also proposed integration of the database with a GIS program. Since the amount of data collected for the USMP project in Alaska would be extensive, a database that could be spatially and visually linked to the state road network was recommended in order to provide easily accessible spatial and temporal analysis. The development of the integrated database and GIS system was part of the final development phase (Phase III) of work.

A-3. USMP PHASE II – RESEARCH REFINEMENT AND INITIAL PROGRAM IMPLEMENTATION

Following completion of Phase I research by UAF, AKDOT&PF began a second phase of USMP research to finalize evaluation criteria and develop rating forms for the USMP based on UAF's work. Technical support for this phase was provided by Landslide Technology of Portland, OR and R&M Consultants of Anchorage, AK. Active and retired AKDOT&PF materials and geotechnical personnel, including Bill Slater, Tom Moses, David Stanley, and others were involved with criteria development, with the goal of making implementation as practical as possible. Following field discussions on the Seward and Glenn Highways (Figure 3-1), the finalized forms were tested, and an initial integrated website and Microsoft Access database were developed in 2010. The rating criteria and database were used in Phase III work, where the database was integrated with an ArcGIS geodatabase.

Figure 3-1: Evaluation of rock cuts (Seward Highway shown), soil slopes, and past mitigation work (Glenn Highway shown) during field training and assessment of Phase II rating criteria.

A-3.1 Refinement of Phase I Rating Criteria

At a meeting in Anchorage, all involved parties met to refine the rating criteria before conducting fieldwork to populate the database. The rating forms proposed in the Phase I report were finalized, along with the cutoffs, descriptions, and scoring of the proposed categories. During this meeting, the proposed M&O Incident Report was incorporated into the M&O Preliminary Report. The reason for this was that once the database was prepared, unstable slope failures impacting the roadway could be entered as additional notes and photos. An additional form was not necessary. The proposed detailed rating forms were also revised based on the field trials and input from researchers, with significant changes made to the Hazard and Risk categories.

In the Hazard form, several changes were made to both landslide and rockfall categories, with an increased focus on developing categories that were more straightforward for assessment by raters. The total number of evaluated categories for soil and rock slopes was also equalized, so that each slope type had the same possible maximum point value, and comparison of slopes across the state was simplified. In the landslide sub-category, all unstable soil slopes, including natural slopes affecting the roadway, unstable soil cuts, and embankment slopes, were evaluated in the same manner rather than being separated into two categories, i.e., embankments and natural slopes. The category measuring the number of freeze-thaw days, which required input from a separate data table, was replaced by one assessing the freeze-thaw stability of the slope that would be based on field observations. Categories describing the length of roadway affected by the slide and the percent impedance of the roadway due to slide activity were also added. The slide height was adjusted to utilize axial slide length, making this category appropriate for dual use with the rockfall slope height measurement. In the rockfall categories, a second failure type, Case II, was incorporated to capture rockfall events from slopes exhibiting differential erosion features, such as glacial till slopes. A category describing ditch effectiveness was also added. Finally, for all slopes, evaluation of drainage was paired with evaluation of total annual rainfall, as a poorly draining slope in a dry climate will not be subject to the same stresses that it would be in a wet one. Detailed descriptions of the final rating categories can be found in Appendix C (Rock Slopes) and Appendix D (Soil Slopes and Embankments Asset).

In the Risk form, an additional category quantifying roadway width was added, as were categories describing failure impacts on the environment and potential impacts beyond agency Right of Way. The Maintenance category was expanded, with event frequency considered separately from event cost. The score carried over from the hazard category was removed, meaning that these categories could be assessed completely separately.

For all categories, the allowable scores range from 0 to 100 with 100 being the highest score assigned. The category scores are summed for an overall unstable slope site score.

Once the USMP rating categories were finalized, an Access database was developed for use in field implementation of the USMP. It contained the preliminary, hazard, and risk rating forms, but only scores from the hazard and risk rating forms were summed and presented as the USMP site score in the site information overview. In addition to the site name, the site information overview contained location information, in terms of both Highway Mile Post and Milepoint, and Latitude/Longitude. It also contained space to add additional comments on slope condition, past failures, and maintenance history that was not adequately captured by simply selecting the appropriate category score. Finally, slope photographs could also be imported into the database for later reference. The opening screen of this database is shown in Figure 3-2.

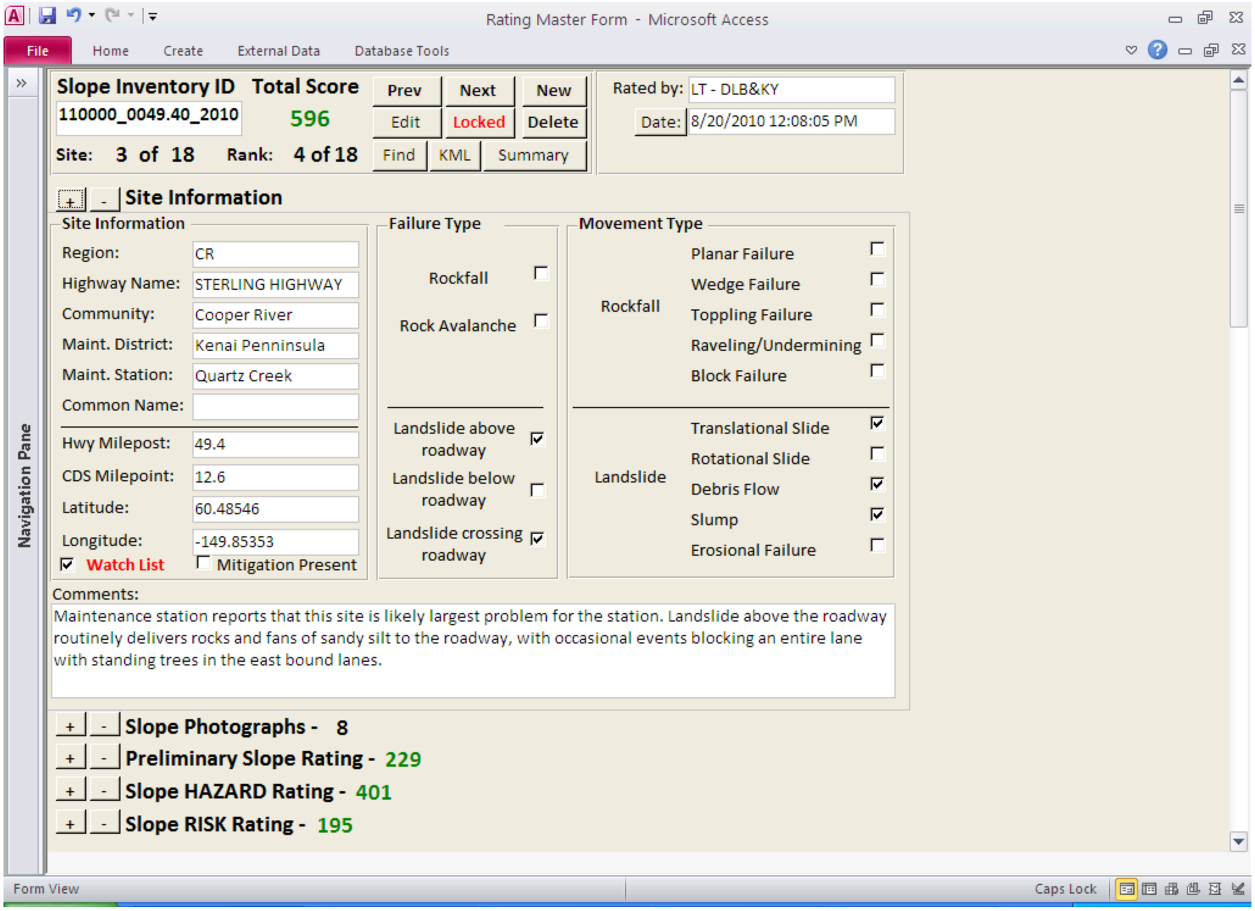

Figure 3-2: Opening Screen in the MS Access Database.

A-3.2 Development of "Top 100" Site List for Initial Field Ratings

Working with AKDOT&PF M&O districts and geotechnical personnel, a preliminary unstable slope list was developed in August, 2010. The goal was to assess the "Top 100" unstable slopes on AKDOT&PF-maintained roads to field test the rating criteria and database system, and to generate a preliminary inventory and condition assessment of the State's slopes. Working with the superintendents of AKDOT&PF's three maintenance regions and geotechnical personnel familiar with the highway system, a list of unstable slopes was developed for each region. These slopes regularly required maintenance effort or were a source of maintenance concern. The lists from the three regions were then combined, and the most critical sites were compiled in the preliminary unstable slope list.

The final list contained 105 sites, but some of these "sites" covered several highway miles. For example, the Anchorage maintenance district provided one "site" along the Seward Highway that spanned Milepost 104 to Milepost 115. The preliminary sites were divided between Landslide Technology and R&M Consultants for field evaluation. Experienced geotechnical engineers and engineering geologists from both firms conducted field assessments of the unstable slopes, met with maintenance personnel, and refined the preliminary site list. Frequently, large milepoint ranges were subdivided into smaller sections for improved rating clarity and to make sites easier to monitor in the future. Fieldwork for the "Top 100" sites was largely completed in September and October, 2010 with some locations in the SE Region being evaluated in 2011. A total of 192 sites were added to the database.

A-3.3 Integration of "Top 100" Sites with website and online accessible database

Following field evaluations and population of the USMP database, geospatial data was integrated with a Google Maps basemap, making spatially integrated data easily available to the general public. The Keyhole Markup Language (KML)-based map product showed the location of each unstable rock or soil slope in the "Top 100" Sites. Different icons were used for the unstable soil and unstable rock slopes, and the icons were color-coded based on where a site ranked relative to the other evaluated slopes. Unstable slopes ranked in the top third of all rated slopes were red, those in the middle third were orange, and those in the lowest third were yellow. Clicking on the icon for any individual site opened a box containing information drawn from the Access database, including photos, detailed rating data, the total site score, and the rank of this score within those for all evaluated unstable slopes. This integrated product was recently updated with data collected in 2014 and was initially available at http://www.akdot-usmp.com (Figure 3-3). The Phase II inventory work has since been merged with subsequent GAM inventory work, and is available via the Department's Transportation GIS service.

Paired with the map, a searchable database was also developed for use by AKDOT&PF. Within this password-protected site, it was possible to add additional slopes to the database, or to look up slopes that had already been rated and entered. Sites were organized by Highway name and milepost. In addition to containing all the location, rating, and photo data available to the general public in the KML-map, it also contained spaces for incident reports, so that activity at a site can be updated by M&O or geotechnical personnel. There was also a tab to upload additional documents. This online database is no longer available. All asset data has been migrated to AKDOT&PF's Transportation GIS server.

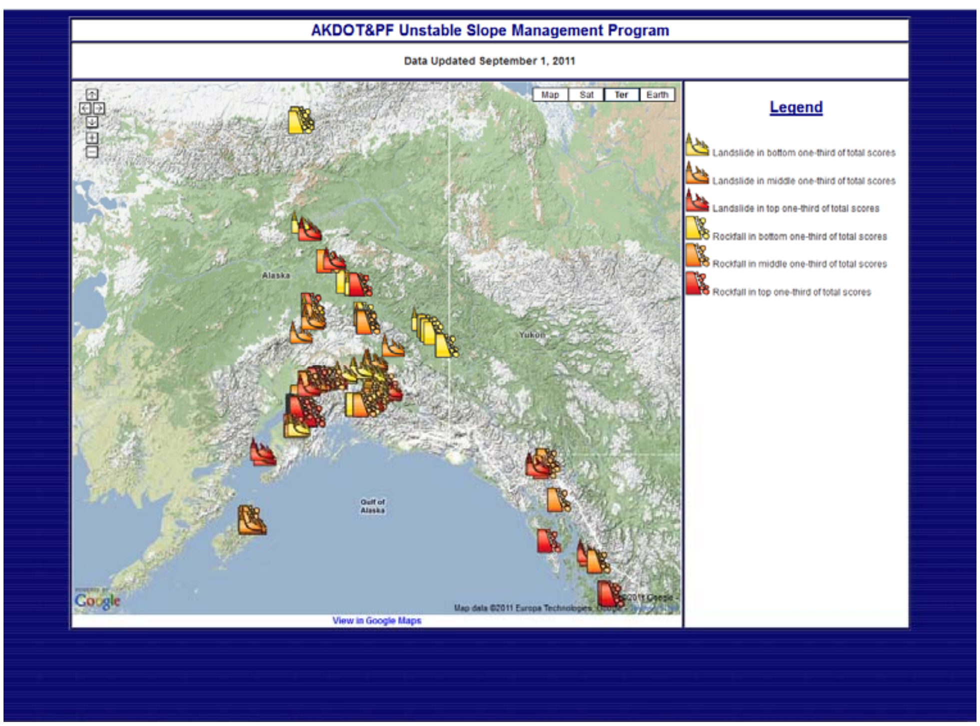

Figure 3-3: Webpage Geodatabase Following "Top 100" data collection.

A-4. USMP PHASE II – DEVELOPMENT OF INITIAL SERVICE LIFE AND PERFORMANCE MEASURES

One of the guiding principles of GAM is the use of field ratings, site inspections, etc., to enable better management of geotechnical assets that support the continued functionality of the transportation corridor. However, to use GAM as a planning tool, the initial ratings must be developed into performance measures that can be used to evaluate geotechnical assets in a way that is easily accessible to upper-level planners and easily translatable to the general public. Very little research on or examples of the development of performance measures for geotechnical assets had been carried out prior to the AKDOT&PF USMP project, and AKDOT&PF has remained at the forefront of performance measure development throughout Phases II and III of this project.

A goal of Phase II was to develop Levels of Service and Performance Measures for geotechnical assets conceptually similar to those already used in Transportation Asset Management for structures such as bridges and pavements. One of the initial goals of the USMP Project was to develop a method to translate the risk and hazard ratings collected in the field into an assessment of the site's Service Life State (SLS). The Service Life State in turn fed into the development of a Service Life Index (SI), Level of Service Index (LI), Benefit Cost Index (BI), and ultimately a Corridor Slope Index (CSI). These proposed performance measures would classify slope performance and quantify maintenance interventions/actions that could maintain or improve the slope's level of service classification. Applied over multiple sites in a multi-mile stretch, they would also provide a measure of the overall health of the transportation corridor, which could be used in the long-term strategic development process. The performance measures and indices discussed in the following section influenced the development of the Condition State, Resiliency Measures, and Deterioration Measures proposed in the current GAM Program.

A-4.1 Service Life Classification (AIM)

The initial SLS classification scheme was based on AIM criteria (Accidents, Interruptions in Service, Maintenance/Performance), as shown in the table below. The Service Life Classification defines where the slope is within its service life. This data could be used to develop maintenance operations and appropriate levels of action for a given slope based on its SLS Class. An unstable slope that was not meeting the performance standards for a transportation corridor could be improved to a higher SLS class through mitigation work. This classification system also helps make apparent the positive effect that mitigation actives can have on extending an unstable slope's service life.

Table 4-1: Unstable Slope Service Life State Classification

UNSTABLE SLOPES SERVICE LIFE STATE CLASSIFICATION			
SLS Class	Accidents	Interruptions in Service	Maintenance/Performance >
1	No Reported Accidents/ Good Performance	Minor Service Disruption, traffic flow unaffected/Repaired upon arrival	New - Minimal Maintenance/ Good Performance
2	1 to 2 Non-serious* Accidents in Past 10 Years Related to Slope Failures	1 to 3 Service Interruptions+ in Past 10 Years/Detour available	Routine Maintenance/ Acceptable Performance

3	1 to 3 Accidents[**] in Past 5 Years Related to Slope Failures	1 to 3 Service Interruptions[++] In Past 5 years lasting up to 3 days/Detour available	Regular or Unscheduled Maintenance/Moderate Performance
4	1 to 3 Accidents[**] in Past 2 Years Related to Slope Failures	1 to 3 Service Interruptions[+++] In Past 5 years lasting up to 5 days with no detour available	Constant and/or Regular Unscheduled Maintenance/ Poor Performance
5	1 Serious Accident[***] in Past Year Related to Slope Failures - Failed Condition	Major Service Interruption[++++] Road closed (1 month w/ detour, or >1 week w/o detour) - **Failed Condition**	Unacceptable and Unsafe Maintenance and Performance - **Failed Condition**

Building on the Maintenance/Performance guidelines discussed in the AIM criteria table, distinct maintenance and mitigation/intervention actions were developed for unstable rock slope and unstable soil slopes. These proposed maintenance and mitigation activities were organized to match the SLS class assigned to the slope under the AIM criteria. Generally speaking, Maintenance Actions were those required to keep the road clear, and reflected the work required to maintain the current SLS Class based on the activity level of the unstable slope. In contrast, mitigation/intervention activities reflected the work required to improve an unstable slope by some number of SLS Classes as required to meet transportation corridor goals. The mitigation activities, also organized by SLS category, were subdivided into protection, stabilization, and avoidance. The table also sought to quantify the amount of SLS improvement that could be expected to result from a given intervention. These proposed actions are presented in Table 4-2 through 4-4 below.

Table 4-2: Proposed Unstable Slope Maintenance Actions based on Service Life State Class

UNSTABLE SLOPES MAINTENANCE ACTIONS		
SLS Class	Rock Slope	Unstable Soil Slope/Debris Flow Condition
1	Occasional ditch cleaning to maintain catchment and drainage	Annual inspection for surface condition. Typically no crack repair, surface leveling or debris flow cleanup required. Install warning sign
2	Routine seasonal ditch cleaning	Annual inspection. Requires crack repair, surface leveling or debris flow cleanup every five years.
3	Occasional rock on road - regular seasonal road patrol/occasional unscheduled road and ditch clearing	Regular movement inspection required. Crack repair, surface leveling or debris flow cleanup required every one to five years.
4	Rockfall routinely reaches roadway – year round road patrol and unscheduled emergency response required	Significant movement occurs annually. Crack repair, surface leveling or debris flow cleanup required annually or more often to maintain safe service.
5	Unacceptable maintenance required to keep road clear/safe	Major movement or debris flow that closes the roadway. Requires unreasonable or unacceptable M&O mitigation efforts. Services require a specialty Contractor.

Table 4-3: Proposed Maintenance/Intervention Activities for Rock Slopes Based on Service Life State Class

ROCKFALL INTERVENTION				
SLS Class	Protection	Stabilization	Avoidance	SLS Improvement
1	Jersey rail, berm, ditch shape improvements	NA	NA	Maintains current class
2	Jersey rail, berm, ditch shape improvements	Slope scaling	NA	Maintains and/or upgrades current class
3	Draped mesh, attenuator fence, enhanced fallout area (see avoidance)	Rock bolts, shotcrete, trim blasting, slope scaling, anchored mesh, cable lashing	Alignment Adjustment	Upgrades current class
4	Draped mesh, attenuator fence, flexible barrier fence, or improve catchment area	Rock bolts, shotcrete, reslope, slope scaling, anchored mesh, cable lashing	Minor realignment within R/W	Upgrades current class
5	Construct new catchment area, flexible barrier fence, rockfall shed	Major slope reinforcement program, anchored mesh, reslope	Major realignment, elevated structure, tunnel	Creates a New Slope/Upgraded to SLS Class 1 or 2

Table 4-4: Proposed Maintenance/Intervention Activities for Unstable Soil Slopes based on Service Life State Class

UNSTABLE SOIL SLOPE OR DEBRIS FLOW INTERVENTION				
SLS Class	Unstable Slope		Debris Flow	SLS Improvement
	Stabilization	Avoidance		
1	NA	NA	NA	Maintains current class
2	Excavate small slides, place a rock inlay, repair road surface	Minor alignment adjustment, repair road surface	Improve road drainage system/storage capacity, repair roadway surface	Maintains or upgrades current class
3	Reshape slide, install deep patch/rock inlay/shear key/buttress, drain slide, repair road surface	Shift alignment and repair road surfacing, reset guardrail as needed	Improve drainage system, create a storage basin, repair roadway surface, install debris flow barrier	Upgrades current class
4	Reshape slide mass, install deep patch, drain slide, place light-weight fill	Realign roadway away from or off the unstable slope. Stay within existing corridor-R/W	Improve drainage system, excavate storage basin, repair roadway surface, install debris flow barrier/ RCC road surface	Upgrades current class

5	Stabilize landslide Rock inlay/Shear key/Buttress	Complete realignment Revise road corridor away from slide terrain	Excavate large collection basin, reshape source area, install series of debris flow barriers, span the flow path with an elevated structure	Creates a New Slope/Upgraded to SLS Class 1 or 2

This initial performance measurement system did not draw entirely from data collected during the USMP field ratings and relied on information inconsistently and sporadically collected by AKDOT&PF personnel or other State agencies, such as the State or Local Police. Maintenance and Performance information was directly collected during the field risk and hazard ratings. Accident data has not been found that attributed, directly or indirectly, accidents caused by contributing factors attributable to unstable slopes, such as avoidance of rocks on the road or uneven pavements preventing avoidance of other roadway or wildlife hazards. The Interruptions in Service category was partially assessed in the field ratings, with the rater estimating potential traffic impacts, but the service history is not collected in the Maintenance Management System (MMS) in a fashion that is comprehensive or granular enough to provide a reliable data source. Successful analysis of both categories required data beyond that which was initially collected in the field rating, which had focused almost exclusively on data that could be measured or judged at the site by the field rater, regardless of time of visit. Nevertheless, the initial Service Life State work played an import role in the development of the criteria used in calculating the Condition State Indices developed for unstable slopes, retaining walls, and material sites. The intervention tables are built upon for the Condition State-Mitigation Cost estimates. These cost correlation estimates do not attempt to make mitigation activities SLS class-specific, but do demonstrate that the overall project cost to improve the performance of a slope in poor condition is much higher than to improve a slope in fair condition.

A-4.2 Service Life State Index, Level of Service Index, Benefit Cost Index, and Corridor Slope Index for the USMP Program

Four index performance measures were developed to work with the Service Life Classification: Service Life State Index, Level of Service Index, Benefit Cost Index, and Corridor Slope Index. The Service Life State Index and the Level of Service Index were both designed to translate USMP data into an initial Service Life State that could be compared to the SLS class developed under the AIM criteria. The Benefit Cost Index related operational and maintenance costs to overall slope performance. All indexes contained 5 levels corresponding with the 5 SLS classes. The Service Life State Index, Level of Service Index, and Benefit Cost Index would all be combined to calculate the Corridor Slope Index. This final index would be used to finalize the SLS for a site, and would be the index ultimately used in transportation planning.

Final category rating criteria for the indexes was not finalized during Phase II work, and index scoring ultimately developed along a significantly different path in Phase III. The indexes discussed in the following sections are as presented in the final white paper for Phase II. The concepts raised in these indexes remains relevant to the ongoing GAM work, but the general rating emphasis has been towards greater simplicity and transparency, with the multiple Phase II indexes subsumed into indices developed within Phase III.

A-4.2.1 Service Life State Index

The Service Life Index (SI) was developed to describe performance and serviceability of slopes based on the USMP hazard score, known construction methods, known geotechnical design data, and select scores from the USMP rating risk categories. Scores tied various slope attributes to benchmarks for a specific point in the slope service life. Based on scores in the various service life attribute categories, budget could better be directed to those facets of an unstable slope that were having, or had the potential to have, the greatest negative impact on the SLS classification. These proposed attributes and scores are presented in the following table. Continuing work led to an emphasis on different index categories to assess slope performance and serviceability, and to a return to using the USMP field rating to develop performance indexes to the greatest extent possible. In addition, most of the items described in Table 4-5 can be directly attributable to the performance of the slope, its effect on the roadway, and the suitability of the original design; all of which can be derived from the USMP scoring criteria.

Table 4-5: Phase II Service Life State Index Rating Categories

UNSTABLE SLOPES SERVICE LIFE INDEX (SI)				
SERVICE LIFE ATTRIBUTES	0 - 25 POINTS	25 - 50 POINTS	50 - 75 POINTS	75 to 100 POINTS
USMP Hazard Score	V to W	W to X	X to Y	>Y
Construction				
Time	Post-2000	1980 - 2000	1960 - 1980	Pre-1960
Method/Standard	Built Highway to Current AASHTO	Built Highway to Earlier AASHTO	Built Highway Not to AASHTO Standards	Original Dirt Tract Non-AASHTO
Geologic Material	Very Suitable - Meets Design Requirements	Good to Adequate for Design	Moderate to Poor for Design	Weak and Unsuitable for Design
Geotechnical Design				
Rock Cut Slope	Design Matches Structure	Design Matches Most Structure	Poor Structural Design	Design Ignored Structure
Soil Cut Slope	≤ 2H:1V	1.5H:1V	1H:1V or Minor Unstable Natural Slope	≥ 1H:1V or Major Unstable Natural Slope Present
Embankment	Good Foundation and Compaction	Adequate Foundation and Compaction	Poor Foundation -Experiencing Minor Distress	Permafrost Foundation - Experiencing Major Distress
Geometric Design	Multiple Lanes (>2) with Clear Zone	Standard Two-lane / Wide Shoulder	Standard Two-lane / Narrow Shoulder	Substandard Road Width / No Shoulder

Slope Deterioration Value (Based on the predicted rate of deterioration)	TBD	TBD	TBD	TBD
Right of Way	Unlimited	Adequate	Restrictive	Very Restrictive
Environmental Limitations	None	Minor	Some	Significant
Maintenance Requirements	Rare	Occasional	Often	Constant
Corridor Significance (the value assigned could be factored)	Low	Moderate	High	Very High

A-4.2.2 Level of Service Index

The Level of Service Index (LI) was meant to reflect how well the unstable slope was meeting the public's expectations for the transportation system, based on a qualitative rating of the multiple service level indicators, such as the USMP risk score and several additional slope maintenance requirements.

Table 4-6: Level of Service Index Rating Categories

UNSTABLE SLOPES LEVEL OF SERVICE INDEX (LI)				
LEVEL OF SERVICE	0 - 25 POINTS	25 - 50 POINTS	50 - 75 POINTS	75 to 100 POINTS
Slope Performance	Excellent	Good	Fair	Poor
USMP Preliminary Score	V to W	W to X	X to Y	>Y
USMP Risk Score (Safety)	V to W	W to X	X to Y	>Y
Maintenance Complexity	Low	Moderate	High	Very High
Roadway Availability	Continuous Service	Rare Interruptions of Service	Short Interruptions Common	Routine or Major Interruptions
Slope Condition	Good	Adequate	Poor	Very Poor
Loss of Lifeline Route	TBD	TBD	TBD	TBD
Service Life State Class	1 to 2	2 to 3	3 to 4	5

A-4.2.3 Benefit Cost Index

As shown in Table 4-7 below, the Benefit Cost Index (BI) related the preceding 5-year cost of all accidents that were tied to activity at a given site, the projected 20-year maintenance cost at the site, service interruption costs, and mitigation/replacement costs. None of the rating categories were directly drawn from the USMP field ratings. Accident costs were to be drawn from NHTSA (Blincoe, et al., 2002) or AASHTO (AASHTO, 2010) standards for crashes resulting in fatality, injury, or property damage. This Benefit/Cost approach may be utilized for a corridor where a number of unstable slopes aggregate into a poor condition and/or a high risk highway segment where infrequent, slope-specific accidents may not be common, but are significantly more likely when considering a number of slopes together.

The BI was conceived of as a tool for use in maintenance budget development and long-term mitigation planning. Changes in the BI would indicate a potential change in the SLS class of a site. In large part because so many of the rating categories required unavailable data, this index remained the most conceptual of the performance indexes developed during Phase II.

Table 4-7: Benefit Cost Index Rating Categories

UNSTABLE SLOPES BENEFIT COST INDEX (BI)				
BENEFIT COST ATTRIBUTES	0 - 25 POINTS	25 - 50 POINTS	50 - 75 POINTS	75 to 100 POINTS
B/C Ratio	<0.25	0.25 to 0.50	0.50 to 0.75	> 0.75
Projected 20-year Maintenance Cost	TBD	TBD	TBD	TBD
Accident Costs **(quantitative $ amounts TBD)**	Minor Property Damage Low Cost	Major Property Damage Moderate Cost	Injury High Cost	Fatality Very High Cost
Segment Replacement Cost/Initial investment Cost Ratio	TBD	TBD	TBD	TBD
Service Interruptions				
Out of Direction Cost	TBD	TBD	TBD	TBD
Socio-economic Cost	TBD	TBD	TBD	TBD
Loss of Life Route	TBD	TBD	TBD	TBD

A-4.2.4 Corridor Slope Index

The individual Service Life State Index, Level of Service Index, and Benefit Cost Index would be summed and averaged to calculate the Corridor Slope Index (CSI). This CSI could be converted directly into the Service Life State Class. The CSI values for multiple slopes could be combined to develop an SLS class for the corridor as a whole, or the CSI could be used to identify worst-condition slopes within a corridor already targeted for significant mitigation work. This would make the CSI a useful investment analysis tool for broadly capturing the overall health of a given highway corridor.

As with the SLS classification itself, the main weakness of the Indexes was the requirement of data above and beyond that collected in the USMP site survey, some of which may have required significant coordination with multiple agencies to obtain. These three indices were ultimately integrated into the Condition State Index and/or the Condition State-Mitigation Cost estimates discussed in Sections 3 and 4. The thought process behind the CSI has not changed, but it is no longer given a specific name. Instead, it is presented graphically in the ArcGIS database, and projected corridor mitigation costs are based on the total of mitigation costs for each individual unstable slope in the corridor.

A-5. RETAINING WALL MANAGEMENT PROGRAM

During the latter part of Phase II, the USMP program was used as a model when developing asset management procedures for retaining walls. A rating system for evaluation and management of these geotechnical assets had not yet been developed by the end of Phase II, but some initial work was done on developing Service Life States and SLS Class – Maintenance Action correlations.

The Service Life State Class criteria are presented in Table 5-1. The SLS Classification developed for unstable slopes drew from the AIM classification system, because an unstable slope can be the source of multiple events, such as rockfall or debris deposits, that can repeatedly impact roadway performance. In contrast, retaining walls are generally not the source of recurring incidents, though failure of the wall as a whole would have a negative impact on corridor performance. To account for this difference, the retaining wall classification looked at the overall significance of the retaining wall to the transportation corridor, the age of the wall, and the general condition of wall components. Because retaining walls, unlike slopes, are designed with a lifespan of years in mind, the age of the wall was considered as a component of the rating process. The development of deterioration curves to more closely correlate wall age with SLS class was recommended.

Although the "equivalent age" of the wall could be estimated from its current performance and the proposed deterioration curves, ultimately determining the age of a retaining wall would require additional input from AKDOT&PF. Input from AKDOT&PF regardless would be required in developing deterioration curves that accurately match decay under the weathering conditions common in Alaska. When available, the equivalent age could be compared to the actual age and could determine that if the wall has over performed, under performed, or matched deterioration expectations.

Unlike mitigation work on unstable slopes, mitigation work on retaining walls is rarely feasible. Improvement from one SLS class to another should not be part of the regular maintenance plan, although routine maintenance of some walls may be able to extend the wall's lifespan indefinitely. The SLS class for retaining walls would be used to project maintenance costs, and to aid in transportation corridor budget allocation if a retaining wall needed to be replaced.

Table 5-1: Retaining Wall Service Life State Classification developed in Phase II

RETAINING WALLS SERVICE LIFE STATE CLASSIFICATION			
SLS Class**	Cracks/Distortion/Corrosion	Estimated Equivalent Age*	Wall Significance - Performance>
1	No Cracks, Alignment Distortion or evidence of Corrosion	New	Minor Significance or Excellent Performance
2	Small Cracks, Minor Distortion or Evidence of Incipient Corrosion	5 to 20 years old	Moderate Significance or Good Performance
3	Cracks, Distortion or Evidence of Corrosion	20 to 40 years old	Significant Wall with Moderate Performance
4	Significant Cracking or Distortion or Evidence of Internal Corrosion	40 to 100 years old	Moderate to Significant Wall with Substandard Performance
5	Unacceptable Wall Cracking and Distortion or Structurally Significant Corrosion - Failed Condition	More than 100 years old - End of Design Life Failed Condition	Any Wall with Unacceptable Performance - Failed Condition

* Actual age, performance, and physical evidence will be used to establish the equivalent age
**The assigned SLS class will coincide with the highest rated attribute in any of the three columns

Once the SLS class was determined, maintenance actions were outlined based on the calculated SLS class. The proposed activities were independent of wall type, and any individual maintenance action would need to be drafted specifically for the wall to be maintained or repaired. The table is founded on the assumption that routine maintenance and minor repairs may increase the life span of a retaining wall significantly beyond the original design life.

Table 5-2: Retaining Wall Maintenance Actions vs. SLS Class developed in Phase II

RETAINING WALLS MAINTENANCE ACTIONS*				
SLS Class	Wall Type			
	Gravity	Semi-Gravity	Cantilevered	Anchored
1	No action required			
2	Monitor and Maintain			
3	Repair Elements			
4	Replace Elements			
5	Replace Wall			

***No Action**: The wall is fully functioning; no action is required.
Monitor and Maintain: The wall requires regular monitoring and/or investigation to determine the nature of observed distresses and the action that may be required. Routine recurring maintenance is required to correct minor or low severity deficiencies in order to minimize or delay further deterioration.

Repair Elements: Minor to extensive repair of wall element(s) is required to prevent rapid element deterioration, loss of performance or failure.
Replace Elements: Replacement of specific wall element(s) or an entire section of wall is required in the near-term to preserve wall stability.
Replace Wall: Replacement of the entire structure is required to reestablish the intended function of the wall.

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Appendix B

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Appendix C

ROCK SLOPE FIELD RATING GUIDE

CONTENTS

C-1. INTRODUCTION

The Alaska Department of Transportation and Public Facilities developed the Unstable Slope Management Program (USMP) to inventory and assess rock slopes, unstable soil slopes, and embankments throughout the state.

Within the USMP, both rock and soil assets are scored in a categories that describe slope hazard and risk. As in the well-established Rockfall Hazard Rating System (RHRS), these category scores are exponential. Many of the rating categories, particularly those describing risk, are identical for rock slopes, unstable soil slopes, and embankments. However, the asset types have different hazard rating components and different database acceptance criteria. This field guide is focused on rating rock slopes. A companion field rating guide covers unstable soil slopes and embankment assets in detail.

Rock slopes are inherently unstable and nearly all produce rockfalls in differing amounts and at various times, though event frequency can vary from rarely to almost constantly. These events represent safety concerns that can cause accidents and disrupt mobility and local economies. They can also put inordinate demands on maintenance operations and budgets and create safety concerns for maintenance staff. All rock slopes that could potentially generate rockfall requiring maintenance attention, even on an infrequent basis, are categorized as either *Class A* or *Class B* slopes and entered into the rock slope asset database. However, only *Class A* slopes receive detailed hazard and risk ratings.

C-2. ROCK SLOPE ACCEPTANCE CRITERIA

All rock slopes inspected during the USMP field rating and inventorying process are visually evaluated and separated into three basic categories, Class A, B, or C. This initial classification is based on a combination of the professional judgement of the field rater and Maintenance input. *Class A* slope are entered into the database and receive a detailed rating. *Class B* slopes are entered into the database, but do not receive a detailed rating. *Class C* slopes are not entered into the database and do not receive a detailed rating.

Class A rock slopes are those that, based on slope and ditch geometry, are capable of producing rockfall that reaches the roadway, have a history of producing rockfalls that reach the roadway, present a regular maintenance issue, or could have impacts outside the ROW in a rockfall event. Photos of a sample of *Class A* rock slopes are shown in Figure 2-1, Figure 2-2, and Figure 2-3.

Class B rock slopes are those that, based on slope and ditch geometry, are unlikely to produce rocks that reach the roadway, but have an infrequent history of doing so or of requiring unscheduled action from maintenance. These sites are judged to be well performing slopes with regard to safety and maintenance for the next 10 to 20 years. *Class B* slopes are photographed and entered into the USMP database, but they do not receive the detailed hazard and risk ratings given to *Class A* sites. Photos of sample *Class B* rock slopes are shown in Figure 2-4 and Figure 2-5.

Although all rock slopes are inherently unstable, not all of them are capable of producing rockfalls that will affect the roadway, require maintenance attention, or cause impacts beyond agency ROW in the event of failure. Failures at *Class C* slopes are very unlikely to do any of these things. The research team determined that eliminating *Class C* slopes from the asset inventory provided maximum return on the asset inventory budget. Examples of *Class C* rock slopes include those that are cut much flatter than any adverse rock structure that is present (e.g. 2H:1V), those that are well vegetated, and those that have no history or evidence of rockfall activity that has ever impacted the roadway or caused maintenance concerns. *Class C* rock slopes are not entered into the database and do not received a detailed rating. Photos of sample Class C rock slopes are shown in Figure 2-6 and Figure 2-7.

Figure 2-1: Class A rock slope due to adverse geologic character, activity levels, and insufficient ditch catchment. Klondike Hwy MP 3.9.

Figure 2-2: Class A slope due to active rock deposition into the ditch, shoulder, and/or travel lane. Road curvature and moderate decision sight distance also contributes to the overall risk. Richardson Hwy MP 209.9.

Figure 2-3: Class A slope. The rockfall activity and unmitigated geologic structure require a detailed rating even though a relatively large ditch is present. Parks Highway, MP 344.9.

Figure 2-4: Class B rock slope. The slope does not pose a safety concern, but the consequence of rockfall events blocking the ditch and culverts, leading to sheet flow over the road, warrants inclusion into the database. Steese Hwy MP 86.5.

Figure 2-5: Class B rock slope. The slope is relatively well vegetated, indicating a low level of activity, but the ditch is narrow in comparison to the slope height. Parks Hwy MP 338.7.

Figure 2-6: Class C rock slope. Typically, such a tall and long cut would be an "A" or “B” slope, but the heavy vegetation indicates exceptionally low activity and high stability. Parks Hwy MP 339.6.

Figure 2-7: Class C rocky slope. Excluded from database due to stable configuration and short height. Either criteria would be sufficient. This could also be reasonably judged a soil slope due to the small rock size. Parks Hwy, approximately MP 340.

C-3. PERFORMING FIELD RATINGS

After determining if a rock slope is Class A, B, or C, the field inspector collects site information, photographs, and rating criteria as appropriate. This information is entered into the Excel rating sheet or a paper copy of the field rating sheet and the ArcGIS-based geodatabase. This subsection outlines the various elements used in generating rock slope ratings.

The detailed rating categories developed for rock slopes, unstable soil slopes and embankments, and retaining walls all use an exponential scoring system similar to what was developed as part of the Rockfall Hazard Rating System (RHRS) (Pierson, et al., 1993). Each category includes four subcategories that represent logical breaks that occur as part of a continuum in nature. Adaptations of the RHRS rating categories to meet the needs of Alaska are detailed in the following subsections.

The field forms and equations used in these ratings are also included at the end of this appendix.

C-3.1 Integration of External Data Sources

In order to make the field ratings as independent and robust as possible, ratings are based on site observations. Outside information is incorporated only where necessary. A complete rating should not depend on information entered later in the office, as that step could be neglected, unavailable, or inconsistently evaluated statewide. However, some information, such as average daily traffic or average annual rainfall, is necessary for realistic hazard and risk scores, and this information is not observable during a site visit. This external data required for rock slope ratings is generally obtained from AKDOT&PF and includes:

- Route map with CDS or Route ID numbers for all AKDOT&PF- affiliated roadways
- Location of all mileposts on the Alaskan Highway and National Highway Systems (AHS and NHS)
- A geospatially referenced route map showing all department roadways, which may be obtained from AKDOT&PF's Transportation Geographic Information Section (TGIS)
- The starting and ending mileposts (in tabular and database format) delineating maintenance station management responsibility for each roadway segment along highway routes
- AADT for all department roadways. To date, Year 2010 data has been used throughout the inventory process to maintain comparability between ratings conducted over multiple inventory seasons
- Average annual rainfall, in inches, presented as a geospatially referenced polygon file. This data was obtained from the USGS (United States Geological Survey, 1994) based on data compiled in 1994.

Some of this external data, like the AADT and CDS route numbers, are incorporated directly into the Excel rating workbook, where it can be automatically referenced by rating category equations. The geospatially referenced layers can be added to ArcGIS maps used on mobile devices in the field. Some additional information, such as maintenance frequency, is obtained by interview AKDOT&PF Maintenance and Operations personnel.

Interviews with maintenance station supervisors may be conducted before or after the majority of field assessment work is completed in a maintenance section. They should be conducted face-to-face, but may be conducted via phone when schedules did not allow for in-person meetings. These interviews help gauge unstable slope activity at various locations, and provide the opportunity to identify those sites that required the most frequent or extensive maintenance attention. Although informal and anecdotal, these interviews provide important external data, thus improving the quality of the data collected during inventory fieldwork.

C-3.2 Determination of Failure Type

At the beginning of the site assessment, the field rater must decide if the slope is a landslide or rockfall failure type. Within the rockfall category, two main failure types were identified: rockfall and rock avalanche, along with a set of rockfall movement types. Simple schematics of these failure types are shown in Figure 3-1.

The rockfall movement types include both classic failure mechanisms such as planar, wedge, and toppling failures, along with raveling/undermining rock slopes (i.e. talus slopes or slopes controlled by differential erosion) and block failure. Block failure is for sites where the rockfall mechanism is a complex interaction between multiple joints, and where the straightforward planar, wedge, or toppling models are insufficient to describe the failure.

Field personnel were encouraged to mark all failure types that were present at an unstable slope, even if this called for the selection of multiple movement types.

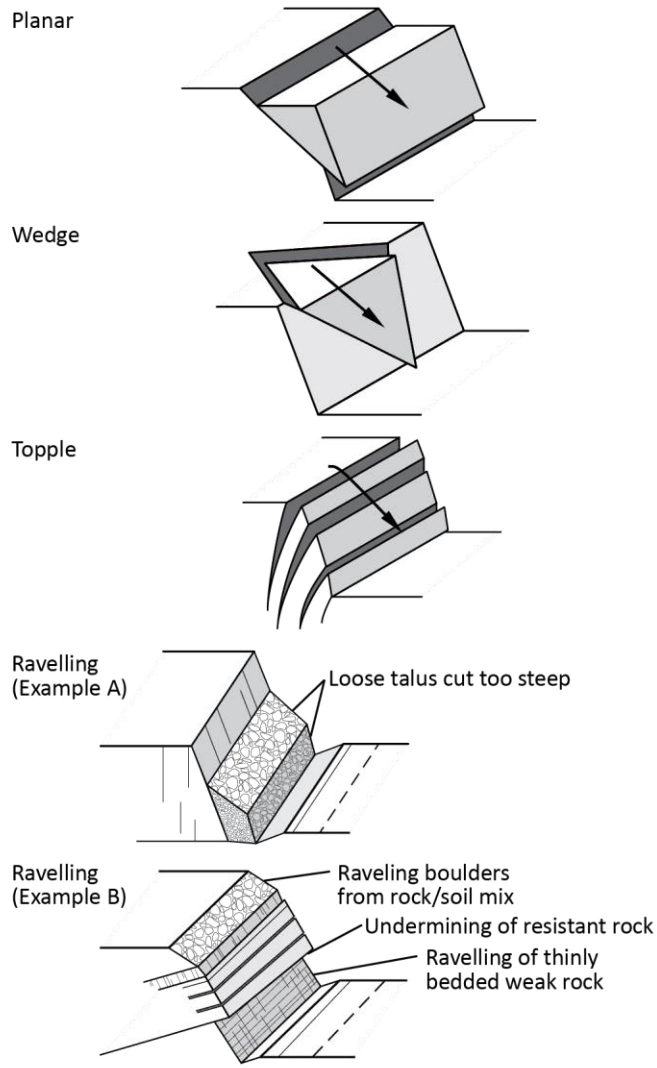

Figure 3-1: Sample Rockfall Failure Types.

C-3.3 Field Collection of Geospatial Location Data

During inventory work, field inspectors will ideally use a laptop or tablet loaded with the ArcGIS program to collect site locations and linear site limits, as measured along the highway centerline. The highway map layer is obtained through AKDOT&PF's Transportation GIS (TGIS) web portal. The Milepost data associated with the route maps is used as a reference to determine the slope's midpoint location along the highway centerline to the nearest hundredth of a mile. This information is used to calculate the site ID. A rock slope's site ID is based on the CDS Route assignment, CDS Milepoint of the wall midpoint, and the year initially entered into the inventory.

For example, a rock slope on the Haines Highway (CDS Route Number 298000), whose midpoint is located 0.22 miles north from the mile post 4 marker was rated in 2014. The milepost sign is located at CDS Milepoint 3.54 and therefore the rock slope midpoint is at Milepoint 3.76. The site ID would be 2980000003762014:

298000 000376 2014

CDS Route Milepoint Year

*Note that the Milepoint is in the form of #,###.##, with two decimal places and leading zeros leaving room for

In additional to determining the rock slope's mipdpoint location, linear extents are collected manually using either a handheld GPS unit or a GPS-enabled laptop or tablet. Site photographs should be taken and uploaded to the database.

C-4. FIELD RATING CATEGORIES

In the detailed rating, each rock slope is scored in eight Hazard Rating categories and nine Risk Rating categories. Collectively, the hazard ratings seek to quantify the likelihood that a rockfall event will occur at a site and affect the roadway, requiring some level of maintenance response. The risk ratings assess the consequences and inconvenience which an event will pose to the travelling public and the potential costs of this event, resulting from maintenance involvement, slope or roadway repairs, or right of way purchase should the failure extend beyond current ROW boundaries. The hazard and risk rating categories for rock slopes are summarized in Table 4-1.

Table 4-1: Rock slope asset detailing rating categories for the hazard and risk scores.

Hazard Rating Categories		**Risk Rating Categories**
Geologic Condition - Case 1	Structural Condition	Roadway Width
	Rock Friction	
Geologic Condition - Case 2	Structural Condition	Annual Average Daily Traffic (AADT)
	Difference in Erosion Rates	
Ditch Effectiveness		Average Annual Vehicle Risk (AVR)
Maintenance Frequency		Percent Decision Sight Distance
Rockfall History		Potential Impact on Traffic
Block Size/Event Volume		Right of Way Impacts
Slope Height		Environmental Impacts
Water on Slope	Annual Precipitation	Maintenance Complexity
	Slope Drainage	Event Cost

Each category is worth a maximum of 100 points. The Water on Slope category score is obtained by averaging the two sub-categories. The maximum possible Hazard Rating score for a rock slope is 800 points. The maximum possible Risk Rating score for an unstable slope is 900 points. Scores from the Risk Rating and Hazard Rating categories are summed to calculate the total USMP score for a site.

For those rating categories which are not directly scored through equations, the field rater estimates the most reasonable score based on professional judgement, input from maintenance personnel, and past performance history. The following subsections describe the various rating categories in detail.

C-4.1 Detailed Hazard Rating Categories – Rock Slopes

C-4.1.1 Geologic Condition

It is well documented that the stability of rock slopes is largely controlled by one of two geologic conditions. To reflect this, two categories, Case 1 and Case 2, are used to reflect the geologic differences in a rock slope that can lead to rockfall. Case 1 is for rock slopes where joints, fractures, bedding planes, or other discontinuities are the dominant structural features that control rockfall activity. Case 2 is for slopes where differential erosion within the rock slope face or oversteepening is the dominant condition that leads to rockfall events.

The case that best fits the slope should be used for the rating. If both situations are present, and it is unclear to the rater which dominates rockfall activity, both are scored, but only the worst case (highest score) is used for the final USMP rating.

4.1.1.1 Case 1

Rockfall from Case 1 slopes occurs as a result of movement along discontinuities. The word "joint" as applied here, represents all possible types of discontinuities, including bedding planes, foliations, fractures, and faults. The term "continuous" refers to joints that are greater than 10 feet in length, which enable the release of larger blocks during failure events. The term "adverse” applies not only to the joint's spatial orientation within the slope, but also to such things as rock friction angle, joint filling, and the effects of water, if present.

4.1.1.1.1 Case 1 - Structural Condition

Jointed rock is much more prone to rockfall than is massive rock. Movement occurs along these joints, where the resistance to movement is significantly less than through intact rock. When the joints are orientated adversely to the slope, the potential for rockfall is greater. Adverse joints are those that singularly or in combination with other joints form planar, circular, block, wedge, or toppling failures. Except for toppling failures, the joints typically dip out of the slope. Table 4-2 presents category narratives.

Table 4-2: Detailed Rock Slope Hazard Rating – Case 1 Structural Condition Category Narratives

3 points	<u>Discontinuous joints with favorable orientations.</u> Slope contains jointed rock with no adversely oriented joints.
9 points	<u>Discontinuous joints with random (both favorable and unfavorable) orientations.</u> Slope contains randomly oriented joints creating a variable pattern. The slope is likely to have some scattered blocks with adversely oriented joints, but no dominant adverse pattern is present.
27 points	<u>Discontinuous joints with adverse orientations.</u> Rock slope exhibits a prominent joint pattern with an adverse orientation, but these features have less than 10 feet of continuous length.
81 points	<u>Continuous joints with adverse orientations.</u> Rock slope exhibits a dominant joint pattern with an adverse orientation and a length greater than 10 feet.

4.1.1.1.2 Case 1 - Rock Friction

The potential for rockfall by movement along discontinuities is controlled by the condition of the joints. The condition of the joints is described in terms of micro and macro roughness.

This parameter directly affects the potential for one block to move relative to another. Friction along a joint, bedding plane or other discontinuity is governed by the macro and micro roughness of the surfaces. Macro roughness is the degree of undulation of the joint relative to the direction of possible movement. Micro roughness is the texture of the joint surface. On slopes where the joints contain hydrothermally altered or weathered material, previous movement has caused slickensides or fault gouge to form, or the joints are open or filled with water, the rockfall potential is much greater. Category narratives are presented in Table 4-3.

Table 4-3: Detailed Rock Slope Hazard Rating – Case 1 Rock Friction Category Narratives

3 points	Rough, Irregular. The joint surface is rough and the joint planes are irregular enough to cause interlocking.
9 points	Undulating. Joint surfaces are macro and micro rough, but without interlocking ability.
27 points	Planar. Macro smooth and micro rough joint surfaces. Friction is derived strictly from the roughness of the joint surface.
81 points	Clay Infilling, Open, or Slickensides. Low friction materials separate the rock surfaces, negating any micro or macro roughness of the joint surfaces. Slickensided joints also have a lower friction angle and are rated in this category.

4.1.1.2 Case 2

This case is used for slopes where differential erosion or oversteepening is the dominant condition leading to rockfall. Erosion features include oversteepened slopes, unsupported rock units (overhangs), or exposed resistant rocks on a slope, all of which may eventually lead to a rockfall event.

4.1.1.2.1 Case 2 - Structural Condition

Rockfall can be caused either by erosion that leads to a loss of support locally or throughout a slope. The types of slopes that may be susceptible to this condition are: layered units (those containing more easily erodible rock layers that undermine the more durable rock as erosion takes place); oversteepened talus slopes; highly variable units, such as conglomerates and mudflows that can weather differentially, allowing resistant rocks and blocks to fail; and rocky soil slopes where rocks fall out as the soil matrix material erodes. Table 4-4 contains category narratives.

Table 4-4: Detailed Rock Slope Hazard Rating – Case 2 Structural Category Narratives

3 points	Few Differential Erosion Features. Minor differential erosion features that are not distributed throughout the slope.
9 points	Occasional Differential Erosion Features. Minor differential erosion features that are widely distributed throughout the slope.
27 points	Many Differential Erosion Features. Differential erosion features that are large and numerous throughout the slope.
81 points	Major Differential Erosion Features. Severe cases such as dangerous erosion-created overhangs, significantly oversteepened soil and rock slopes or talus slopes.

4.1.1.2.2 Case 2 - Differential Erosion Rate

The materials that comprise a slope can have markedly different characteristics that control how rapidly weathering and erosion occur within the different materials exposed in the rock slope. As erosion progresses, resulting in portions of the slope becoming unsupported and the likelihood of a rockfall event increases.

The rate of erosion on a Case Two slope directly relates to the potential for a future rockfall event. As erosion progresses, unsupported or oversteepened slope conditions develop. The impact of the common physical and chemical erosion processes and the effects of man's actions (such as over excavating and steepening the roadside ditch) should be considered. The degree of hazard caused by erosion and, thus, the score given in this category should reflect the rate at which erosion is occurring; the size of rocks, blocks, or units being exposed; and the frequency with which events occur; and the likely amount of material released during an event. Category narratives are presented in Table 4-5.

Table 4-5: Detailed Rock Slope Hazard Rating – Case 2 Differential Erosion Rate Category Narratives

3 points	Small Difference. Erosion features take many years to develop. Slopes that are near equilibrium with their environment are covered by this category.
9 points	Moderate Difference. The difference in erosion rates allows erosion features to develop over a period of a few years.
27 points	Large Difference. The difference in erosion rates allows noticeable changes in the slope to develop annually.
81 points	Extreme Difference. The difference in erosion rates allows rapid and continuous development of erosional features.

C-4.1.2 Ditch Effectiveness

his is one of the two categories used to determine rock slope Condition State.

The effectiveness of a rock slope catchment ditch is measured by its ability to restrict falling rock from reaching the roadway. Many factors must be considered in evaluating this category and the reliability of the result depends heavily on the rater's experience. Ditch Effectiveness is therefore a subjective category. See Figure 4-1 for a graphic diagram of ditch effectiveness for guidance and Table 4-6 for category narratives.

The risk associated with a particular rock slope section is dependent on how well the ditch captures rockfall and restricts it from entering the roadway. Whenever the amount of rockfall debris reaching the roadway is small, regardless of how large the rockfall event is, the danger to the public is lower and the category score assigned is also lower. Conversely, if rockfall events are rare occurrences but ditch containment is nonexistent, the resulting hazard is greater and a higher score is assigned to this category.

A wide fallout area does not necessarily guarantee that rockfall will be restricted from the highway. In estimating the ditch effectiveness, the rater should consider several factors, such as: 1) slope height and angle; 2) ditch width, depth and shape; 3) anticipated volume of rockfall per event; and 4) impact of slope irregularities (launch features) on falling rocks. Evaluating the effect of slope irregularities is especially important because they can completely negate the benefits anticipated for a certain sized fallout area. Maintenance personnel can provide valuable information on ditch performance.

Table 4-6: Detailed Rock Slope Hazard Rating – Ditch Effectiveness Category Narratives

3 points	Good Catchment. All or nearly all falling rocks are restricted from the roadway.
9 points	Moderate Catchment. Falling rocks occasionally reach the roadway.
27 points	Limited Catchment. Falling rocks frequently reach the roadway.
81 points	No Catchment. No roadside ditch or ditch is totally ineffective. All or nearly all falling rocks reach the road.

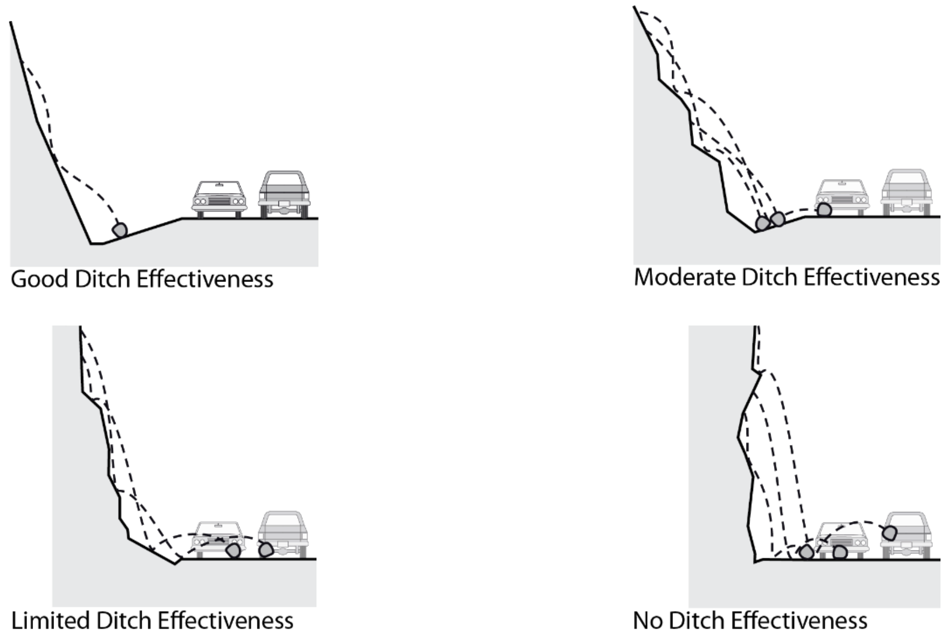

Figure 4-1: Ditch effectiveness explanatory diagram

C-4.1.3 Maintenance Frequency

The frequency of maintenance work due to rockfall is an indicator of both rockfall activity and long-term cost to the agency. When there is little to no maintenance and only scheduled ditch cleaning required, the risk to both maintenance staff and the travelling public is typically lower, as are the required maintenance expenditures. As rockfall activity increases, additional road patrols may be warranted, particularly after storm events, and rockfall clean-up activities and costs are higher. Table 4-7 presents category narratives.

Table 4-7: Detailed Rock Slope Hazard Rating – Maintenance Frequency Category Narratives

3 points	Scheduled ditch maintenance. Only routine, scheduled ditch maintenance is required on an infrequent (3-5 year) basis. Few rocks accumulate in the ditch between maintenance intervals.
9 points	Road Patrols conducted after storm events. Maintenance routinely inspects for rock adjacent to or on the roadway after extreme storm events. Unscheduled removal of rockfall debris may be required in addition to scheduled annual ditch cleaning.
27 points	Routine seasonal road patrols. Rockfall patrols occur regularly throughout a high rockfall activity season (fall, winter, spring). Unscheduled ditch cleaning is required seasonally and scheduled ditch cleaning is performed two or more times per year.
81 points	Routine year-round road patrols. Maintenance staff routinely patrols for rockfall on the roadway year-round. Ditch cleanout of rockfall debris is frequently required.

C-4.1.4 Rockfall History

This is one of the two categories used to determine rock slope Condition State.

Rockfall history directly represents the known rockfall activity at the rated site. This information is an important check on the potential for future rockfalls. If the total score assigned to a slope does not compare well with the rockfall history score, a review of the rating is advisable.

This information is best obtained from the maintenance person responsible for the slope. There may be no history available at newly constructed sites or where documentation practices are poor. The maintenance cost at a site may be the only information that reflects the rockfall activity. Category narratives are presented in Table 4-8.

Table 4-8: Detailed Rock Slope Hazard Rating – Rockfall History Category Narratives

3 points	Few Falls. Rockfalls occur only a few times a year (or less), or only during severe storms. This category is also used if no rockfall history data is available.
9 points	Occasional Falls. Rockfall occurs regularly. Rockfall can be expected several times per year and during most storms.
27 points	Many Falls. Typically, rockfall occurs frequently during a certain season, such as the winter or spring wet period, or the winter freeze/thaw, etc. This category is for sites where frequent rockfalls occur during a certain season but are not a significant problem during the rest of the year. This category may also be used where severe rockfall events have occurred.
81 points	Constant Falls. Rockfalls occur frequently throughout the year. This rating is also applied to sites where severe rockfall events are common.

C-4.1.5 Block Size/Event Volume

Larger blocks or volumes of falling rock produce more total kinetic energy and greater impact force than smaller events. In addition, larger events obstruct more of the ditch and roadway, reducing the possibility of safely avoiding the rock(s). In both cases, larger block or volume events create a greater hazard and, thus a higher score is assigned.

This measurement should be representative of the largest type of rockfall event that is likely to occur. If individual blocks are typical, block size should be used for scoring. If the rockfall event typically involves a number of blocks, volume per event should be used. The decision on which to use can be determined from the maintenance history or estimated from observed conditions when no history is available. This information will also be beneficial in determining remedial measures.

The category score is calculated according to Equation 4-1 or Equation 4-2, as appropriate, and sample scores are presented in Table 4-9. If the rater is uncertain, rate the category using both equations, and only use the higher score of the two in calculating the total USMP score.

Equation 4-1: Block Size Score

$$Block\ Size\ Score = 3^{x};\ where\ x = block\ size\ (ft); maximum\ score = 100$$

Equation 4-2: Volume Size Score

$$Volume\ Size\ Score = 3^x;\ where\ x = \left(\frac{yds^3}{3}\right); maximum\ score = 100$$

Table 4-9: Detailed Rock Slope Hazard Rating – Sample Calculated Scores from Block Size or Volume Size Equations

	Block Size	Volume Size
3 points	1 foot	3 cubic yards
9 points	2 feet	6 cubic yards
27 points	3 feet	9 cubic yards
81 points	4 feet	12 cubic yards

C-4.1.6 Slope Height

This category evaluates the hazard associated with the height of a rock slope. The slope height measurement is to the highest point from which rockfall is expected, as shown in Figure 2-22. If rockfall is generated from the natural slope above the cut slope, the measurement should include both the vertical cut height and the additional vertical height on the natural slope to the rockfall source. This category is directly measured in the field and scored using Equation 4-3. Sample category scores are presented in Table 4-10.

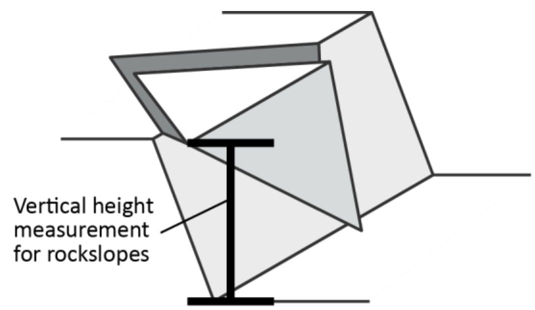

Figure 4-2: Slope height measurement

Equation 4-3: Slope Height Score

$$Score = 3^x;\ where\ x = \frac{slope\ height}{25}; maximum\ score = 100$$

Table 4-10: Detailed Rock Slope Hazard Rating – Sample Calculated Scores from Slope Height Equation

3 points	25 feet
9 points	50 feet
27 points	75 feet
81 points	100 feet

C-4.1.7 Water on Slope

Both total precipitation amounts and the nature of drainage on the rock slope contribute to the weathering and movement of rock materials and a reduction in overall slope stability. This category evaluates the amount of precipitation and free-draining capacity, because both of these qualities directly relate to conditions that cause rockfall. In addition, water flowing on a slope promotes erosion and, therefore the effectiveness of controlling flowing water factors into this category.

This category is scored as the average of both the rainfall amount score and the slope drainage score, as presented in Equation 4-4. By averaging the two water-related categories, it is possible to capture both the stress that high annual precipitation places even on a well-draining slope and the stress that poorly controlled drainage or the constant presence of water on a slope causes even in areas with low annual precipitation.

Equation 4-4: Water on Slope Score

$$Score = \frac{Rainfall\ Score + Slope\ Drainage\ Score}{2}$$

4.1.7.1 Annual Precipitation

The amount of annual rainfall is a rough indicator of the frequency of potential for high pore water pressures to accumulate. Areas with frequent, intense storms typically produce more unstable rock slopes. This subcategory is rated based on rainfall ranges, as shown in Table 4-11. During field ratings, this rainfall data iss obtained from a state precipitation geodatabase obtained from the USGS.

Table 4-11: Detailed Rock Slope Hazard Rating – Rainfall Amount Categories

3 points	0-10 inches of precipitation annually
9 points	10-30 inches of precipitation annually
27 points	30-60 inches of precipitation annually
81 points	60+ inches of precipitation annually

4.1.7.2 Slope Drainage

In conjunction with rainfall quantity, the ability of the slope materials to be free draining and the presence of springs (indicating a relatively constant water source) provide information on the ability of the slope to cope with rainfall and freeze-thaw events. This subcategory is based on subjective evaluations. Category narratives are presented in Table 4-12.

Note that rating this category at different times of the year may produce different results as creeks and springs can dry up during late summer months. For guidance in field evaluation, see Figure 4-3.

Table 4-12: Detailed Rock Slope Hazard Rating – Slope Drainage Category Narratives

3 points	Well Drained. Slope appears dry or well drained; surface runoff well controlled; slope is dry within hours after rain events.
9 points	Moderately Well Drained. Water is intermittently on slope; moderately well drained; surface runoff moderately controlled; slope is dry within days after rain events.
27 points	Moderately Poorly Drained. Water usually on slope; poorly drained; surface runoff poorly controlled; slope is still wet a week or two following rain events, but may dry during prolonged dry spells.
81 points	Poorly Drained. Water always on slope; very poorly drained; or surface water runoff control not present.

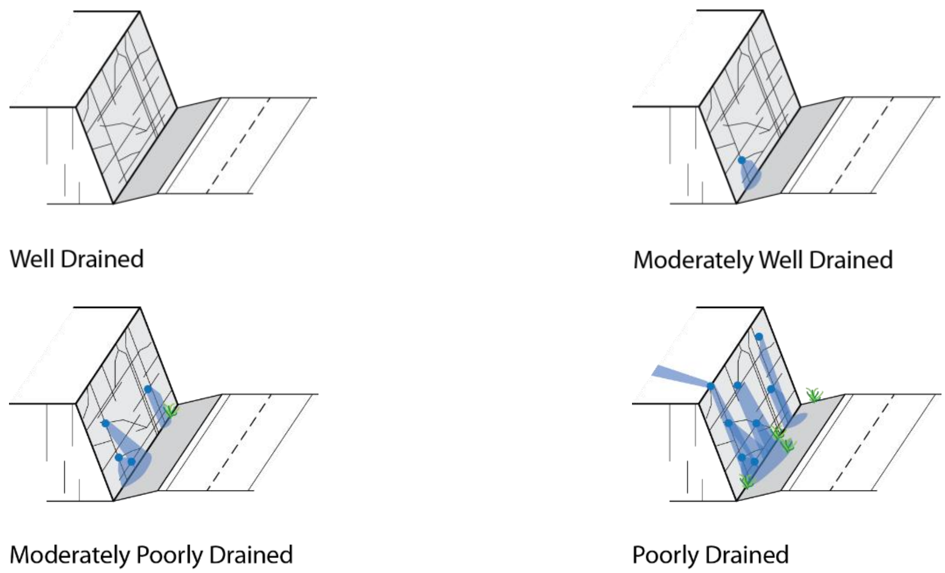

Figure 4-3: Simple schematic figure of the various slope drainage rating categories.

C-4.2 Detailed Risk Rating Categories – Rock Slopes

Detailed Risk Rating categories in the Unstable Slope Management Program are the same for both rock slope and unstable soil slope/embankment assets.

C-4.2.1 Roadway Width

If a driver notices rocks or other debris on the road surface, it is possible for the driver to react and take evasive action to avoid them. The more room there is for this maneuver, the greater the likelihood that the driver will able to avoid the unanticipated hazard without hitting another roadside hazard or oncoming vehicle. The roadway width category score represents the available maneuvering room for the roadway.

The roadway width is measured perpendicular to the highway centerline. If roadway width is not constant, then the minimum width throughout the slope section is used. During development of rating categories, it was difficult to get uniform estimates among different raters as to what portion of an unpaved shoulder can safely be used as a maneuverable side slope. For this reason, none of the unpaved shoulder adjacent to the roadway is included in the width measurement. On divided roadways, only that portion of the roadway available to the driver is measured.

This category score is calculated from the actual roadway measurements according to Equation 4-5. Sample calculated scores are presented in Table 4-13.

Equation 4-5: Roadway Width Score

$$Score = 3^x;\ where\ x = \frac{52 - Roadway\ Width\ (feet)}{8};maximum\ score = 100$$

Table 4-13: Detailed Rock Slope Risk Rating – Sample Calculated Scores from Roadway Width Equation

3 points	44 feet
9 points	36 feet
27 points	28 feet
81 points	20 feet

C-4.2.2 Annual Average Daily Traffic (AADT)

The AADT of a route indicates both its significance and the potential risk a rockfall or landslide event could pose to the public. This category score is calculated from the actual agency derived traffic counts provided by AKDOT&PF, according to Equation 4-6. Sample scores are presented in Table 4-14.

Equation 4-6: Annual Average Daily Traffic Score

$$Score = 3^x;\ where\ x = \sqrt{\frac{AADT}{500}};maximum\ score = 100$$

Table 4-14: Detailed Rock Slope Risk Rating – Sample Calculated Scores from AADT Equation

3 points	500
9 points	2,000
27 points	4,500
81 points	8,000

C-4.2.3 Average Vehicle Risk (AVR)

The Average Vehicle Risk (AVR) category assesses the risk posed by an unstable slope as a function of the percentage of time a vehicle is actually present within the impacted section. That percentage is obtained as part of Equation 4-7 and incorporates the slope length, average annual daily traffic (AADT), and the posted speed limit. In other words, this equation describes how many vehicles are within the potential impact zone of an unstable slope section at any one time. A rating of 100% means that, on average, a vehicle is within the defined slope section 100% of the time. Where high ADT's or longer slope lengths exist, values greater than 100% may result, meaning that at any particular time, more than one vehicle is present within the measured section. The result approximates the likelihood of vehicles being present and the risk that a vehicle will be involved in a failure incident. Sample category scores are presented in Table 4-15.

Equation 4-7: Average Vehicle Risk Score

$$Score = 3^x;\ where\ x = \frac{\left(\frac{\frac{AADT}{24} \times slope\ length\ (miles) \times\ 100}{posted\ speed\ limit}\right)}{25};maximum\ score = 100$$

Table 4-15: Detailed Rock Slope Risk Rating – Sample Calculated Scores from Average Vehicle Risk Equation

3 points	Vehicle within unstable slope section 25% of the time
9 points	Vehicle within unstable slope section 50% of the time
27 points	Vehicle within unstable slope section 75% of the time
81 points	Vehicle within unstable slope section 100% of the time

C-4.2.4 Percent Decision Sight Distance (PDSD)

The Percent Decision Sight Distance (PDSD) category describes the available sight distance as a percentage of the low design sight distance prescribed under AASHTO standards. Sight distance is the shortest distance that debris in the road would be continuously visible to a driver either approaching or within an unstable slope section. Decision sight distance (DSD) is the distance required by a driver to perceive and react to an unanticipated problem and then to bring his vehicle to a stop. The required DSD increases with increased vehicle speed and this distance is critical when obstacles in the road surface are difficult to see, or when unexpected or unusual maneuvers are required. Decision sight distances for typical posted speeds are presented in Table 4-16 below.

Table 4-16: AASHTO Recommended Minimum Decision Sight Distance for selected speed limits

Posted Speed Limit (mph)	AASHTO Recommended Minimum Decision Sight Distance (ft)
25	375
30	450
35	525
40	600
45	675
50	750
55	875
60	1,000
65	1,050

Sight distance can change appreciably throughout a roadway section. Horizontal and vertical highway curves, along with obstructions such as rock outcrops, roadside vegetation, guardrails, etc. can severely limit a driver's ability to notice and react to a hazardous road condition. In calculating this category score, the sight distance is determined in both travel directions, and the most restricted sight distance is used. Both horizontal and vertical sight distances are evaluated.

The measurement, generally made with a roller tape or laser range finder, is the distance required for a six-inch object positioned on the fogline (or on the edge of pavement if there is no fogline) to disappear from view at an eye height of 3.5 feet above the road surface. The posted speed limit throughout the rockfall section is used because unstable slopes are often located within highway curves, where the posted speed limit is lower than the highway design speed.

The category score is calculated from the direct measurements described above using Equation 4-8. Sample scores are presented in Table 4-17.

Equation 4-8: Decision Sight Distance Score

$$Score = 3^x;\ where\ x = \frac{120 - \left(\frac{Measured\ Minimum\ Sight\ Distance}{AASHTO\ Recommended\ Decision\ Sight\ Distance} \times\ 100\right)}{20};$$

$$maximum\ score = 100$$

Table 4-17: Detailed Rock Slope Risk Rating – Sample Calculated Scores from Decision Sight Distance Equation

3 points	Adequate, 100% of low design value
9 points	Moderate, 80% of low design value
27 points	Limited, 60% of low design value
81 points	Very Limited, 40% of low design value

C-4.2.5 Potential Impact on Traffic

The overall transportation system impacts due to a rockfall or landslide event can be minimized if a detour around the site is available or the effects on the system are minimal. Conversely, system performance is significantly degraded if a long detour is required or no detour is available. The scoring should take into account a *probable* worst case scenario, the unstable slope history, and geologic conditions when judging the impacts on traffic. Category narratives are presented in Table 4-18, below.

Table 4-18: Detailed Rock Slope Risk Rating – Impact on Traffic Category Narratives

3 points	Traffic continues with minor delay. A wide shoulder is available for traffic diversion for moderately sized events; small rockfall events are contained in the ditch; alternate nearby roadways are available for detours.
9 points	One lane remains open, traffic control required. Traffic control for a lane closure is required for maintenance or clean-up. Clean-up and related traffic control takes 1 to 3 days. Delays are less than 15 minutes.
27 points	All lanes are blocked, detour less than 100 miles or less than 1 day closure. A full closure for one day or less is required. Detours will divert traffic 100 miles or less.
81 points	All lanes are blocked, no road-based detour less than 100 miles is available, road closure for more than 1 day required. If a full closure lasting longer than 3 days is required or major reconstruction is required with no detour available, then the category score is 100 points.

C-4.2.6 Right of Way Impacts

Adjacent land owners may be impacted by a slope crest retrogressing beyond property boundaries or, less often, by the deposition of rockfall debris on private property. If neighboring structures or transportation systems are potentially impacted by events, then the risk to the agency is significantly higher. Maps displaying agency ROW are helpful when performing evaluations, particularly in urban areas, and should be obtained from the agency or bureau when possible. If ROW maps are not available, the field rater should use her best judgement based on observed site characteristics. Category narratives are presented in

Table 4-19.

Table 4-19: Detailed Rock Slope Risk Rating – Right of Way Impacts Category Narratives

3 points	No ROW implications. Impacts very unlikely to extend beyond agency ROW.
9 points	Minor effects beyond ROW. Unstable slope impacting non-agency ROW, but adjoining landowner indifferent to minor impacts. Minor impacts include overburden slumping, minimal drainage changes, or cut slope crest retrogression.
27 points	Private property, no structures affected. Unstable slope actively retrogressing into private property but not impacting or likely to threaten structures. ROW acquisition of private lands may be required.
81 points	Structures, roads, RR, utilities, or parks affected. Unstable slope actively threatens adjacent structures, transportation systems, or Federal or State Park lands. In this score range, ROW acquisition of private lands would likely be required. Coordination of mitigation approaches with outside agency landowner(s) is likely required.

C-4.2.7 Environmental Impacts if Left Unattended

Continued activity of an unstable slope may eventually lead to environmental impacts if left unattended. These impacts can include culvert plugging, interference with fish passage, habitat impacts, etc. Due to the highly variable nature of potential environmental impacts, a basic yes/no approach is taken to rate this category. If impacts are anticipated, a future review by Department environmental staff may be required. Category narratives are presented in Table 4-20.

Table 4-20: Detailed Rock Slope Risk Rating – Environmental Impacts Category Narratives

0 points	No Environmental implications. No known sensitive environmental issues are present or anticipated if a *probable* worst case scenario occurs.
50 points	Environmental impacts anticipated. If a probable or historically common failure occurs or the slope retrogresses, environmental impacts are anticipated.

C-4.2.8 Maintenance Complexity

The complexity of the maintenance required following a failure event directly relates to the cost of maintenance interventions and the associated risks to the public and agency personnel during maintenance operations. Maintenance may be straightforward, such as cleaning debris off the road, or complex enough that specialized equipment or capabilities are required. In some cases, installation of rockfall mitigation measures, such as installing an attenuator fence or MSE wall, may be required. Category narratives are presented in Table 4-21.

Table 4-21: Detailed Rock Slope Risk Rating – Maintenance Complexity Category Narratives

3 points	Routine Effort Required. Maintenance can be accomplished with available state-owned equipment with only minor impacts to traffic flow.
9 points	Specialized Equipment Required. Maintenance requires mobilization of specialized equipment such as a backhoe, excavator, paver, guardrail post driver, etc.
27 points	Difficult Effort and/or Location. Maintenance requires specialized equipment brought in from a significant distance or requires assistance from an outside roadway contractor. May also require standard engineering efforts (subgrade design, asphalt mixes, etc.).
81 points	Complex or Dangerous Effort. Specialty contractor is required to perform maintenance (i.e., slope scaling or repairing a rockfall attenuator fence). More complex maintenance designs (i.e., rock bolts) requiring geotechnical design efforts; or difficult/dangerous access (rope access, spider hoe, etc.) is required.

C-4.2.9 Event Cost

The estimated or actual cost to perform maintenance or repair work following a *probable* worst case scenario or a historically bad failure should be considered. The costs are estimated based on comparable private-sector equipment rental and operator rates. If an extreme event requires outside assistance (planning, design, and/or construction), the cost should include both those outside costs and the agency contracting and management costs. Category narratives are presented in Table 4-22.

Table 4-22: Detailed Rock Slope Risk Rating – Event Costs Category Narratives

3 points	$10,000. Event maintenance efforts and costs involve only agency maintenance staff using existing equipment. No design work required.
9 points	$50,000. Event cost and response is more involved and may require input from agency engineering staff.
27 points	$100,000. Costs indicate extensive, multi-day efforts, likely input from engineering staff, and possibly specialized equipment rental.
81 points	$250,000. Costs include outside contractors and design services.

Alaska DOT&PF Rock Slope Rating Calculator

Fill in orange cells		Rated By	G. Washington
Ver. 1.00		Rating Date	1/1/2016

Site Information

Site ID

Region	NR	Community		**Rockfall Type**	
Highway Name	RICHARDSON HIGHW	Maint. District	Denali	Rock Avalanche	NO
CDS Route Number	191600	Maint. Station	Cantwell	Planar Failure	NO
Hwy MP	200	Common Name		Wedge Failure	YES
CDS Milepoint	243.3	B-Slope	NO	Toppling Failure	NO
Latitude	54.00000	Mitigation Present	NO	Raveling/Undermining	NO
Longitude	-145.00000	Site Rating Status	ACTIVE	Block Failure	YES
Comments	Test Site				

Character Count 9

Site Measurements

Slope Height (ft)		Roadway Width (ft)		Sight Distance (ft)	
Slope Length (ft)		Speed Limit (mph)		AASHTO DSD (ft)	#N/A
Block Size (ft)		Annual Precipitation (in)		*GIS Alaska Precipitation Map - http://arcg.is/1kmhCL*	
Event Volume (cy)		AADT (Count)		*GIS 2012/2013 AADT Map - http://arcg.is/1MnAI6W*	

Evaluation Result Summary

Condition Index	N/A	Total USMP Rating	#VALUE!	**Programmatic Improvement Cost to CS1**	
Condition State	1	Hazard Rating	N/A	*Note calculation is programmatic and does not reflect site-specific needs. Actual costs may differ significantly.*	SITE IS GOOD
Condition State Text	GOOD	Risk Rating	#N/A		

Slope Hazard Rating

			Highest of size or volume scores	1
			Slope Height Score	1
Case 1 Structure Score		*Discon. Fav, discon rand, discon adverse, cont. adverse*		
Case 1 Joint Friction Score		*Rough irreg, undulating, planar, clay filled/slicks*		
Case 2 Features Score		*Few features, Occ, Many, Major*		
Case 2 Diff Erosion Score		*Small diff, Mod, Large w/ fave, Large w/un fave*		
			Geologic Character Score (Highest sum of Case 1 or Case 2 Scores)	0
Ditch Effectiveness Score		*Good, Moderate, Limited, None*		
			Ditch Effectiveness Score	0
Maintenance Freq. Score		*Sched. ditch maint, patrols after storms, daily seasonal patrols, daily patrols*		
			Maintenance Frequency Score	0
Rockfall History Score		*Few, Occ, Many, Constant*		
			Rockfall History Score	0
Annual Precipitation Score	3			
Slope Drainage Score		*Dry or well drained, intermittent water, usually on slope, always on slope*		
			Water on Slope Score	3
			Hazard Subtotal	N/A

Slope Risk Rating

			Decision Sight Distance Score	#N/A
			Roadway Width Score	1263
			AADT Score	1
% Time Car Within Site	#DIV/0!			
			Average Vehicle Risk Score	#DIV/0!
Impact on Traffic Score		*Minor Delay, One Lane Open, 100 mi or 1 day closure, no detour or 3 days +*		
			Traffic Impacts Score	0
ROW Impacts Score		*None, minor, private prop-no structures, structures/roads/RR/util/parks*		
			Right of Way Impacts Score	0
Envir. Impacts Score		*Zero points if no environmental impacts are likely, 50 pts if some possible*		
			Environmental Impacts Score	0
Maint. Complexity Score		*Routine, Specialized equip, difficult effort/location, complex or dangerous*		
			Maintenance Complexity Score	0
Event Cost Score		*$10k, $50k, $100k, $250k in reasonable worst case*		
			Event Cost Score	0
			Risk Subtotal	#N/A

GIS Field Code	Field Name	Field Value
ISiteIDN	Site ID	
IRtDateN	Rating Date	1/1/2016
IRaterT	Rated By	G. Washington
ICDSRtNN	CDS Route Number	191600
IStatusT	Site Rating Status	ACTIVE
IRegionT	Region	NR
IHwyNamT	Highway Name	ARDSON HIGHWAY
ICmmntyT	Community	
IMntDstT	Maintenance District	Denali
IMntStnT	Maintenance Station	Cantwell
ICmnNamT	Common Name	0
IHwyMPN	Highway Milepost	200
ICDSMPN	CDS Milepoint	243.3
ILatN	Latitude	54.00000
ILongN	Longitude	-145.00000
IBSlopeT	B-Slope	NO
IMitgtnT	Mitigation Present	NO
ICmmntsT	Comments	Test Site
IAvlnchT	Rock Avalanche	NO
IPlanarT	Planar Failure	NO
IWedgeT	Wedge Failure	YES
IToppleT	Toppling Failure	NO
IRavelT	Raveling/Undermining Failure	NO
IBlockT	Block Failure	YES
MBlckSzN	Block Size	0
MEvntVlN	Event Volume	0
MSLengtN	Slope Length	0
MSHeigtN	Slope Height	0
ESAreaN	Estimated Slope Area	0
MRdWdthN	Roadway Width	0
DSpdLmtN	Speed Limit	0
DAADTN	AADT	0
MSghtDiN	Sight Distance	0
SCndtIxN	Condition Index	N/A
SCndtStN	Condition State Number	1
SCndtStT	Condition State Text	GOOD
SUSMPRtN	Total USMP Score	#VALUE!
SHazardN	Hazard Score	N/A
SRiskN	Risk Score	#N/A
EImpCstN	Estimated Improvement Cost	SITE IS GOOD
IGeoChT	Geologic Character	C2
SC1StrN	Case 1 Structure Score	0
SC1JtFrN	Case 1 Joint Friction Score	0
SC2FeatN	Case 2 Features Score	0
SC2DfErN	Case 2 Diff Erosion Rate Score	0
SGeoChN	Geologic Character Score	0
SDitchEN	Ditch Effectiveness Score	0
SMntFrqN	Maintenance Frequency Score	0
SRfHistN	Rockfall History Score	0
SBSzEVlN	Block Size/Event Volume Score	1
SSHeigtN	Slope Height Score	1
SPrecipN	Precipitation Score	3
SDrainN	Drainage Score	0
SWaterN	Water on Slope Score	3
SRdWdthN	Roadway Width Score	1263
SAADTN	AADT Score	1
SAVRN	AVR Score	#DIV/0!
SSghtDiN	Sight Distance Score	#N/A
STrfImpN	Traffic Impacts Score	0
SROWImpN	ROW Impacts Score	0
SEnviroN	Environmental Impacts Score	0
SMntCmpN	Maintenance Complexity Score	0
SEvntCsN	Event Cost Score	0

Field Values are populated from the "Site Rating Calculator" Sheet and are manually entered in the "Rock Slope Add New Site" AGOL Application or in the "Rock Slope - Edit Exisiting Data Form" AGOL Application. The GIS Field Code is referred to when editing field values for an exisiting site. The Field Name is referred to when filling out field values for a new site.

AKDOT&PF UNSTABLE SLOPE MANAGEMENT PROGRAM INVENTORY
SITE INFORMATION

Region NR CR SE **District**	**Borough**	**Date**	**Rater**

Maint. Station	**Common Name**	**Weather**
CDS Route Name	**CDS Number**	**Watch List** Y | N
Highway Milepost	**CDS Milepoint**	**Mitigation Present** Y | N
Latitude	**Longitude**	**Datum**

Failure Type	Rockfall | Rock Avalanche | 'B' Slope Landslide above roadway | Landslide below roadway | Landslide crossing roadway
Rockfall Movement Type	Planar Failure | Wedge Failure | Toppling Failure | Raveling/Undermining | Block Failure
Landslide Movement Type	Translational Slide | Rotational Slide | Debris Flow | Slump | Erosional Failure

Slope Height/Axial Length of Slide	**Length of Roadway Affected**	**Annual Rainfall**

Rockfall Block Size (ft)/Rockfall Volume per Event (yd^3)	**AADT**

Roadway/Trail Width	**Speed Limit**	**Sight Distance**

Comments / Photos

Site Sketch (if applicable)

PRELIMINARY RATING					
Category Rating	**3 (100)**	**9 (75)**	**27 (50)**	**81 (25 to 0)**	**Score**
Roadway Impacts	Entire paved surface unaffected	Travel lanes unaffected	One-half of roadway affected	Entire roadway affected	
Traffic Impacts	Normal two-way traffic with minor delays	Two-way traffic affected with some delay	One-half of roadway closed with significant traffic delays	Entire roadway blocked with significant delays	
Sight Distance	Good Sight Distance	Moderate Sight Distance	Poor Sight Distance	Very Limited Sight Distance	
Roadway Affected Frequency	Rarely; less than once every 3 years	Routinely; once a year	Often; 3-6 times a year, seasonal or weather controlled	Frequently; >6 times per year, events occur throughout the year	
Maintenance Action Required Frequency	Rarely; once every 3 to 5 years	Regularly; once every 1 to 3 years	Often; 1 to 3 times per year	Frequently; 4 or more times per year	
Volume or Size per Event (Rockfall) or Length of Roadway Affected (Landslide)	3 yd^3 or 1 ft (Rockfall) *or* 25 ft (Landslide)	6 yd^3 or 2 ft (Rockfall) *or* 100 ft (Landslide	9 yd^3 or 3 ft (Rockfall) *or* 225 ft (Landslide)	12 yd^3 or 4 ft (Rockfall) *or* 400 ft (Landslide)	
Potential for Roadway Affects	Little to none	Low	Moderate	High	
				PRELIMINARY RATING TOTAL	

SLOPE HAZARD RATING					
Category Rating	**3 (100)**	**9 (75)**	**27 (50)**	**81 (25 to 0)**	**Score**
Slope Height or Axial Length of Slide	25 ft	50 ft	75 ft	100 ft	CALC
Water on Slope – **Annual Rainfall**	1-10”	10-30”	30-60”	60”+	CALC
Water on Slope – **Drainage**	Slope appears dry or well drained; surface runoff well controlled	Intermittent water on slope; moderately well drained or surface water moderately well controlled	Water usually on slope; poorly drained or surface runoff poorly controlled	Water always on slope; very poorly drained or surface runoff control not present	
Select One Unstable Slope Type – **Landslides** – **Length of Roadway Affected**	25 ft	100 ft	225 ft	400 ft	CALC
Landslides – **Thaw Stability**	Unfrozen/Thaw Stable	Slightly Thaw Unstable	Moderately Thaw Unstable	Highly Thaw Unstable	
Landslides – **Roadway Impedance**	Shoulder only	Half Roadway	3/4 roadway	Full Roadway	
Landslides – **Maintenance Frequency**	Every 4 years	Every 2 years	Every year	Twice a year	
Landslides – **Roadway Displacement or Slide Deposit**	Visible Crack or slight deposit of material on road	1-inch offset or 2 inches of material on road	2-inch offset or 6 inches of material on road	4-inch offset or 12 inches of material on road	
Landslides – **Movement History**	Minor movement or sporadic creep	Up to 6 inches annual or steady annual creep	Up to 6 inches per event, more than two events per year	>1 ft displacement in hours (include all debris flows)	
Rockfall – **Ditch Effectiveness**	Good	Moderate	Limited	No Catchment	
Rockfall – **Maintenance Frequency**	Scheduled ditch maintenance	Road patrols after every storm event	Routine seasonal patrols	Routine year-round road patrols	
Rockfall – **Rockfall History**	Few Falls	Occasional Falls	Many Falls	Constant Falls	
Rockfall – **Block Size *or* Volume per Event**	1 ft *or* 3 yd^3	2 ft *or* 6 yd^3	3 ft *or* 9 yd^3	4 ft *or* 12 yd^3	
Rockfall – **Geologic Character** – **Case 1** – **Structural Condition**	Discontinuous Favorable	Discontinuous Random	Discontinuous Adverse	Continuous Adverse	
Rockfall – **Geologic Character** – **Case 1** – **Rock Friction**	Rough/Irregular	Undulating	Planar	Clay infilled/slickensided	
Rockfall – **Geologic Character** – **Case 2** – **Structural Condition**	Few differential erosion features	Occasional differential erosion features	Many differential erosion features	Major differential erosion features	
Rockfall – **Geologic Character** – **Case 2** – **Difference in Erosion Rates**	Small difference	Moderate difference	Large difference	Extreme difference	
				LANDSLIDE HAZARD TOTAL	
				ROCKFALL HAZARD TOTAL (Select greater score of Case 1 or Case 2)	

RISK RATING					
Category Rating	**3 (100)**	**9 (75)**	**27 (50)**	**81 (25 to 0)**	**Score**
Roadway Width	44 ft	36 ft	28 ft	20 ft	CALC
Annual Average Daily Traffic (AADT)	500	2,000	4,500	8,000	CALC
Average Vehicle Risk (AVR)	25% of the time	50% of the time	75% of the time	100% of the time	CALC
% Decision Sight Distance (PDSD)	Adequate, 100% of low design value	Moderate, 80% of low design value	Limited, 60% of low design value	Very Limited, 40% pf low design value	CALC
Impact on Traffic	Traffic continues with minor delay	One lane remains open, traffic control required	All lanes blocked, detour less than 100 miles or less than 1 day closure	All lanes blocked, no road based detour or closure longer than 3 days	
Right of Way Impacts	No R/W implications	Minor effects beyond R/W	Private property, no structures affected	Structures, roads, RR, utilities, or parks affected	
Environmental Impacts of Left Unattended	No environmental implications		Environmental impacts		
Maintenance Complexity	Routine Effort	Specialized Equipment	Difficult effort/location	Complex or dangerous effort	
Event Cost	$10k	$50k	$100k	$250k	
TOTAL RISK SCORE					
TOTAL USMP SCORE: LANDSLIDE | ROCKFALL					

For the directly measurable categories (marked with CALC), use the following formulas to calculate the exponent value (x) for the scoring formula $y = 3^x$.

Length of roadway affected exponent:

$$x = \sqrt{\frac{length\ (ft)\ of\ roadway\ affected}{25}}$$

Wall height exponent formula:

$$x = \frac{slope\ height\ or\ axial\ length\ of\ slide}{25}$$

Water on slope formula:

$$Score = \frac{Rainfall\ Score + Slope\ Drainage\ Score}{2}$$

Roadway width exponent formula:

$$x = \frac{52 - Road\ width\ (ft)}{8}$$

AADT exponent formula:

$$x = \sqrt{\frac{AADT}{500}};\ maximum\ category\ score = 100$$

Average vehicle risk exponent formula:

$$x = \frac{\left(\frac{\frac{ADT}{24} \times slope\ length\ (miles)\ \times 100}{posted\ speed\ limit}\right)}{25}$$

Percent decision sight exponent formula:

$$x = \frac{120 - \left(\frac{measured\ sight\ distance}{AASHTO\ decision\ sight\ distance} \times 100\right)}{20}$$

Appendix D

SOIL SLOPE AND EMBANKMENT FIELD RATING GUIDE

CONTENTS

D-1. INTRODUCTION

The Alaska Department of Transportation and Public Facilities developed the Unstable Slope Management Program (USMP) to inventory and assess rock slopes, unstable soil slopes, and embankments throughout the state. Unstable soil slopes in the USMP database include unstable soil cut slopes and embankments as well as sites that experience debris flows or river erosion. The phrase “unstable soil slopes” is frequently used to refer to all of these assets collectively.

Within the USMP, both rock and soil assets are scored in a categories that describe slope hazard and risk. As in the well-established Rockfall Hazard Rating System (RHRS), these category scores are exponential. Many of the rating categories, particularly those describing risk, are identical for rock slopes, unstable soil slopes, and embankments. However, the asset types have different hazard rating components and different database acceptance criteria. This field guide is focused on rating unstable soil slopes and embankments. A companion field rating guide covers rock slope assets in detail.

Unlike rock slopes, soil slopes cut or constructed to a stable angle can remain stable indefinitely, unless impacted by external threats, such as river erosion. This is true for both cut slopes and well-constructed earthen embankments. At the beginning of a site evaluation, inspectors determined if the unstable slope met the criteria for *Class A, B, or C*, which are described in greater detail in the following section. All unstable soil slopes and embankments that could potentially generate failures requiring maintenance attention, even on an infrequent basis, are categorized as either *Class A* or *Class B* slopes and entered into the unstable soil slope and embankment asset database. However, only *Class A* slopes receive a detailed rating. Stable soil slopes and embankments are *Class C* slopes. In order to keep the inventory fieldwork within reasonable bounds of time and budget, and hold the database to a reasonable size, *Class C* slopes are not entered into the USMP database.

D-2. UNSTABLE SOIL SLOPE AND EMBANKMENT ACCEPTANCE CRITERIA

All soil slopes and embankments inspected during the USMP field rating and inventorying process are visually evaluated and separated into three basic categories, Class A, B, or C. This initial classification is based on a combination of the professional judgement of the field rater and Maintenance input. *Class A* slope are entered into the database and receive a detailed rating. *Class B* slopes are entered into the database, but do not receive a detailed rating. *Class C* slopes are not entered into the database and do not receive a detailed rating.

Class A soil slopes exhibit signs of instability that could affect public safety, require regular maintenance action, or threaten the functionality of the surrounding infrastructure in the event of a failure. In addition to the classic unstable slope failures experienced by Departments of Transportations nationwide, many roadway segments in interior Alaska exhibit signs of settlement or instability due to freeze-thaw processes, commonly associated with thawing permafrost or frost susceptible embankment fill materials. Those segments that show clear signs of sunken or uneven grade, with or without evidence of patching or other maintenance activity, are treated as *Class A* soil slope sites. Photos of sample *Class A* unstable soil slopes and embankments are shown in Figure 2-1 through Figure 2-7.

Class B soil slopes are those that exhibit signs of minor instability but are relatively short (typically less than 10 feet tall) with a wide ditch, have required little or no unscheduled maintenance attention in the past, or that are deemed unlikely to require maintenance attention or threaten the functionality of the surrounding infrastructure in the future. Slopes that can be reasonably assumed to be threatened by future erosion were also included in the *Class B* category. Photos of sample *Class B* unstable soil slopes and embankments are shown in Figure 2-8 and Figure 2-9.

Class C soil slopes and embankments exhibit no signs of instability and/or would not affect the roadway in the event of failure. This category includes the vertical cuts up to 5 feet tall in loess deposits that cap some slopes in interior Alaska. Based on past performance, these steep loess soil cuts are often stable and were not added to the database unless they were very close to the roadway. Photos of sample *Class C* unstable soil slopes are shown in Figure 2-10, Figure 2-11, and Figure 2-12.

Debris flows were also determined to belong in the unstable soil slope category despite failure mechanisms and rates that differ considerably from typical slope instabilities. All debris flows that have the capacity to affect the roadway and/or require maintenance to maintain flow channels were classified as *Class A* slopes.

Slope instability caused by erosion of embankments and soil slopes due to river encroachment could ultimately undermine the road and is rated and inventoried accordingly. Erosion that is already affecting the roadway prism is rated as a *Class A* slope. River erosion that is not yet affecting the road prism but which will do so if conditions remain unchanged is rated as a *Class B* slope.

Figure 2-1: Class A soil slope. Slope height and active sloughing warrants a detailed rating. Richardson Hwy MP 328.7.

Figure 2-2: Class A soil slope. Slope is receding towards roadway due to piping around spring at base of slope. Sterling Hwy MP 153.3.

Figure 2-3: Class A soil embankment. Roadway surface exhibiting thaw-unstable settlement with an uneven pavement surface. Alaska Hwy MP 1361.9.

Figure 2-4: Class A soil embankment. Full width roadway patch, with roadway exhibiting wavy, uneven pavement surface associated with continuing thaw-unstable deformation. Elliott Hwy MP 66.4.

Figure 2-5: Class A slope. Debris flow with containment berms. Regular maintenance required to maintain road. Whistler Ck., Richardson Hwy MP 223.

Figure 2-6: Class A slope. Debris flow deposits cleared from roadway. Emergency maintenance frequently required to restore use of the roadway. Haines Hwy MP 19.5.

Figure 2-7: Class A slope. Alluvial material comprising the shoulder of roadway is actively being eroding by river action. Armor stone is visible in the distance along portions of the side slope. Richardson Hwy MP 226.

Figure 2-8: Class B soil slope. Short soil cut exhibiting thawing permafrost. Site poses minimal safety risks, but appears to require ongoing minor maintenance attention to maintain the roadside ditch. Steese Hwy MP 68.4.

Figure 2-9: Class B soil cut. Relatively small ditch and semi-active raveling/erosion will necessitate occasional ditch maintenance with a low possibility of a soil slump reaching the roadway. Elliott Hwy MP 64.3.

Figure 2-10: Class C soil slope: New soil cut is performing well and is not unstable at this time. Do not include in database unless instability develops. Parks Hwy MP 257.2

Figure 2-11: Class C soil slope: The soil cut is set back far from the roadway and not affecting structures beyond the ROW. Richardson Hwy MP 319.8.

Figure 2-12: Class C soil slope: This slope is performing well and does not show signs of instability. A mossy vegetative mat that has developed across the slope also indicates stability. Richardson Hwy MP 310.3.

D-3. PERFORMING FIELD RATINGS

After determining if a soil slope or embankment asset is Class A, B, or C, the field inspector collects site information, photographs, and rating criteria as appropriate. This information is entered into the Excel rating sheet or a paper copy of the field rating sheet and the ArcGIS-based geodatabase. This subsection outlines the various elements used in generating rock slope ratings.

The detailed rating categories developed for rock slopes, unstable soil slopes and embankments, and retaining walls all use an exponential scoring system similar to what was developed as part of the Rockfall Hazard Rating System (RHRS) (Pierson, et al., 1993). Each category includes four subcategories that represent logical breaks that occur as part of a continuum in nature. Adjustments made to the rating categories to meet the needs of Alaska are detailed in the following subsections.

The field forms and equations used in these ratings are also included at the end of this appendix.

D-3.1 Integration of External Data Sources

In order to make the field ratings as independent and robust as possible, ratings are based on site observations. Outside information is incorporated only where necessary. A complete rating should not depend on information entered later in the office, as that step could be neglected, unavailable, or inconsistently evaluated statewide. However, some information, such as average daily traffic or average annual rainfall, is necessary for realistic hazard and risk scores, and this information is not observable during a site visit. This external data required for unstable soil slope and embankment ratings is generally obtained from AKDOT&PF and includes:

- Route map with CDS or Route ID numbers for all AKDOT&PF- affiliated roadways
- Location of all mileposts on the Alaskan Highway and National Highway Systems (AHS and NHS)
- A geospatially referenced route map showing all department roadways, which may be obtained from AKDOT&PF's Transportation Geographic Information Section (TGIS)
- The starting and ending mileposts (in tabular and database format) delineating maintenance station management responsibility for each roadway segment along highway routes
- AADT for all department roadways. To date, Year 2010 data has been used throughout the inventory process to maintain comparability between ratings conducted over multiple inventory seasons
- Average annual rainfall, in inches, presented as a geospatially referenced polygon file. This data was obtained from the USGS (United States Geological Survey, 1994) based on data compiled in 1994.

Some of this external data, like the AADT and CDS route numbers, are incorporated directly into the Excel rating workbook, where it can be automatically referenced by rating category equations. The geospatially referenced layers can be added to ArcGIS maps used on mobile devices in the field. Some additional information, such as maintenance frequency, is obtained by interview AKDOT&PF Maintenance and Operations personnel.

Interviews with maintenance station supervisors may be conducted before or after the majority of field assessment work is completed in a maintenance section. They should be conducted face-to-face, but may be conducted via phone when schedules did not allow for in-person meetings. These interviews help gauge unstable slope activity at various locations, and provide the opportunity to identify those sites that required the most frequent or extensive maintenance attention. Although informal and anecdotal, these interviews provide important external data, thus improving the quality of the data collected during field work.

D-3.2 Determination of Failure Type

At the beginning of the site assessment, the field rater must decide if the slope is a landslide or rockfall failure type. Within the landslide category, three main failure types were identified based on the location of the instability relative to the roadway: above the roadway, below the roadway, and crossing the roadway. A basic set of landslide movement types was developed, consisting of translational slides, rotational slides, debris flows, slumps, and erosional failures. Simple schematics of these failure types are shown in Figure 3-1.

Translational slides are composed of intact bocks that move on a flat or gradually inclined discrete failure plane that is comprised of weaker soil than the surrounding geologic material. Rotational slides are typically deeper seated and form along a circular failure surface on steeper slopes. Debris flows are water-laden masses of soil, fragmented rock and other debris that move very quickly down mountainsides, typically in existing drainage channels. They are seasonal and much more likely to occur during rainy seasons and periods of snow melt runoff. Shallow slumps are common on transportation systems below the road surface, where the shoulder or outside lane is failing within the fill material. Shallow slumps impact performance of soil cut slopes in thaw-unstable frozen soils and where poor drainage exists.. Erosional failures comprise an approaching threat to the transportation system, where a river or culvert outfall is eroding the embankment or slope below the roadway.

Field personnel are encouraged to mark all failure types that were present at a site, even if this calls for the selection of multiple movement types.

D-3.3 Field Collection of Geospatial Location Data

During inventory work, field inspectors will ideally use a laptop or tablet loaded with the ArcGIS program to collect site locations and linear site limits, as measured along the highway centerline. The highway map layer is obtained through AKDOT&PF’s Transportation GIS (TGIS) web

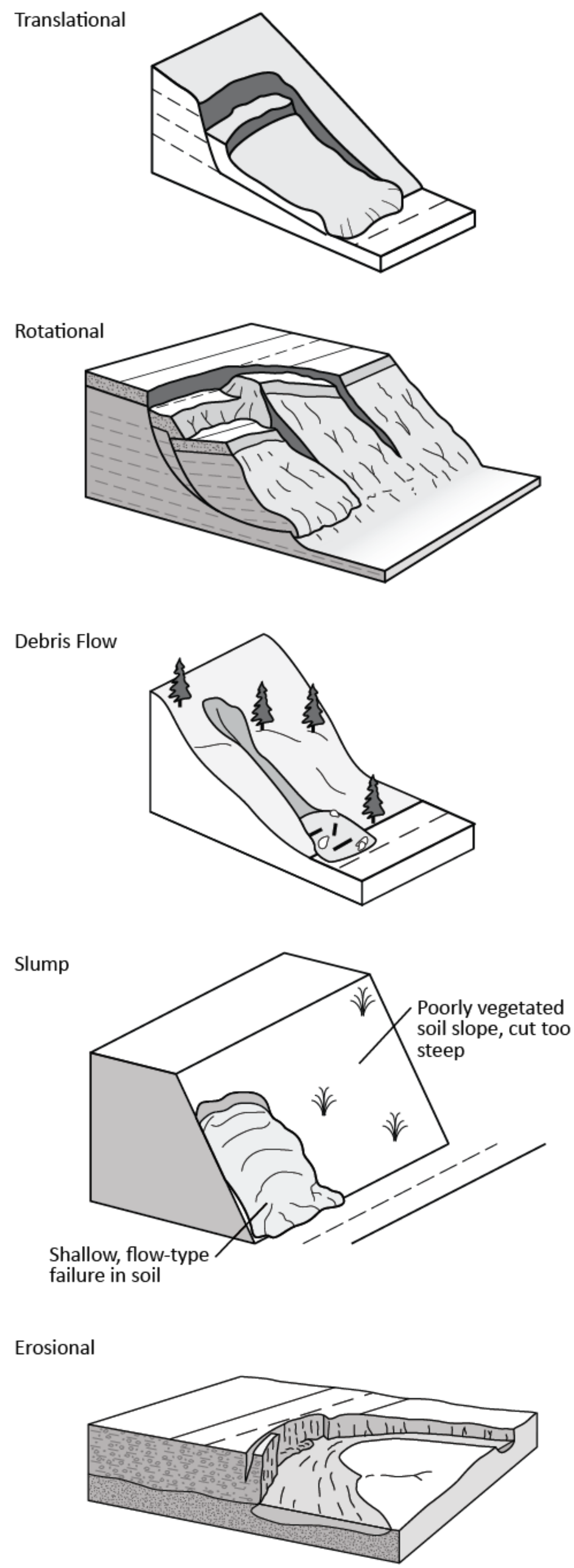

Figure 3-1: Sample Landslide Failure Types.

portal. The Milepost data associated with the route maps is used as a reference to determine the slope's midpoint location along the highway centerline to the nearest hundredth of a mile. This information is used to calculate the site ID. A rock slope's site ID is based on the CDS Route assignment, CDS Milepoint[1] of the wall midpoint, and the year initially entered into the inventory.

For example, a slope on the Haines Highway (CDS Route Number 298000), whose midpoint is located 0.22 miles north from the mile post 4 marker was rated in 2014. The milepost sign is located at CDS Milepoint 3.54 and therefore the slope midpoint is at Milepoint 3.76. The site ID would be 2980000003762014:

298000 000376 2014

CDS Route Milepoint Year

*Note that the Milepoint is in the form of #,###.##, with two decimal places and leading zeros leaving room for

In additional to determining the soil slope or embankment's mipdpoint location, linear extents are collected manually using either a handheld GPS unit or a GPS-enabled laptop or tablet. Site photographs should be taken and uploaded to the database.

[1] Note that the CDS Milepoints are based on linear distances from the designated beginning of the CDS Route, which frequently do not correspond to mile post 0. In some cases, such as the Alaska Highway, signed mile posts may differ by many miles from the CDS Milepoints.

D-4. FIELD RATING CATEGORIES

In the detailed rating, each unstable soil slope or embankment is scored in eight Hazard Rating categories and nine Risk Rating categories. Collectively, the hazard ratings seek to quantify the likelihood that an event will occur at a site and affect the roadway, requiring some level of maintenance response. The risk ratings assess the consequences and inconvenience which an event will pose to the travelling public and the potential costs of this event, resulting from maintenance involvement, slope or roadway repairs, or right of way purchase should the failure extend beyond current ROW boundaries. The hazard and risk rating categories for unstable soil slopes and embankments are summarized in Table 4-1.

Table 4-1: Unstable soil slope and embankment asset detailed rating categories for the hazard and risk scores.

<table>
<tr><th colspan="2">Hazard Rating Categories</th><th>Risk Rating Categories</th></tr>
<tr><td colspan="2">Length of Roadway Affected</td><td>Roadway Width</td></tr>
<tr><td colspan="2">Thaw Stability</td><td>Annual Average Daily Traffic (AADT)</td></tr>
<tr><td colspan="2">Roadway Impedance</td><td>Average Annual Vehicle Risk (AVR)</td></tr>
<tr><td colspan="2">Maintenance Frequency</td><td>Percent Decision Sight Distance</td></tr>
<tr><td colspan="2">Roadway Displacement or Slide Deposit</td><td>Potential Impact on Traffic</td></tr>
<tr><td colspan="2">Movement History</td><td>Right of Way Impacts</td></tr>
<tr><td colspan="2">Axial Length of Slide</td><td>Environmental Impacts</td></tr>
<tr><td rowspan="2">Water on Slope</td><td>Annual Precipitation</td><td>Maintenance Complexity</td></tr>
<tr><td>Slope Drainage</td><td>Event Cost</td></tr>
</table>

Each category is worth a maximum of 100 points. The Water on Slope category score is obtained by averaging the two sub-categories. The maximum possible Hazard Rating score for an unstable soil slope or embankment is 800 points. The maximum possible Risk Rating score for an unstable slope is 900 points. Scores from the Risk Rating and Hazard Rating categories are summed to calculate the total USMP score for a site.

For those rating categories which are not directly scored through equations, the field rater estimates the most reasonable score based on professional judgement, input from maintenance personnel, and past performance history. For those categories with multiple assessment options, it is incumbent on the field rater to choose the rating category that best captures observed conditions at the slope. The following subsections describe the various rating categories in detail.

D-4.1 Detailed Hazard Rating Categories – Unstable Soil Slopes and Embankments

D-4.1.1 Length of Affected Roadway

This category is one of the four used to determine unstable soil slope/embankment Condition State.

Longer segments of affected roadway expose the travelling public to higher relative hazard because it takes longer to pass through the slide area. This increases the opportunity for a vehicle to be affected by such things as debris on the roadway, surface irregularities or actual slide movements. To an agency, the length is also proportional to the maintenance efforts and costs associated with managing the slide. Typically, a greater length of effected roadway will require extended duration lane closures during maintenance or repair activities. This category score is directly calculated from field measurements using Equation 4-1. Sample category narratives are presented in Table 4-2.

Equation 4-1: Length of Roadway Affected Score for thaw stable slopes

$$Score = 3^x;\ where\ x = \sqrt{\frac{length\ (feet)\ of\ roadway\ affected}{25}};maximum\ score = 100$$

Table 4-2: Detailed Unstable Soil Slope and Embankment Hazard Rating – Length of Roadway Affected Sample Calculated Scores

3 points	25 feet
9 points	100 feet
27 points	225 feet
81 points	400 feet

D-4.1.2 Thaw Stability

Unlike Alaska, other state DOTs do not routinely contend with permafrost. In the northern part of the state, it is continuously present, while in roughly the southern 1/3 and coastal areas permafrost is discontinuous or absent. Although this phenomenon may have a minor impact on unstable rock slopes, some slopes have failed due to freeze-thaw cycles and thawing due to climatic warming. Permafrost plays such a large role in the performance of the Department's soil slope/embankment assets that a new rating category, Thaw Stability, was added to the detailed hazard ratings to assess the presence of thaw unstable materials in the slope and their likely impact.

Melting of thaw unstable soils may cause overlying road surfaces to become rough and wavy, while embankments founded on melting permafrost can become unstable. Thawing slopes above the road can also be unstable, creating a greater potential for debris to be deposited on the roadway. Depending on the gradation of the soil particles, soils containing frozen water can produce significant maintenance problems if the ice thaws. The magnitude and likelihood of related problems is higher for finer-grained soils that contain larger amounts of ice within the pore space or for materials containing segregated ice strata. Category narratives are presented in Table 4-3. R&M Consultants, which performed the majority of the soil slope ratings in permafrost-affected areas, confirmed the applicability of these rating criteria with Northern Region M&O personnel during fieldwork.

Table 4-3: Detailed Unstable Soil Slope and Embankment Hazard Rating – Thaw Stability Category Narratives

3 points	Unfrozen / Thaw Stable. Soil may be coarse- or fine-grained. No ice is visible with the naked eye but if present, it does not occupy space in excess of the original voids. These soils are usually thaw-stable. No thaw unstable slopes should be rated in this subcategory.
9 points	Slightly Thaw Unstable. Soil is coarse-grained. Ice occupies space equal to or in excess of the original voids. It is present as crystals or lenses visible with the naked eye. These soils may be thaw-unstable depending on soil density. Few thaw unstable slopes should be rated in this subcategory.
27 points	Moderately Thaw Unstable. Soil is fine-grained. Ice occupies space equal to or in excess of the original voids and is present as crystals or lenses visible with the naked eye. These soils are typically thaw-unstable. Most thaw unstable slopes are rated in this subcategory based on relative performance of the roadway.
81 points	Highly Thaw Unstable. Soil layers contain significant quantities of ice well in excess of the original void space. The ice is readily visible with the naked eye and is present as large lenses or as separate ice layers. These materials are highly thaw-unstable. Any embankment sections with characteristics indicating a likelihood or history for rapid failure or severe displacement due to the presence of thaw unstable materials should be rated in this subcategory.

D-4.1.3 Roadway Impedance

This category is one of the four used to determine unstable soil slope/embankment Condition State.

When a portion of roadway is lost or blocked due to slope or embankment activity, accidents can occur when a vehicle impacts slide debris, drives off a scarp, or attempts an emergency evasive maneuver where the driver goes off the road or into oncoming traffic. The hazard is related to the proportion of the roadway width affected.

In addition to damage from classic earth instabilities, descriptive text was added to this category to capture permafrost issues. Following input from maintenance and other AKDOT&PF personnel, we expanded this definition to capture the severity of the undulating nature of a permafrost-impacted slope by including analogs for both wavelength and amplitude, and resulting impacts on driver behavior, even in the absence of traffic control. The final category narratives are presented in Table 4-4.

Table 4-4: Detailed Unstable Soil Slope and Embankment Hazard Rating – Roadway Impedance Category Narratives

3 points	Shoulder only. The travel lanes are not affected by the landslide event, but the available paved surface is reduced. A detour or traffic control is typically not required except during maintenance activities. For thaw unstable slopes, normal highway speed and driving behavior is maintained and little effect to the inspection vehicle is felt while maintaining the speed limit.

9 points	Half Roadway. Events affect 50% of the travel lanes but adequate paved surface is available to maneuver around the event. A detour is typically not required but traffic control would be needed during maintenance/repair activities. For thaw unstable slopes, tire marks are observed and a notable vertical movement to the inspection vehicle is felt while traversing the section at the speed limit.
27 points	3/4 Roadway. Events affect 75% of the surface dedicated to travel lanes. Maneuvering actions may still be possible by using paved or unpaved shoulders, if available. A detour or complete vehicle stoppage may be required. For thaw unstable slopes, breaking or evasive maneuvering is required when travelling the speed limit.
81 points	Full Roadway. Events or deformation affect the entire road with no opportunity to maneuver around the event. A detour or halted traffic flow is required. For thaw unstable slopes, this subcategory is reserved for those sites that have already been marked by maintenance crews with warning signs, cones, or a temporary reduction of the speed limit.

D-4.1.4 Maintenance Frequency

Landslide maintenance work puts staff and equipment in or near the road, which may impede traffic flow or be hazardous to the public or to maintenance personnel. The more often maintenance activity is required at a site, the greater the hazards posed to the public and M&O staff, and the greater the overall maintenance cost. Category narratives are presented in Table 4-5.

Table 4-5: Detailed Unstable Soil Slope and Embankment Hazard Rating – Maintenance Frequency Category Narratives

3 points	Every 4 years. Events requiring maintenance intervention are relatively rare or nonrecurring and/or the repair activities can typically be completed in less than a few hours using standard equipment with minimal impacts to traffic flow.
9 points	Every 2 years. Maintenance intervention is required on a regular basis and/or the repair activities can usually be completed in less than a day using standard equipment. Traffic flow is reduced and flagging is required.
27 points	Every year. Maintenance action is routinely required and/or the repair activities require non-standard equipment or more than one day to complete; or the traffic flow is significantly impeded for more than a day and flagging is required.
81 points	Twice a year. Maintenance is required two or more times per year; or when a major event has occurred, response efforts are required over several days to restore traffic. This category also applies if an outside contractor was required to restore the highway.

D-4.1.5 Roadway Displacement or Slide Deposit

This category is one of the four used to determine unstable soil slope/embankment Condition State.

Unanticipated obstructions in a travel lane can result in unsafe driver maneuvers or loss of vehicle control. Larger obstructions increase the likelihood of an accident, and these obstructions require greater maintenance effort and cost more to repair. This category is scored based on site observations and input from maintenance personnel.

As in the Roadway Impedance category, narrative text was added to capture permafrost impacts. In addition to cracking or material deposits, raters include settlement of the roadway embankment due to the presence of thaw-unstable foundation materials, measured both in total inches of settlement and settlement over a range of embankment lengths. The final category narratives are presented in Table 4-6.

Table 4-6: Detailed Unstable Soil Slope and Embankment Hazard Rating – Roadway Displacement or Slide Deposit Category Narratives

3 points	<u>Visible crack, slight settlement, or slight deposit of material on road.</u> Slight pavement cracking or heaving, or a thin deposit of slide debris has occurred, but effects are small enough not to disrupt traffic flow or require evasive maneuvers. Scheduled roadway maintenance is required. Slight (0-6 inches) untreated pavement settlement is observed within the thaw-unstable embankment section.
9 points	<u>1 inch offset, or 2 inches of material on road surface, or moderate settlement.</u> A noticeable drop or heave in the pavement or a deposit of slide debris has occurred requiring lower speeds to traverse. Untreated pavement settlement is 6 to 12-inches over a 450-foot section. Maintenance attention may be required.
27 points	<u>2-inch offset, 6 inches of material on road, or significant settlement.</u> A large drop or heave in the pavement or a deposit of slide debris has occurred requiring significantly lower speeds to traverse and may elicit unsafe driver reactions. Untreated pavement settlement is 12 to 36-inches over a 450-foot long section.
81 points	<u>4-inch offset, 12 inches of material on road, or extreme settlement.</u> A major drop or heave in the pavement or deposit of slide debris has occurred that cannot be traversed. Unsafe driver reactions are likely and immediate maintenance attention is required to reestablish safe traffic flow. Untreated settlement is 24-inches or greater over a 300-foot or shorter section.

D-4.1.6 Movement History

This category is one of the four used to determine unstable soil slope/embankment Condition State.

The rate of slide movement per event and the frequency of events relate to the resulting public hazard and maintenance requirements. Higher rates of slope movement are more likely to create unanticipated roadway conditions that require highly reactive maneuvers and immediate unscheduled maintenance in order to preserve safe conditions on the transportation corridor. Category narratives are presented in Table 4-7.

Table 4-7: Detailed Unstable Soil Slope and Embankment Hazard Rating – Movement History Category Narratives

3 points	Minor movement, sporadic creep, or very slow settlement. The rate of movement is low and non-continuous. Pavement disturbance is minor on an annual basis and maintenance requirements are minimal and carried out as a scheduled activity. Settlement rate is very slow (inch-scale movement over 10 years).
9 points	Up to 6 inches annually, steady annual creep, or moderate settlement rate. The rate of movement is low but continuous. Roadway maintenance is routinely required to avoid road closures but maintenance action can generally be carried out on a scheduled basis. Settlement rate is slow to moderate (inches per 5 year scale) and steady.
27 points	Up to 6 inches per event, more than two events per year, or fast settlement. The rate of movement is moderately high. Events occur more than twice a year that require immediate and unscheduled maintenance, creating a persistent maintenance problem. Settlement rate is fast (inches per year) and may be steady or accelerating.
81 points	>1 ft displacement in hours (includes all debris flows) or rapid, continuous settlement. The rate of movement is high. Significant roadway disturbance develops quickly. Emergency unscheduled maintenance intervention is required to maintain traffic flow and correct unsafe conditions. Settlement is rapid and continuous (feet per month).

D-4.1.7 Axial Length of Slope

This category evaluates the hazard associated with the axial length of a landslide or debris flow. A longer slide contains a larger soil mass and is therefore more difficult to effectively mitigate. The slope axial length (slope distance) of an earth movement is the greatest distance from the head scarp/initiation point to the toe, as shown in Figure 4-1. This category is directly measured in the field and scored using Equation 4-2. Sample calculated scores are presented in Table 4-8.

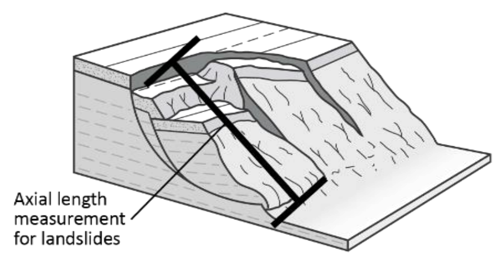

Figure 4-1: Axial length of slope measurement

Equation 4-2: Axial Length of Slope Score

$$Score = 3^x;\ where\ x = \frac{axial\ length}{25};maximum\ score = 100$$

Table 4-8: Detailed Unstable Soil Slope and Embankment Hazard Rating – Sample Calculated Scores from Slope Axial Length Equation

3 points	25 feet
9 points	50 feet
27 points	75 feet
81 points	100 feet

D-4.1.8 Water on Slope

Both total precipitation amounts and the nature of drainage on the soil/embankment slope contribute to the weathering and movement of rock materials and a reduction in overall slope stability. This category evaluates the amount of precipitation and free-draining capacity, because both of these qualities directly relate to conditions that cause slope failure. In addition, water flowing on a slope promotes erosion and, therefore the effectiveness of controlling flowing water factors into this category.

This category is scored as the average of both the rainfall amount score and the slope drainage score, as presented in Equation 4-3. By averaging the two water-related categories, it is possible to capture both the stress that high annual precipitation places even on a well-draining slope and the stress that poorly controlled drainage or the constant presence of water on a slope causes even in areas with low annual precipitation.

Equation 4-3: Water on Slope Score

$$Score = \frac{Rainfall\ Score + Slope\ Drainage\ Score}{2}$$

4.1.8.1 Annual Precipitation

The amount of annual rainfall is a rough indicator of the frequency of potential for high pore water pressures to accumulate. Areas with frequent, intense storms typically produce more unstable slopes. This subcategory is rated based on rainfall ranges, as shown in Table 4-9. During field ratings, this rainfall data was obtained from a state precipitation geodatabase built from USGS data.

Table 4-9: Detailed Unstable Soil Slope and Embankment Hazard Rating – Rainfall Amount Categories

3 points	0-10 inches of precipitation annually
9 points	10-30 inches of precipitation annually
27 points	30-60 inches of precipitation annually
81 points	60+ inches of precipitation annually

4.1.8.2 Slope Drainage

In conjunction with rainfall quantity, the ability of the slope materials to be free draining and the presence of springs (indicating a relatively constant water source) provide information on the ability of the slope to cope with rainfall and freeze-thaw events. This subcategory is based on subjective evaluations. Category narratives are presented in Table 4-10.

Note that rating this category at different times of the year may produce different results as creeks and springs can dry up during late summer months. For guidance in field evaluation, see Figure 4-2.

Table 4-10: Detailed Unstable Soil Slope and Embankment Hazard Rating – Slope Drainage Category Narratives

3 points	Well Drained. Slope appears dry or well drained; surface runoff well controlled; slope is dry within hours after rain events.
9 points	Moderately Well Drained. Water is intermittently on slope; moderately well drained; surface runoff moderately controlled; slope is dry within days after rain events.
27 points	Moderately Poorly Drained. Water usually on slope; poorly drained; surface runoff poorly controlled; slope is still wet a week or two following rain events, but may dry during prolonged dry spells.
81 points	Poorly Drained. Water always on slope; very poorly drained; or surface water runoff control not present.

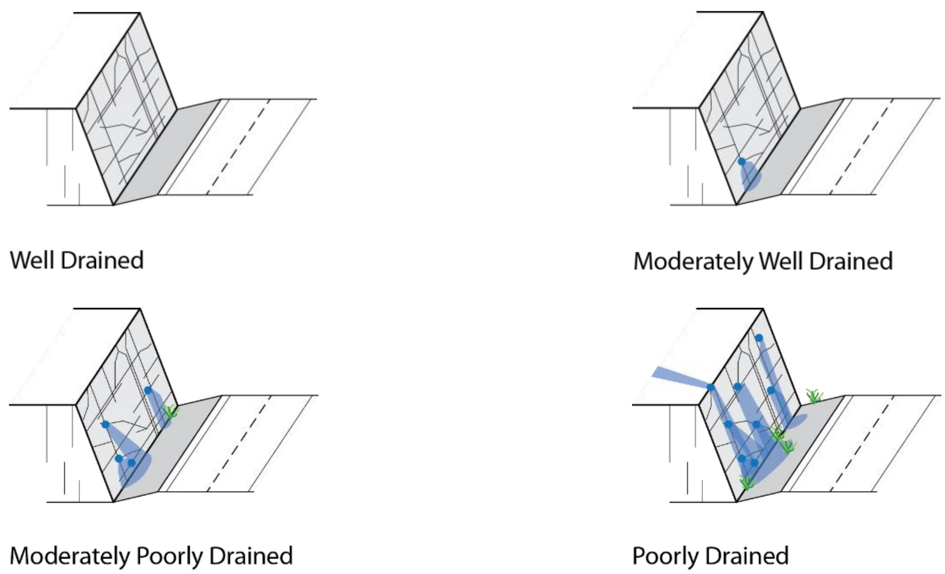

Figure 4-2: Simple schematic figure of the various slope drainage rating categories.

D-4.2 Detailed Risk Rating Categories – Unstable Soil Slopes & Embankments

Detailed Risk Rating categories in the Unstable Slope Management Program are the same for both rock slope and unstable soil slope/embankment assets.

D-4.2.1 Roadway Width

If a driver notices debris on the road surface, it is possible for the driver to react and take evasive action to avoid them. The more room there is for this maneuver, the greater the likelihood that the driver will able to avoid the unanticipated hazard without hitting another roadside hazard or oncoming vehicle. The roadway width category score represents the available maneuvering room for the roadway.

The roadway width is measured perpendicular to the highway centerline. If roadway width is not constant, then the minimum width throughout the slope section is used. During development of rating categories, it was difficult to get uniform estimates among different raters as to what portion of an unpaved shoulder can safely be used as a maneuverable side slope. For this reason, none of the unpaved shoulder adjacent to the roadway is included in the width measurement. On divided roadways, only that portion of the roadway available to the driver is measured.

This category score is calculated from the actual roadway measurements according to Equation 4-4. Sample calculated scores are presented in Table 4-11.

Equation 4-4: Roadway Width Score

$$Score = 3^{x};\ where\ x = \frac{52 - Roadway\ Width\ (feet)}{8}; maximum\ score = 100$$

Table 4-11: Detailed Unstable Soil Slope and Embankment Risk Rating – Sample Calculated Scores from Roadway Width Equation

3 points	44 feet
9 points	36 feet
27 points	28 feet
81 points	20 feet

D-4.2.2 Annual Average Daily Traffic (AADT)

The AADT of a route indicates both its significance and the potential risk a landslide event could pose to the public. This category score is calculated from the actual agency derived traffic counts provided by AKDOT&PF, according to Equation 4-5. Sample scores are presented in Table 4-12.

Equation 4-5: Annual Average Daily Traffic Score

$$Score = 3^{x};\ where\ x = \sqrt{\frac{AADT}{500}}; maximum\ score = 100$$

Table 4-12: Detailed Unstable Soil Slope and Embankment Risk Rating – Sample Calculated Scores from AADT Equation

3 points	500
9 points	2,000
27 points	4,500
81 points	8,000

D-4.2.3 Average Vehicle Risk (AVR)

The Average Vehicle Risk (AVR) category assesses the risk posed by an unstable slope as a function of the percentage of time a vehicle is actually present within the impacted section. That percentage is obtained as part of Equation 4-6 and incorporates the slope length, average annual daily traffic (AADT), and the posted speed limit. In other words, this equation describes how many vehicles are within the potential impact zone of an unstable slope section at any one time. A rating of 100% means that, on average, a vehicle is within the defined slope section 100% of the time. Where high ADT's or longer slope lengths exist, values greater than 100% may result, meaning that at any particular time, more than one vehicle is present within the measured section. The result approximates the likelihood of vehicles being present and the risk that a vehicle will be involved in a failure incident. Sample category scores are presented in Table 4-13.

Equation 4-6: Average Vehicle Risk Score

$$Score = 3^x;\ where\ x = \frac{\left(\frac{\frac{AADT}{24} \times slope\ length\ (miles) \times\ 100}{posted\ speed\ limit}\right)}{25};maximum\ score = 100$$

Table 4-13: Detailed Unstable Soil Slope and Embankment Risk Rating – Sample Calculated Scores from Average Vehicle Risk Equation

3 points	Vehicle within unstable slope section 25% of the time
9 points	Vehicle within unstable slope section 50% of the time
27 points	Vehicle within unstable slope section 75% of the time
81 points	Vehicle within unstable slope section 100% of the time

D-4.2.4 Percent Decision Sight Distance (PDSD)

The Percent Decision Sight Distance (PDSD) category describes the available sight distance as a percentage of the low design sight distance prescribed under AASHTO standards. Sight distance is the shortest distance that debris in the road would be continuously visible to a driver either approaching or within an unstable slope section. Decision sight distance (DSD) is the distance required by a driver to perceive and react to an unanticipated problem and then to bring his vehicle to a stop. The required DSD increases with increased vehicle speed and this distance is critical when obstacles in the road surface are difficult to see, or when unexpected or unusual maneuvers are required. Decision sight distances for typical posted speeds are presented in Table 4-14 below.

Table 4-14: AASHTO Recommended Minimum Decision Sight Distance for selected speed limits

Posted Speed Limit (mph)	AASHTO Recommended Minimum Decision Sight Distance (ft)
25	375
30	450
35	525
40	600
45	675
50	750
55	875
60	1,000
65	1,050

Sight distance can change appreciably throughout a roadway section. Horizontal and vertical highway curves, along with obstructions such as rock outcrops, roadside vegetation, guardrails, etc. can severely limit a driver's ability to notice and react to a hazardous road condition. In calculating this category score, the sight distance is determined in both travel directions, and the most restricted sight distance is used. Both horizontal and vertical sight distances are evaluated.

The measurement, generally made with a roller tape or laser range finder, is the distance required for a six-inch object positioned on the fogline (or on the edge of pavement if there is no fogline) to disappear from view at an eye height of 3.5 feet above the road surface. The posted speed limit throughout the rockfall section is used because unstable slopes are often located within highway curves, where the posted speed limit is lower than the highway design speed.

The category score is calculated from the direct measurements described above using Equation 4-7. Sample scores are presented in Table 4-15.

Equation 4-7: Decision Sight Distance Score

$$Score = 3^x;\ where\ x = \frac{120 - \left(\frac{Measured\ Minimum\ Sight\ Distance}{AASHTO\ Recommended\ Decision\ Sight\ Distance} \times\ 100\right)}{20};$$

$$maximum\ score = 100$$

Table 4-15: Detailed Unstable Soil Slope and Embankment Risk Rating – Sample Calculated Scores from Decision Sight Distance Equation

3 points	Adequate, 100% of low design value
9 points	Moderate, 80% of low design value
27 points	Limited, 60% of low design value
81 points	Very Limited, 40% of low design value

D-4.2.5 Potential Impact on Traffic

The overall transportation system impacts due to a landslide event can be minimized if a detour around the site is available or the effects on the system are minimal. Conversely, system performance is significantly degraded if a long detour is required or no detour is available. The scoring should take into account a *probable* worst case scenario, the unstable slope history, and geologic conditions when judging the impacts on traffic. Category narratives are presented in Table 4-16: Detailed Unstable Soil Slope and Embankment Risk Rating – Impact on Traffic Category Narratives.

Table 4-16: Detailed Unstable Soil Slope and Embankment Risk Rating – Impact on Traffic Category Narratives

3 points	Traffic continues with minor delay. A wide shoulder is available for traffic diversion for moderately sized events; small events are contained in the ditch; alternate nearby roadways are available for detours.
9 points	One lane remains open, traffic control required. Traffic control for a lane closure is required for maintenance or clean-up. Clean-up and related traffic control takes 1 to 3 days. Delays are less than 15 minutes.
27 points	All lanes are blocked, detour less than 100 miles or less than 1 day closure. A full closure for one day or less is required. Detours will divert traffic 100 miles or less.
81 points	All lanes are blocked, no road-based detour less than 100 miles is available, road closure for more than 1 day required. If a full closure lasting longer than 3 days is required or major reconstruction is required with no detour available, then the category score is 100 points.

D-4.2.6 Right of Way Impacts

Adjacent land owners may be impacted by a slope crest retrogressing beyond property boundaries or, less often, by the deposition of landslide debris on private property. If neighboring structures or transportation systems are potentially impacted by events, then the risk to the agency is significantly higher. Maps displaying agency ROW are helpful when performing evaluations, particularly in urban areas, and should be obtained from the agency or bureau when possible. Category narratives are presented in Table 4-17.

Table 4-17: Detailed Unstable Soil Slope and Embankment Risk Rating – Right of Way Impacts Category Narratives

3 points	No ROW implications. Impacts very unlikely to extend beyond agency ROW.
9 points	Minor effects beyond ROW. Unstable slope impacting non-agency ROW, but adjoining landowner indifferent to minor impacts. Minor impacts include overburden slumping, minimal drainage changes, or cut slope crest retrogression.
27 points	Private property, no structures affected. Unstable slope actively retrogressing into private property but not impacting or likely to threaten structures. ROW acquisition of private lands may be required.
81 points	Structures, roads, RR, utilities, or parks affected. Unstable slope actively threatens adjacent structures, transportation systems, or Federal or State Park lands. In this score range, ROW acquisition of private lands would likely be required. Coordination of mitigation approaches with outside agency landowner(s) is likely required.

D-4.2.7 Environmental Impacts if Left Unattended

Continued activity of an unstable slope may eventually lead to environmental impacts if left unattended. These impacts can include culvert plugging, interference with fish passage, habitat impacts, etc. Due to the highly variable nature of potential environmental impacts, a basic yes/no approach is taken to rate this category. If impacts are anticipated, a future review by Department environmental staff may be required. Category narratives are presented in Table 4-18.

Table 4-18: Detailed Unstable Soil Slope and Embankment Risk Rating – Environmental Impacts Category Narratives

0 points	No Environmental implications. No known sensitive environmental issues are present or anticipated if a *probable* worst case scenario occurs.
50 points	Environmental impacts anticipated. If a probable or historically common failure occurs or the slope retrogresses, environmental impacts are anticipated.

D-4.2.8 Maintenance Complexity

The complexity of the maintenance required following a failure event directly relates to the cost of maintenance interventions and the associated risks to the public and agency personnel during maintenance operations. Maintenance may be straightforward, such as cleaning debris off the road, or complex enough that specialized equipment or capabilities are required. In some cases, installation of landslide mitigation measures, such as installing horizontal drains or a buttress, may be required. Category narratives are presented in Table 4-19.

Table 4-19: Detailed Unstable Soil Slope and Embankment Risk Rating – Maintenance Complexity Category Narratives

3 points	Routine Effort Required. Maintenance can be accomplished with available state-owned equipment with only minor impacts to traffic flow.
9 points	Specialized Equipment Required. Maintenance requires mobilization of specialized equipment such as a backhoe, excavator, paver, guardrail post driver, etc.
27 points	Difficult Effort and/or Location. Maintenance requires specialized equipment brought in from a significant distance or requires assistance from an outside roadway contractor. May also require standard engineering efforts (subgrade design, asphalt mixes, etc.).
81 points	Complex or Dangerous Effort. Specialty contractor is required to perform maintenance. More complex maintenance designs (i.e., landslide buttress) requiring geotechnical design efforts; or difficult/dangerous access is required.

D-4.2.9 Event Cost

The estimated or actual cost to perform maintenance or repair work following a *probable* worst case scenario or a historically bad failure should be considered. The costs are estimated based on comparable private-sector equipment rental and operator rates. If an extreme event requires outside assistance (planning, design, and/or construction), the cost should include both those outside costs and the agency contracting and management costs. Category narratives are presented in Table 4-20.

Table 4-20: Detailed Unstable Soil Slope and Embankment Risk Rating – Event Costs Category Narratives

3 points	$10,000. Event maintenance efforts and costs involve only agency maintenance staff using existing equipment. No design work required.
9 points	$50,000. Event cost and response is more involved and may require input from agency engineering staff.
27 points	$100,000. Costs indicate extensive, multi-day efforts, likely input from engineering staff, and possibly specialized equipment rental.
81 points	$250,000. Costs include outside contractors and design services.

Alaska DOT&PF Soil Slope and Embankment Rating Calculator

Fill in orange cells

Ver. 1.00

Rated By	
Rating Date	
Site ID	

Site Information

Region		Community		**Landslide Type**	
Highway Name		Maint. District		Above Roadway	
CDS Route Number	#N/A	Maint. Station		Below Roadway	
Hwy MP		Common Name		Crossing Roadway	
CDS Milepoint		B-Slope		**Landslide Movement Type**	
Latitude		Mitigation Present		Translational Slide	
Longitude		Site Rating Status		Rotational Slide	
				DebrisFlow	
				Slump	
				Erosional Failure	

Comments

Character Count 0

Site Measurements

Axial Length of Slide (ft)		Sight Distance (ft)		
Rdwy Length Affected (ft)		AASHTO DSD (ft)	#N/A	
Roadway Width (ft)		Annual Precipitation (in)		*GIS Alaska Precipitation Map - http://arcg.is/1kmhCU*
Speed Limit (mph)		AADT (Count)		*GIS 2012/2013 AADT Map - http://arcg.is/1MnAI6W*

Evaluation Result Summary

Condition Index	N/A	Total USMP Rating	#VALUE!	**Programmatic Improvement Cost to CS1**
Condition State	1	Hazard Rating	N/A	SITE IS GOOD
Condition State Text	GOOD	Risk Rating	#N/A	

Note calculation is programmatic and does not reflect site-specific needs. Actual costs may differ significantly.

Slope Hazard Rating

			Length of Roadway Affected Score	1
			Axial Length of Slide Score	1
Thaw Stability Score		*Unfrozen, Slightly thaw unstable, Mod. unstable, Highly unstable*	*Thaw Stability Score*	0
Rdwy Impedence Score		*shoulder, 1/2, 3/4, full roadway*	*Roadway Impedence Score*	0
Maintenance Freq. Score		*Sched. ditch maint, patrols after storms, daily seasonal patrols, daily patrols*	*Maintenance Frequency Score*	0
Roadway Displacement or Slide Deposit Score		*visible crack, 1" offset/2" deposited, 2" offset/6" deposited, 4" offset/ 12" depositied*	*Roadway Displacement/Slide Deposit Score*	0
Movement History Score		*sporadic creep, up to 6" annually, more than two 6" events/year, >12" in hours (all debris flows)*	*Movement History Score*	0
Annual Precipiation Score	3			
Slope Drainage Score		*Dry or well drained, intermittent water, usually on slope, always on slope*	*Water on Slope Score*	3
			Hazard Subtotal	N/A

Slope Risk Rating

			Decision Sight Distance Score	#N/A
			Roadway Width Score	1263
			AADT Score	1
% Time Car Within Site	#DIV/0!		*Average Vehicle Risk Score*	#DIV/0!
Impact on Traffic Score		*Minor Delay, One Lane Open, 100 mi or 1 day closure, no detour or 3 days +*	*Traffic Impacts Score*	0
ROW Impacts Score		*None, minor, private prop-no structures, structures/roads/RR/util/parks*	*Right of Way Impacts Score*	0
Envir. Impacts Score		*Zero points if none likely, 50 pts if some possible*	*Environmental Impacts Score*	0
Maint. Complexity Score		*Routine, Specialized equip, difficult effort/location, complex or dangerous*	*Maintenance Complexity Score*	0
Event Cost Score		*$10k, $50k, $100k, $250k in reasonable worst case*	*Event Cost Score*	0
			Risk Subtotal	#N/A

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

GIS Field Code	Field Name	Field Value
ISiteIDN	Site ID	
IRtDateN	Rating Date	1/0/1900
IRaterT	Rater	1/0/1900
IStatusT	Site Rating Status	0
ICDSRtNN	CDS Route Number	#N/A
IRegionT	Region	0
IHwyNamT	Highway Name	0
ICmmntyT	Community	
IMntDstT	Maintenance District	
IMntStnT	Maintenance Station	
ICmnNamT	Common Name	
IHwyMPN	Highway Milepost	0
ICDSMPN	CDS Milepoint	0
ILatN	Latitude	0.00000
ILongN	Longitude	0.00000
IBSlopeT	B-Slope	0
IMitgtnT	Mitigation Present	0
ICmmntsT	Comments	0
ILAbvRdT	Landslide Above Roadway	0
ILBlwRdT	Landslide Below Roadway	0
ILCrsRdT	Landslide Crossing Roadway	0
ITranslT	Translational Slide	0
IRotatnT	Rotational Slide	0
IDebFlwT	Debris Flow	0
ISlumpT	Slump	0
IErosnT	Erosional Failure	0
MSLengtN	Length of Roadway Affected	0
MSAxHgtN	Axial Length of Slide	0
MRdWdthN	Roadway Width	0
DSpdLmtN	Speed Limit	0
DAADTN	AADT	0
MSghtDiN	Sight Distance	0
SCndtIxN	Condition Index	N/A
SCndtStN	Condition State Number	1
SCndtStT	Condition State Text	GOOD
SUSMPRtN	Total USMP Rating	#VALUE!
SHazardN	Hazard Rating	N/A
SRiskN	Risk Rating	#N/A
EImpCstN	Programmatic Improvement Cost to CS1	0
SSlLgthN	Length of Roadway Affected Score	1
SThwStbN	Thaw Stability Score	0
SRdImpdN	Roadway Impedence Score	0
SMntFrqN	Maintenance Frequency Score	0
SRdDispN	Roadway Displacement or Slide Deposit Score	0
SMvHistN	Movement History Score	0
SSAxHtN	Axial Length of Slide Score	1
SPrecipN	Annual Precipitation Score	3
SDrainN	Slope Drainage Score	0
SWaterN	Water on Slope Score	3
SRdWdthN	Roadway Width Score	1263
SAADTN	AADT Score	1
SAVRN	Average Vehicle Risk Score	#DIV/0!
SSghtDiN	Precent Decision Sight Distance Score	#N/A
STrfImpN	Impact on Traffic Score	0
SROWImpN	Right of Way Impacts Score	0
SEnviroN	Environmental Impacts Score	0
SMntCmpN	Maintenance Complexity Score	0
SEvntCsN	Event Cost Score	0

Field Values are populated from the "Site Rating Calculator" Sheet and are manually entered in the "Soil Slope Add New Site" AGOL Application or in the "Soil Slope - Edit Exisiting Data Form" AGOL Application. The GIS Field Code is referred to when editing field values for an exisiting site. The Field Name is referred to when filling out field values for a new site.

AKDOT&PF UNSTABLE SLOPE MANAGEMENT PROGRAM INVENTORY
SITE INFORMATION

Region NR CR SE **District**	**Borough**	**Date**	**Rater**
Maint. Station	**Common Name**	**Weather**	
CDS Route Name	**CDS Number**	**Watch List** Y | N	
Highway Milepost	**CDS Milepoint**	**Mitigation Present** Y | N	
Latitude	**Longitude**	**Datum**	
Failure Type	Rockfall | Rock Avalanche | 'B' Slope Landslide above roadway | Landslide below roadway | Landslide crossing roadway		
Rockfall Movement Type	Planar Failure | Wedge Failure | Toppling Failure | Raveling/Undermining | Block Failure		
Landslide Movement Type	Translational Slide | Rotational Slide | Debris Flow | Slump | Erosional Failure		
Slope Height/Axial Length of Slide	**Length of Roadway Affected**	**Annual Rainfall**	
Rockfall Block Size (ft)/Rockfall Volume per Event (yd^3)		**AADT**	
Roadway/Trail Width	**Speed Limit**	**Sight Distance**	

Comments / Photos

Site Sketch (if applicable)

PRELIMINARY RATING					
Category Rating	**3 (100)**	**9 (75)**	**27 (50)**	**81 (25 to 0)**	**Score**
Roadway Impacts	Entire paved surface unaffected	Travel lanes unaffected	One-half of roadway affected	Entire roadway affected	
Traffic Impacts	Normal two-way traffic with minor delays	Two-way traffic affected with some delay	One-half of roadway closed with significant traffic delays	Entire roadway blocked with significant delays	
Sight Distance	Good Sight Distance	Moderate Sight Distance	Poor Sight Distance	Very Limited Sight Distance	
Roadway Affected Frequency	Rarely; less than once every 3 years	Routinely; once a year	Often; 3-6 times a year, seasonal or weather controlled	Frequently; >6 times per year, events occur throughout the year	
Maintenance Action Required Frequency	Rarely; once every 3 to 5 years	Regularly; once every 1 to 3 years	Often; 1 to 3 times per year	Frequently; 4 or more times per year	
Volume or Size per Event (Rockfall) or Length of Roadway Affected (Landslide)	3 yd^3 or 1 ft (Rockfall) *or* 25 ft (Landslide)	6 yd^3 or 2 ft (Rockfall) *or* 100 ft (Landslide	9 yd^3 or 3 ft (Rockfall) *or* 225 ft (Landslide)	12 yd^3 or 4 ft (Rockfall) *or* 400 ft (Landslide)	
Potential for Roadway Affects	Little to none	Low	Moderate	High	
				PRELIMINARY RATING TOTAL	

SLOPE HAZARD RATING									
			Category Rating	**3 (100)**	**9 (75)**	**27 (50)**	**81 (25 to 0)**	**Score**
			Slope Height or Axial Length of Slide	25 ft	50 ft	75 ft	100 ft	CALC
Water on Slope			**Annual Rainfall**	1-10”	10-30”	30-60”	60”+	CALC
Water on Slope			**Drainage**	Slope appears dry or well drained; surface runoff well controlled	Intermittent water on slope; moderately well drained or surface water moderately well controlled	Water usually on slope; poorly drained or surface runoff poorly controlled	Water always on slope; very poorly drained or surface runoff control not present	
Select One Unstable Slope Type	**Landslides**		**Length of Roadway Affected**	25 ft	100 ft	225 ft	400 ft	CALC
Select One Unstable Slope Type	**Landslides**		**Thaw Stability**	Unfrozen/Thaw Stable	Slightly Thaw Unstable	Moderately Thaw Unstable	Highly Thaw Unstable	
Select One Unstable Slope Type	**Landslides**		**Roadway Impedance**	Shoulder only	Half Roadway	3/4 roadway	Full Roadway	
Select One Unstable Slope Type	**Landslides**		**Maintenance Frequency**	Every 4 years	Every 2 years	Every year	Twice a year	
Select One Unstable Slope Type	**Landslides**		**Roadway Displacement or Slide Deposit**	Visible Crack or slight deposit of material on road	1-inch offset or 2 inches of material on road	2-inch offset or 6 inches of material on road	4-inch offset or 12 inches of material on road	
Select One Unstable Slope Type	**Landslides**		**Movement History**	Minor movement or sporadic creep	Up to 6 inches annual or steady annual creep	Up to 6 inches per event, more than two events per year	>1 ft displacement in hours (include all debris flows)	
Select One Unstable Slope Type	**Rockfall**		**Ditch Effectiveness**	Good	Moderate	Limited	No Catchment	
Select One Unstable Slope Type	**Rockfall**		**Maintenance Frequency**	Scheduled ditch maintenance	Road patrols after every storm event	Routine seasonal patrols	Routine year-round road patrols	
Select One Unstable Slope Type	**Rockfall**		**Rockfall History**	Few Falls	Occasional Falls	Many Falls	Constant Falls	
Select One Unstable Slope Type	**Rockfall**		**Block Size *or* Volume per Event**	1 ft *or* 3 yd^3	2 ft *or* 6 yd^3	3 ft *or* 9 yd^3	4 ft *or* 12 yd^3	
Select One Unstable Slope Type	**Rockfall**	**Geologic Character – Case 1**	**Structural Condition**	Discontinuous Favorable	Discontinuous Random	Discontinuous Adverse	Continuous Adverse	
Select One Unstable Slope Type	**Rockfall**	**Geologic Character – Case 1**	**Rock Friction**	Rough/Irregular	Undulating	Planar	Clay infilled/slickensided	
Select One Unstable Slope Type	**Rockfall**	**Geologic Character – Case 2**	**Structural Condition**	Few differential erosion features	Occasional differential erosion features	Many differential erosion features	Major differential erosion features	
Select One Unstable Slope Type	**Rockfall**	**Geologic Character – Case 2**	**Difference in Erosion Rates**	Small difference	Moderate difference	Large difference	Extreme difference	
							LANDSLIDE HAZARD TOTAL	
							ROCKFALL HAZARD TOTAL (Select greater score of Case 1 or Case 2)	

RISK RATING					
Category Rating	**3 (100)**	**9 (75)**	**27 (50)**	**81 (25 to 0)**	**Score**
Roadway Width	44 ft	36 ft	28 ft	20 ft	CALC
Annual Average Daily Traffic (AADT)	500	2,000	4,500	8,000	CALC
Average Vehicle Risk (AVR)	25% of the time	50% of the time	75% of the time	100% of the time	CALC
% Decision Sight Distance (PDSD)	Adequate, 100% of low design value	Moderate, 80% of low design value	Limited, 60% of low design value	Very Limited, 40% pf low design value	CALC
Impact on Traffic	Traffic continues with minor delay	One lane remains open, traffic control required	All lanes blocked, detour less than 100 miles or less than 1 day closure	All lanes blocked, no road based detour or closure longer than 3 days	
Right of Way Impacts	No R/W implications	Minor effects beyond R/W	Private property, no structures affected	Structures, roads, RR, utilities, or parks affected	
Environmental Impacts of Left Unattended	No environmental implications		Environmental impacts		
Maintenance Complexity	Routine Effort	Specialized Equipment	Difficult effort/location	Complex or dangerous effort	
Event Cost	$10k	$50k	$100k	$250k	
TOTAL RISK SCORE					
TOTAL USMP SCORE: LANDSLIDE | ROCKFALL					

For the directly measurable categories (marked with CALC), use the following formulas to calculate the exponent value (x) for the scoring formula $y = 3^x$.

Length of roadway affected exponent:

$$x = \sqrt{\frac{length\ (ft)\ of\ roadway\ affected}{25}}$$

Wall height exponent formula:

$$x = \frac{slope\ height\ or\ axial\ length\ of\ slide}{25}$$

Water on slope formula:

$$Score = \frac{Rainfall\ Score + Slope\ Drainage\ Score}{2}$$

Roadway width exponent formula:

$$x = \frac{52 - Road\ width\ (ft)}{8}$$

AADT exponent formula:

$$x = \sqrt{\frac{AADT}{500}};\ maximum\ category\ score = 100$$

Average vehicle risk exponent formula:

$$x = \frac{\left(\frac{\frac{ADT}{24} \times slope\ length\ (miles)\ \times 100}{posted\ speed\ limit}\right)}{25}$$

Percent decision sight exponent formula:

$$x = \frac{120 - \left(\frac{measured\ sight\ distance}{AASHTO\ decision\ sight\ distance} \times 100\right)}{20}$$

Appendix E

RETAINING WALL FIELD RATING GUIDE

CONTENTS

E-1. INTRODUCTION

Like unstable slopes, retaining walls play an important role in supporting the roadway and enabling the transportation system to function smoothly. However, unlike unstable rock and soil slopes, retaining walls are constructed with known materials, the behavior of which under various conditions and influences is generally well understood. This enables a degree of control not available in the excavation of soil and rock slopes, where materials may vary widely throughout the road section. These differences are reflected in the rating categories used to assess retaining walls.

The Retaining Walls Management Program (RWMP) builds on the Department's Retaining Wall Inventory (RWI). The RWI is a baseline system-wide inventory compiled by the Statewide Materials Section. It contains general information describing wall location, classification (category, type, function), and dimension characteristics. Acceptance criteria, data field definitions, and process methodology are described in the draft document *Retaining Wall Inventory Procedures Manual* (last revised in February 2017).

The RWI will be maintained by the Department as a baseline inventory, but it does not address condition assessment. AKDOT&PF uses the *Retaining Wall Management Program (RWMP)* to integrate retaining walls into the GAM program. The RWMP rates retaining walls across a mix of hazard, risk, and public perception categories. All retaining walls deemed capable of affecting the roadway in the event of failure were inventoried, with the exception of those retaining walls related to bridge construction and already regularly inspected by the Bridge Group.

E-2. BACKGROUND INFORMATION FOR PERFORMING FIELD RATINGS

E-2.1Integration of External Data

The RWMP uses the RWI as a starting point for field assessments. The RWI is extremely helpful in locating retaining walls in the field, particularly those constructed below the roadway grade, and in compiling what was known about the year of construction and the planned wall design for easy reference. However, because the RWI generally has not been field-checked, some walls are not included in the database, while others which were included had not, in fact, been built. All field-work conducted for the RWMP should also be taken as an opportunity to field-verify the RWI. Proposed edits should be tracked and made upon return to the office, as necessary.

As when rating rock slopes, unstable soil slopes, and embankments, some data must be obtained prior to starting field work. This external data is obtained from AKDOT&PF and includes:

- Precipitation data
- Route map with CDS or Route ID numbers
- AADT
- Retaining Wall Inventory

Some of this data, like the AADT and CDS numbers, are incorporated directly into the Excel rating workbook, where it can be automatically referenced by equations employed in some of the rating categories. The precipitation and RWI are available in geospatial layers in ArcGIS and can be added to maps used on mobile devices in the field. Some additional information, such as maintenance frequency, is obtained directly from AKDOT&PF maintenance personnel.

E-2.2Retaining Wall Acceptance Criteria

Retaining walls assessed in the RWMP generally meet the RWI's criteria for a *highway retaining wall* or *culvert headwall.* Assessed walls are:

- Not inside a bridge zone
- For highway walls: at least 4 feet tall at the point of maximum wall height
- For culvert walls: at least 6 feet tall at the point of maximum wall height
- Regardless of height or setback, if a wall showed evidence of developing problems that could impact the road, it was assessed in the RWMP

The bridge zone is defined in the Retaining Wall Inventory Procedures Manual. Retaining walls supporting bridges are evaluated by the Bridge Group, which conducts routine inspections under the Department's Bridge Management System. In general, bridge-related retaining walls whose length was less than twice the height of the bridge structure were not included in the condition rating campaign.

E-2.3Collecting Measurements During Field Rating

E-2.3.1 Determination of Retaining Wall Type

Identify and enter the general retaining wall type into the RWMP database, since different retaining walls employ different construction techniques, apply various materials, and are susceptible to various threats. The list of wall types ultimately available for selection by the field rater was based on the list of wall types in the National Park Service Procedures Manual "Retaining Wall Inventory and Condition Assessment Program (WIP)." Each wall type, such as mechanically stabilized earth (MSE) walls, contains several sub-types, such as geosynthetic wrapped face, precast panel face, segmental block, and welded wire face. In all, 30 retaining wall options are available for the inspector to choose from in the RWMP. Figure 2-1 contains simple schematics of some of these wall types.

Retaining wall type is determined by field observation and by reference to the RWI and any available as-built plans. Since not all retaining walls contained in the plan sets were built as planned, the final confirmation of wall type is provided by the field rater.

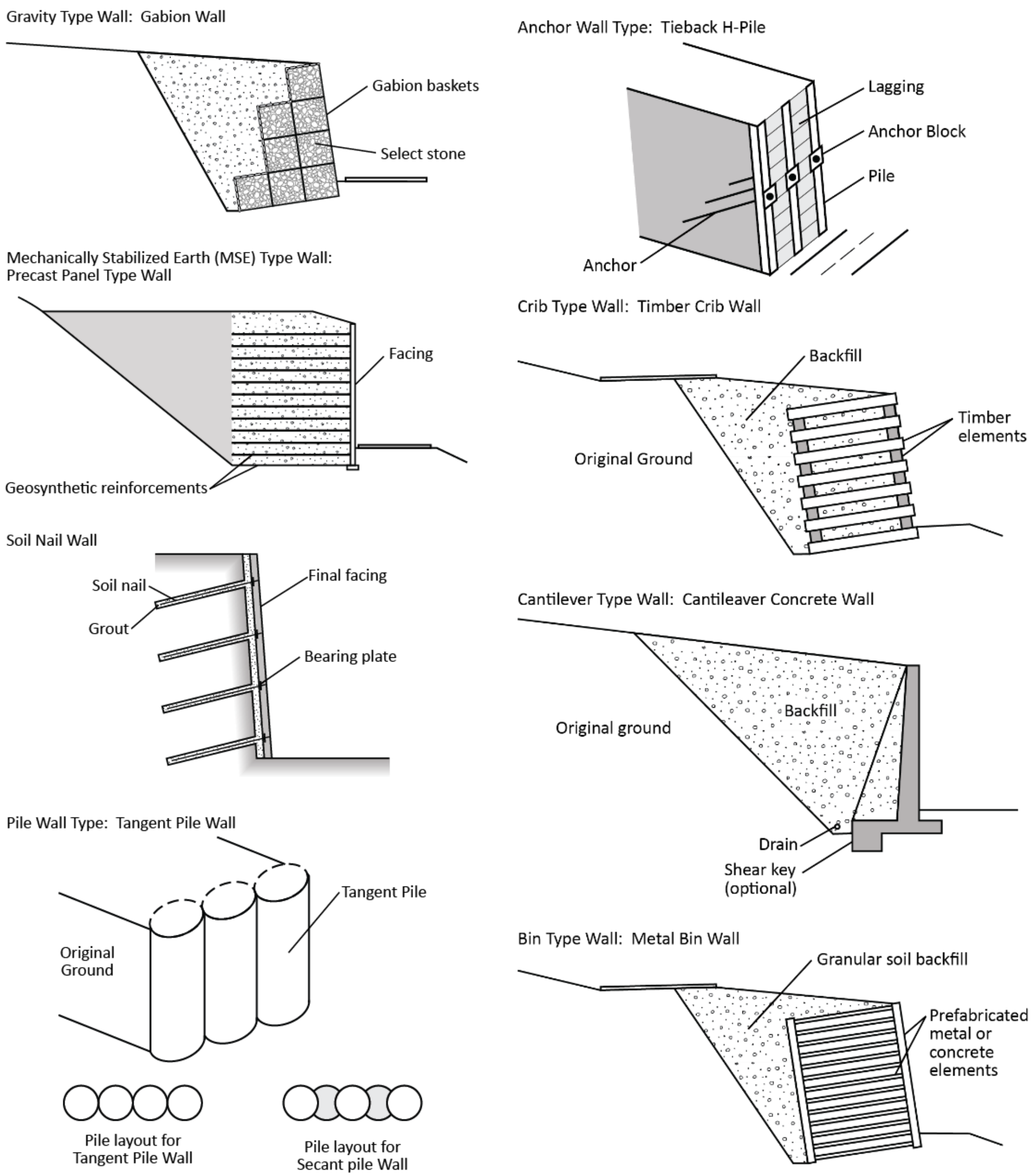

Figure 2-1: Simple schematics of select retaining wall types entered in the RWMP database.

E-2.3.2 Field Collection of Geospatial Data

During inventory work, field inspector must develop a unique ID for each inventoried retaining wall. Following the same process used for rock slopes and unstable soil slopes and embankments, the ID is based on a wall's CDS Route assignment, CDS Milepoint, and the year initially entered into the RWMP inventory. The CDS Milepoint is measured relative to the midpoint of the wall.

For example, a bin wall on the Seward Highway (CDS Route Number 130000), with the wall midpoint located 0.27 miles north of the mile post 105 marker (the sign is located at CDS Milepoint 104.30 and therefore the rock slope is at Milepoint 104.57) was rated in 2015. The site ID would be 1300000104572015:

130000	010457	2015
CDS Route	Milepoint	Year

*Note that the Milepoint is in the form of #,###.##, with two decimal places and leading zeros leaving room for

In addition to determining the wall's midpoint location, the wall's linear extents are collected manually using either a handheld GPS unit or a GPS-enabled laptop or tablet. Site photographs should be taken and uploaded to the database.

E-3. FIELD RATING CATEGORIES

The rating criteria used to evaluate retaining walls are intentionally similar in style to those developed for the unstable slope programs. Retaining wall elements are classified and rated using observable hazard and risk parameters. However, a third rating category was added to capture wall appearance parameters since both public and technical perception of how well a wall is performing is relatively easy to judge based on how it “looks.” Three of the detailed rating categories – wall alignment, length of affected roadway, and critical component health – are used to determine a wall’s Condition State.

Several important retaining wall components are not visible during a field inspection, including foundations, tie-backs, soil reinforcing, etc. Only components or features observable by a trained inspector during the assessment were included in the element ratings. The field form used during retaining wall condition rating work is presented at the end of this guide. Individual retaining wall rating categories are discussed in detail in the following sections.

E-3.1Detailed Hazard Rating Categories

Scores from the detailed Hazard Rating categories are combined with those from the detailed Risk Rating categories (Section 0) and Appearance categories (Section 0) to calculate the final score for a retaining wall. Collectively, the hazard ratings seek to quantify the likelihood that a retaining wall could perform poorly and affect the roadway, requiring some level of maintenance response to reduce or eliminate this likelihood. For categories that are not directly scored through equations, the field rater estimates the score based on professional judgement and/or input from Maintenance personnel.

E-3.1.1 Wall Height

This category considers the hazard associated with wall height. As taller walls retain more material and have a greater potential to impact the roadway and adjacent ROW, increased wall height poses an increased worst-case hazard scenario in the event of failure. The wall height used for this rating is measured to the highest point at the crest of the retaining wall. Sample category scores are shown in Table 3-1.

Equation 3-1: Wall Height Score

$$Score = 3^x \text{ (max 100)}; \; where \; x = \frac{wall\ height}{10}$$

Table 3-1: Retaining Wall Hazard Ratings – Sample Calculated Scores from Wall Height Equation

3 points	10 feet
9 points	20 feet
27 points	30 feet
81 points	40 feet

E-3.1.2 Vertical and/or Horizontal Alignment

This category is one of three used to determine retaining wall Condition State.

Proper vertical or horizontal wall alignment is one of the most easily observed indicators of wall performance. Poor alignment can be related to construction deficiencies or an unstable wall foundation, and it can also indicate potential wall failure. This category is scored based on visual appearance, not by equation. Measure the vertical alignment of the wall at multiple locations and record the information in the site comments. This creates a benchmark for future reference. Category narratives are presented in Table 3-2.

Table 3-2: Retaining Wall Hazard Ratings – Vertical/Horizontal Wall Alignment Category Narratives

3 points	Good wall alignment. Wall appears stable with expected batter. Alignment matches that shown on as-built or plan sets, if available.
9 points	Fair wall alignment. Acceptable alignment, but not as shown in available as-built drawings or plan sets. Condition may be related to the quality of construction or the use of poor materials.
27 points	Portion of wall shows poor alignment. Segments of wall are inconsistently aligned with possible cracking, settlement, or loss of retained material.
81 points	Entire wall shows poor alignment or failed, unrepaired sections. Wall is visibly distressed with numerous cracks, localized settlement or displacement, and/or loss of retained material.

E-3.1.3 Roadway Displacement due to Wall Movement

This category is one of the three used to determine retaining wall Condition State.

Unanticipated displacement in a travel lane can result in unsafe maneuvers or loss of vehicle control. Cracks in a retaining wall or the adjacent roadway can be caused by wall movement, which could lead to further displacement, undermining, or deposition of debris on the roadway. Larger displacements increase the likelihood of an accident, require greater maintenance attention, and cost more to repair or patch. Category narratives are presented in Table 3-3.

Table 3-3: Retaining Wall Hazard Rating – Roadway Displacement Category Narratives

3 points	No visible crack in wall or roadway. Wall and roadway maintenance occurs as scheduled.
9 points	Visible crack in wall or roadway; no displacement. A noticeable crack in the wall or roadway. Wall and roadway maintenance continues as scheduled.
27 points	Minor crack in wall or roadway with minor displacement. A noticeable crack in the wall or roadway with evidence of minor movement. Increased maintenance inspection of wall and roadway is required.
81 points	Crack in wall or roadway with measurable displacement to significant displacement impeding traffic. Cracks with measureable offset in the wall, or a major drop in the pavement associated with a progressing retaining wall failure. Unsafe driver reactions are likely and regular maintenance attention is required to maintain or reestablish safe traffic flow.

E-3.1.4 Length of Roadway Affected

The longer the wall, the higher the relative hazard to the travelling public in the event of a wall failure. To an agency, length is also proportional to the maintenance efforts and costs associated with managing the retaining wall. Typically, a greater length of effected roadway will require extended duration lane closures during maintenance or repair activities. This category score is directly calculated from field measurements using Equation 3-2. Sample category narratives are presented in Table 3-4.

Equation 3-2: Length of Roadway Affected Score for thaw stable slopes

$$Score = 3^x;\ where\ x = \sqrt{\frac{length\ (feet)\ of\ roadway\ affected}{25}};maximum\ score = 100$$

Table 3-4: Retaining Wall Hazard Rating – Length of Roadway Affected Sample Calculated Scores

3 points	25 feet
9 points	100 feet
27 points	225 feet
81 points	400 feet

E-3.1.5 Maintenance Frequency

The frequency of maintenance is an indicator of retaining wall health, serviceability and long-term cost to the agency. Generally, maintenance requirements for retaining walls are low. However, as a wall ages, additional road patrols or patch work may be required. This increases the associated maintenance costs, especially if inspections and repairs are beyond the scope of maintenance station capabilities and require the services of an outside contractor. Category narratives are presented in Table 3-5.

Table 3-5: Retaining Wall Hazard Rating – Wall Maintenance Frequency Category Narratives

3 points	No scheduled wall maintenance. Only routine inspection is required on an infrequent basis.
9 points	Wall maintenance after major storm events. Maintenance routinely inspects wall for damage following extreme storm events. Unscheduled repair work may be required.
27 points	Routine wall maintenance required. Maintenance patrols occur regularly throughout a high storm activity season (fall, winter, spring). Repair of wall or roadway generally required annually.
81 points	Year-round wall inspection and maintenance required. Maintenance staff routinely checks retaining wall year-round. Repair work to wall or roadway is required more than once per year.

E-3.1.6 Wall Drainage System

In conjunction with rainfall quantity, the ability of the wall backfill material to be free draining, along with the presence and functionality of drains within the wall, is very important. It provides information on the ability of the wall to cope with rainfall events and on the potential for excess water pressure to damage the wall. Vegetation on the wall face, particularly in rockery and geo-walls, is a good indicator of the presence of water behind the wall face. This category is based on a subjective evaluation. Note that rating this category at different times of the year may produce different results since poor drainage control is not as obvious during drier months. Category narratives are presented in Table 3-6.

Table 3-6: Retaining Wall Hazard Rating – Wall Drainage System Category Narratives

3 points	Good performing drainage system; surface water well controlled. Wall appears dry or well drained. Drains installed in wall appear clean and free-flowing. Surface runoff near wall crest is well controlled. Wall face is dry hours after rain events.
9 points	Fair performing drainage system; surface water moderately well controlled. Water is intermittently on wall, particularly along cracks in the face. Drains installed are flowing, but partially obstructed by debris or vegetation. Surface runoff near wall crest is moderately controlled. Wall face is dry within days after rain events.
27 points	Damaged or poorly performing drainage system; surface runoff poorly controlled. Seeps at the wall face are common, particularly along cracks in the face. Installed drains are largely obstructed by debris. Surface runoff near wall crest may be poorly controlled. Wall face is still wet several weeks following rain events, but may appear dry during prolonged dry spells.
81 points	Non-performing wall drainage system; surface water runoff control not present. Water regularly seeping from cracks in the wall face and wall drains appear fully obstructed or ineffective. No surface water control present or effective above wall crest. Wall face is wet year-round.

E-3.1.7 Annual Precipitation

The amount of annual rainfall is a rough indicator of the potential for elevated pore-water pressure within the retaining wall backfill. Areas with frequent, intense storms typically place greater demands on retaining wall design and construction. This category is rated based on local average annual precipitation totals. During field ratings, this rainfall data was obtained from a state precipitation geodatabase based on data from the USGS.

The methodology is identical to that used to calculate the annual precipitation subscore for unstable slope assets.

Table 3-7: Retaining Wall Hazard Rating – Rainfall Amount Categories

3 points	0-10 inches of precipitation annually
9 points	10-30 inches of precipitation annually
27 points	30-60 inches of precipitation annually
81 points	60+ inches of precipitation annually

E-3.1.8 Critical Component Health

This category is one of the three used to determine retaining wall Condition State.

Retaining walls encompass many different materials and construction methods with distinct wall elements that can be prone to displacement and/or failure. As walls age, cracking and distortion of the wall face may develop, along with corrosion and/or loss of bearing elements, soil reinforcement and other components. Each type of retaining wall can exhibit different performance problems and fail in different ways. Because of that, a comprehensive category was developed that allows the evaluation of a range of operational issues while maintaining the ability to compare the performance of different wall types.

The general condition of the retaining wall and its *observable* components are scored during the field inspection based on the category descriptions in the following table. Components which are buried or otherwise obscured from view are, by definition, not captured by the field rating. Category narratives are presented in Table 3-8.

Table 3-8: Retaining Wall Hazard Rating – Critical Component Health Category Narratives

3 points	<u>No evidence of corrosion, cracking, distortion, or lost bearing/missing elements.</u> Wall face and all observable wall components are in excellent shape. Any cracking is minor (i.e., due to concrete curing process) and does not affect wall structure.
9 points	<u>Evidence of minor corrosion, cracking, distortion or lost bearing/missing elements.</u> Minor cracking on wall face, wall alignment slightly distorted, or evidence of minor weathering or similar damage to wall elements.
27 points	<u>Evidence of moderate corrosion, cracking, distortion, or lost bearing/missing elements.</u> Moderate cracking on wall face, portions of wall are distorted, or exposed wall components are corroded or damaged.
81 points	<u>Evidence of major corrosion, cracking, distortion, or lost bearing/missing elements.</u> Extensive cracking on face, wall shows poor alignment over length, or exposed wall components are destroyed by corrosion, removed, or otherwise entirely broken.

E-3.1.9 Movement History

The rate and frequency of wall displacement and/or the amount of wall distortion per event relates to maintenance requirements and the potential for developing roadside hazards. More frequent events increase the probability of unanticipated conditions that require a driver to make reactive maneuvers, as well as the need for immediate unscheduled maintenance. The category score is estimated based on historical observed displacement, evidence of previous repairs, and maintenance input. Category narratives are presented in Table 3-9.

Table 3-9: Retaining Wall Hazard Ratings – Movement History Category Narratives

3 points	Sporadic episodes of minor movement/distortion. The rate of movement/distortion is extremely low and occurrence is rare. Changes in condition are unnoticeable on an annual basis and maintenance is generally not required or it is very minimal and carried out as a scheduled activity.
9 points	Minor annual movement/cracking. The rate of movement/distortion is very low but occurrence is more common. Pavement or retaining wall damage is noticeable to a trained observer between inspections, and annual maintenance is required but it is minimal and done as a scheduled activity.
27 points	Measureable annual movement. Damage to roadway or retaining wall is increasing noticeably on an annual basis. Movement may create irregularities in the pavement or upslope of the wall that require regular maintenance attention. Some wall components may require replacement after extreme storm events.
81 points	Measurable seasonal movement. The rate of movement/distortion is high with significant disturbance effects developing quickly. Wall is approaching a failed condition. Unscheduled maintenance intervention is required to maintain traffic flow and correct unsafe conditions.

E-3.2Detailed Risk Rating Categories

Scores from the detailed Risk Rating categories are combined with those from the detailed Hazard Rating categories (Section 2.2.5) and the Appearance Rating Categories (Section 0) to calculate the final score for a retaining wall. Collectively, the risk ratings seek to assess the risks and inconvenience that poor retaining wall performance will pose to the travelling public, and the potential costs to the agency for maintenance and repairs, or for right of way (ROW) acquisition if a failure occurs that extends beyond agency ROW boundaries. For the risk categories that are not directly scored through equations, the field rater estimates the most reasonable score based on professional judgement and input from maintenance personnel.

E-3.2.1 Annual Probability of Complete Failure

Using engineering judgment, the annual probability of a retaining wall failure is estimated by the field inspector. Failure is defined as deterioration of the wall to the point that repair work is no longer sufficient or feasible, and total replacement of the wall is required. Walls rated "High" include walls that have failed and require replacement, but that continue to perform some residual function. This category score is estimated from the observed wall alignment, drainage system performance, and other potential problems. The probability of wall failure is estimated in percent as provided by analysis work by Shannon and Wilson (Shannon and Wilson 2015). Category narratives are presented in Table 3-10.

Table 3-10: Retaining Wall Hazard Rating – Annual Probability of Failure Category Narratives

3 points	Low to Medium Low (0.01-0.035). Wall appears stable, unlikely to fail under average conditions.
9 points	Medium (0.125). Wall appears in need of some repair or maintenance work, but likely stable under routine conditions.
27 points	Medium High (0.40). Wall appears in need of significant work. Susceptible to failure if deterioration is left unaddressed or the wall is exposed to extreme conditions.
81 points	High (0.99). Wall appears about to fail or is already in a failed condition.

E-3.2.2 Potential Impact on Traffic

The overall transportation system impacts due to a retaining wall failure can be minimized if a detour around the site is available or the effects on the system are minimal. Conversely, system performance is significantly degraded if a long detour is required or no detour is available. The scoring should take into account a *probable* worst case scenario and wall history when judging the impacts on traffic.

The same rating category narratives are used to score potential traffic impacts of unstable slope and retaining wall failures. These narratives are presented in Table 3-11.

Table 3-11: Retaining Wall Risk Rating – Impact on Traffic Category Narratives

3 points	Traffic continues with minor delay. A wide shoulder is available for traffic diversion for moderately sized events; small rockfall events are contained in the ditch; alternate nearby roadways are available for detours.
9 points	One lane remains open, traffic control required. Traffic control for a lane closure is required for maintenance or clean-up. Clean-up and related traffic control takes 1 to 3 days. Delays are less than 15 minutes.
27 points	All lanes are blocked, detour less than 100 miles or less than 1 day closure. A full closure for one day or less is required. Detours will divert traffic 100 miles or less.
81 points	All lanes are blocked, no road-based detour less than 100 miles is available, road closure for more than 1 day required. If a full closure lasting longer than 3 days is required or major reconstruction is required with no detour available, then the category score is 100 points.

E-3.2.3 Roadway Width

If a driver notices debris on the road surface, he may take evasive action to avoid it. The more room there is for this maneuver, the greater the likelihood that the driver will able to avoid the unanticipated hazard without hitting another roadside hazard or oncoming vehicle. The roadway width category score represents the available maneuvering room for the roadway.

The roadway width is measured perpendicular to the highway centerline. If roadway width is not constant, then the minimum width throughout the slope section is used. During development of rating categories, it was difficult to get uniform estimates among different raters as to what portion of an unpaved shoulder can safely be used as a maneuverable side slope. For this reason, none of the unpaved shoulder adjacent to the roadway is included in the width measurement. On divided roadways, only that portion of the roadway available to the driver is measured.

This category score is calculated from the actual roadway measurements according to Equation 3-3. The same equation is used for retaining wall and unstable slope assets. Sample calculated scores are presented in Table 3-12.

Equation 3-3: Roadway Width Score

$$Score = 3^x;\ where\ x = \frac{52 - Roadway\ Width\ (feet)}{8}; maximum\ score = 100$$

Table 3-12: Retaining Wall Risk Rating – Sample Calculated Scores from Roadway Width Equation

3 points	44 feet
9 points	36 feet
27 points	28 feet
81 points	20 feet

E-3.2.4 Average Annual Daily Traffic (AADT)

The AADT of a route indicates both its significance and the potential risk a wall failure could pose to the public. This category score is calculated from the actual agency derived traffic counts provided by AKDOT&PF, according to Equation 3-4. The same equation is used for retaining wall and unstable slope assets. Sample scores are presented in Table 3-13.

Equation 3-4: Annual Average Daily Traffic Score

$$Score = 3^x;\ where\ x = \sqrt{\frac{AADT}{500}}; maximum\ score = 100$$

Table 3-13: Retaining Wall Risk Rating – Sample Calculated Scores from AADT Equation

3 points	500
9 points	2,000
27 points	4,500
81 points	8,000

E-3.2.5 Failure Impact on Roadway

Retaining wall failures affect the roadway to different extents and are indicative of the agency's risk exposure in the course of an event. For instance, if the wall failure only impacts the unpaved shoulder, there is typically time to investigate causes, schedule repair or maintenance, and traffic flow would only be marginally affected. If the entire roadway is covered by debris, traffic flow would be stopped and a major effort would likely be required to reopen the roadway. Further movement of areas previously supported by the retaining wall could produce progressive slope failures, posing hazards to the public, or to maintenance personnel or outside contractors tasked with repairing or replacing the retaining wall. It could also complicate temporary construction shoring requirements. Category narratives are presented in Table 3-14.

Table 3-14: Retaining Wall Risk Rating – Wall Failure Significance Category Narratives

3 points	Shoulder only. Some debris deposited on shoulder or wall failure undermines shoulder.
9 points	Half roadway. Half of the roadway is affected by debris or undermined by wall failure.
27 points	Three-quarters roadway. Three-quarters of roadway is affected. Widening to create a temporary shoofly detour adjacent to the roadway is possible.
81 points	Full roadway. Entire roadway is affected. No shoofly detour is possible.

E-3.2.6 Average Vehicle Risk within 100 ft of Wall Length

The Average Vehicle Risk (AVR) category assesses the risk posed by a retaining wall as a function of the percentage of time a vehicle is actually present within the wall area. That percentage is obtained as part of Equation 3-5 and incorporates the slope length, average annual daily traffic (AADT), and the posted speed limit. In other words, this equation describes how many vehicles are within the potential impact zone of a retaining wall at any one time. A rating of 100% means that, on average, a vehicle is within the defined section 100% of the time. Where high ADT's or longer wall lengths exist, values greater than 100% may result, meaning that at any particular time, more than one vehicle is present within the measured section. The result approximates the likelihood of vehicles being present and the risk that a vehicle will be involved in a failure incident.

The same equation is used for retaining wall and unstable slope assets. Sample category scores are presented in Table 3-15.

Equation 3-5: Average Vehicle Risk Score

$$Score = 3^x;\ where\ x = \frac{\left(\frac{\frac{AADT}{24} \times slope\ length\ (miles) \times\ 100}{posted\ speed\ limit}\right)}{25};\ maximum\ score = 100$$

Table 3-15: Retaining Wall Risk Rating – Sample Calculated Scores from Average Vehicle Risk Equation

3 points	Vehicle within unstable slope section 25% of the time
9 points	Vehicle within unstable slope section 50% of the time
27 points	Vehicle within unstable slope section 75% of the time
81 points	Vehicle within unstable slope section 100% of the time

E-3.2.7 Percent of Decision Sight Distance

The Percent Decision Sight Distance (PDSD) category describes the available sight distance as a percentage of the low design sight distance prescribed under AASHTO standards. Sight distance is the shortest distance that debris in the road would be continuously visible to a driver either approaching or within a retaining wall section. Decision sight distance (DSD) is the distance required by a driver to perceive and react to an unanticipated problem and then to bring his vehicle to a stop. The required DSD increases with increased vehicle speed and this distance is critical when obstacles in the road surface are difficult to see, or when unexpected or unusual maneuvers are required. Decision sight distances for typical posted speeds are presented in **Error! Reference source not found.** below.

Table 3-16: AASHTO Recommended Minimum Decision Sight Distance for selected speed limits

Posted Speed Limit (mph)	AASHTO Recommended Minimum Decision Sight Distance (ft)
25	375
30	450
35	525
40	600
45	675
50	750
55	875
60	1,000
65	1,050

Sight distance can change appreciably throughout a roadway section. Horizontal and vertical highway curves, along with obstructions such as rock outcrops, roadside vegetation, guardrails, etc. can severely limit a driver's ability to notice and react to a hazardous road condition. In calculating this category score, the sight distance is determined in both travel directions, and the most restricted sight distance is used. Both horizontal and vertical sight distances are evaluated.

The measurement, generally made with a roller tape or laser range finder, is the distance required for a six-inch object positioned on the fogline (or on the edge of pavement if there is no fogline) to disappear from view at an eye height of 3.5 feet above the road surface. The posted speed limit throughout the section is used.

The category score is calculated from the direct measurements described above using Equation 3-6. The same equation is used for retaining wall and unstable slope assets. Sample scores are presented in Table 3-17.

Equation 3-6: Decision Sight Distance Score

$$Score = 3^x;\ where\ x = \frac{120 - \left(\frac{Measured\ Minimum\ Sight\ Distance}{AASHTO\ Recommended\ Decision\ Sight\ Distance} \times 100\right)}{20};$$

$$maximum\ score = 100$$

Table 3-17: Retaining Wall Risk Rating – Sample Calculated Scores from Decision Sight Distance Equation

3 points	Adequate, 100% of low design value
9 points	Moderate, 80% of low design value
27 points	Limited, 60% of low design value
81 points	Very Limited, 40% of low design value

E-3.2.8 Right of Way Impacts

In the event of a retaining wall failure, adjacent land owners may be impacted by a the upslope crest retrogressing beyond property boundaries, or by the deposition of debris on private property. If neighboring structures or transportation systems are potentially impacted by events, then the risk to the agency is significantly higher. Maps displaying agency ROW are helpful when performing evaluations, particularly in urban areas, and should be obtained from the agency or bureau when possible. If ROW maps are not available, the field rater should use her best judgement based on observed site characteristics. Category narratives are presented in Table 3-18.

Table 3-18: Retaining Wall Risk Rating – Right of Way Impacts Category Narratives

3 points	No ROW implications. Impacts very unlikely to extend beyond agency ROW.
9 points	Minor effects beyond ROW. Unstable slope impacting non-agency ROW, but adjoining landowner indifferent to minor impacts. Minor impacts include overburden slumping, minimal drainage changes, or cut slope crest retrogression.
27 points	Private property, no structures affected. Unstable slope actively retrogressing into private property but not impacting or likely to threaten structures. ROW acquisition of private lands may be required.
81 points	Structures, roads, RR, utilities, or parks affected. Unstable slope actively threatens adjacent structures, transportation systems, or Federal or State Park lands. In this score range, ROW acquisition of private lands would likely be required. Coordination of mitigation approaches with outside agency landowner(s) is likely required.

E-3.2.9 Environmental Impacts

Since retaining walls are often built as a way of minimizing potential environmental impacts, wall failure may lead to signification environmental impacts. These impacts can include culvert plugging, interference with fish passage, habitat impacts, etc. Due to the highly variable nature of potential environmental impacts, a basic yes/no approach is taken to rate this category. If impacts are anticipated, a future review by Department environmental staff may be required. Category narratives are presented in Table 3-19.

Table 3-19: Retaining Wall Risk Rating – Environmental Impacts Category Narratives

0 points	No Environmental implications. No known sensitive environmental issues are present or anticipated if a *probable* worst case scenario occurs.
50 points	Environmental impacts anticipated. If a probable or historically common failure occurs or the slope retrogresses, environmental impacts are anticipated.

E-3.2.10 Maintenance Complexity

The same rating category narratives are used to assess maintenance complexity for both unstable slopes and retaining walls. .

In the event of failure, maintenance complexity is directly related to maintenance cost and associated risks to the public and agency personnel during maintenance operations. Maintenance may be straightforward, such as cleaning existing drains, or complex enough that specialized equipment or capabilities are required. Category narratives are presented in Table 3-20.

Table 3-20: Retaining Wall Risk Rating – Maintenance Complexity Category Narratives

3 points	Routine Effort Required. Maintenance can be accomplished with available state-owned equipment with only minor impacts to traffic flow.
9 points	Specialized Equipment Required. Maintenance requires mobilization of specialized equipment such as a backhoe, excavator, paver, guardrail post driver, etc.
27 points	Difficult Effort and/or Location. Maintenance requires specialized equipment brought in from a significant distance or requires assistance from an outside roadway contractor. May also require standard engineering efforts (subgrade design, asphalt mixes, etc.).
81 points	Complex or Dangerous Effort. Specialty contractor is required to perform maintenance (i.e., repairing a retaining wall below the roadway). More complex maintenance designs (i.e., replacement of corroded welded wire facing) with geotechnical design efforts; or difficult/dangerous access is required.

E-3.2.11 Wall Failure Cost

This category considers the estimated cost to repair a *probable* worst-case scenario. As most retaining wall construction or repair is conducted by private contractors, the costs should be based on private-sector equipment rental and operator rates. If a retaining wall failure requires outside services (planning, design, and/or construction), the cost used should also include the cost for the state to manage these services. Category narratives are presented in Table 3-21.

Table 3-21: Retaining Wall Risk Rating – Event Costs Category Narratives

3 points	Less than $50,000. Event cleanup and repair costs involve only agency maintenance staff using existing equipment with any necessary design input coming from agency staff. Minimal design work is required.
9 points	$50,000 to $250,000. Event cost and response is more involved, with construction or repair by private-sector contractors required. Greater work from the agency is also required in terms of construction management.
27 points	$250,000 to $1,000,000. Costs indicate significant emergency repair effort, outside design efforts, and extensive final repair work by outside contractors.
81 points	Greater than $1,000,000. Costs include emergency repair efforts, complex design and/or permitting procedures, outside contractors and design services.

E-3.3 Appearance Rating Categories

Unlike the other geotechnical assets managed in AKDOT&PF's GAM program, it is possible for both inspectors with technical expertise and members of the general public with limited engineering experience to quickly form an opinion on wall condition based solely on its physical appearance. Because retaining walls are constructed typically of manmade materials, they follow a more uniform pattern than other geotechnical assets. The following two categories attempt to capture the general sense of how wall appearance reflects wall performance.

E-3.3.1 Technical Appearance

The first impression of how well a retaining wall is performing based on its appearance is a useful evaluating tool for the inspector. This category is based on professional judgment and although it includes the observations made when rating other wall categories, it is not directly calculated from any measurements taken at the site. Category narratives are presented in Table 3-22.

Table 3-22: Retaining Wall Appearance Rating – Technical Appearance Category Narratives

3 points	Exceeds expectations. Wall appears well-designed and very well-constructed.
9 points	Meets expectations. Wall design and construction meet requirements.
27 points	Needs improvement. Wall appearance indicates need for maintenance and/or repair.
81 points	Clearly needs work/failed already. Retaining wall requires significant repair work or total replacement.

E-3.3.2 Public Perception

This category attempts to capture the potential difference in the evaluation of a retaining wall by a member of the general public and by an engineer. The general public will notice the appearance of a retaining wall, but lack the expertise to evaluate it in greater detail. Normally, the public can readily distinguish between a wall that is in good condition and a wall that is failing. However, it is possible that a generally functional wall may be perceived as unsafe due to surficial damage, or a poorly functioning wall is not considered to be in poor condition because the wall face cannot be observed from the roadway. Category narratives are presented in Table 3-23.

Table 3-23: Retaining Wall Appearance Rating – Public Perception Category Narratives

3 points	Wise use of public money, well maintained. Wall is attractive, well-maintained and the public would feel it represents a good value for the funds expended.
9 points	Routine DOT Investment. Wall is functional and well-maintained. Generally unnoticed by general public.
27 points	Investment needs work. Wall is noticeably in need of maintenance work or repair and it is not receiving the attention needed.
81 points	Wall looks about to fail or has already failed. Wall is noticeably deficient in meeting public expectations and appearance elicits public concern of wall performance & safety.

Alaska DOT&PF Retaining Wall Rating Calculator

Fill in orange cells

Ver. 1.00

Rated By	
Rating Date	
Wall ID	

Site Information

Region		Community		**Wall Information**	
Highway Name		Maint. District		Wall Category	
CDS Route Number	#N/A	Maint. Station		Wall Function	
Hwy MP		State/Fed Proj. No.		Wall Type	
CDS Milepoint		Construction Date		Offset	
Latitude		Status			
Longitude					
Comments					

Character Count 0

Site Measurements

Wall Height (ft)		Sight Distance (ft)		
Wall Length (ft)		AASHTO DSD (ft)	#N/A	
Roadway Width (ft)		Annual Precipitation (in)		*GIS Alaska Precipitation Map - http://arcg.is/1kmhCU*
Speed Limit (mph)		AADT (Count)		*GIS 2012/2013 AADT Map - http://arcg.is/1MnAl6W*

Evaluation Result Summary

Condition Index	N/A	Total USMP Rating	#VALUE!	**Programmatic Improvement Cost to CS1**
Condition State	1	Hazard Rating	N/A	SITE IS GOOD
Condition State Text	GOOD	Risk Rating	#N/A	
		Perception Rating	N/A	

Note calculation is programmatic and does not reflect site-specific needs. Actual costs may differ significantly.

Wall Hazard Rating

			Wall Height Score	1
			Length of Roadway Affected Score	1
			Annual Precipitation Score	3
Vertical and Horizontal Alignment Score		*Good, fair, poor, failed*	*Wall Alignment Score*	0
Rdwy Displacement due to Wall Movement Score		*none, visible crack, minor displacement, measurable displacement*	*Roadway Displacement Score*	0
Maintenance Freq. Score		*none, occasional, routine, year-round*	*Maintenance Frequency Score*	0
Drainage System Score		*good, fair, damaged/poor, non-functional/not present*	*Drainage System Score*	0
Other Problems		*evidence of cracking, corrosion, or damaged elements - none, minor, mod., major*	*Other Problems Score*	0
Movement History		*sporadic, minor, measureable annual, and measurable seasonal displacement*	*Movement History Score*	0
			Hazard Subtotal	N/A

Wall Risk Rating

			Decision Sight Distance Score	#N/A
			Roadway Width Score	1263
			AADT Score	1
% Time Car Within Site	#DIV/0!		*Average Vehicle Risk Score*	#DIV/0!
Impact on Traffic Score		*Minor Delay, One Lane Open, 100 mi or 1 day closure, no detour or 3 days +*	*Failure Impact on Traffic Score*	0
Impact on Roadway Score		*shoulder, 1/2, 3/4, full roadway*	*Failure Impact on Roadway Score*	0
ROW Impact Score		*None, minor, private prop-no structures, structures/roads/RR/util/parks*	*Right of Way Impacts Score*	0
Envir. Impacts Score		*Zero points if none likely, 50 pts if some possible*	*Environmental Impacts Score*	0
Likelihood of Failure Score		*low, medium, medium-high, high*	*Estimated Likelihood of Failure Score*	0
Maint. Complexity Score		*Routine, Specialized equip, difficult effort/location, complex or dangerous*	*Maint Complexity Score*	0
Event Cost Score		*<$50k, $250k, $1,000k, >$1,000 in reasonable worst case*	*Event Cost Score*	0
			Risk Subtotal	#N/A

LANDSLIDE TECHNOLOGY
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GIS Field Code	Field Name	Field Value
ISiteIDN	Site ID	
IRtDateN	Rating Date	1/0/1900
IRaterT	Rater	1/0/1900
IStatusT	Site Rating Status	0
IRegionT	Region	0
IHwyNamT	Highway Name	0
ICDSRtNN	CDS Route Number	#N/A
ICmmntyT	Community	0
IMntDstT	Maintenance District	0
IMntStnT	Maintenance Station	0
IProjNmN	State/Federal Project Number	0
IConstDN	Construction Date	0
IHwyMPN	Highway Milepost	0
ICDSMPN	CDS Milepoint	0.00
ILatN	Latitude	0.00000
ILongN	Longitude	0.00000
ICmmntsT	Comments	0
IWCatgrT	Wall Category	0
IWFunctT	Wall Function	0
IWTypeT	Wall Type	0
IOffsetT	Wall Offset	0
MWHeigtN	Wall Height (ft)	0
MWLengtN	Wall Length (ft)	0
EWAreaN	Wall Area (sq ft)	0
MRdWdthN	Roadway Width (ft)	0
DSpdLmtN	Speed Limit (mph)	0
DAADTN	AADT	0
MSghtDiN	Sight Distance (ft)	0
SCndtIxN	Condition Index	N/A
SCndtStN	Condition State Number	1
SCndtStT	Condition State Text	GOOD
SUSMPRtN	Total USMP Rating	#VALUE!
SHazardN	Hazard Rating	N/A
SRiskN	Risk Rating	#N/A
SPercepN	Appearance/Public Perception Rating	N/A
EImpCstN	Programmatic Improvement Cost to CS1	$ -
SWHeigtN	Wall Height Score	1
SAlignN	Vertical/Horizontal Alignment Score	0
SRdDispN	Displacement due to Wall Movement Score	0
SWLngthN	Length of Roadway Affected Score	1
SMntFrqN	Maintenance Frequency	0
SDrainN	Drainage System Score	0
SPrecipN	Annual Precipitation Score	3
SOtherN	Other Problems Score	0
SMvHistN	Movement History Score	0
SSghtDiN	Percent Decision Sight Distance	#N/A
SRdWdthN	Roadway Width Score	1263
SAADTN	AADT Score	1
SAVRN	AVR Score	#DIV/0!
STrfImpN	Impact on Traffic Score	0
SRdImptN	Impact on Roadway Score	0
SROWImpN	ROW Impacts Score	0
SEnviroN	Environmental Impacts Score	0
SFlrPrbN	Likelihood of Failure Score	0
SMntCmpN	Maintenance Complexity Score	0
SEvntCsN	Event Cost Score	0
STechApN	Technical Appearance Score	0
SPubPerN	Public Perception Score	0

Field Values are populated from the "Site Rating Calculator" Sheet and are manually entered in the "Retaining Wall - Add New Site" AGOL Application or in the "Retaining Wall - Edit Exisiting Data Form" AGOL Application. The GIS Field Code column shows the abbrievieted field name used in the shaprefile and is a useful referrence when editing field values for an exisiting site. The complete Field Name is shown in the "Retaining Wall - Add New Site" GeoForm.

AKDOT&PF RETAINING WALL INVENTORY
SITE INFORMATION

Region NR CR SR **District**	**Borough**	**Date**	**Weather**
CDS Route Name	**CDS Number**	**Offset** L R	**Rater**
Milepost	**CDS Milepoint**	**State/Fed Project No.**	
Latitude	**Longitude**	**Datum**	**AADT**

Wall Category	Bridge Abutment | Bridge Zone RW | Hwy RW | Minor RW | Culvert Headwall
Wall Function	Bridge assoc. | Grade sep. | Slope stab. | Earth ret., cut | Earth ret., fill | Ped. X-ing | Flood Cont. | Seawall | Other
Wall Type	Anchor-Tieback h-pile, Micropile, or Tieback Sheet Pile | Bin-Concrete or Metal | Soil Nail Cantilever-Concrete, Soldier, or Sheet Pile | Crib-Concrete, Metal, Timber | Tangent/Secant Pile Gravity-Block/Brick, Mass Concrete, Gabion, Dry Stone, or Mortared Stone MSE-Geosynthetic Wrapped Face, Precast Panel, Segmental Block, or Welded Wire Face

Maximum Wall Height	**Wall Length**	**Annual Rainfall**
Sight Distance	**Roadway/Trail Width**	**Speed Limit**

Preliminary Site Evaluation Good | Fair | Poor

Comments / Photos

Site Sketch (if applicable)

RETAINING WALL CONDITION CATEGORIES					
Category Rating	**3 (100)**	**9 (75)**	**27 (50)**	**81 (25 to 0)**	**Score**
HAZARD RATING					
Wall Height	≤ 10 feet	10 – 20 feet	20 -30 feet	≥ 40 feet	
Vertical and Horizontal Wall Alignment (take applicable measurements)	Good wall alignment	Fair wall alignment	Portion of wall showing poor alignment	Poor alignment entire wall to failed, unrepaired sections.	
Roadway Displacement due to wall movement	No visible crack in wall or roadway	Visible crack in wall or roadway, no displacement	Minor crack in wall or roadway with minor displacement	Crack in wall or roadway with measureable displacement to sig. displacement impeding traffic	
Length of Roadway Affected	25 feet	100 feet	225 feet	400 feet	
Wall Maintenance Frequency	No scheduled wall maintenance	Wall maintenance after major storm events	Routine wall maintenance required	Year-round wall inspection and maintenance required	
Wall Drainage System	Good performing drainage system; surface water well controlled	Fair performing drainage system; surface water moderately well controlled	Damaged or poorly performing drainage system; surface runoff poorly controlled	Non-performing wall drainage system; surface water runoff control not present	
Annual Rainfall	0-10”	10-30”	30-60”	60”+	
Other Problems	No evidence of corrosion, cracking, distortion, or lost bearing/missing elements	Evidence of minor corrosion, cracking, distortion, or lost bearing/missing elements	Evidence of moderate corrosion, cracking, distortion, or lost bearing/missing elements	Evidence of major corrosion, cracking, distortion, or lost bearing/missing elements	
Movement History	Sporadic episodes of minor movement/ distortion	Minor annual movement/ cracking	Measurable annual movement	Measurable seasonal movement	
RISK RATING					
Estimation of likelihood of complete failure (annual probability)	Low to Medium Low (0.01 – 0.035)	Medium (0.125)	Medium High (0.40)	High (0.99)	
Potential Impact of Wall Failure to Traffic Flow	Traffic continues with minor delay	One lane remains open - traffic control required	All lanes are blocked Detour less than 100 miles or less than 1 day closure	All lanes are blocked No road-based detour or closure longer than 3 days	
Roadway Width	44 feet	36 feet	28 feet	20 feet	
AADT	500	2,000	4,500	8,000	
Wall Failure Significance to Rdwy.	Shoulder only	Half Roadway	¾ Roadway	Full Roadway	
Average Vehicle Risk within 100 feet of Wall Length	25% of the time	50% of the time	75% of the time	100% of the time	
Percent of Decision Sight Distance	Adequate, 100% of low design value	Moderate, 80% of low design value	Limited, 60% of low design value	Very Limited, 40% of low design value	
Right of Way (R/W) Impacts above/below Wall	No R/W implications	Minor effects beyond R/W	Private property, no structures affected	Structures, roads, RR, utilities, or Parks affected	
Envir. Impacts if Left Unattended	No environmental implications		Yes environmental impacts (50 pts)		
Maintenance Complexity	Routine effort	Requires Specialized equipment	Difficult effort/location	Complex or dangerous effort	
Wall Failure Cost	<$50 k	$50 k - $250 k	$250 k - $1,000 k	>$1,000 k	
APPREARANCE/PERCEPTION RATING					
Technical Appearance	Exceeds expectations	Meets Expectations	Needs Improvement	Clearly needs work/ failed already	
Public Perception	Wise use of public money, well maintained	Routine DOT Investment	Investment needs work	Looks like about to fail/ already failed	

For the directly measurable categories, use the following formulas to calculate the exponent value (x) for the scoring formula $y = 3^x$. This will allow the calculation of a precise score for the category measurement and development of category scoring tables.

Wall height exponent formula:

$$x = \frac{slope\ height}{10}$$

Length of roadway affected exponent:

$$x = \sqrt{\frac{length\ affected}{25}}$$

Roadway width exponent formula:

$$x = \frac{52 - Road\ width\ (ft)}{8}\ \text{for vehicles}$$

AADT exponent formula:

$$x = \sqrt{\frac{AADT}{500}}$$

For trails, ADT is daily trail traffic and the speed limit would be the average walking speed.

Average vehicle risk exponent formula:

$$x = \frac{\left(\dfrac{\frac{ADT}{24} \times wall\ length\ (miles)\ \times 100}{posted\ speed\ limit}\right)}{25}$$

Percent decision sight exponent formula:

$$x = \frac{120 - \left(\dfrac{measured\ sig\ \ t\ distance}{AASHTO\ decision\ sig\ \ t\ distance} \times 100\right)}{20}$$

Appendix F

PRIORITIZATION AND DESIGN EFFORT ESTIMATION OF SOUTHCOAST REGION UNSTABLE SLOPES

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December 15, 2014 2337

Mitch McDonald, C.P.G. and Barry Benko, C.P.G.
Alaska Department of Transportation and Public Facilities
Juneau and Anchorage, Alaska

Prioritization and Design Effort Estimation for Southcoast Region Unstable Slopes
Alaska Geotechnical Asset Management Program Development

Background

The Southcoast Region of the Alaska Department of Transportation & Public Facilities (AKDOT&PF) is planning to allocate up to 2 million dollars of construction funds annually for repairing and rehabilitating unstable slopes, pavements, and culverts. AKDOT&PF's objective is to provide rockfall and landslide mitigation designs while incorporating recently completed geotechnical asset management (GAM) inventory and condition assessments. Other maintenance efforts, such as pavement and culvert improvements may also be addressed using these same funds. This document describes target unstable slopes identified as part of the recent GAM efforts and provides recommendations on the priority of mitigation efforts.

Beginning in 2008, AKDOT&PF has been researching and developing a system for GAM, a major component of which is inventory and condition assessment of the State's geotechnical assets, such as unstable rock and soil slopes and embankments, retaining walls, and material sources. These inventories and assessments complement existing asset management efforts, such as bridge and pavement inventories and ratings. By compiling these inventories and assessments, rehabilitative treatments to prolong the life of geotechnical assets can be undertaken and programmed into construction activities.

Site Selection Methodology

In September and October 2014, NHS routes with known unstable slopes as well as the AHS portion of Glacier Highway and North and South Tongass, were inventoried and assessed using the Unstable Slope Management System procedures developed during an earlier phase of GAM program development. The SR routes that have been evaluated, south to north, are:

- South Tongass (AHS)
- North Tongass (AHS)
- Mitkof Highway (NHS)
- Halibut Point Road (NHS)
- Egan Drive/Glacier Highway (NHS/AHS)
- Haines Highway (NHS)

- Lutak Road (NHS)
- Klondike Highway (NHS)
- Richardson Highway (NHS)

These ratings evaluate 18 to 20 individual hazard or risk criteria for each of the unstable slopes identified by either experienced geotechnical field personnel, M&O staff, or regional AKDOT&PF geotechnical personnel. These criteria are then utilized to formulate overall slope ratings, condition states, and other indices still under development. The condition states are measured on a one to five scale, with State 1 being Very Good (low rockfall activity and an effective ditch, or minimal, slow displacement over a short distance for soil slopes and embankments), to State 5 being Very Poor (constant rockfall activity with limited to no ditch, or regularly occurring fast moving landslides with significant displacement or deposits over a wide stretch, such as debris flows). Plots and maps for condition states calculated from provisional rating data for each route are contained in the appendices. Pavement Present Serviceability Rating (PSR) values based on 2013 data are plotted alongside slope condition states to visually evaluate where poor pavement quality corresponds to poor slope condition slope condition states. Additional condition data on walls and culvert function are provided on plots for North and South Tongass, where that data was collected as part of a separate GAM research project.

Selection of candidate sites and groupings for proposed rehabilitation work are based on an evaluation of condition states, M&O input, a review of photographs obtained during the rating process, the possibility of combining with upcoming projects, potential economic impacts of road closure, and expert judgment. Site groupings are intended to achieve an economy of scale by using similar mitigation measures on the same highway or within the same locale to avoid excessive mobilization costs. Groupings of sites for a single construction contract could be performed in a single season provided the contractor staffs the job adequately.

Design Level of Efforts

Cost estimates to provide design services are heavily dependent on the goals and objectives of the Owner. Design of modest performance improvements typically requires both less design time and less construction cost. More robust mitigation measures correspondingly require more design effort and can include such tasks as subsurface investigations, rope access geologic investigations, helicopter reconnaissance and extensive modelling efforts.

The projects and level of effort discussed below and in the Appendices attempt to describe the geotechnical evaluations required and do not assume to capture input from other disciplines, such as the ROW acquisition or easements process, survey, hydraulics, roadway design, public involvement, etc. These level-of-effort costs include PS&E for the locations discussed. Once AKDOT&PF decides on the sites to prioritize, considers the level of improvement desired, and prepares an anticipated schedule, cost estimates for a first phase of geotechnical design efforts, generation of a work plan, can be formulated.

Low level design effort: cost range $10,000 to $40,000. This level of effort assumes no subsurface explorations, no rope access, little to no modelling, and that plans can be developed with photos or scaled aerial photos or otherwise minimal efforts. Design efforts would typically include a one or two day site visit with one or two staff and subsequent PS&E limited to two to four design drawings. For example, the emergency response project design efforts at the 2014 Ketchikan Ward Cove project fit this level of effort.

Moderate level design effort: cost range $40,000 to $100,000. This assumes no geotechnical drilling, some possible test pitting with AKDOT&PF operator and equipment, some rope access and photogrammetry data collection may be required. Office analyses would include stability or rockfall modelling, subgrade geosynthetic reinforcement design, and plans may be annotated photos or developed with assistance from AKDOT&PF survey crews. Some assistance during construction may be required. Design work on the South Tongass MP 6.87 slope in 2007 fit this level of effort.

High level design effort: cost range $100,000+. Assumes that drilling or other investigations may be required with geotechnically complex problems or highly variable geologic conditions. Specialized construction sequencing and traffic control may be required. Alternatively, a large number of unstable slopes may be grouped, or a variety of mitigation approaches may be required.

Design Priority

Listed and mapped below is a suggested prioritization schedule and groupings for the sites and corridors identified in the Southcoast Region. An area map with prioritization is shown below. Further discussion, maps, and plots, organized by locale, are contained in Appendix A through G.

1. Haines Highway Debris Flows, MP 17 to 23. (2015 efforts recommended). This corridor contains the poorest condition unstable slope sites on both a regional and statewide basis. M&O expends extensive time and materials on an annual basis preparing for and reacting to large, sudden debris flows. Members of the public as well as State personnel have been swept up in these debris flows, resulting in non-injury accidents. Previous reports have recommended establishment of an early warning and detection system with an initial monitoring period for threshold establishment, which could take several years depending on debris flow occurrence. This initial monitoring period, the increasing frequency of debris flows, and the very poor conditions measured on both a regional and a statewide basis, indicates that this area would benefit with a start as early as possible. Lutak Road non-NHS debris flows (priority No. 7) could also be combined with this effort for an economy of scale.

2. Klondike Highway Unstable Slopes. (2015 design efforts recommended). The relative high density of high activity slopes and the planned paving project coupled with upcoming design work on the CWHM Bridge project creates a number of potential cost savings in both design and construction work. This NHS roadway is a route that is of international economic importance for transporting outgoing ore concentrates and logging products and incoming equipment and petroleum products via the Port of Skagway.

3. Ketchikan ROW Unstable Slopes. (2015/2016 conceptual design efforts recommended). The relative high number of unstable slopes that AKDOT&PF has had to respond to on an emergency basis is indicative of the relatively unstable foliated and jointed rock found in Ketchikan. This rock and the small to non-existent set-backs create a risk to the Department that can be reduced by installation of rock slope support on both the North and South Tongass and on Shoreline Drive. Mobilization using similar stabilization measures across a number of slopes can achieve an economy of scale and a modular contracting approach, where sites can be added or removed as budget allows could be employed. Since a number of private landowners are involved, the ROW and subsurface easement process may be prolonged. Therefore, an early start on this aspect would be recommended prior to final design activities.

4. Ketchikan Wolfe Point and South Tongass MP 6.87 Slope. These two slopes pose safety issues to the road users and large failures have impacted the sole access routes to portions of Revillagigedo Island. Both sites are known to produce rock on the road and are likely to impact the roadway either continually (at Wolfe Point) or with a large-scale failure (at South Tongass MP 6.87)5. Mitigating these slopes would result in risk reduction to both the public and the Department.

5. Richardson Highway Slopes. These slopes do not pose as significant a hazard as other slopes evaluated in the Southcoast Region, however the economic impact in the event of road blockages, or potential delays in disaster response for both Valdez and the Trans-Alaska Pipeline, warrant improving corridor resiliency. Additional GAM research and analyses into resiliency may affect the relative priority of this segment.

6. Lutak Road NHS Slopes and Ferry Terminal Slope. The rock slope across from the Haines Ferry Terminal has been a high maintenance problem for a number of years. The proximity of the ferry terminal and other critical infrastructure elevates the relative importance of this slope. An active stabilization system, rather than passive catchment at the ditch, would reduce personnel demands and costs for the Haines M&O and improve the safety at this critical AMHS and NHS location. The recently refurbished segment of Lutak Road also has a number of rock slopes and embankment failures that could be improved along with the ferry terminal slope.

7. Lutak Road Debris Flows. These locations were recently improved with large culverts that appear to have partially mitigated the impacts from debris flows and other high flow events. However, the installation of sensors to monitor river stage and sediment deposition would assist in alerting M&O to excessive sedimentation and enable detection of potential culvert blockages, further reducing the potential for flows and deposits on the roadway.

8. Mitkof Highway. The debris flows on Mitkof Highway are relatively infrequent, however given the trends in increased debris flow frequency elsewhere in the region, occurrence frequency may increase in the future. Unfortunately, the recent pavement and culvert improvements indicate that this work may not be coupled with additional planned work in the near future.

9. Glacier Highway. The three varied slopes identified on Glacier Highway do not share similar characteristics so an economy of scale for specific mitigation measures, such as rock bolts, would be difficult to achieve. Nevertheless, these sites could be mitigated collectively in a single contract or separated as individual projects to let as funds become available.

10. Halibut Point Road Slope. This slope can be mitigated and risk reduced with minimal effort and potentially with directed overburden, pavement, or concrete waste disposal associated with other construction contracts. The structure above the slope and the history of failures increases the risk to the Department and may warrant the effort to determine the risk of this slope or adjacent similar slopes failing. The low cost of design efforts and construction may warrant a higher prioritization in order to coincide with any upcoming nearby projects.

Closure

The above prioritization order is preliminary and should be evaluated by AKDOT&PF for consistency with Departmental goals and objectives, slopes on roadways not evaluated as part of GAM program development, and other issues that may not be addressed in this report. We appreciate the opportunity to be of assistance to AKDOT&PF. If you have any questions, please contact Darren Beckstrand at (503) 452-1200.

Sincerely,

LANDSLIDE TECHNOLOGY

Darren Beckstrand, C.P.G.
Senior Associate Geologist

Appendix A: Ketchikan

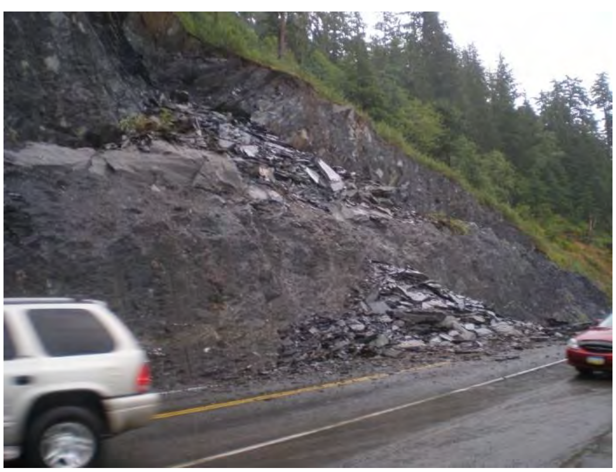
North Tongass CDS MP 0.82 - Wolfe Point
USMP Score: **679** Condition State: **4 - Poor**

Rockfall activity is constant with rock debris entering the road regularly. M&O frequently responds to clean small rock debris and larger material (1'+) on a less frequent basis.

Design level of effort: Low to Moderate. Design efforts would not need to access the slope via rope access or inspect specific rock blocks with a boom-lift. Road closures for design efforts would not be anticipated. The adjacent rock slope also has planar features that could be mitigated. Low level design efforts would be for a roadside barrier, such as a concrete barrier or low energy rockfall fence, but would require annual maintenance and would sustain occasional damage as the result of larger rockfall event(s). A moderate level of design effort would be for scaling of loose rock with subsequent restraint of the remainder of the slope with measures such as a pinned Tecco system to restrain colluvial overburden and installation of rock dowels on the adjacent rock slope. The latter approach would result in reduced M&O efforts and a greater reduction in hazard, risk, and long-term costs.

South Tongass CDS MP 6.87
USMP Score: **562**. Condition State: **2** (due to low activity after failure and effective ditch and bench for most rockfall).

This slope has a history of producing large rockfall events due to a geologic structure permitting pervasive toppling failures. The slope failed during construction and then again after additional mitigation measures were installed and slope geometry was altered to include a bench. Recent inspections show low activity levels (relatively clean ditch and clean bench), but there is still a significant potential for large failures in the central portion of the upper cut.



Design level of effort: Moderate to High. Depending on the efforts advanced, mitigation of this slope may require additional ROW acquisition, rock cut design, and additional stability modelling relative to the required by more typical rockfall mitigation designs. Large open tension cracks are present at the top of the slope adjacent to the failed section, indicating continued vulnerability and low resilience. Based on the satisfactory performance of the remainder of the slope, mitigation efforts would be focused in the immediate vicinity of the failure.

Shoreline Drive

Design level of effort: Moderate. This corridor contains a number of unstable slopes that exhibit adverse geologic structure, produce active rockfall, and are adjacent to both private property and structures. Similar to other slopes on the North and South Tongass Highway, property lines severely encroach into what would normally be the transportation corridor ROW. Unstable slopes that span both public and private property, and structures built with little setback from the top of the slope, have forced the Department to purchase properties that have been affected by unstable slope movement, multiplying the cost of mitigating the slope. Note that Shoreline Drive has not been evaluated as part of the USMP program.

Designing mitigation measures for rock slope support, such as rock bolts and dowels, frequently requires more in-depth reconnaissance to obtain rock structure measurements and to perform subsequent rock slope stability modelling. For this reason, design efforts are classified as moderate, and assumes fewer than five slopes potentially requiring mitigation.

N&S Tongass ROW-vulnerable slopes

Design level of effort: Moderate to High. North and South Tongass Highways have a number of hazardous slopes with private property and structures situated immediately above the slope crest. If a large failure were to occur, the impacts could extend to the adjacent properties. Construction of rock slope support such as rock bolts and dowels would limit rockfall activity and associated undermining of adjacent property and structures. Mitigation such as scaling would be required to ensure worker safety, while items such as roadside barriers and draped mesh would reduce hazard and risk at the roadway. Since installation of rock support may require drilling and installation of permanent elements below existing property lines, subsurface easements may be required. This aspect could meet with landowner resistance and prove to be a time consuming item and require additional Department involvement. Using a qualitative risk assessment, slopes considered to be candidates are those that were greater than two standard deviations from the mean for the formula Condition State x USMP ROW Score. This calculation is shown in the Asset Condition State Plots and the slopes are shown on the following photo table. Based on the ratings and photographs, the slopes demarcated with an asterisk are recommended for further investigation and risk reduction.

N. Tongass, CDS MP 1.78, (utilities above)

N. Tongass, CDS MP 3.97 (tree blowdown area, private prop.)

N. Tongass, CDS MP 4.07 (tree blowdown area, private prop.)

N. Tongass, CDS MP 5.59 (structure above)

N. Tongass, CDS MP 7.61 (mitigated long landslide with structures and no sign of ongoing movement)

** N. Tongass, CDS MP 10.5 ** (utilities above)

** S. Tongass, CDS MP 1.50 ** (multiple structures above)

** S. Tongass, CDS MP 1.55 ** (public meeting house above)

** S. Tongass, CDS MP 1.87 ** (businesses above)

** S. Tongass, CDS MP 1.96 ** (tunnel portal with structures)

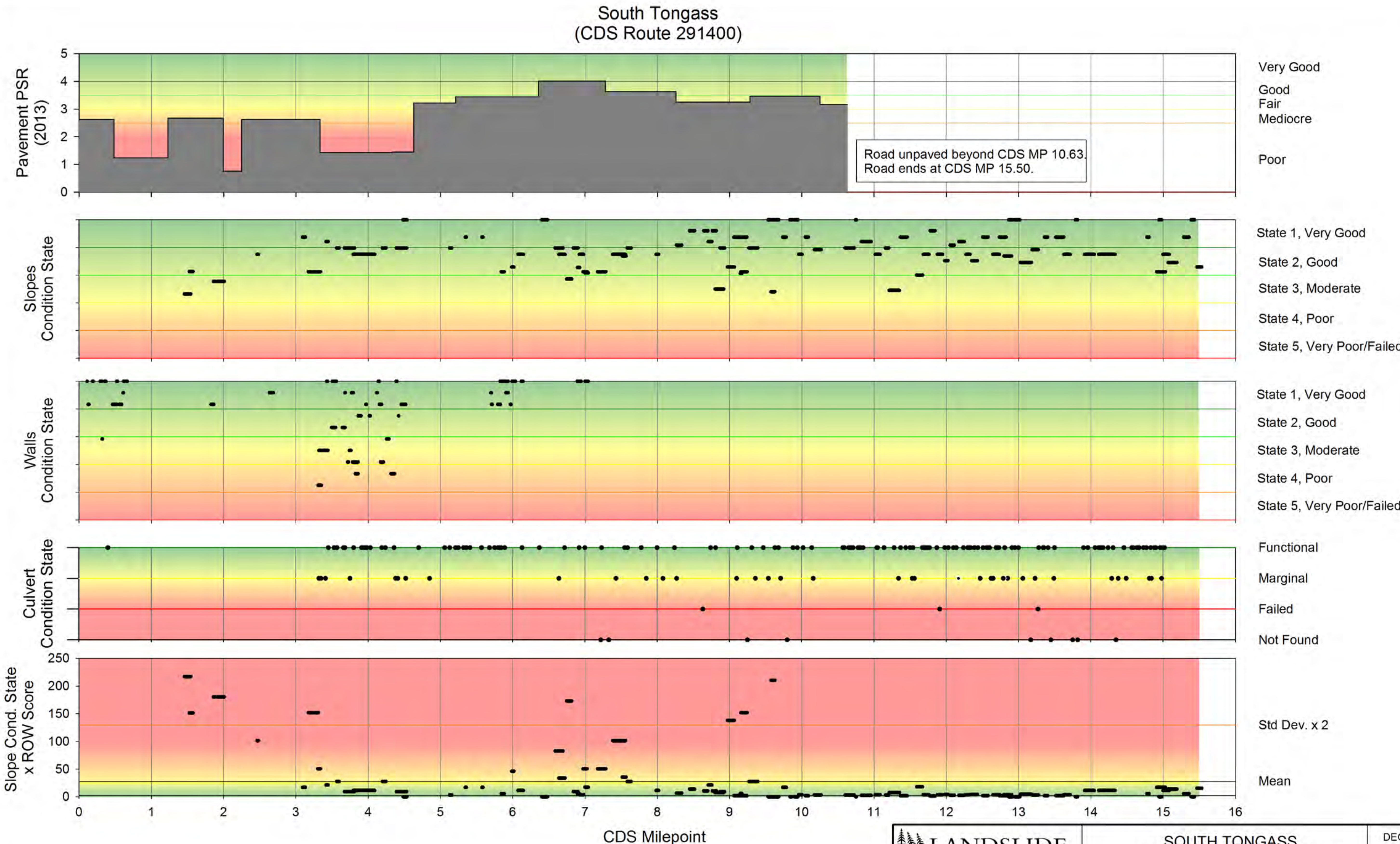
S. Tongass, CDS MP 3.24 (road to CG Facilities above)

S. Tongass, CDS 6.78 (utilities above)

** S. Tongass, CDS MP 9.02 ** (structures above)

S. Tongass, CDS MP 9.60 (Slide/ settlement with utilities)

** Sites demarcated with asterisks are recommended for further investigation and potential grouping.



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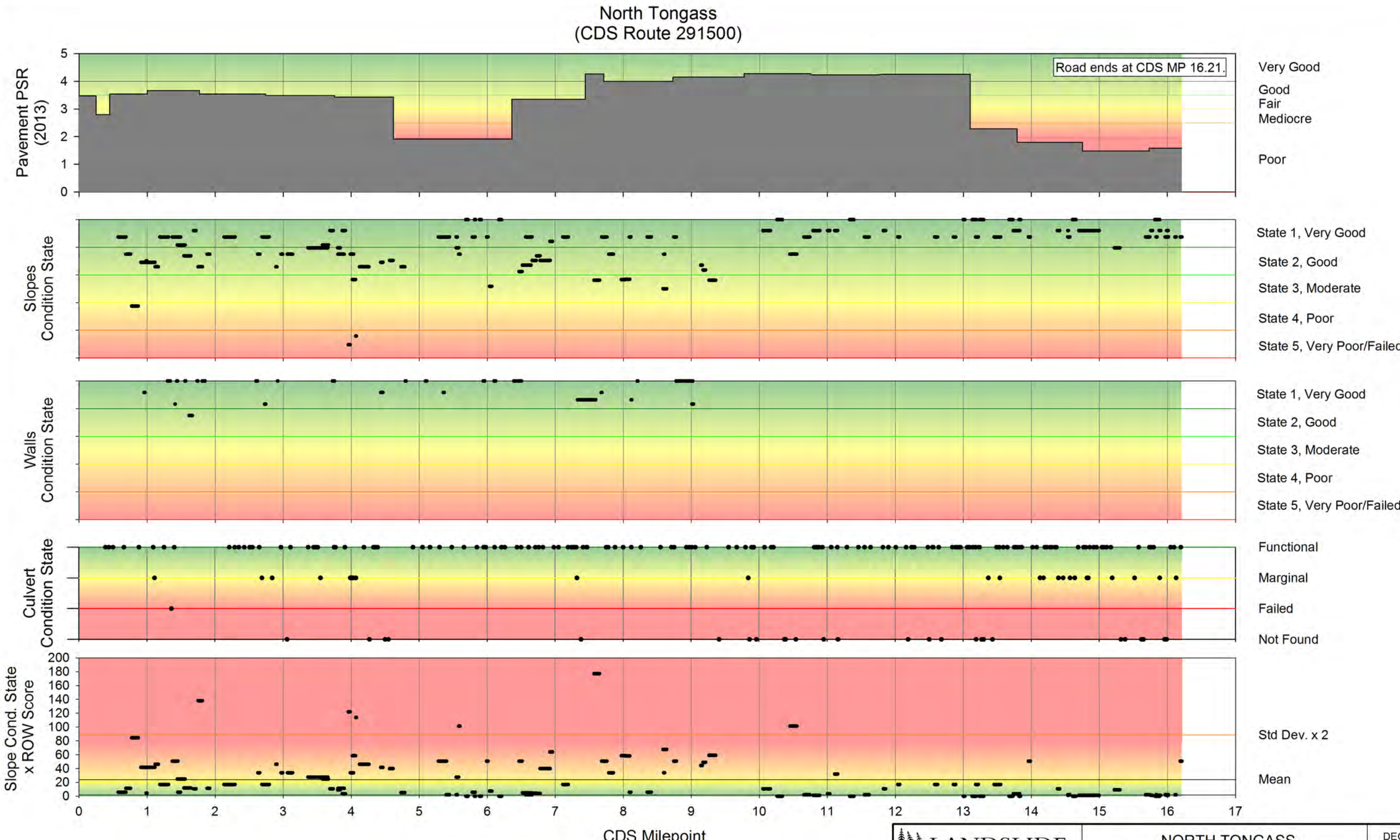
SOUTH TONGASS
ASSET CONDITION STATES

SOUTHCOAST REGION PLANNING
SOUTHCOAST, ALASKA

DEC 2014

PROJ. 2337

FIG.



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NORTH TONGASS ASSET CONDITION STATES		DEC 2014
SOUTHCOAST REGION PLANNING SOUTHCOAST, ALASKA		PROJ. 2337
		FIG.

Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (25)
- 2 - Good (1)
- 3 - Fair (1)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (1)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (7)
- 2 - Good (6)
- 3 - Moderate (0)
- 4 - Poor (1)

Borings (0)

Culverts
- Functional (16)
- Marginal (3)
- Failed (1)
- Not Found (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (1)
- 3 - Fair (2)
- 4 - Mediocre (5)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

North Tongass - Ketchikan

0 0.1 0.2 0.3 Miles

N

LANDSLIDE TECHNOLOGY

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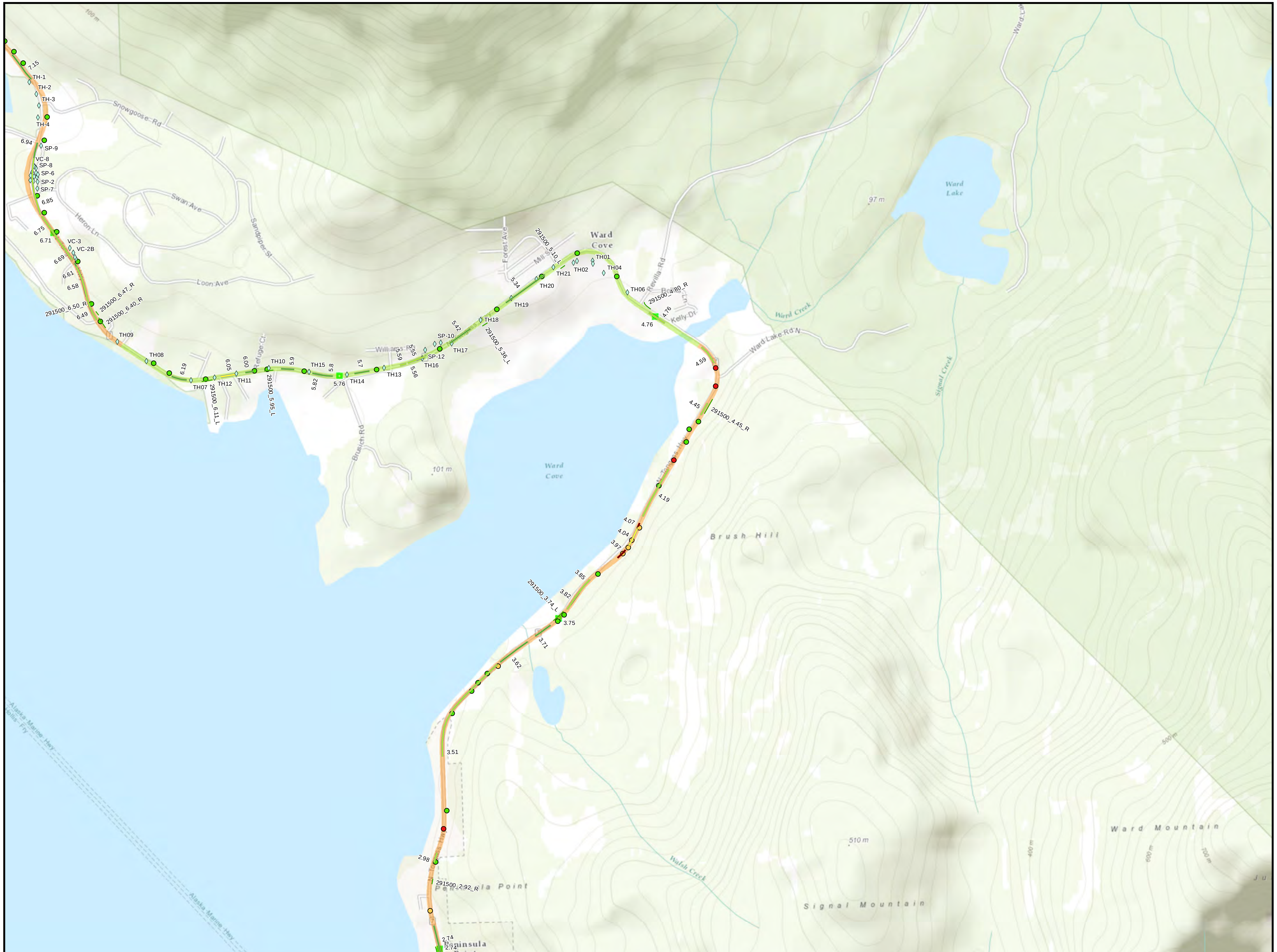

Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (14)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (2)

Rock Slopes' Condition State
- 1 - Very Good (15)
- 2 - Good (15)
- 3 - Moderate (2)
- 4 - Poor (0)

Borings (49)

Culverts
- Functional (36)
- Marginal (6)
- Failed (0)
- Not Found (4)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (1)
- 3 - Fair (0)
- 4 - Mediocre (4)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

North Tongass - Ketchikan

0 0.1 0.2 0.3 Miles

N

LANDSLIDE TECHNOLOGY

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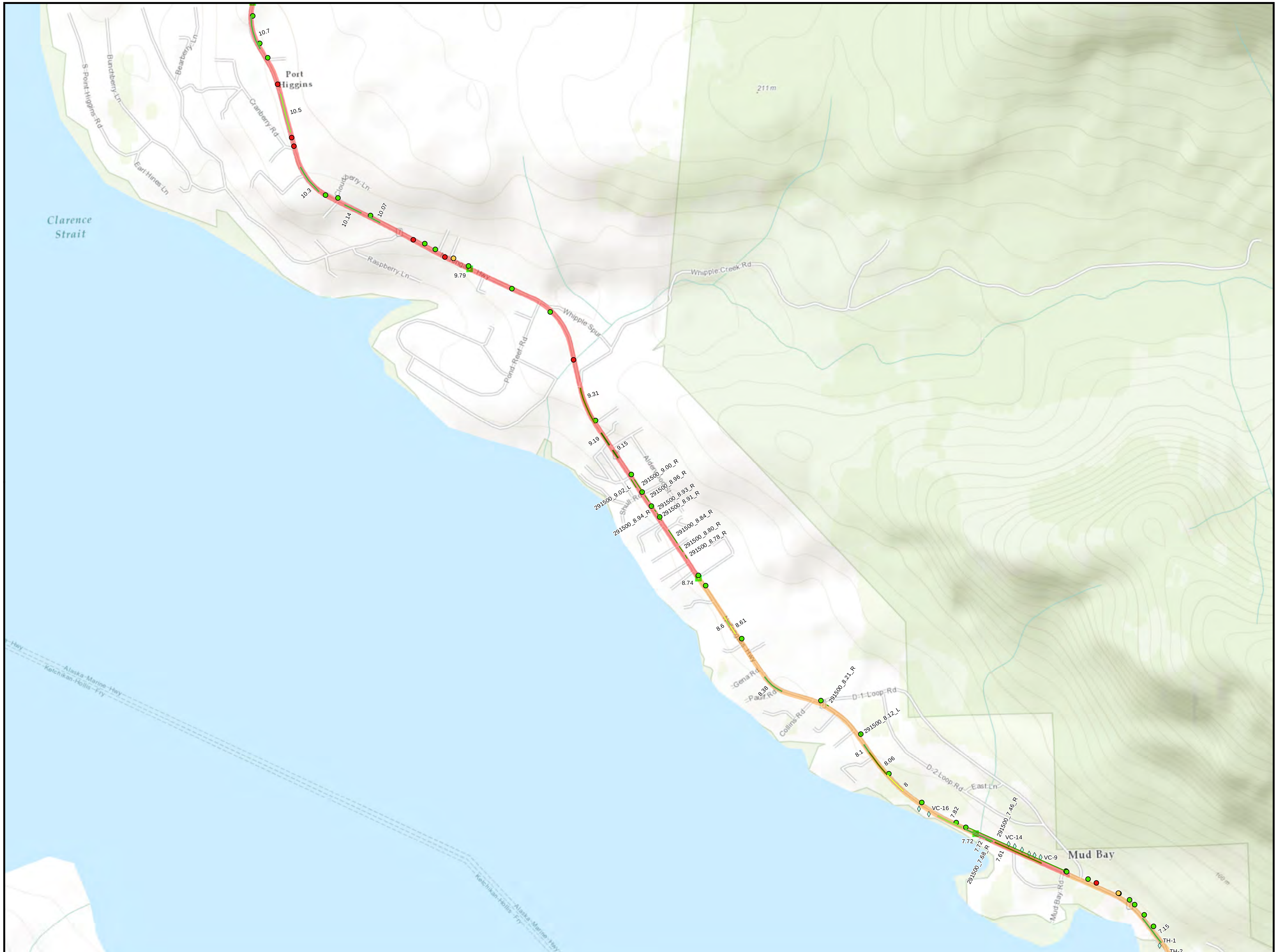

Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (13)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (2)
- 3 - Moderate (3)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (9)
- 2 - Good (3)
- 3 - Moderate (2)
- 4 - Poor (0)

Borings (12)

Culverts
- Functional (33)
- Marginal (2)
- Failed (0)
- Not Found (7)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (2)
- 5 - Poor (4)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

North Tongass - Ketchikan

Miles
0 0.1 0.2 0.3

N

LANDSLIDE TECHNOLOGY
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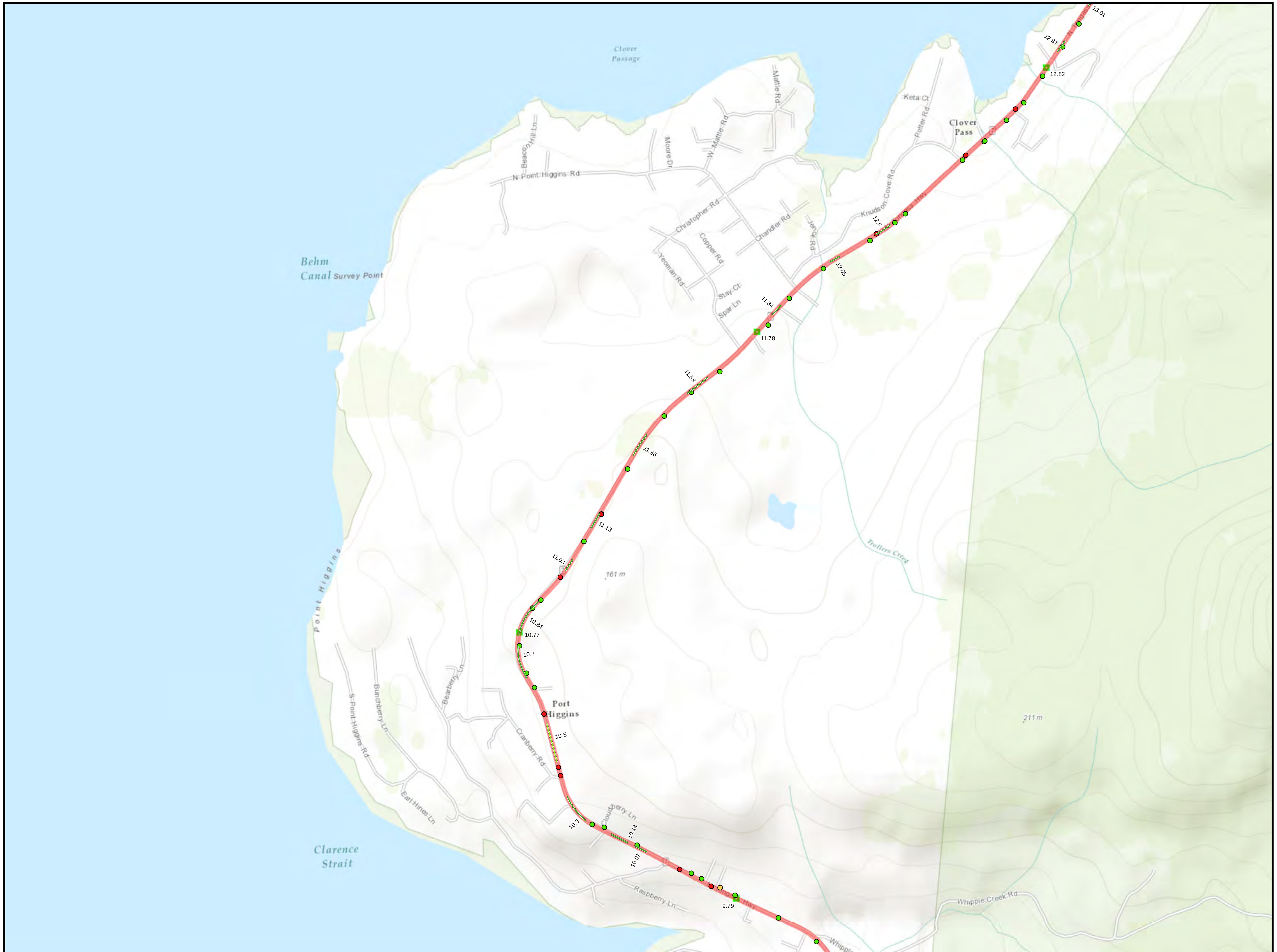

Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (14)
- 2 - Good (1)
- 3 - Moderate (0)
- 4 - Poor (0)

Borings (0)

Culverts
- Functional (33)
- Marginal (1)
- Failed (0)
- Not Found (10)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (0)
- 5 - Poor (4)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

North Tongass - Ketchikan

0 0.1 0.2 0.3 Miles

N

LANDSLIDE TECHNOLOGY

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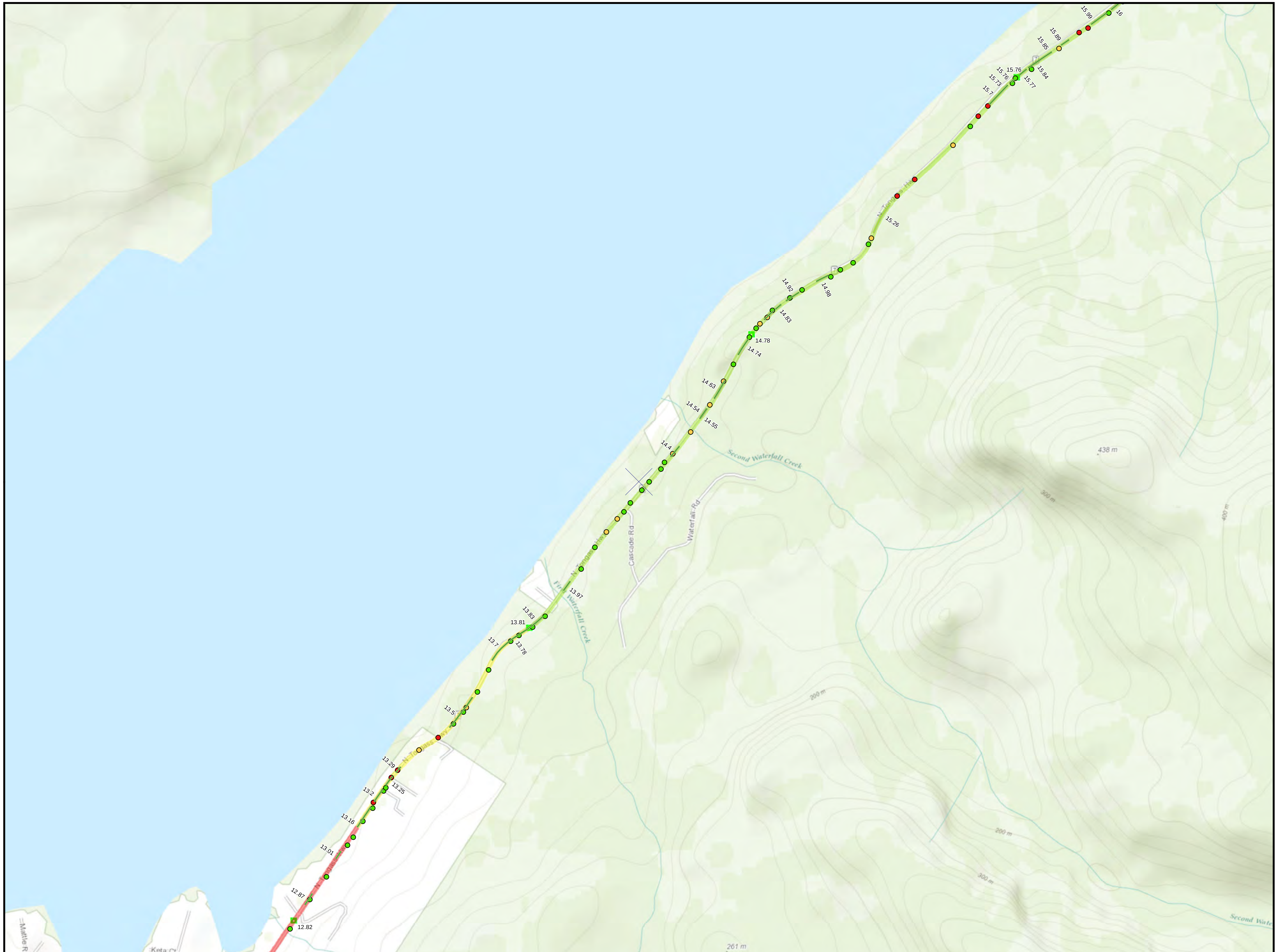

Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (28)
- 2 - Good (1)
- 3 - Moderate (0)
- 4 - Poor (0)

Borings (0)

Culverts
- Functional (42)
- Marginal (13)
- Failed (0)
- Not Found (11)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (3)
- 3 - Fair (1)
- 4 - Mediocre (0)
- 5 - Poor (1)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

North Tongass - Ketchikan

Miles 0 0.1 0.2 0.3

N

LANDSLIDE TECHNOLOGY

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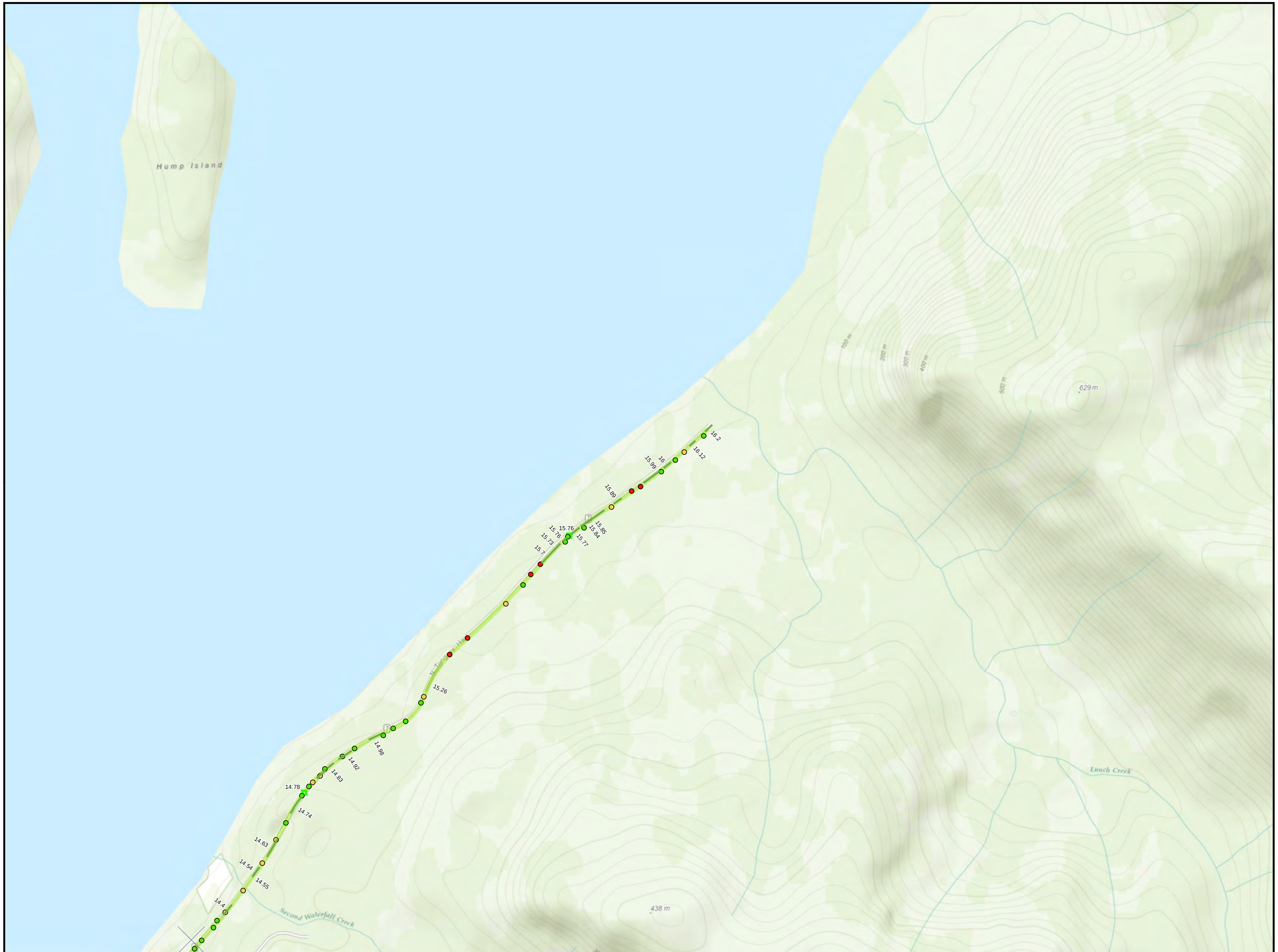


Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (19)
- 2 - Good (1)
- 3 - Moderate (0)
- 4 - Poor (0)

Borings (0)

Culverts
- Functional (22)
- Marginal (10)
- Failed (0)
- Not Found (6)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (3)
- 3 - Fair (0)
- 4 - Mediocre (0)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

North Tongass - Ketchikan

Miles 0 0.1 0.2 0.3

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (23)
- 2 - Good (2)
- 3 - Fair (7)
- 4 - Poor (1)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (2)
- 2 - Good (7)
- 3 - Moderate (3)
- 4 - Poor (0)

Borings (21)

Culverts
- Functional (7)
- Marginal (4)
- Failed (0)
- Not Found (0)

Pavement PSR
- 1 - Very Good (1)
- 2 - Good (2)
- 3 - Fair (4)
- 4 - Mediocre (1)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

South Tongass - Ketchikan

Miles: 0, 0.1, 0.2, 0.3

N

LANDSLIDE TECHNOLOGY

A DIVISION OF CORNFORTH CONSULTANTS

Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (26)
- 2 - Good (5)
- 3 - Fair (8)
- 4 - Poor (4)

Soil Slopes' Condition State
- 1 - Very Good (1)
- 2 - Good (2)
- 3 - Moderate (1)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (6)
- 2 - Good (14)
- 3 - Moderate (0)
- 4 - Poor (0)

Borings (48)

Culverts
- Functional (33)
- Marginal (9)
- Failed (0)
- Not Found (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (2)
- 3 - Fair (1)
- 4 - Mediocre (2)
- 5 - Poor (1)

CDS Milepoint

Asset Inventory Map

December 2014

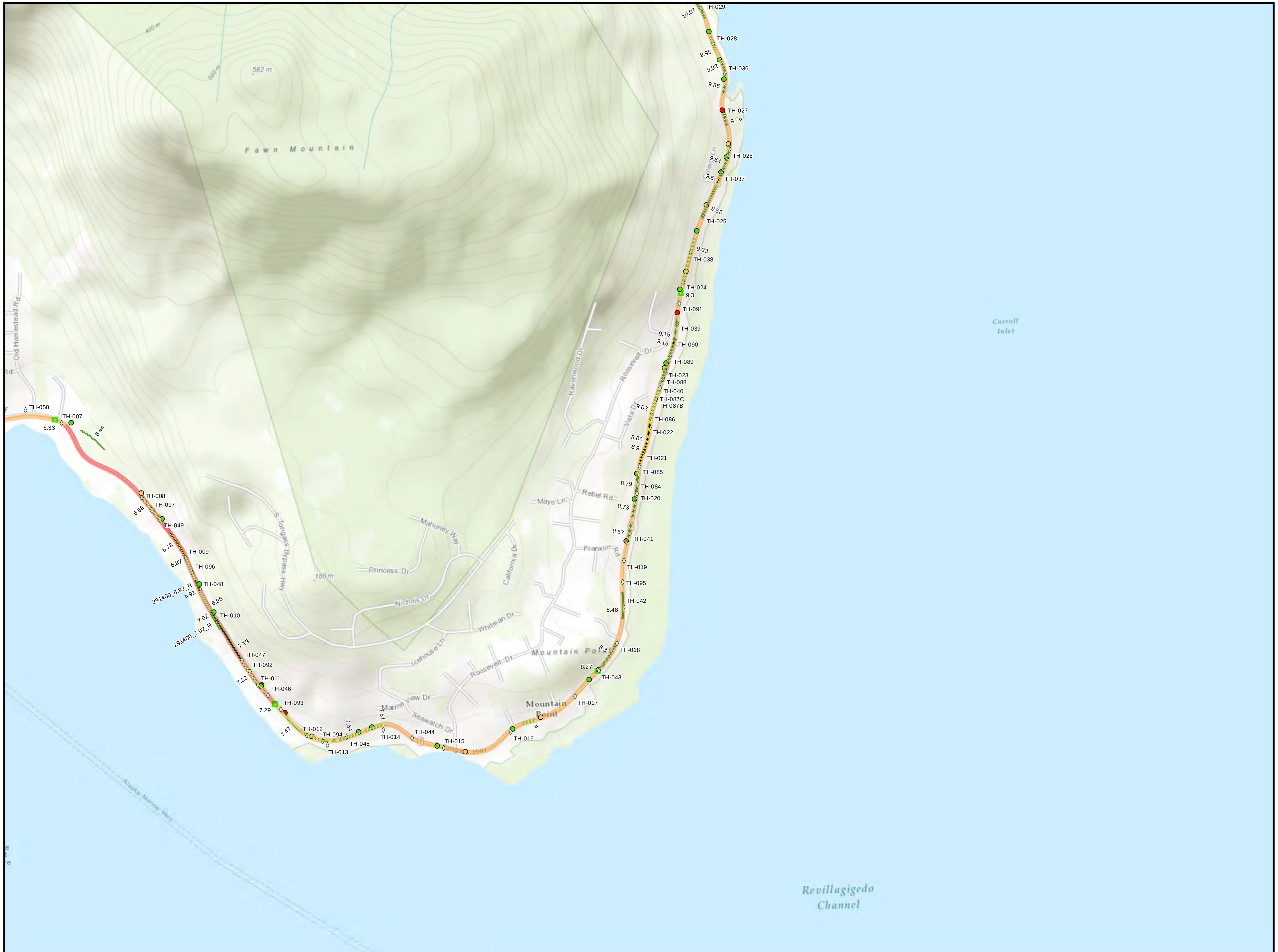
Map Page:

South Tongass - Ketchikan

Miles
0 0.1 0.2 0.3

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (2)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (1)
- 2 - Good (3)
- 3 - Moderate (3)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (13)
- 2 - Good (12)
- 3 - Moderate (0)
- 4 - Poor (0)

Borings (54)

Culverts
- Functional (20)
- Marginal (9)
- Failed (1)
- Not Found (4)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (4)
- 5 - Poor (1)

CDS Milepoint

Asset Inventory Map

December 2014

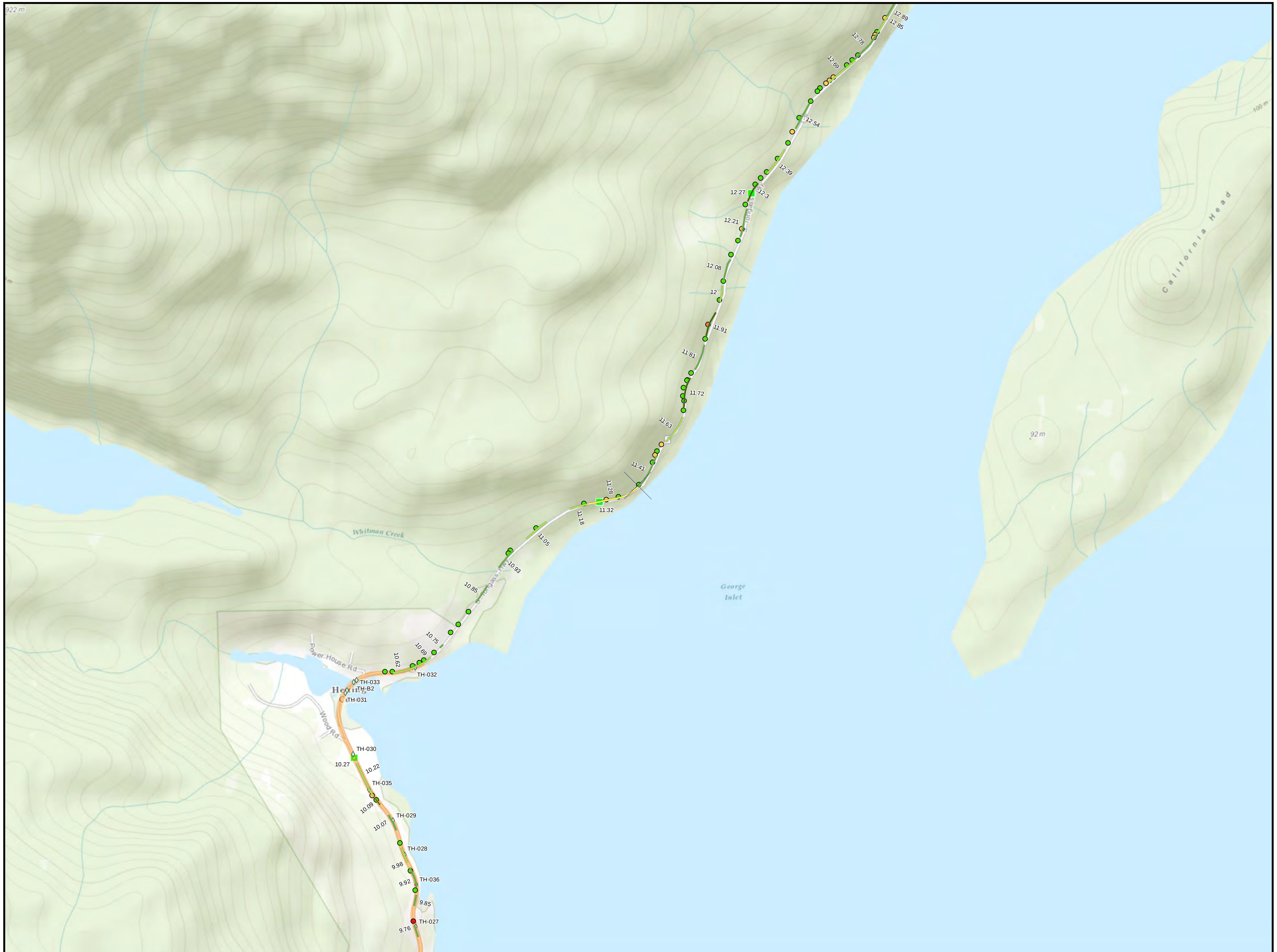
Map Page:

South Tongass - Ketchikan

Miles
0 0.1 0.2 0.3

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (3)
- 3 - Moderate (1)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (15)
- 2 - Good (11)
- 3 - Moderate (1)
- 4 - Poor (0)

Borings (12)

Culverts
- Functional (47)
- Marginal (13)
- Failed (1)
- Not Found (2)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (2)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

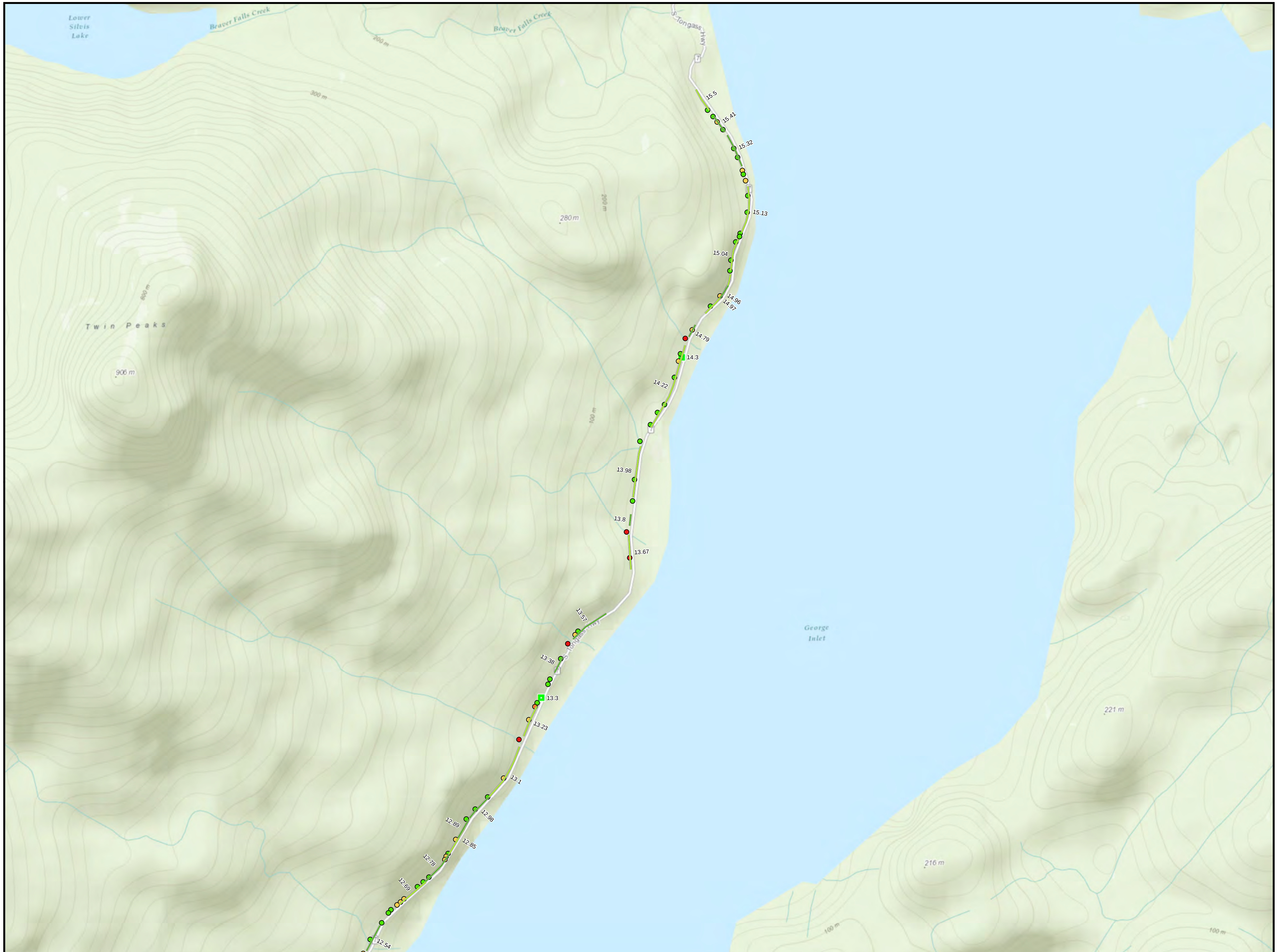
South Tongass - Ketchikan

Miles: 0 0.1 0.2 0.3

N

LANDSLIDE TECHNOLOGY

A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Walls' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Poor (0)

Soil Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (11)
- 2 - Good (11)
- 3 - Moderate (0)
- 4 - Poor (0)

Borings (0)

Culverts
- Functional (38)
- Marginal (16)
- Failed (1)
- Not Found (5)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (0)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

South Tongass - Ketchikan

Miles
0 0.1 0.2 0.3

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Appendix B: Petersburg

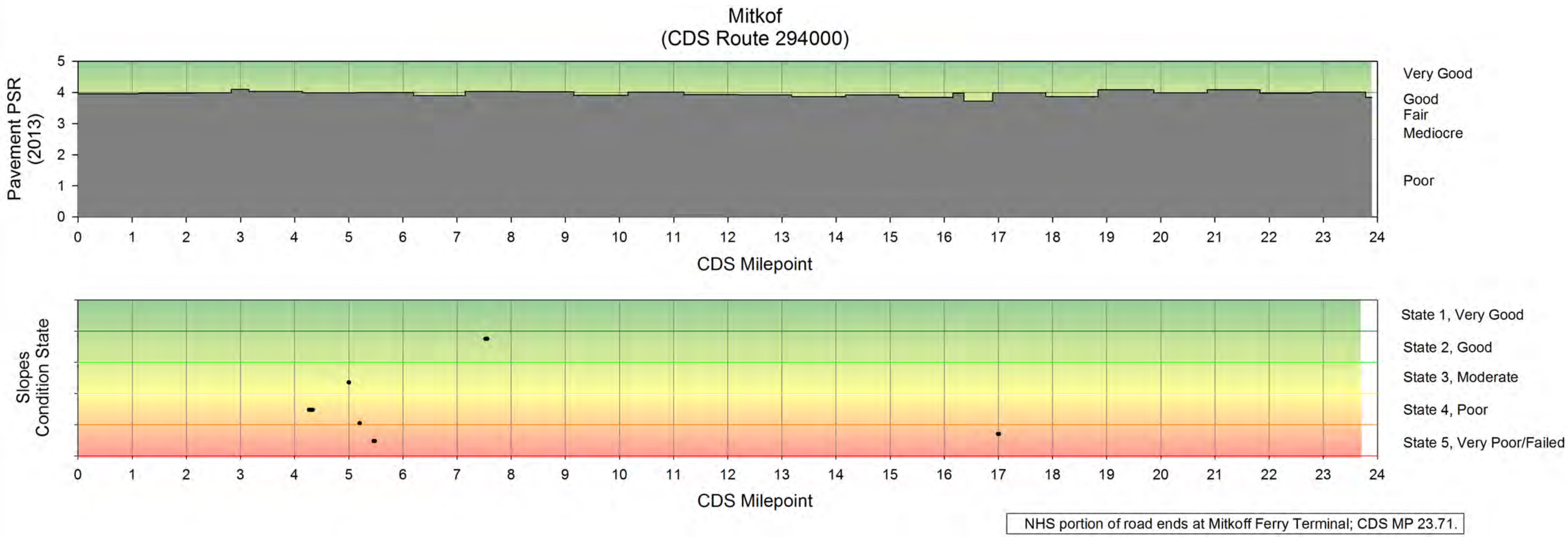
Mitkof Highway
USMP Score Range: **408 - 589**. Condition State: **4/5 Poor to Very Poor** (due to debris flow occurrence).

There are several slopes on the Mitkof Highway that are assessed with a poor to very poor condition. Most locations are debris flow sites where undersized culverts are easily plugged with minor amounts of sedimentation. Four primary sites are located at CDS MPs 4.5, 5.2, 5.5 and 17.4. Debris flow events in 2010 resulted in debris covering the road with previous events in 1994 resulting in similar impacts. The highway was recently resurfaced and some culvert improvements are evident, though still may be undersized to pass debris- and sediment-laden high stream flows.

Channel at MP 5.5

Culverts at MP 5.5

Design level of effort: Moderate to High. Design efforts would focus on the suitability of various methods to reduce the risk and hazard to the roadway and to subsequently design the appropriate mitigation methods. These sites are typically characterized by narrow channels with infrequent debris flows. Since the channels are fairly well established, the possibility to pass the flow beneath the road in large culverts may be a viable option, although trees and other vegetation will still likely not pass. Other methods to catch small-sized debris above the road could be installed, but would require maintenance or replacement following sizable events.



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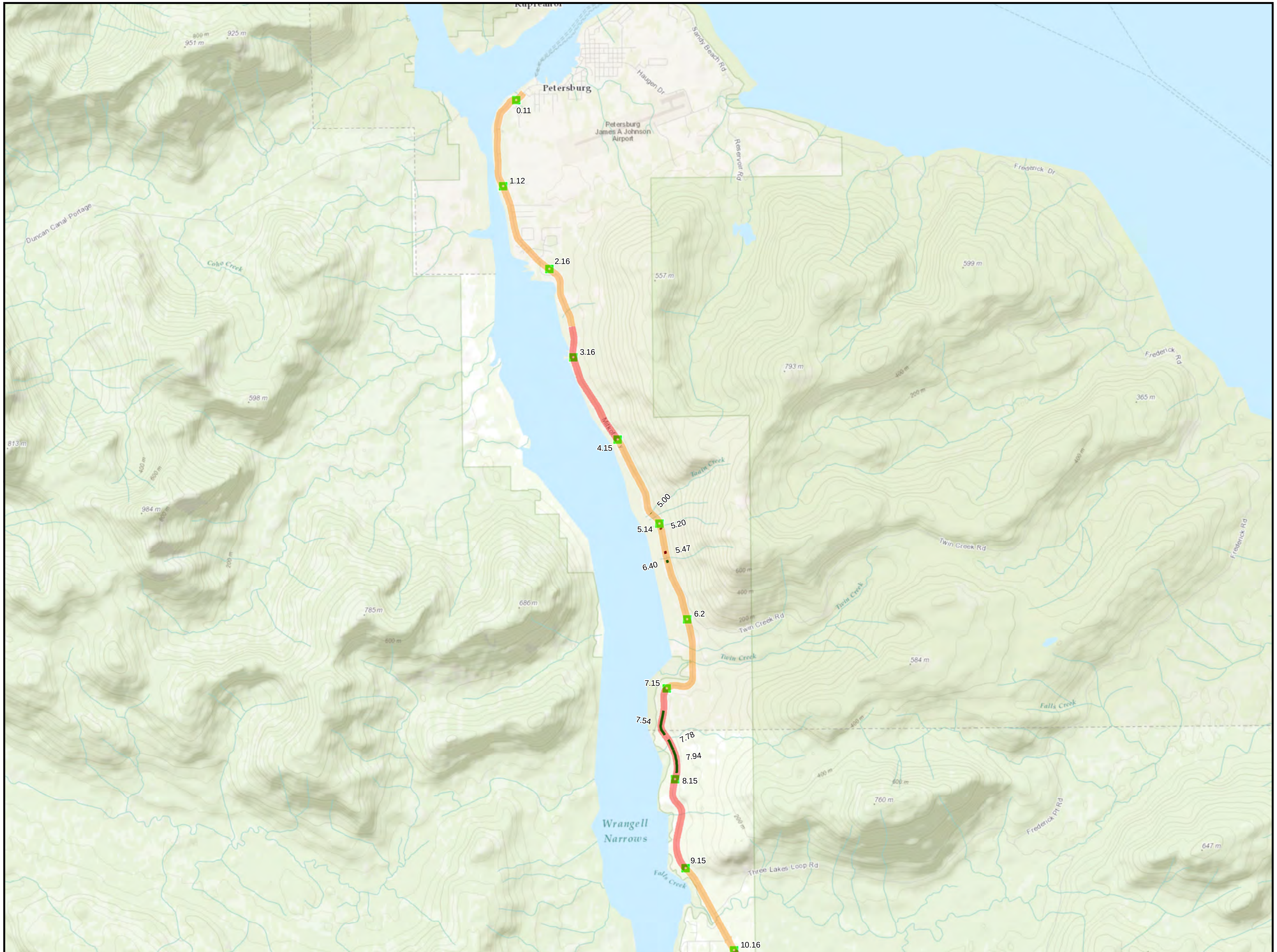
MITKOF HIGHWAY
ASSET CONDITION STATES

SOUTHCOAST REGION PLANNING
SOUTHCOAST, ALASKA

DEC 2014

PROJ. 2337

FIG.



Area shown to left

Legend

Soil Slopes' Condition State

- 1 - Very Good (4)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (1)
- 5 - Very Poor/Failed (1)

Rock Slopes' Condition State

- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR

- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (7)
- 5 - Poor (5)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

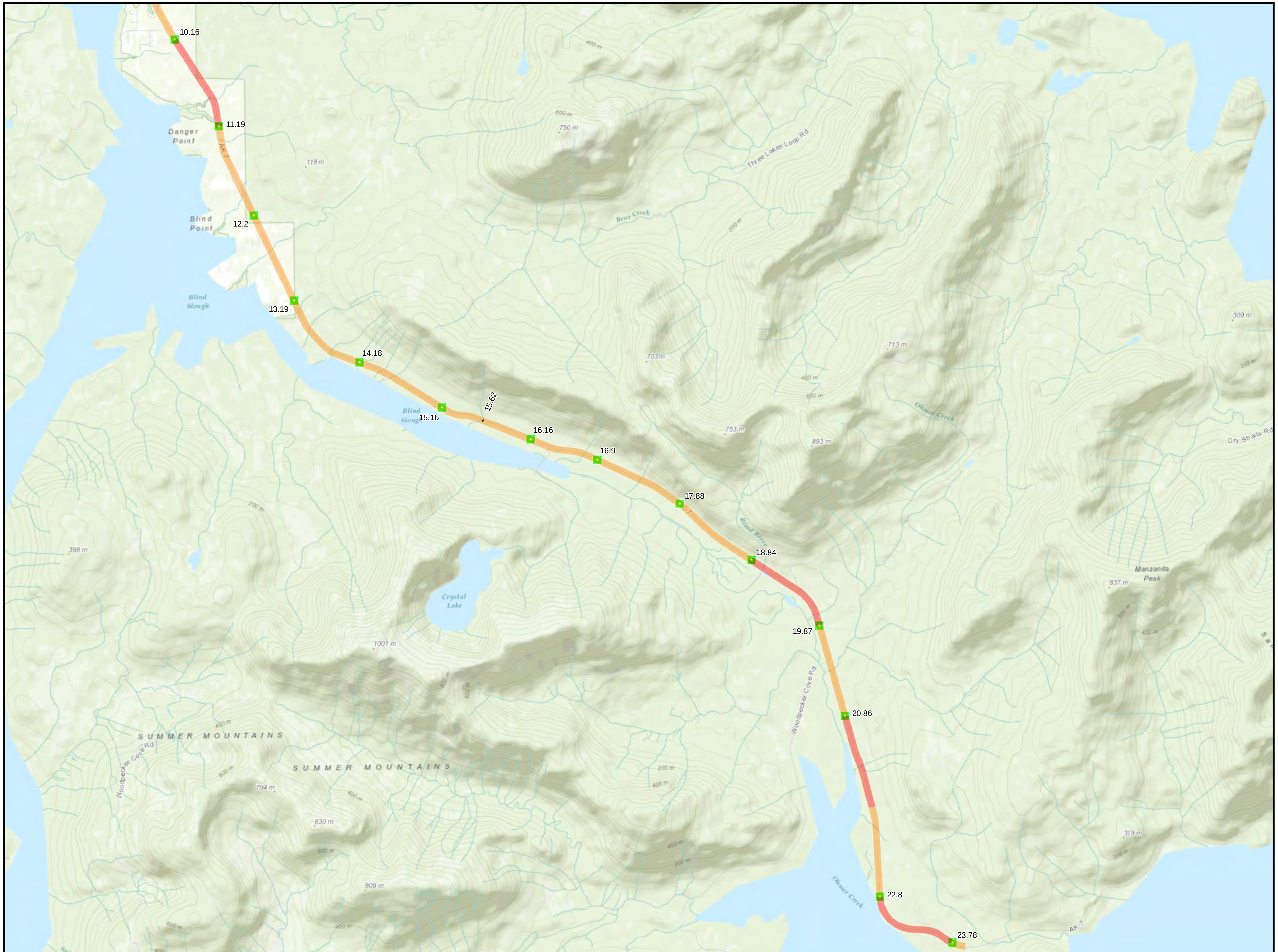
Mitkof Highway - Petersburg

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY

A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Soil Slopes' Condition State

- 1 - Very Good (1)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State

- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR

- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (13)
- 5 - Poor (4)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Mitkof Highway - Petersburg

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY

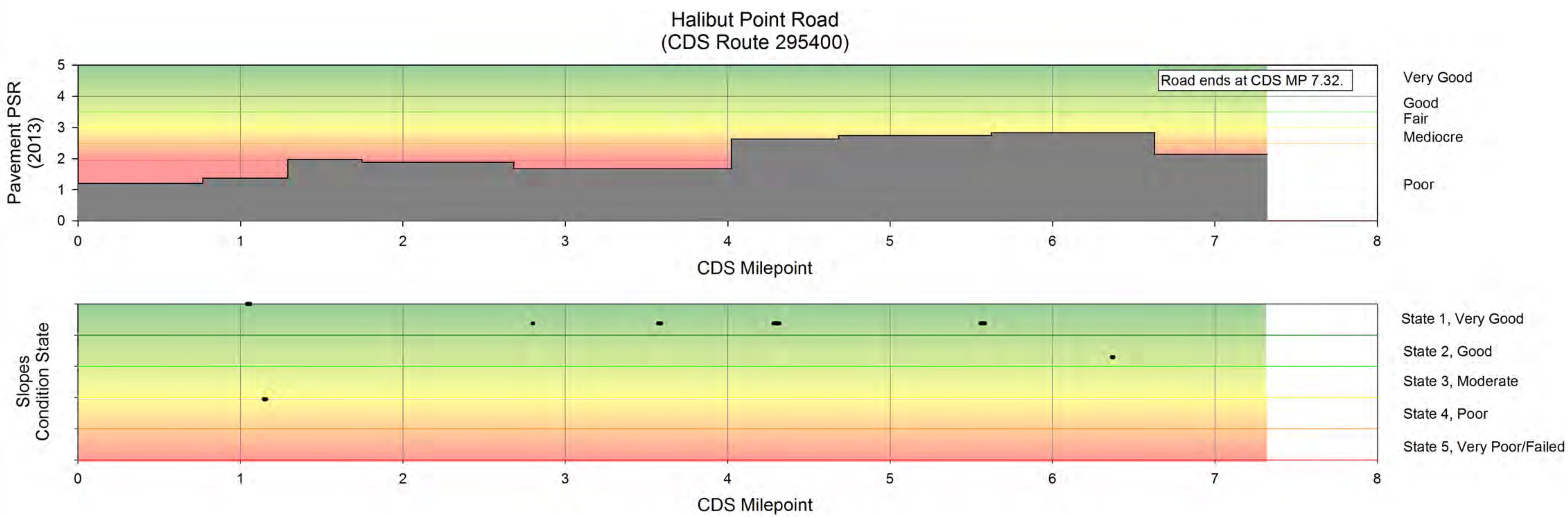
A DIVISION OF CORNFORTH CONSULTANTS

Appendix C: Sitka

Halibut Point Road
USMP Score: **428**. Condition State: **4 - Poor**.

This NHS route has one slope evaluation that resulted in a poor or moderate condition state: a rapid soil slope failure that damaged an AKDOT&PF maintenance facility in 2000. Activity has not been noted by M&O personnel since the failure, however the lack of revegetation 14 years after the failure indicates some degree of instability. Structures above the slope may be at risk if the slope fails again.

Design level of effort: Low. Considering the space available at the base of the slope and the short slope height, a low cost mitigation option such as a buttress could provide support at the slope base and prevent future instability. Considering the poor pavement quality noted in the 2013 PSR data, a pavement rehabilitation project may be performed nearby in the future and produce granular waste material that could be used for buttress construction. Other waste materials, such as fractured concrete waste or compacted overburden could also be used. Design effort would consist of buttress configuration and layout.



LANDSLIDE TECHNOLOGY
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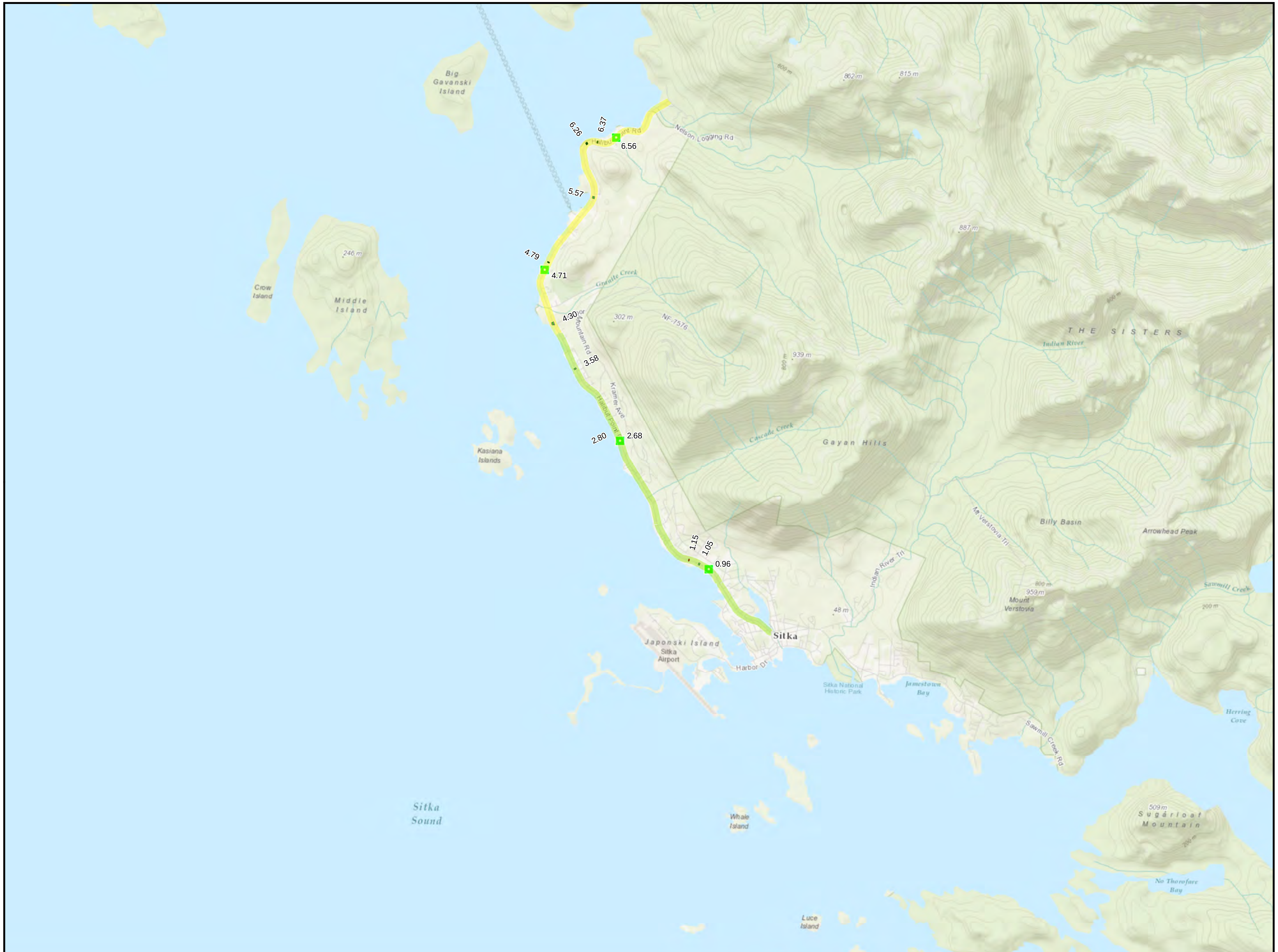
HALIBUT POINT ROAD
ASSET CONDITION STATES

SOUTHCOAST REGION PLANNING
SOUTHCOAST, ALASKA

DEC 2014

PROJ. 2337

FIG.



Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (2)
- 2 - Good (1)
- 3 - Moderate (0)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (5)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (5)
- 3 - Fair (4)
- 4 - Mediocre (0)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Halibut Point Road

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Appendix D: Juneau

Glacier Highway
USMP Score Range: **351 - 488**. Condition State: **3/4 – Moderate to Poor.**

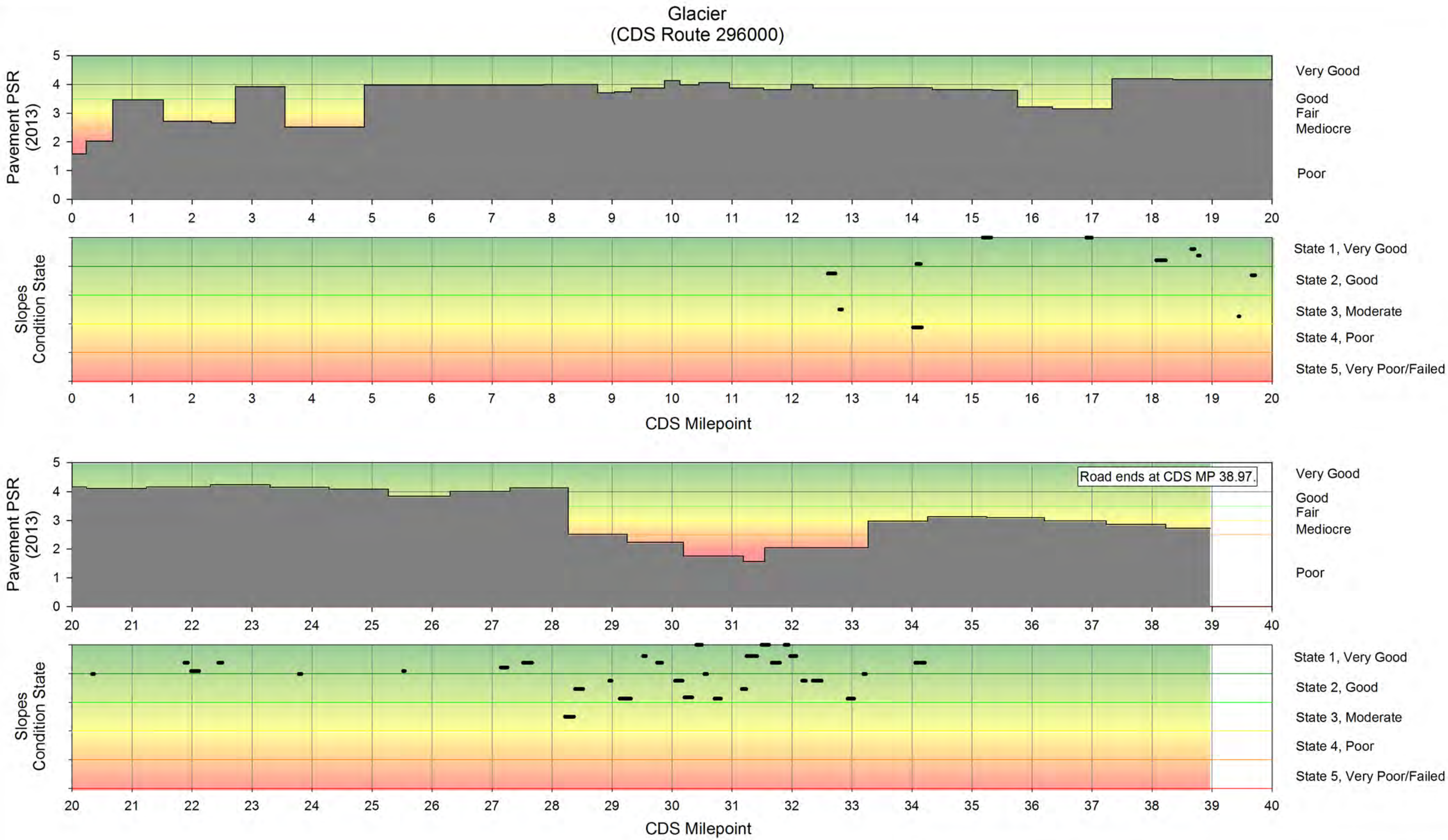
Most slopes identified along Glacier Highway are evaluated in a 'Good' condition, with only one site in 'Poor' condition (CDS MP 14.09) and two in 'Moderate' condition (CDS MP 12.81 and 19.45). The poor condition slope is a low activity rock cut with active, unstable overburden above that requires regular M&O action but poses low hazard to the public due to wide ditch containment.

Slope failure near MP 14.09

Rock slope at MP 12.81

Chute near MP 19.45, low M&O involvement

Design level of effort: Moderate. The design effort for these three slopes would be focused on overburden excavation and removal at MP 14.09, scaling and rock slope support at MP 12.81, and possible roadside barrier installation at MP 19.45. Primary benefits would be long-term M&O cost reduction at MP 14.09, public safety improvement at MP 12.81, and public and Departmental liability risk reduction due to public parking availability at MP 19.45.



LANDSLIDE TECHNOLOGY
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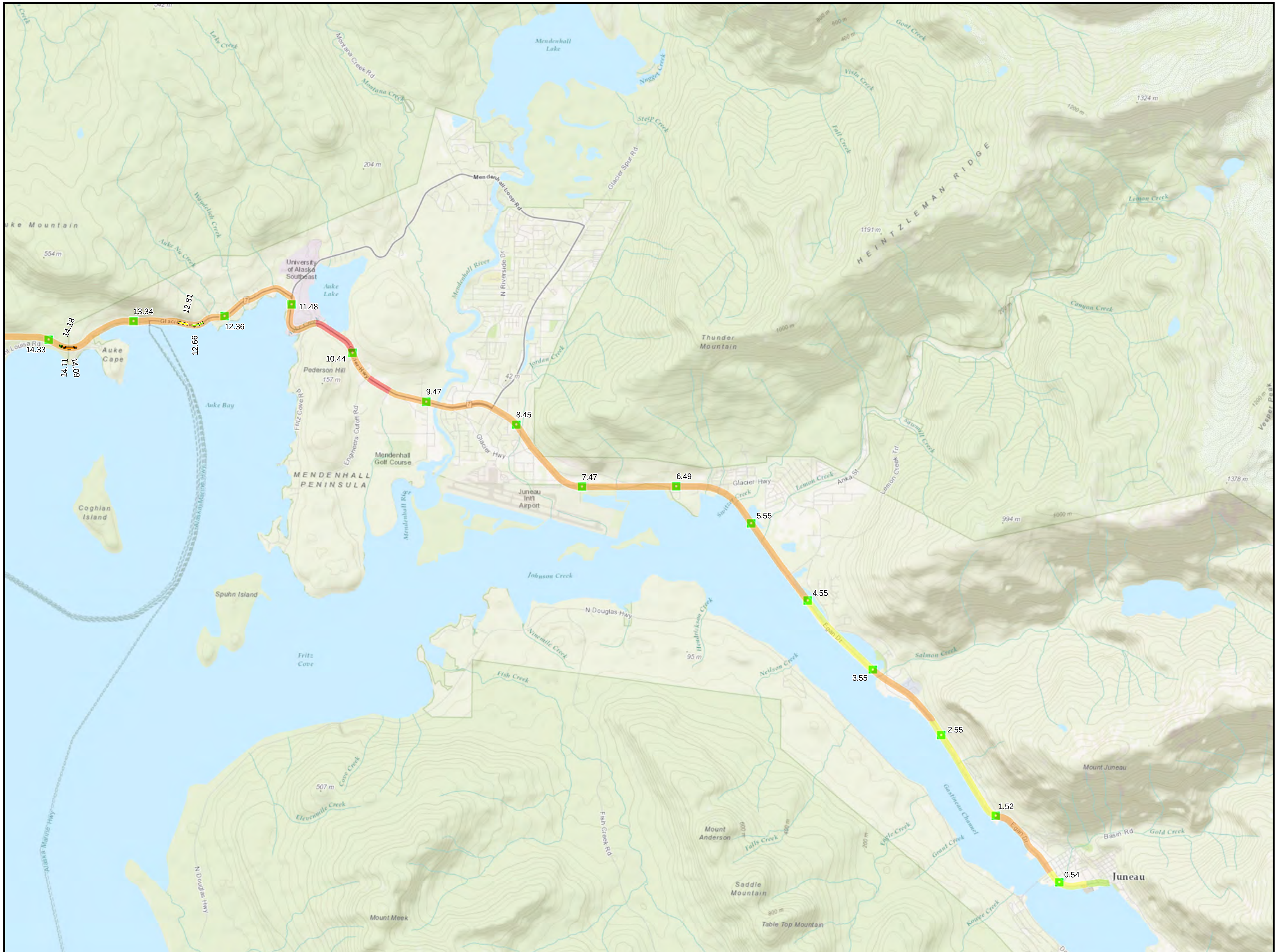
GLACIER HIGHWAY
ASSET CONDITION STATES

SOUTHCOAST REGION PLANNING
SOUTHCOAST, ALASKA

DEC 2014

PROJ. 2337

FIG.



Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (1)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (1)
- 2 - Good (1)
- 3 - Moderate (1)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (1)
- 3 - Fair (4)
- 4 - Mediocre (15)
- 5 - Poor (2)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

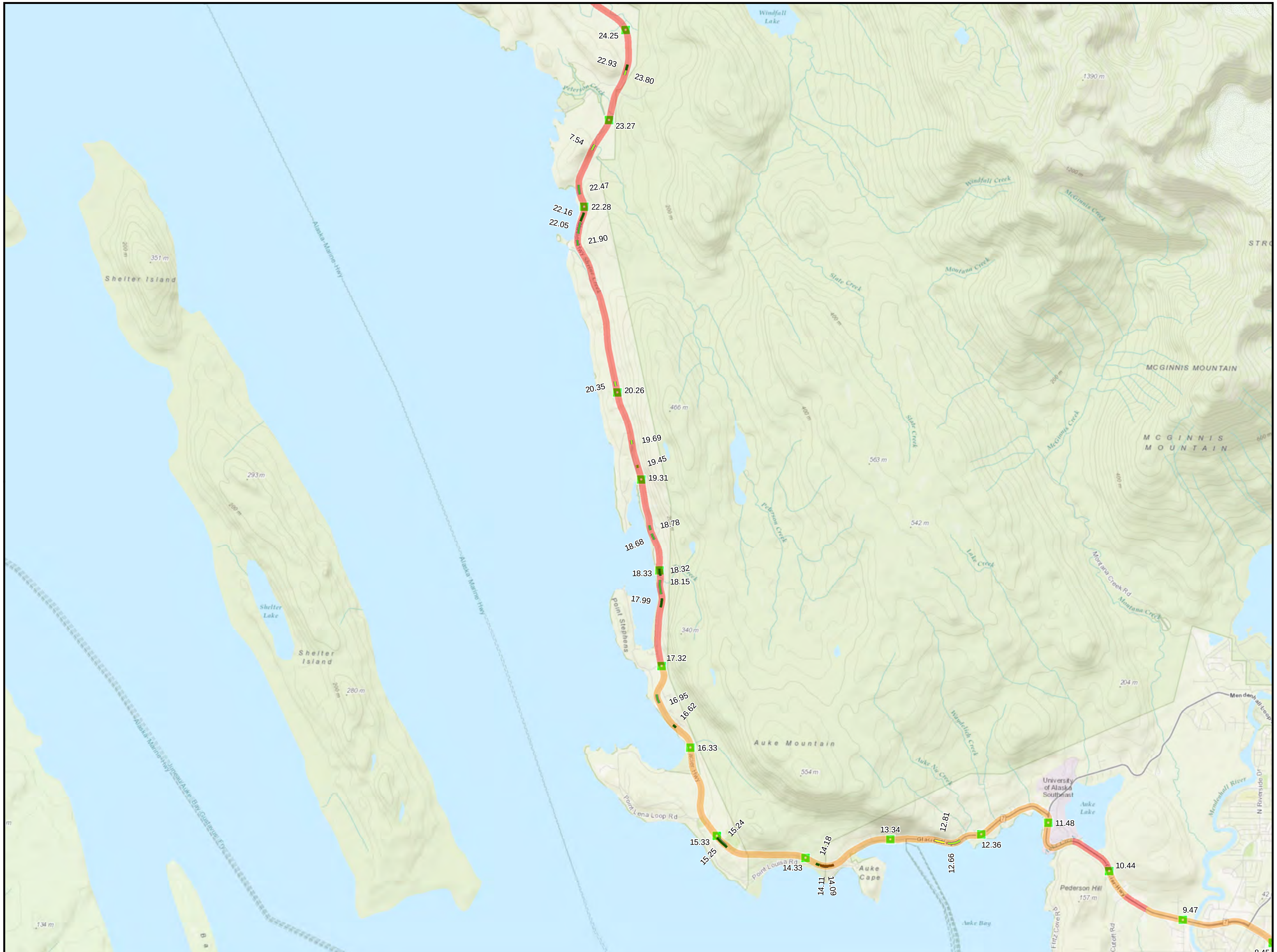
Glacier Hwy_Egan Drive

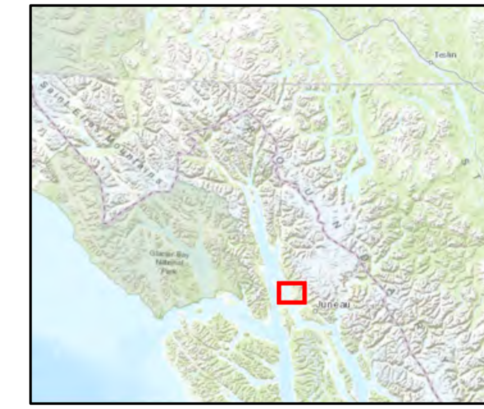
0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY

A DIVISION OF CORNFORTH CONSULTANTS





Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (7)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (9)
- 2 - Good (5)
- 3 - Moderate (1)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (14)
- 5 - Poor (9)

CDS Milepoint

Asset Inventory Map

December 2014

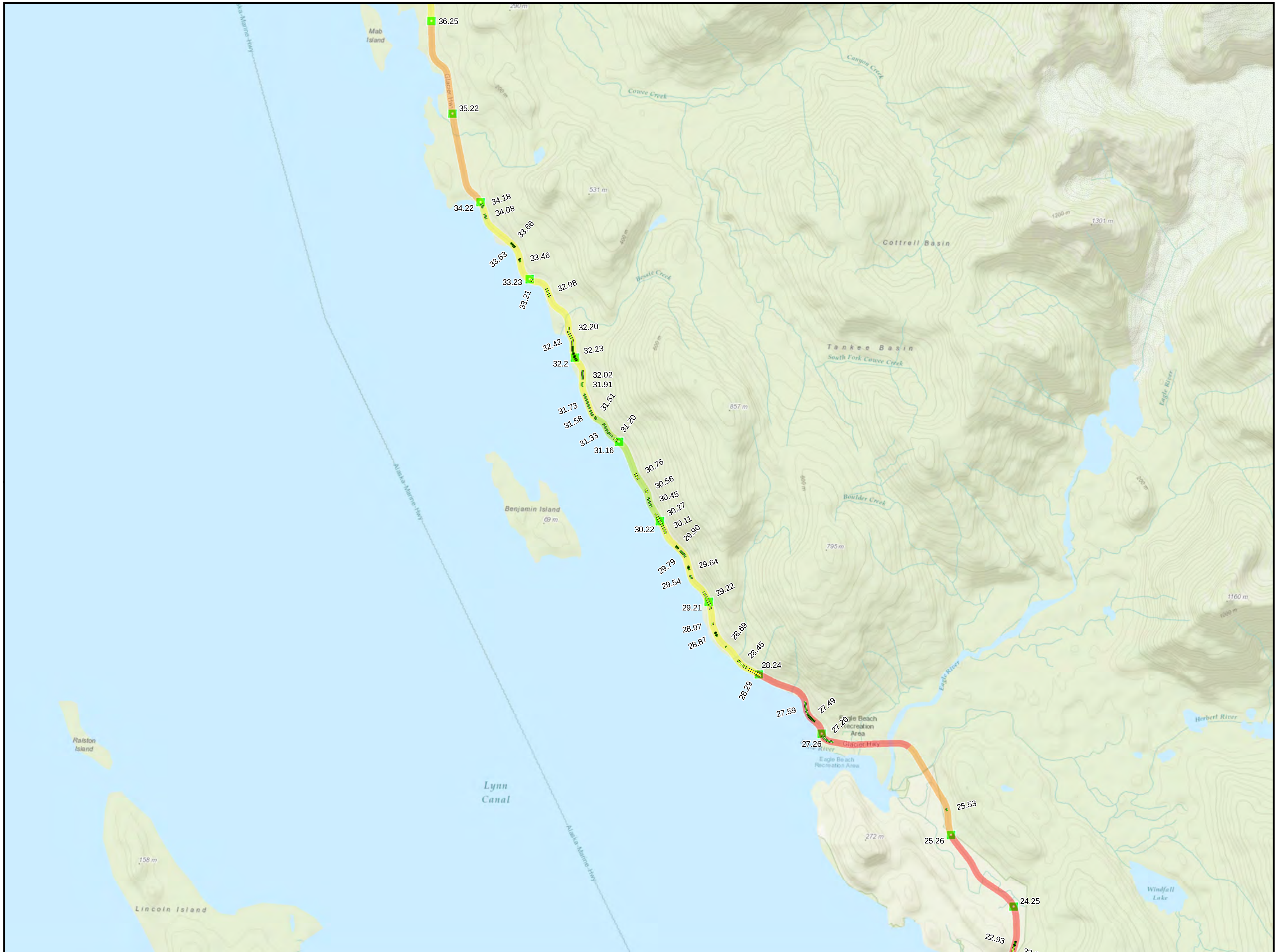
Map Page:

Glacier Hwy_Egan Drive

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (10)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (14)
- 2 - Good (13)
- 3 - Moderate (1)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (2)
- 3 - Fair (5)
- 4 - Mediocre (3)
- 5 - Poor (4)

CDS Milepoint

Asset Inventory Map

December 2014

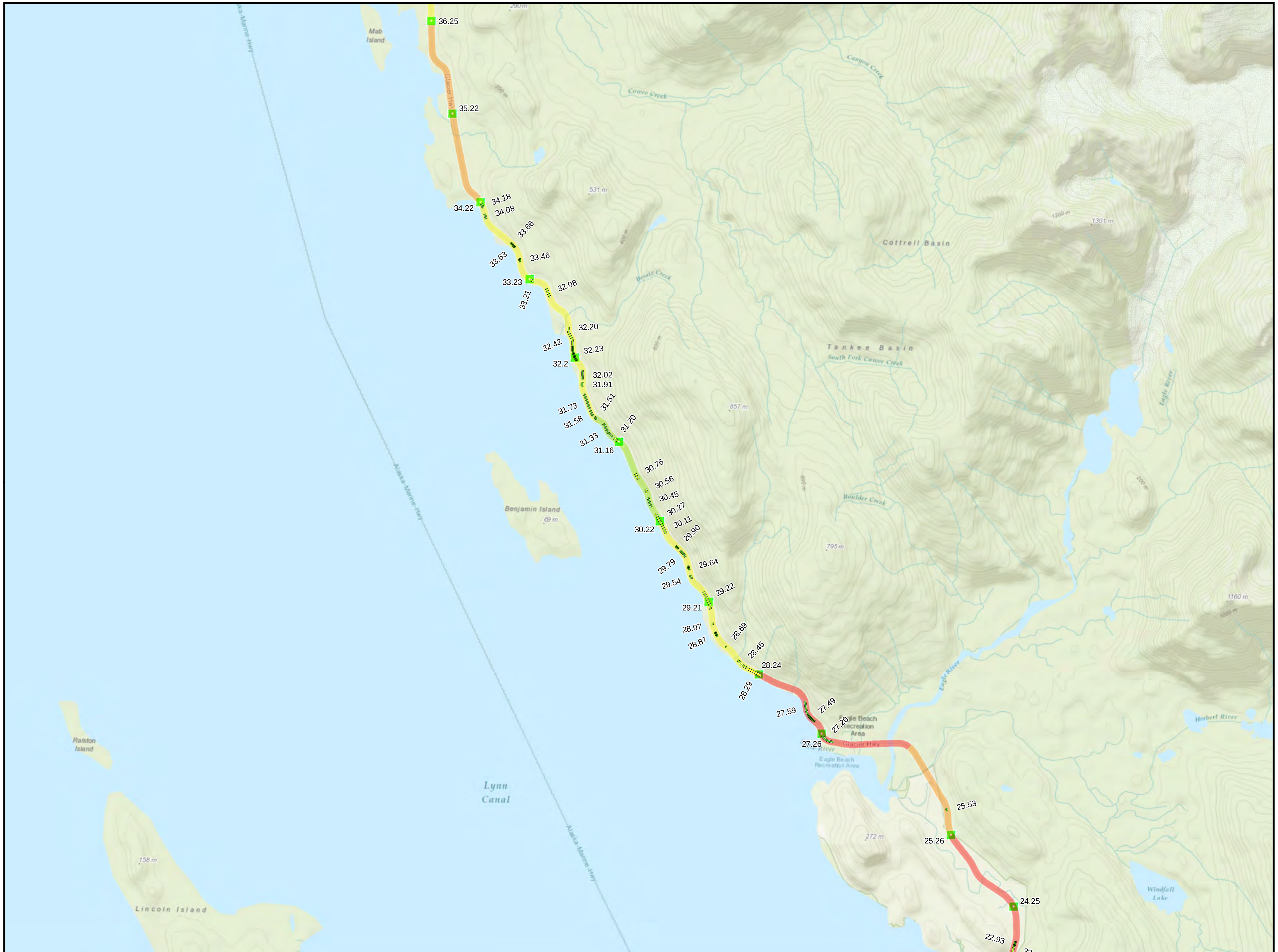
Map Page:

Glacier Hwy_Egan Drive

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (10)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (14)
- 2 - Good (13)
- 3 - Moderate (1)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (2)
- 3 - Fair (5)
- 4 - Mediocre (3)
- 5 - Poor (4)

CDS Milepoint

Asset Inventory Map

December 2014

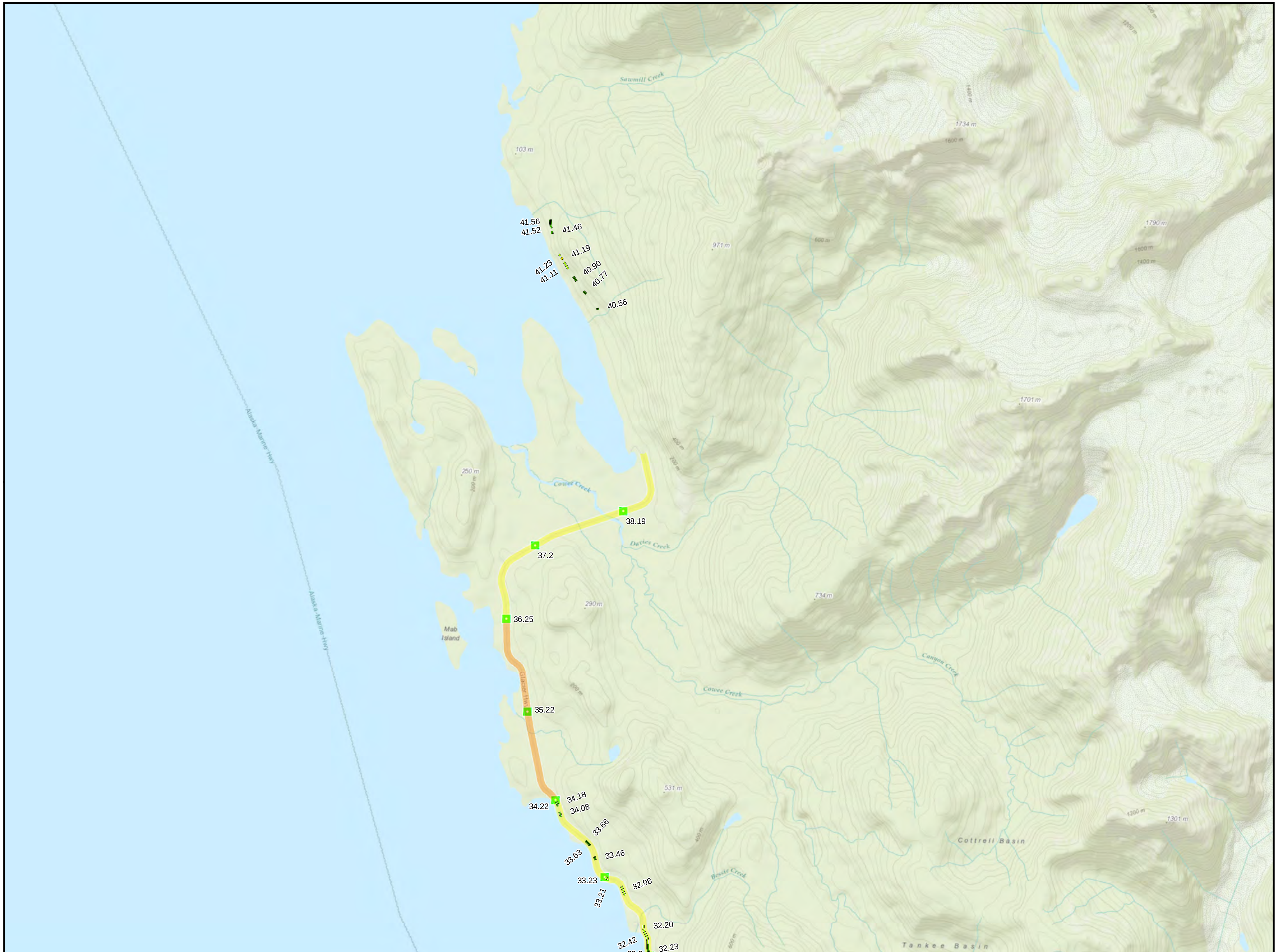
Map Page:

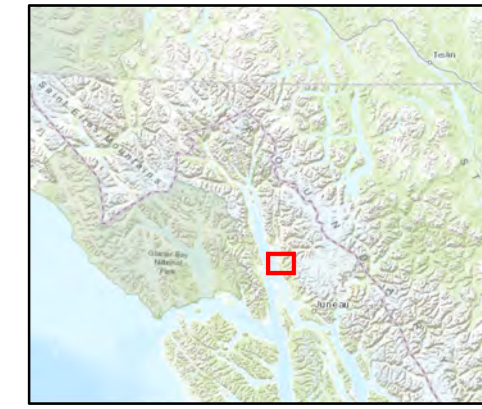
Glacier Hwy_Egan Drive

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS





Legend

Soil Slopes' Condition State
- 1 - Very Good (9)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (3)
- 2 - Good (6)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (5)
- 4 - Mediocre (2)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

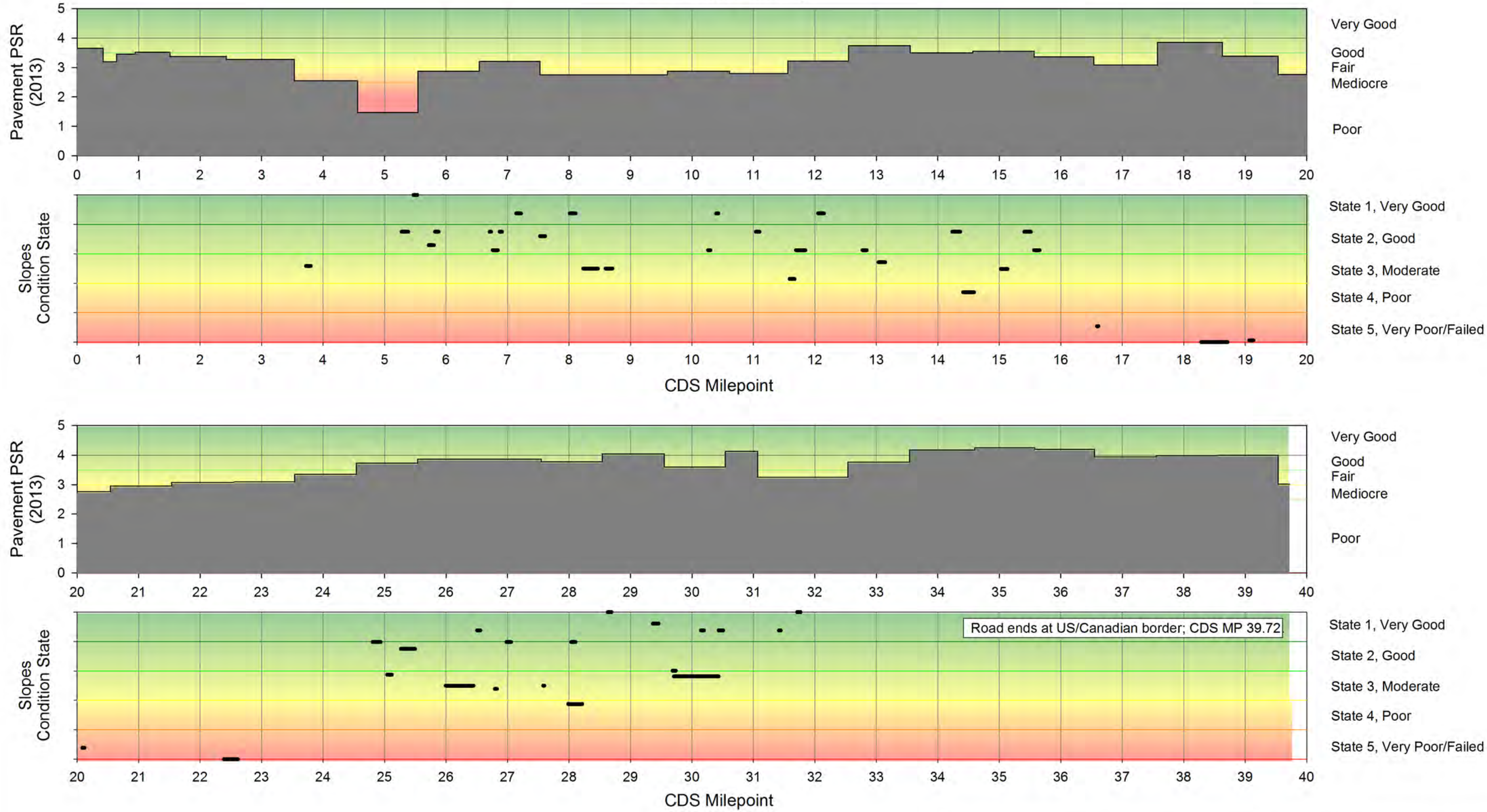
Glacier Hwy_Egan Drive

0 0.25 0.5 1 1.5 Miles

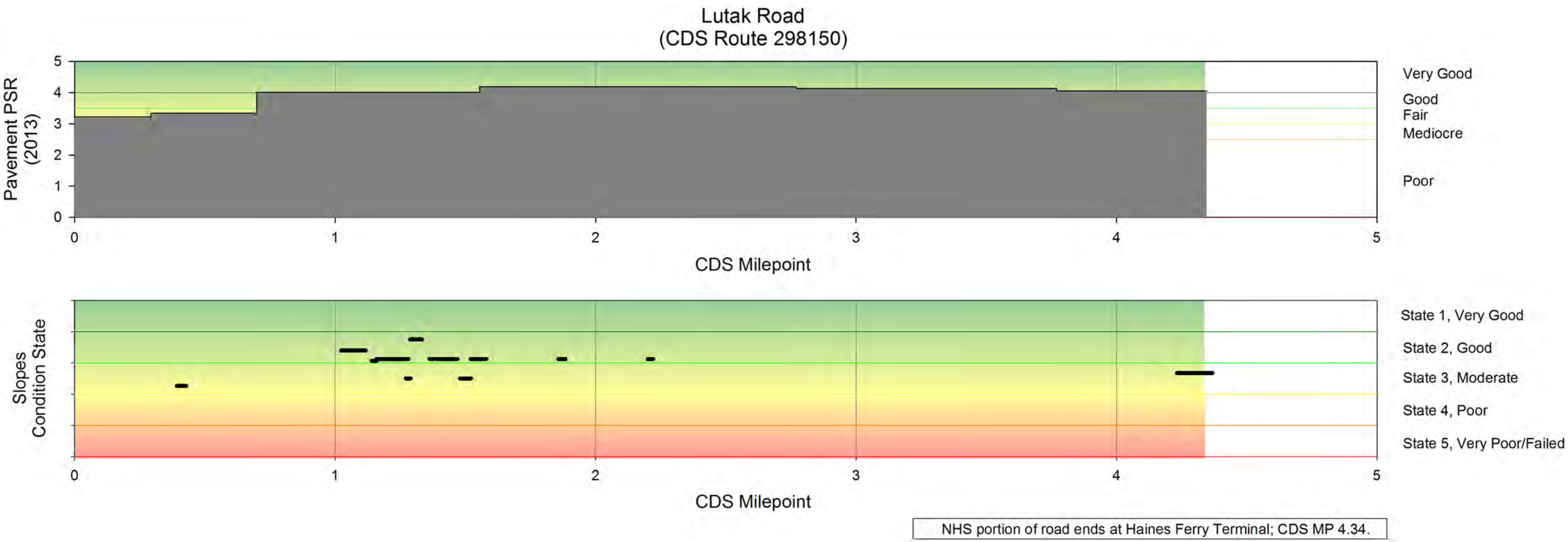
N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

Haines
(CDS Route 298000)



LANDSLIDE TECHNOLOGY A DIVISION OF CORNFORTH CONSULTANTS 10250 S.W. Greenburg Road, Suite 111 Portland, Oregon 97223	HAINES HIGHWAY ASSET CONDITION STATES SOUTHCOAST REGION PLANNING SOUTHCOAST, ALASKA	DEC 2014 PROJ. 2337 FIG.



LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS
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Portland, Oregon 97223

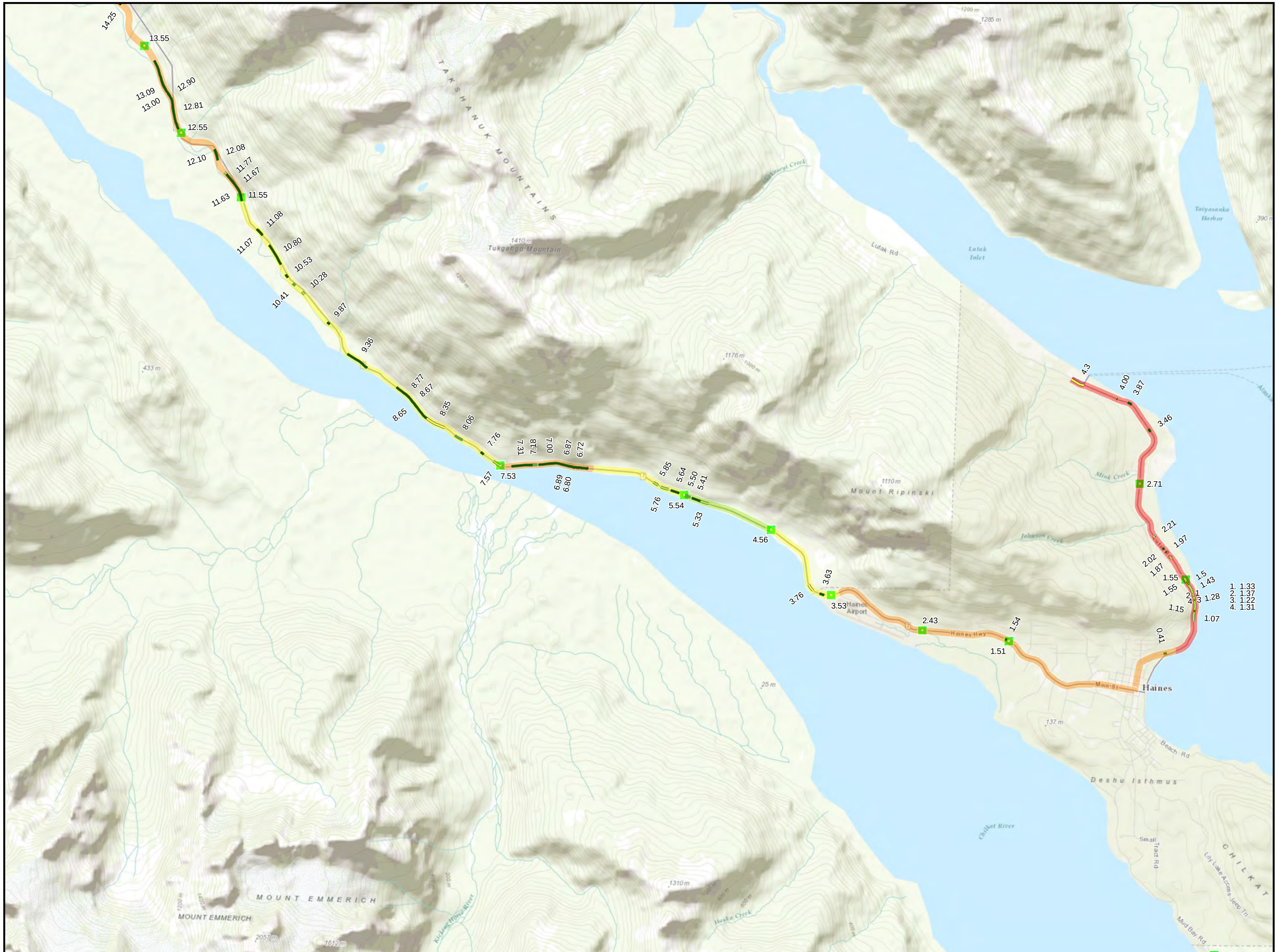
LUTAK ROAD
ASSET CONDITION STATES

SOUTHCOAST REGION PLANNING
SOUTHCOAST, ALASKA

DEC 2014

PROJ. 2337

FIG.



Area shown to left

Legend

Soil Slopes' Condition State

- 1 - Very Good (25)
- 2 - Good (2)
- 3 - Moderate (3)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State

- 1 - Very Good (5)
- 2 - Good (19)
- 3 - Moderate (6)
- 4 - Poor (0)

Pavement PSR

- 1 - Very Good (0)
- 2 - Good (1)
- 3 - Fair (6)
- 4 - Mediocre (12)
- 5 - Poor (4)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

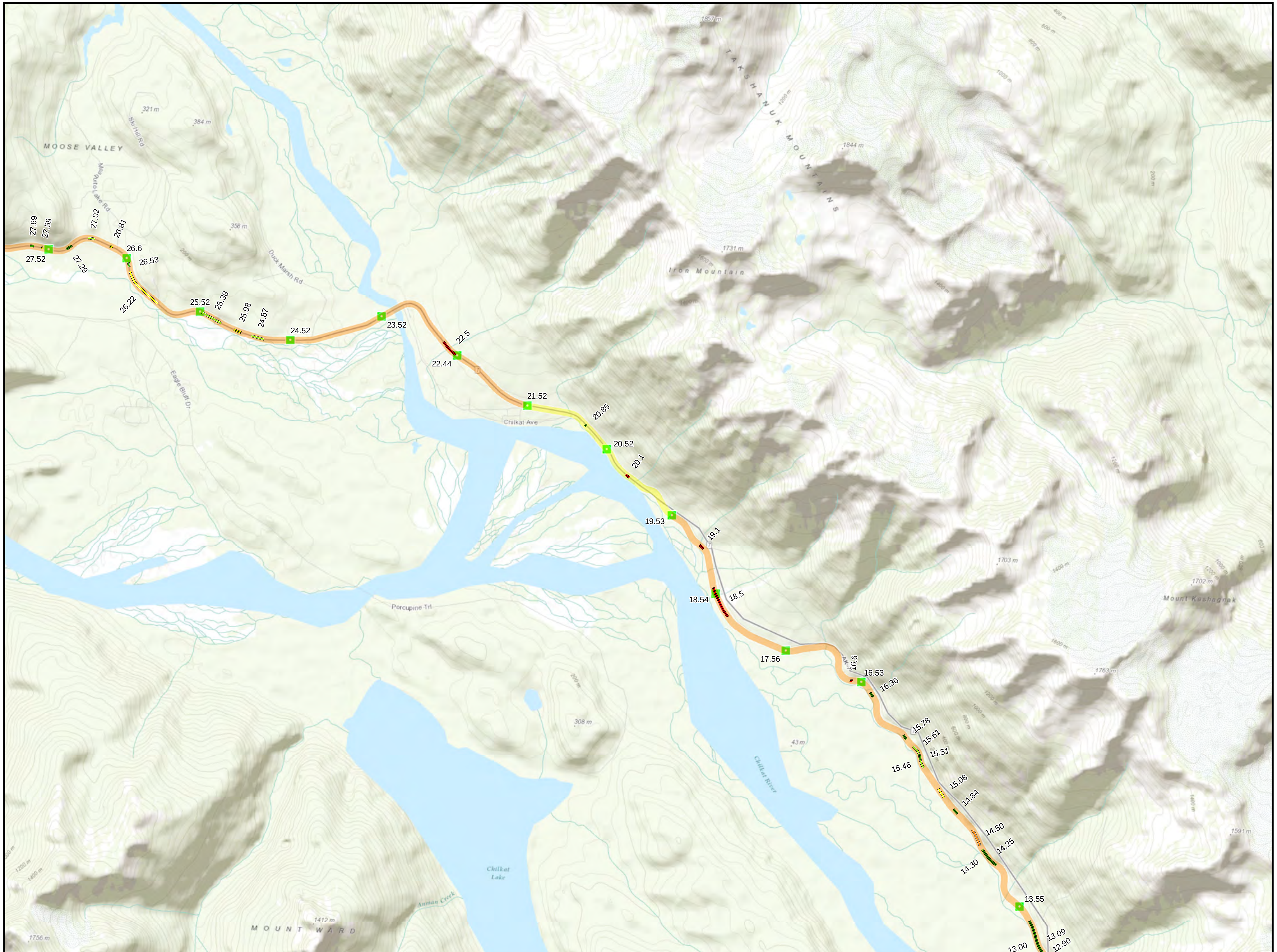
Haines Highway

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY

A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Soil Slopes' Condition State

- 1 - Very Good (10)
- 2 - Good (0)
- 3 - Moderate (3)
- 4 - Poor (0)
- 5 - Very Poor/Failed (5)

Rock Slopes' Condition State

- 1 - Very Good (1)
- 2 - Good (6)
- 3 - Moderate (3)
- 4 - Poor (1)

Pavement PSR

- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (2)
- 4 - Mediocre (14)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

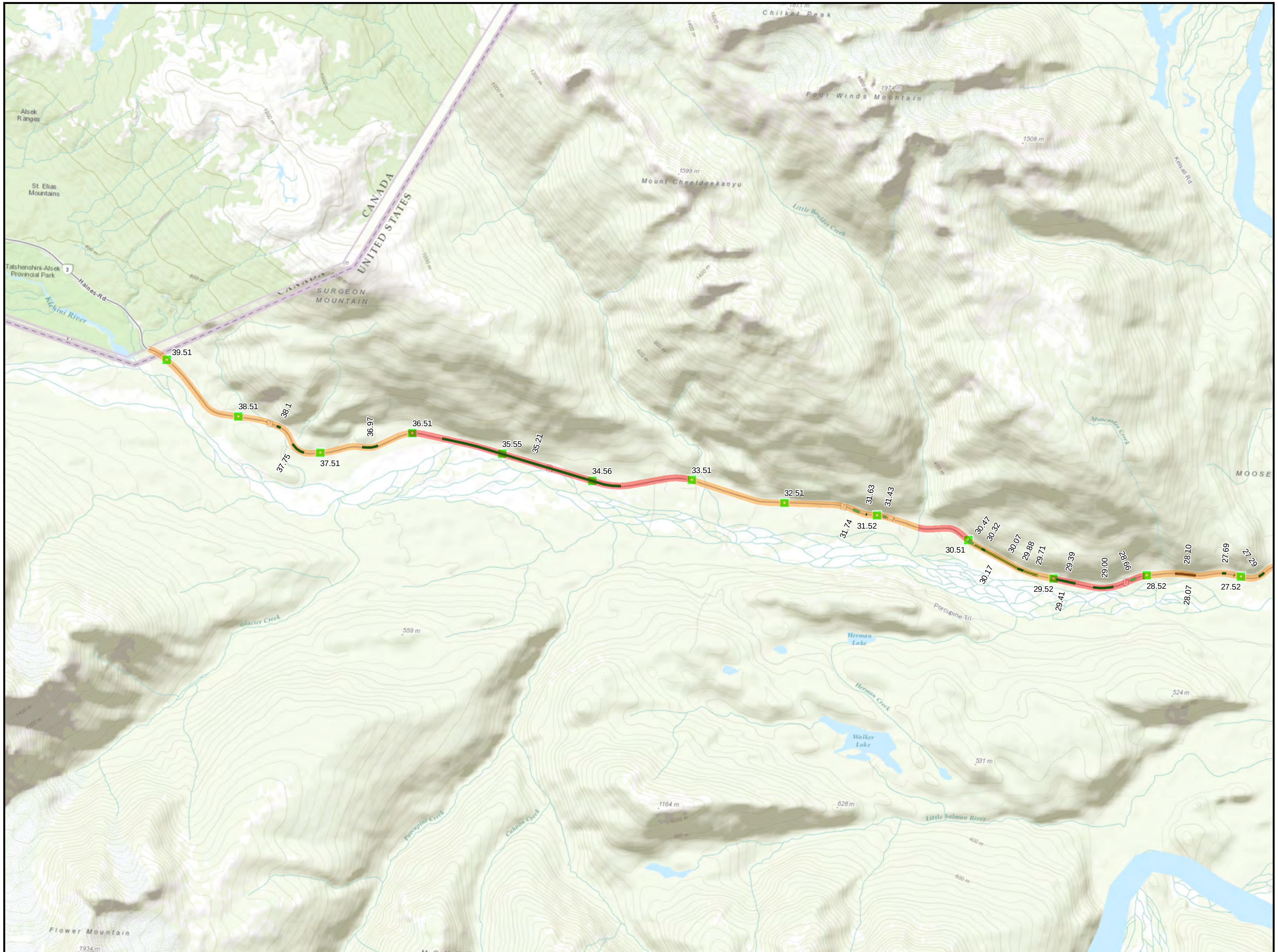
Haines Highway

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY

A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (11)
- 2 - Good (0)
- 3 - Moderate (2)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (6)
- 2 - Good (2)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (9)
- 5 - Poor (5)

CDS Milepoint

Asset Inventory Map

December 2014

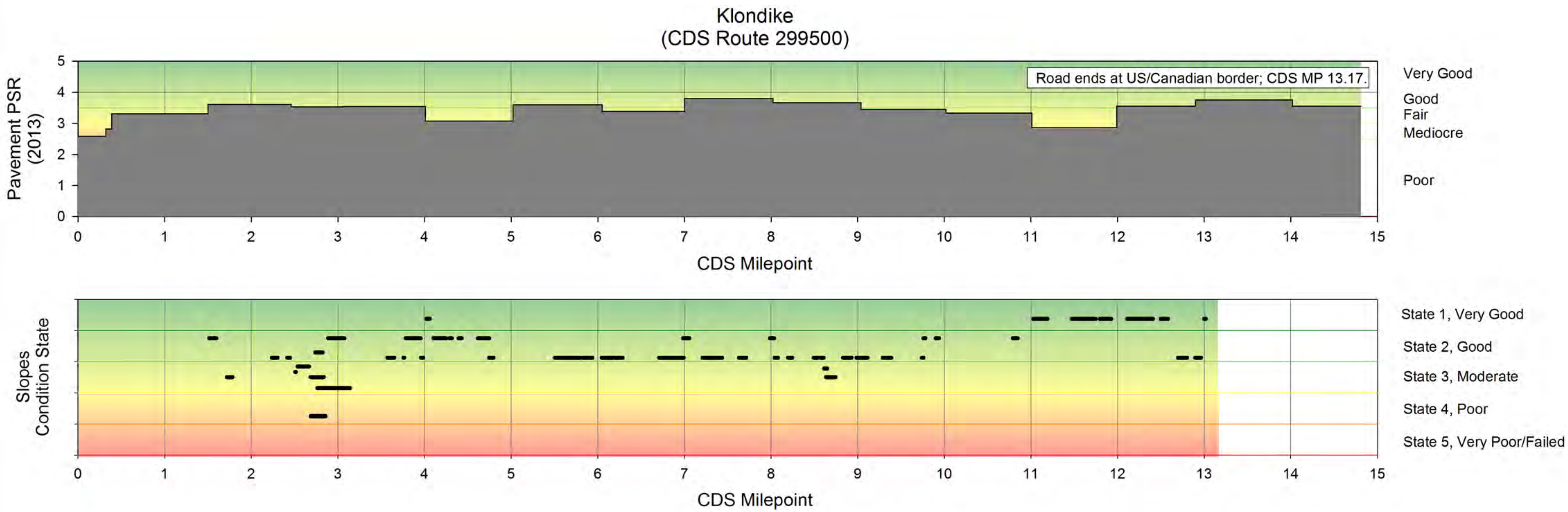
Map Page:

Haines Highway

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS



LANDSLIDE TECHNOLOGY
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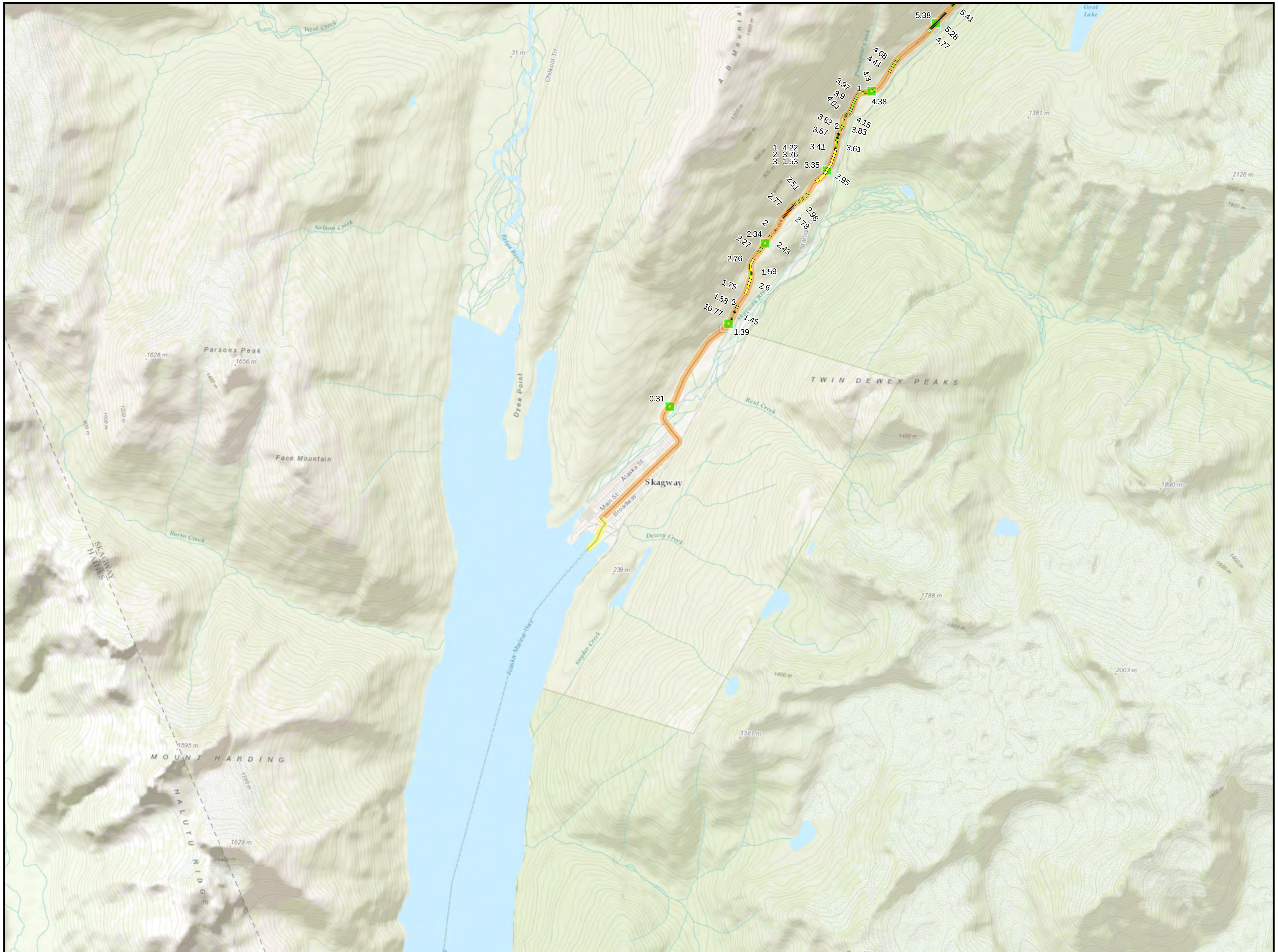
KLODIKE HIGHWAY
ASSET CONDITION STATES

SOUTHCOAST REGION PLANNING
SOUTHCOAST, ALASKA

DEC 2014

PROJ. 2337

FIG.



Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (8)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (1)
- 2 - Good (18)
- 3 - Moderate (4)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (2)
- 4 - Mediocre (8)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

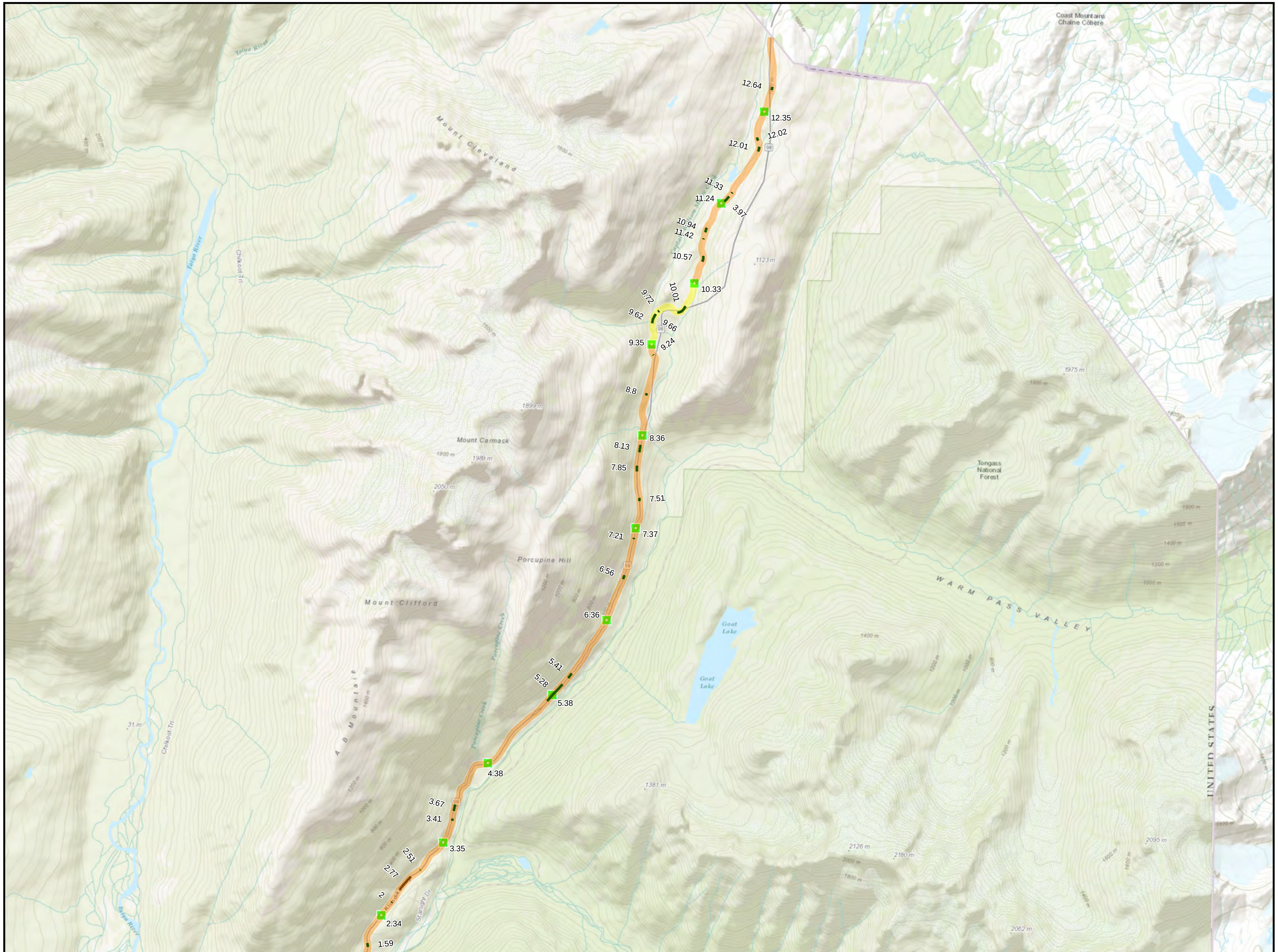
Klondike Highway

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY

A DIVISION OF CORNFORTH CONSULTANTS



Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (25)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (1)
- 4 - Mediocre (12)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Klondike Highway

0 0.25 0.5 1 1.5 Miles

N

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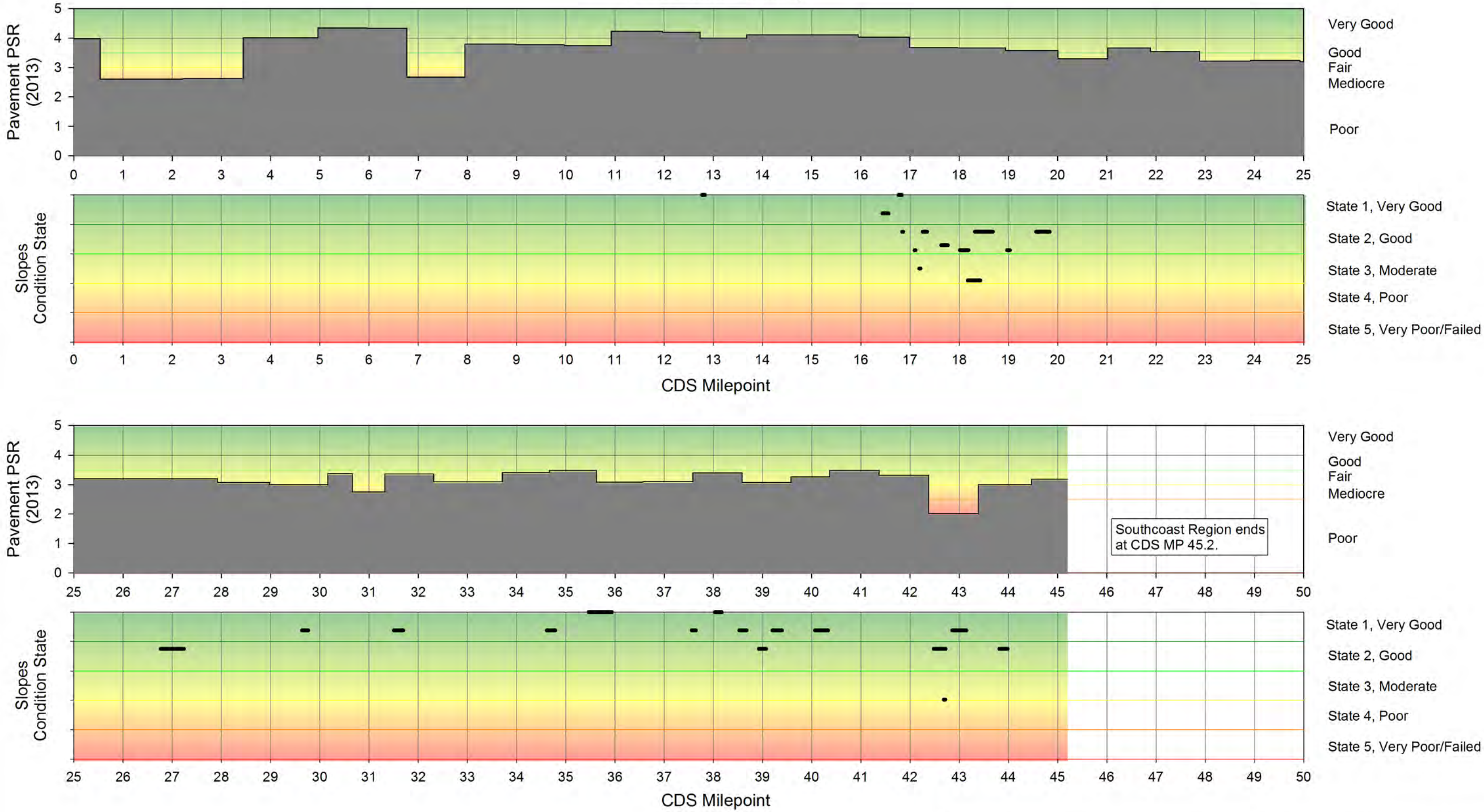
Richardson
(CDS Route 190000)



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RICHARDSON HIGHWAY
ASSET CONDITION STATES

SOUTHCOAST REGION PLANNING
SOUTHCOAST, ALASKA

DEC 2014

PROJ. 2337

FIG.

Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (4)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (1)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (7)
- 4 - Mediocre (8)
- 5 - Poor (11)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Richardson Hwy SB in Valdez

Miles
0 0.25 0.5 1 1.5

N

LANDSLIDE TECHNOLOGY
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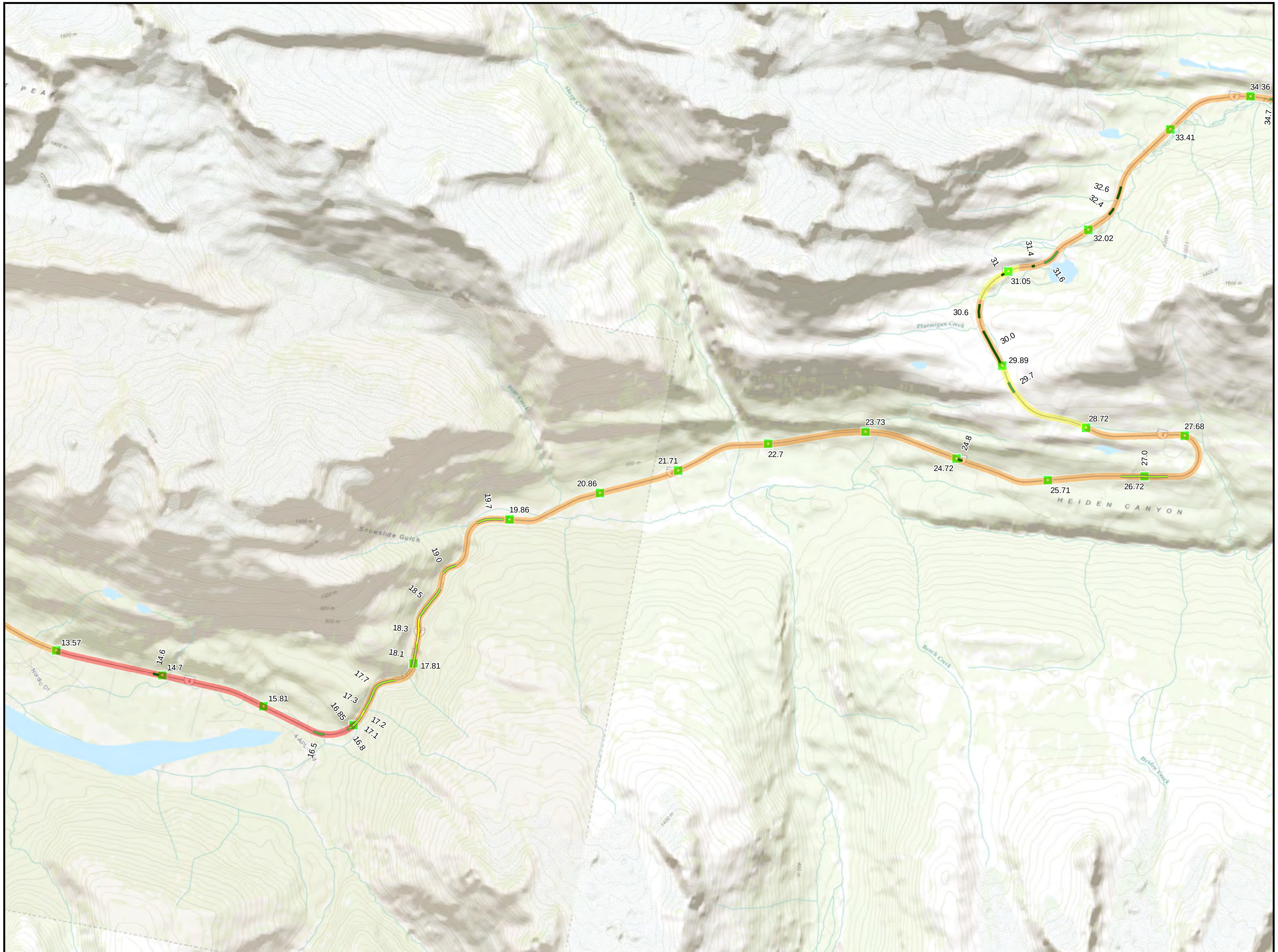

Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (8)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (5)
- 2 - Good (9)
- 3 - Moderate (2)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (2)
- 4 - Mediocre (21)
- 5 - Poor (6)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Richardson Highway

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY
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Area shown to left

Legend

Soil Slopes' Condition State

- 1 - Very Good (7)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State

- 1 - Very Good (8)
- 2 - Good (3)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR

- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (2)
- 4 - Mediocre (9)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Richardson Highway

Miles: 0 0.25 0.5 1 1.5

N

LANDSLIDE TECHNOLOGY

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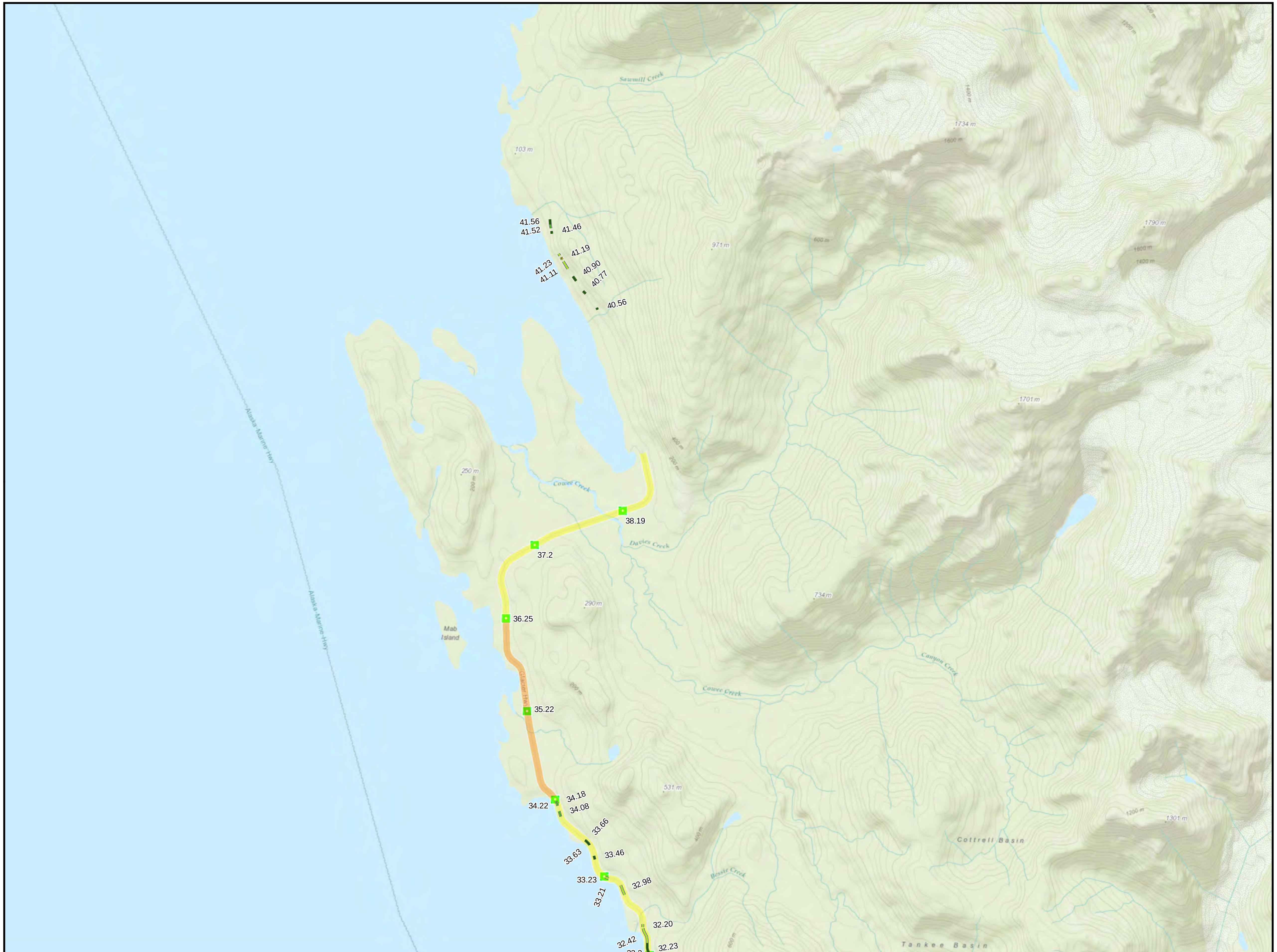

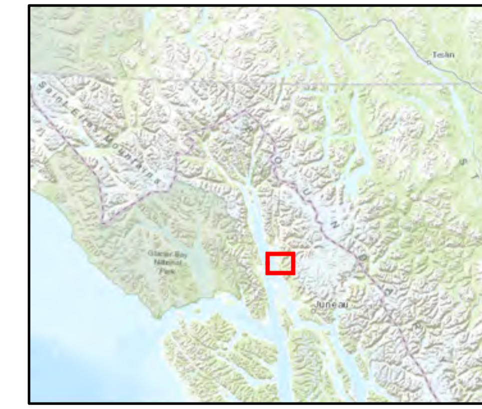

Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (9)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (3)
- 2 - Good (6)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (5)
- 4 - Mediocre (2)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Glacier Hwy_Egan Drive

Miles 0 0.25 0.5 1 1.5

N

LANDSLIDE TECHNOLOGY

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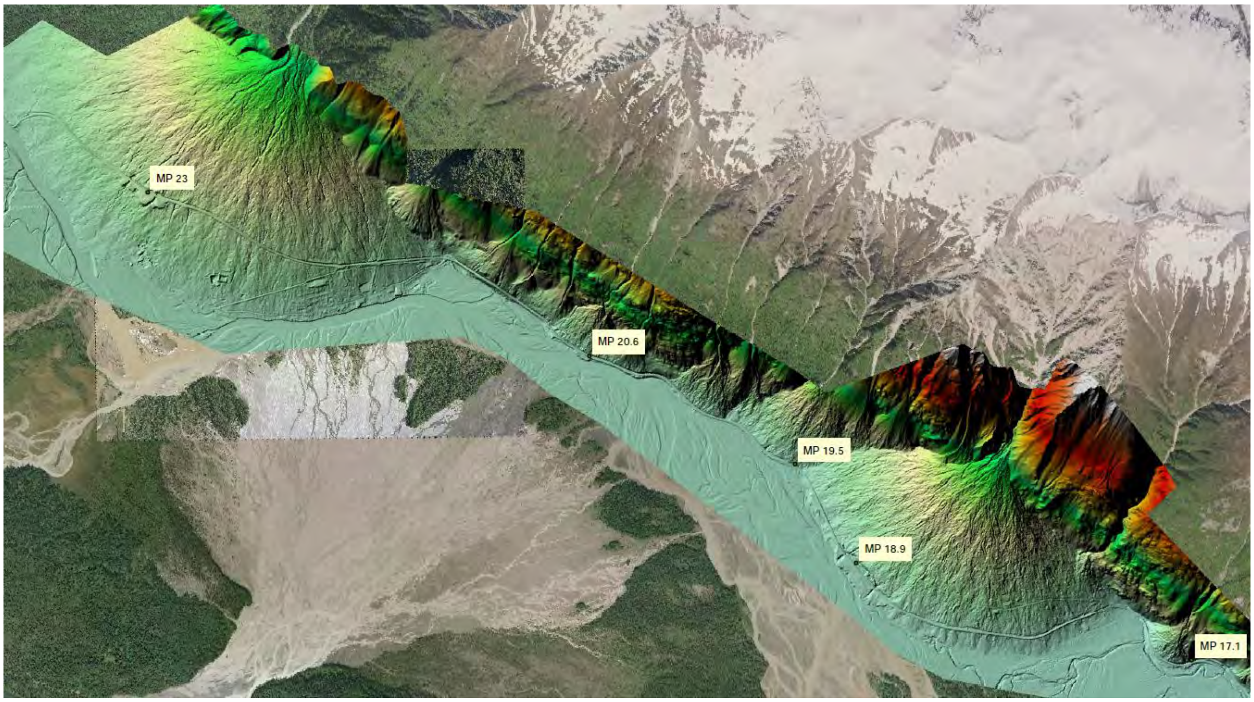
Appendix E: Haines

Haines Highway Debris Flow Corridor – MP 17 to 23

USMP Score Range: **548 – 1064.** Condition State: **5 – Very Poor**.
This corridor contains two of the highest rated and poorest condition sites in the State. Haines M&O has spent hundreds of thousands of dollars annually to open the roadway following debris flows and to prepare for additional, regularly occurring debris flows.



Next phase level of effort: High. A conceptual debris flow detection and early warning system was developed in the fall of 2013 in response to repeated road closures in the summer and fall earlier in the year. The number and frequency of road closing debris flow events have been increasing over the last three to five years, and both members of the public and M&O personnel have become ensnared in debris flow events. Eventually, this conceptual warning system could be deployed to interface with warning signs and a gated road closure system to prevent the public from entering the impacted roadway during debris flow events. If the gated closures are desired, a one to three observation year period (depending on the occurrence and severity of debris flows) to determine sensor thresholds and triggers would be required. Further reconnaissance and monitoring work has been carried out by AKDOT&PF with the Alaska Division of Geology and Geophysical Surveys (DGGS) and have revealed that the debris flows are likely to continue due an abundance of source material. Ultimately, a method to permit passage of the debris flows under the roadway could be studied, designed and constructed as part of a long-term hazard and risk reduction effort.

Additional moderate to poor condition slopes are present through the Haines Highway corridor. For example, a larger rockfall recently occurred at CDS MP 8.65, a high activity slope is present at CDS MP 14.50, a long slope with high activity, large unstable features, and a home above the slope crest is at CDS MP 26.22, and a sliding embankment is present at CDS MP 28.10 are a few that standout. If these slopes are not mitigated as part of an upcoming road realignment and rehabilitation project, they could also become candidate slopes to be addressed during or following construction.

Lutak Road (NHS) Debris Flow and Ferry Terminal Slopes

USMP Score Range: **311 - 379**. Condition State: **3 - Moderate**.
Two segments of the NHS Lutak Road (CDS MP 2.21 and 4.11) contain weak soil and rock material that frequently fails. Concrete traffic barriers are installed at MP 2.21 to reduce the quantity of material reaching the roadway. The rock slope at the ferry terminal (MP 4.11) displays adversely oriented and weathered rock structure and weak soil units and will continue to produce individual and volume rockfall events.

MP 2.21 with concrete barrier

MP 4.11 across from ferry terminal

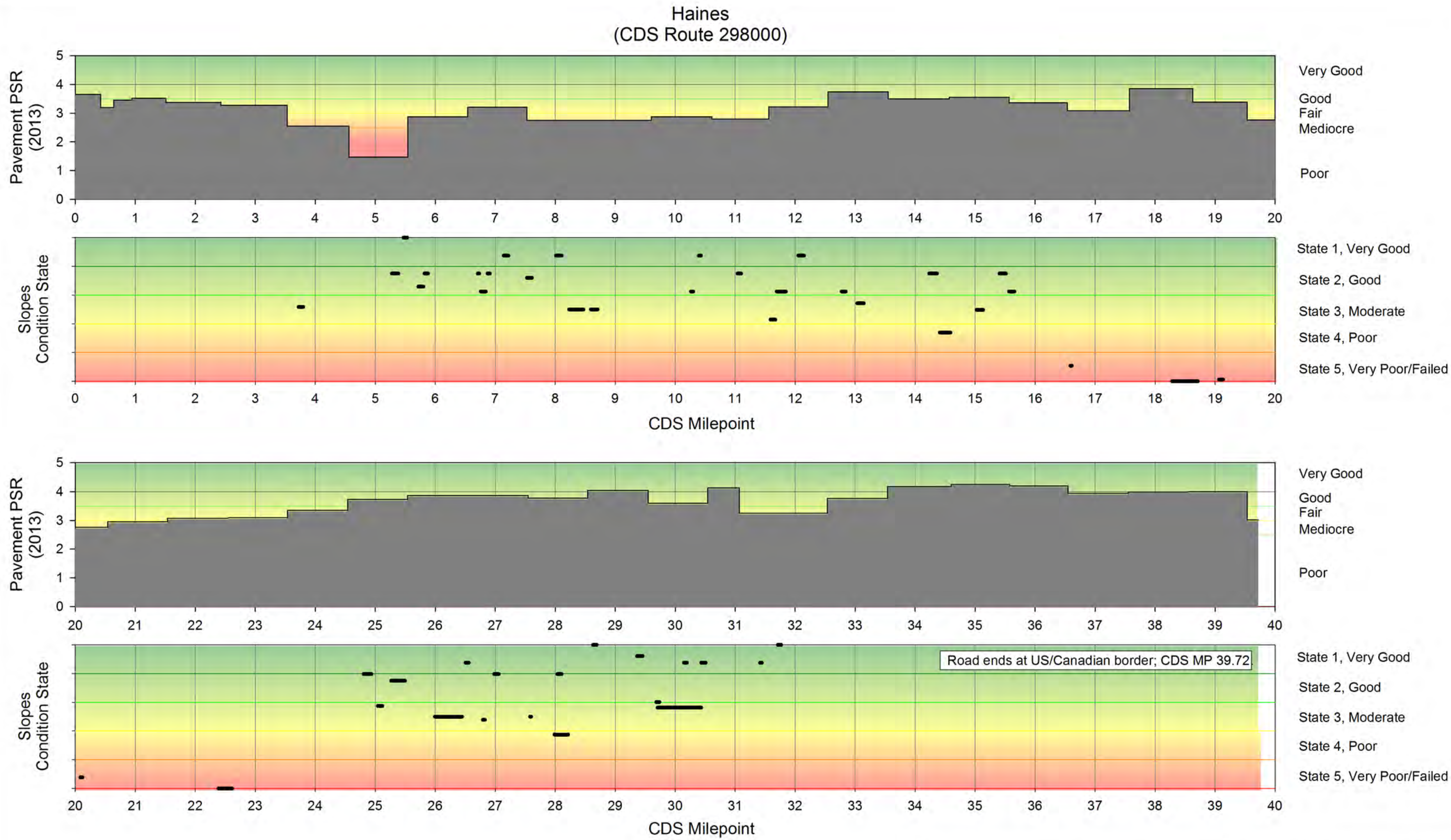
Design Level of Effort: Low to Moderate. Hazard and risk reduction at these slopes can be carried out with roadside barriers (low design effort) or with active restraint systems installed on the unstable cut slopes (moderate design effort). Due to the high levels of activity on these sites, roadside barriers will require frequent cleaning and maintenance, potentially increasing M&O costs but improving safety. A more robust approach consisting of heavy scaling, ditch improvement, slope crest flattening, and support system installation across the slope would significantly reduce rockfall frequency and maintenance demands.

Ten active rock slopes and three embankments showing signs of instability between CDS MP 1 and MP 2 were identified during the USMP inventory process and could also be considered for grouping of mitigation design efforts.

Lutak Road – Non NHS Debris Flows

Three debris flow locations are present past the NHS portion of Lutak Road; at 0.3, 2.3, and 3.9 miles past the ferry terminal. Currently, large culverts are passing water successfully beneath the roadway with occasional debris flows threatening the roadway. Based on satellite photos, the watersheds for these creeks do not have similar characteristics (large areas of bare, highly weathered rocks) to those feeding the very active debris flows on the Haines Highway. This indicates that the debris flows are likely the result of intense storms and resulting high flows entraining streambed cobbles and boulders. In contrast to large quantities of newly eroded materials are common on the Haines Highway debris flows. Note that since these sites were beyond the NHS portion of Lutak Road, they have not yet been rated as part of the USMP efforts.

Design Level of Effort: Low to moderate. A scaled-back and simplified instrumentation system similar to the Haines Highway concepts consisting of sensors at the roadside could be implemented. A sample sensor array to measure stream stage and a load cell to measure total earth pressures at the culvert intake could permit detection of both rapid sediment deposition and provide warning of when the culvert is nearly overwhelmed either by water or by increased sediment load, both scenarios which could potentially result in impacts to the roadway. Developing an implementation plan would be a 'low' design effort, while developing and then installing test sensors would require 'moderate' efforts and assistance from M&O personnel for installation of conduit and instrument posts.



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HAINES HIGHWAY
ASSET CONDITION STATES

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SOUTHCOAST, ALASKA

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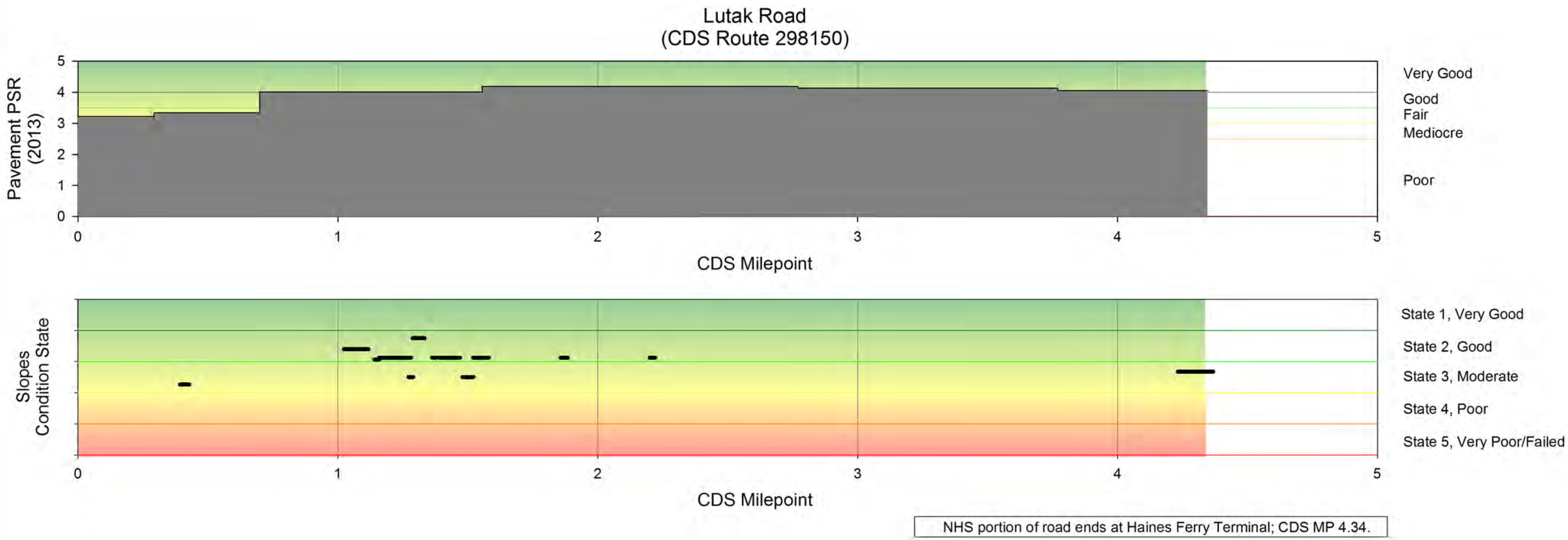
FIG.



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LUTAK ROAD
ASSET CONDITION STATES

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SOUTHCOAST, ALASKA

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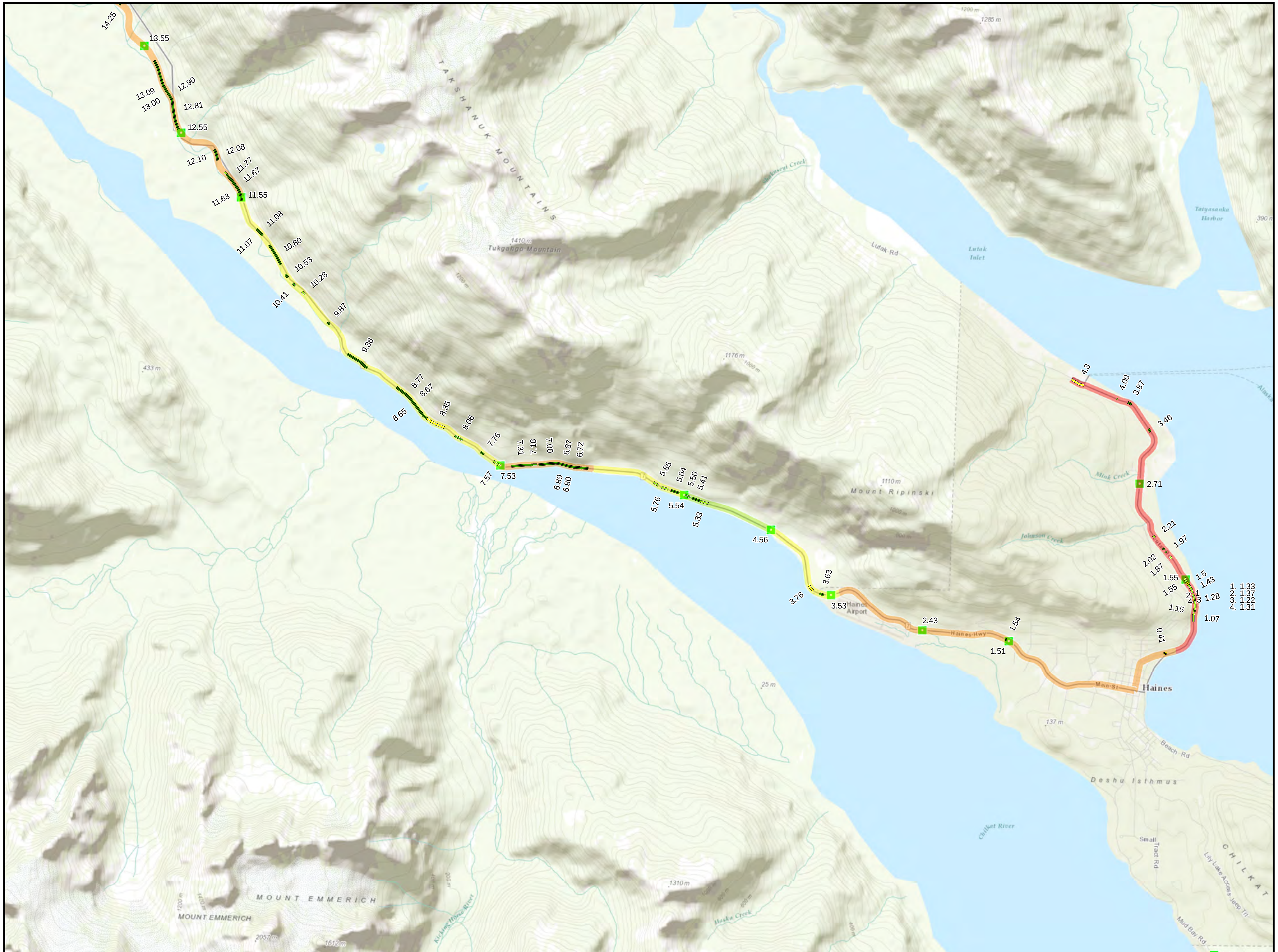
FIG.



Area shown to left

Legend

Soil Slopes' Condition State

- 1 - Very Good (25)
- 2 - Good (2)
- 3 - Moderate (3)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State

- 1 - Very Good (5)
- 2 - Good (19)
- 3 - Moderate (6)
- 4 - Poor (0)

Pavement PSR

- 1 - Very Good (0)
- 2 - Good (1)
- 3 - Fair (6)
- 4 - Mediocre (12)
- 5 - Poor (4)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Haines Highway

Miles
0 0.25 0.5 1 1.5

N

LANDSLIDE TECHNOLOGY
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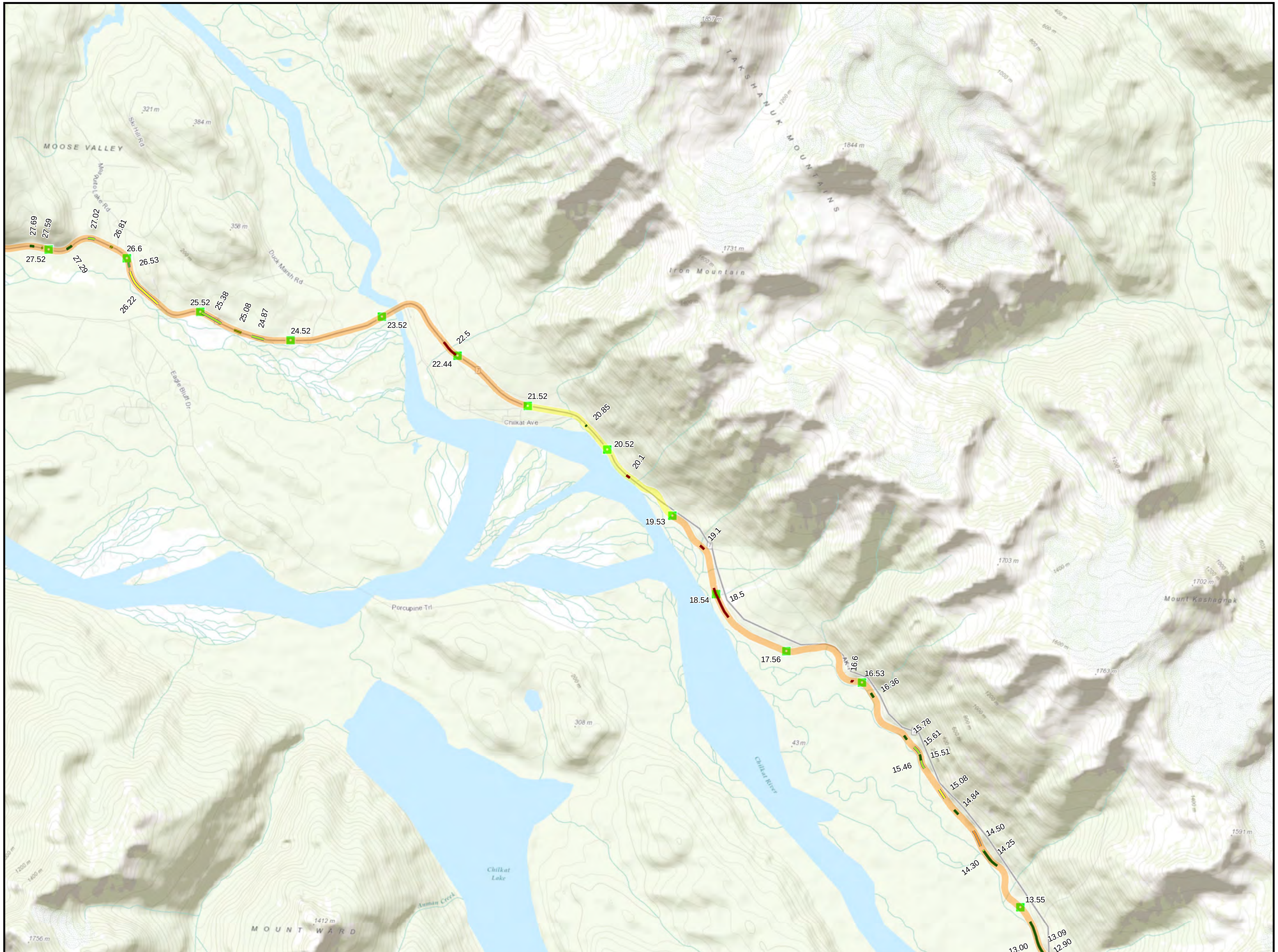

Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (10)
- 2 - Good (0)
- 3 - Moderate (3)
- 4 - Poor (0)
- 5 - Very Poor/Failed (5)

Rock Slopes' Condition State
- 1 - Very Good (1)
- 2 - Good (6)
- 3 - Moderate (3)
- 4 - Poor (1)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (2)
- 4 - Mediocre (14)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Haines Highway

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY
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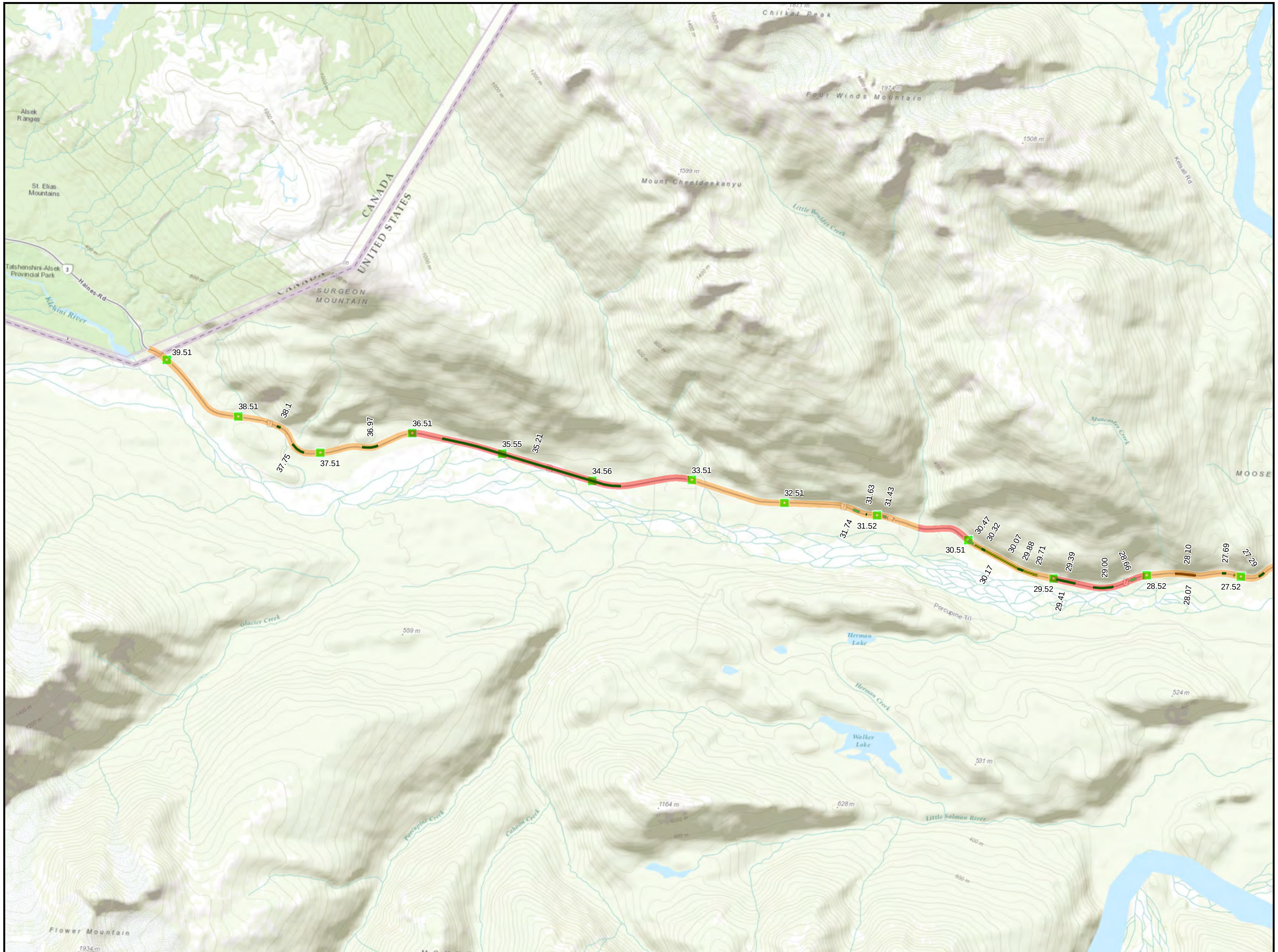

Area shown to left

Legend

Soil Slopes' Condition State

- 1 - Very Good (11)
- 2 - Good (0)
- 3 - Moderate (2)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State

- 1 - Very Good (6)
- 2 - Good (2)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR

- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (0)
- 4 - Mediocre (9)
- 5 - Poor (5)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Haines Highway

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY

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Appendix F: Skagway

Klondike Highway

USMP Score Range: **432 - 476**. Condition State: **3/4 – Moderate to Poor**.

The majority of unstable slopes on the Klondike Highway are rock slopes with the rare exception for unstable embankments. Most of the rock cuts are relatively short and most of the roadside ditches typically provide moderate to limited ditch capacity. An upcoming paving project could include a scaling and reinforcement aspect in order to prolong pavement life due a projected reduction in rockfall damage. Existing slopes with mesh could be repaired and reinforced.

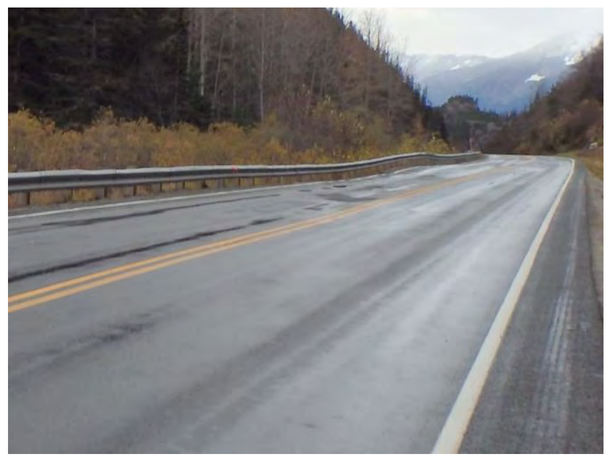
Design Level of Effort: Moderate to High. A segment of the highway between CDS MP 1.75 to about MP 4.15 where a number of moderate to poor condition unstable slopes have been identified requires regular attention from M&O personnel. Wedge failures are common failure mechanisms in this corridor. A cut near Mile Post 5 is known to M&O staff as "5-mile" and regularly produces rockfall and has limited fallout to contain the rockfall debris. Large diameter rock has fallen and entered pullouts on the opposite side of the road, potentially endangering members of the public stopped at the viewpoint. A number of other slopes in this segment exhibit similar geologic characteristics, have equally limited ditch effectiveness, and could benefit from the installation of rock slope support. Mitigation design would consist of obtaining structural measurements and creating an extensive series of annotated photographs exhibiting scaling areas and rock bolt and dowel locations. This work could be combined with the upcoming paving project and should be performed prior to pavement rehabilitation projects due to pavement damage resulting from scaling activities. Design work could also be combined with design work on the nearby Captain William Henry Moore Bridge replacement project, scheduled for summer 2015.

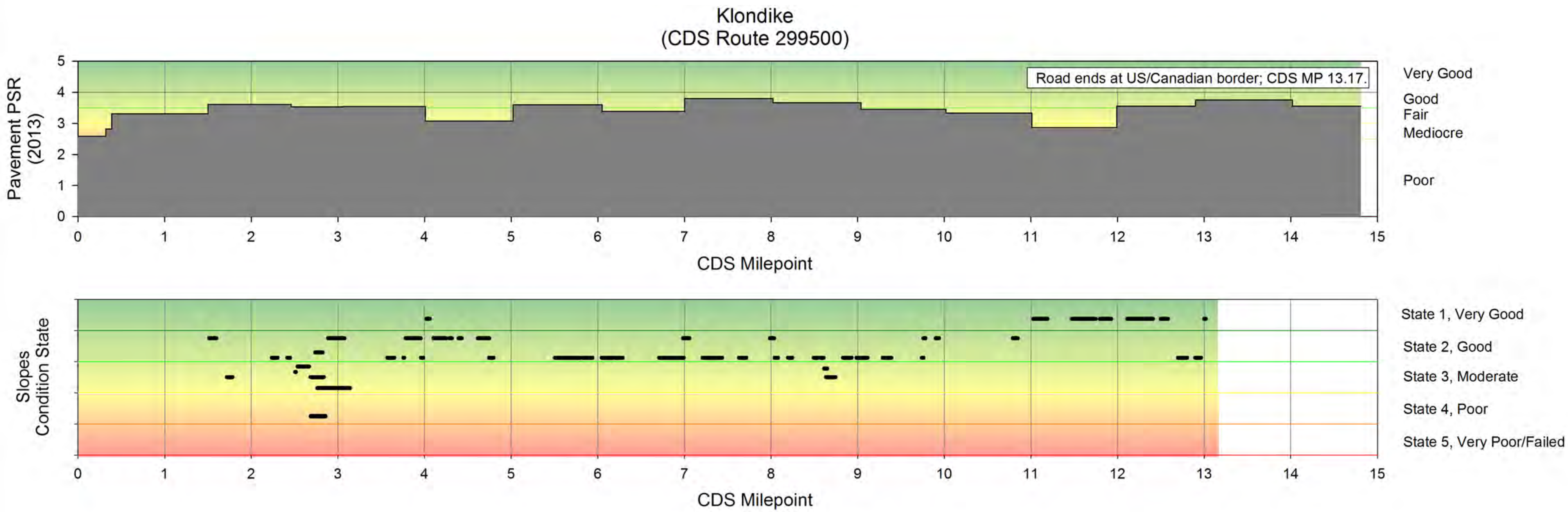
Rock slope failure near MP 2.27

"5-Mile" rock cut

Design Level of Effort: Moderate to High. The unstable soil slope is a 900-foot long section of embankment near CDS MP 2.77 where up to 8 feet of asphalt have slowly accumulated to counter the effects of settlement and instability. In order to prolong the pavement life in this section and reduce M&O costs, investigation of causation and design efforts to increase the resiliency of the pavement with such measures as a geosynthetically reinforced embankment and/or subgrade section can be incorporated into the upcoming pavement improvement contract. Subsurface explorations would likely be required to correctly design the repairs at this site. Opportunities to combine drilling programs with the nearby Captain William Henry Moore Bridge project, scheduled for final design work summer of 2015, would reduce the cost of this program. There is also a small embankment slump near MP 2.98 that should be addressed with similar mitigation methods prior to paving. Potential culvert deficiencies were also noted and could be corrected as part of the paving project.

Photographs of embankment distress at MP 2.77





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KLODIKE HIGHWAY
ASSET CONDITION STATES

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SOUTHCOAST, ALASKA

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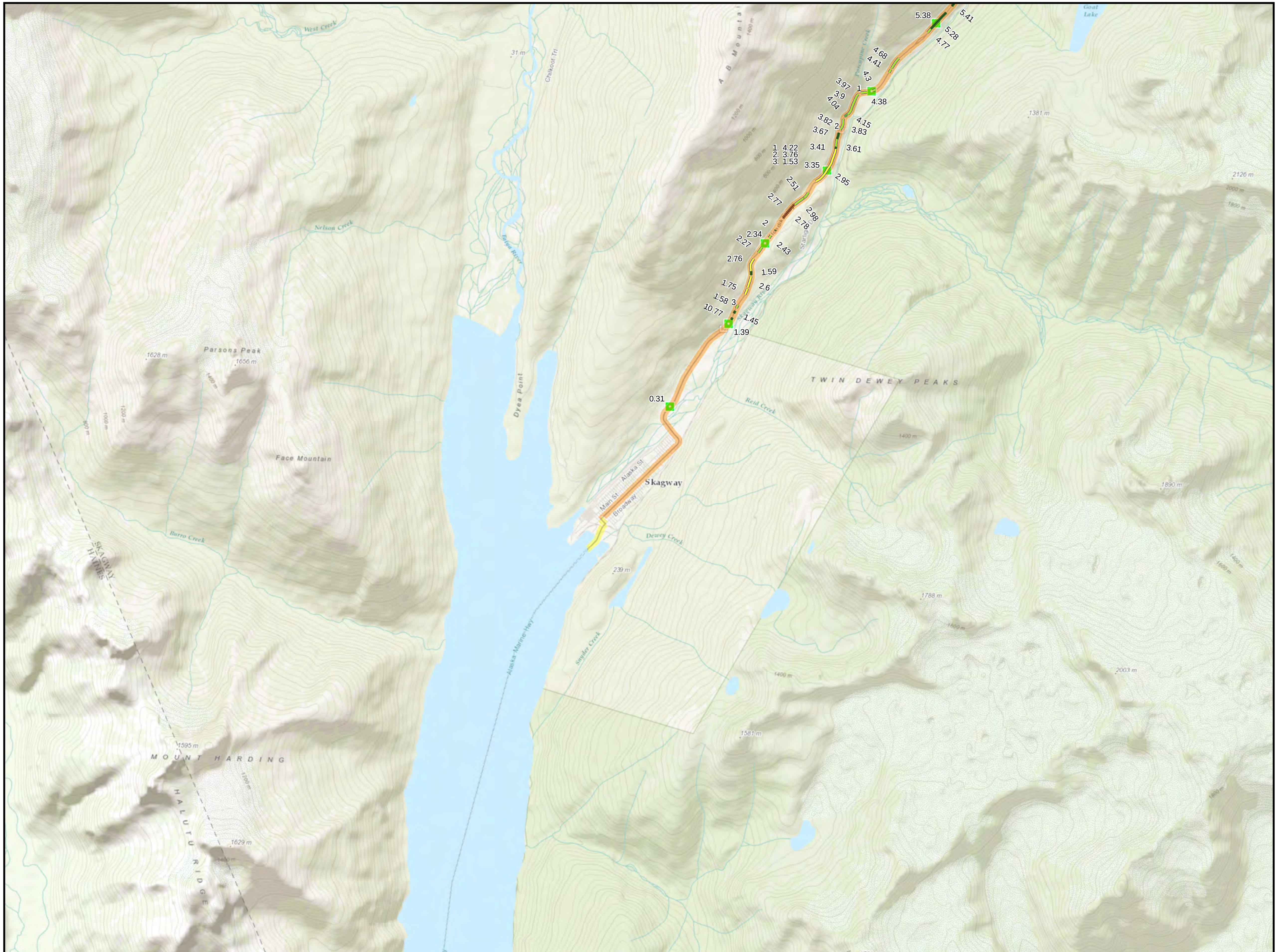
FIG.



Area shown to left

Legend

Soil Slopes' Condition State

- 1 - Very Good (8)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State

- 1 - Very Good (1)
- 2 - Good (18)
- 3 - Moderate (4)
- 4 - Poor (0)

Pavement PSR

- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (2)
- 4 - Mediocre (8)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Klondike Highway

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY

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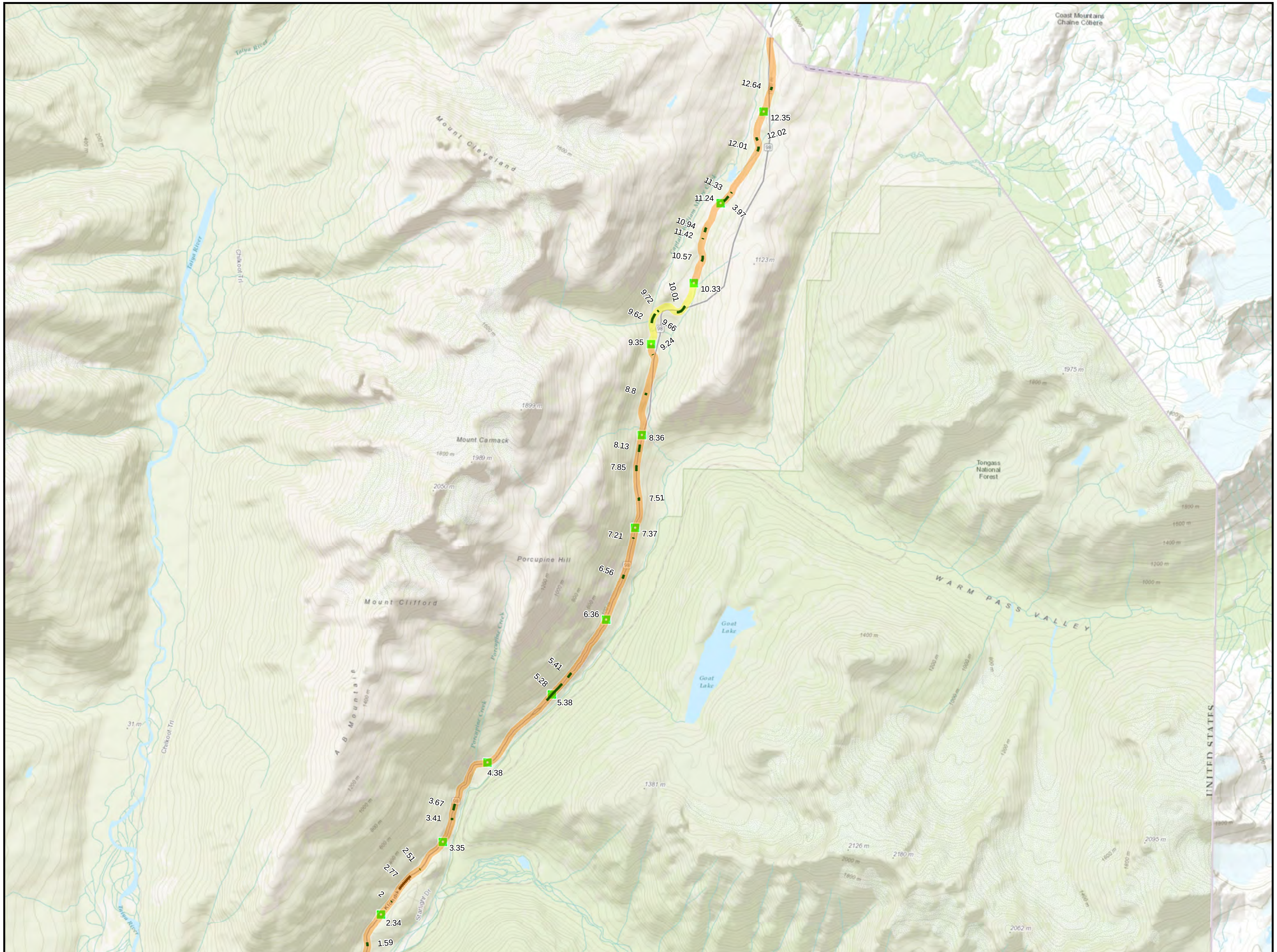

Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (25)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (1)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (1)
- 4 - Mediocre (12)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Klondike Highway

0 0.25 0.5 1 1.5 Miles

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LANDSLIDE TECHNOLOGY
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Appendix G: Valdez

Richardson Highway, Valdez to CDS MP 45.2

USMP Score Range: **314 - 518** Condition State: **3 - Moderate**.

This segment of the Richardson Highway is dominated by Keystone Canyon and Thompson Pass. Most slopes within Keystone Canyon are performing well despite generally limited fallout. CDS MP 17.03 is dominated by a waterfall and debris pile below. CDS MP 18.12 is characterized by failures along structural discontinuities and by limited to no ditch catchment. On Thompson Pass, a failing bin wall was identified by M&O at CDS MP 42.30 and rated during the 2010 USMP ratings as a failing unstable soil slope. The 2014 “Damvalanche” is outside the scope of the unstable slope project and was not rated.

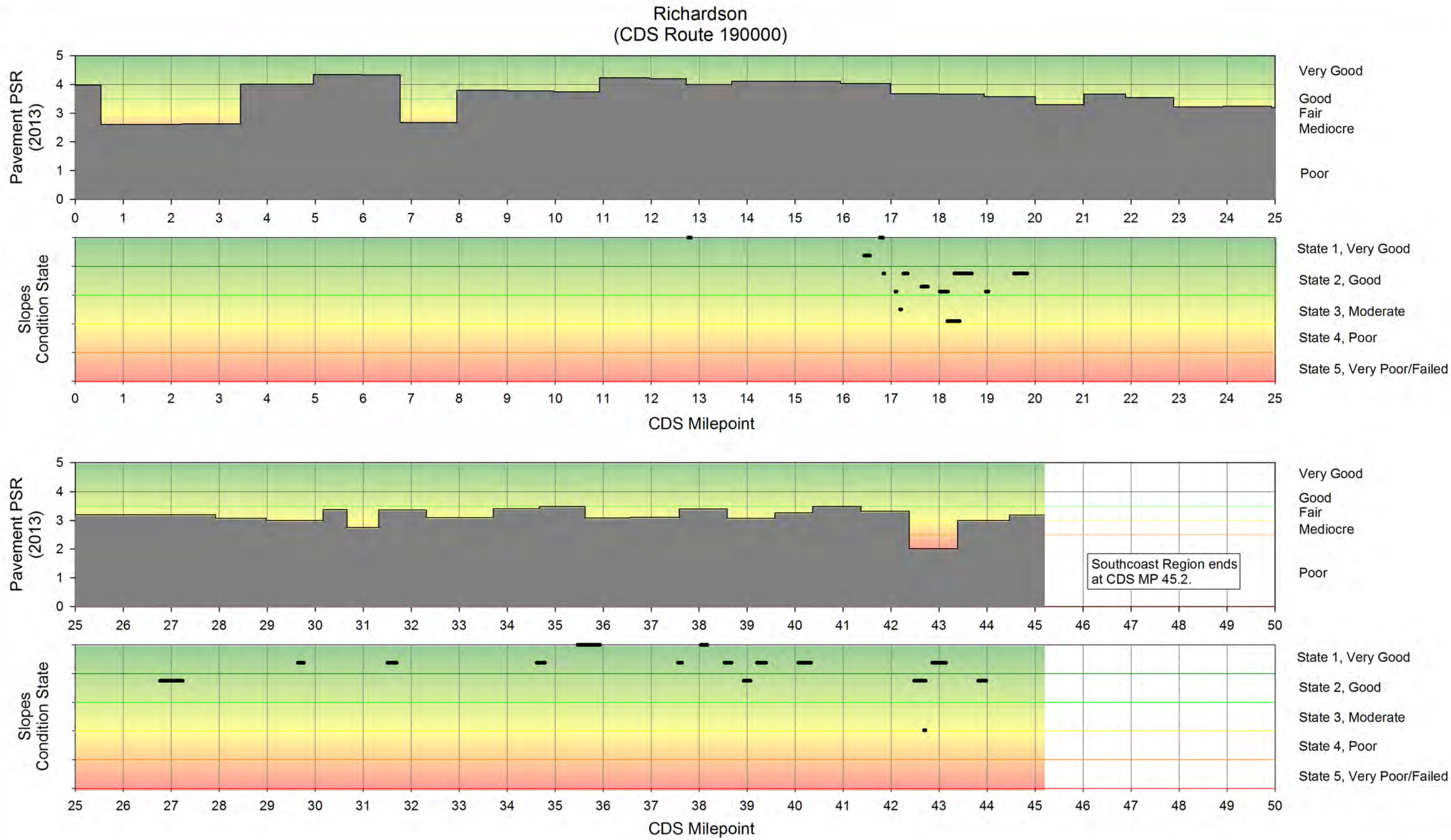
Slope failure near MP 17.03

Rock slope at MP 18.12

Deformed retaining wall, MP 42.30

Design Level of Effort: Moderate. The Keystone Canyon rock slopes could be mitigated with an improved fallout and/or debris retention system at MP 17.03 or rock bolts or dowels at MP 18.12.

For the retaining wall, a replacement investigation and design would require a **Moderate to High** level of effort. The design effort for retaining wall replacement would require subsurface explorations and internal and global stability analyses.



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RICHARDSON HIGHWAY
ASSET CONDITION STATES

SOUTHCOAST REGION PLANNING
SOUTHCOAST, ALASKA

DEC 2014
PROJ. 2337
FIG.


Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (4)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (1)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (7)
- 4 - Mediocre (8)
- 5 - Poor (11)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Richardson Hwy SB in Valdez

0 0.25 0.5 1 1.5 Miles

N

LANDSLIDE TECHNOLOGY
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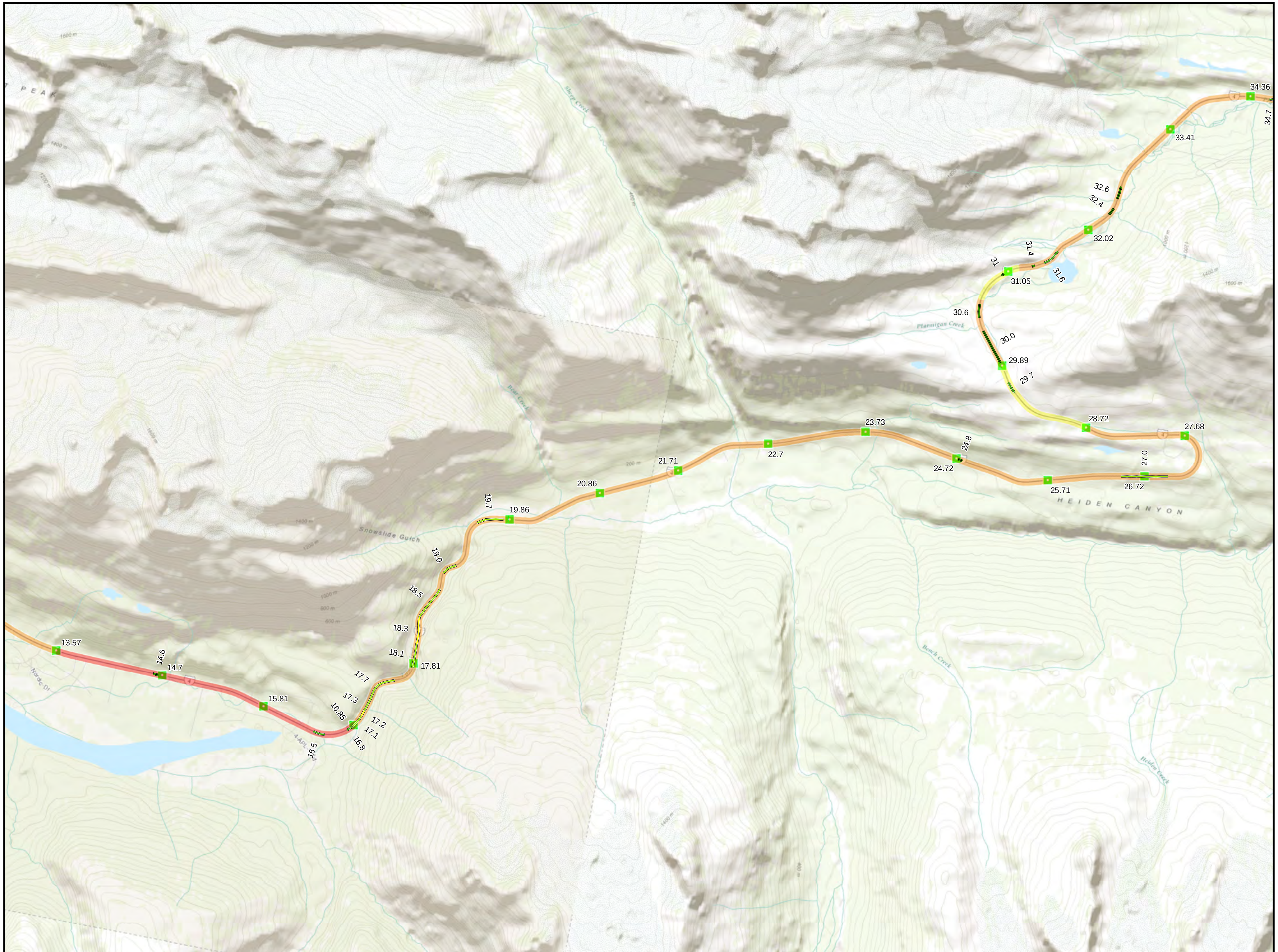

Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (8)
- 2 - Good (0)
- 3 - Moderate (0)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (5)
- 2 - Good (9)
- 3 - Moderate (2)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (2)
- 4 - Mediocre (21)
- 5 - Poor (6)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Richardson Highway

Miles
0 0.25 0.5 1 1.5

N

LANDSLIDE TECHNOLOGY
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Area shown to left

Legend

Soil Slopes' Condition State
- 1 - Very Good (7)
- 2 - Good (0)
- 3 - Moderate (1)
- 4 - Poor (0)
- 5 - Very Poor/Failed (0)

Rock Slopes' Condition State
- 1 - Very Good (8)
- 2 - Good (3)
- 3 - Moderate (0)
- 4 - Poor (0)

Pavement PSR
- 1 - Very Good (0)
- 2 - Good (0)
- 3 - Fair (2)
- 4 - Mediocre (9)
- 5 - Poor (0)

CDS Milepoint

Asset Inventory Map

December 2014

Map Page:

Richardson Highway

Miles: 0 0.25 0.5 1 1.5

N

LANDSLIDE TECHNOLOGY

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Appendix G

GUIDE TO USE AND MAINTENANCE OF THE GAM DATABASE

1. OVERVIEW OF THE ONLINE GAM COMPONENTS

Actively using and maintaining the geotechnical asset databases will assist the Department with effectively tracking their assets, properly incorporating the benefits of this system. To facilitate this, all the asset data is housed within AKDOT&PF's Transportation GIS (TGIS) ArcGIS Online (AGOL) website[1]. The maps and applications used in data management are largely developed from forms created by ESRI™ (originally Earth Systems Resource Institute). Housing the data on this site permits interactive use of the data, both online and on Desktop GIS platforms. Because AGOL can be accessed from any computer or device with an internet connection, and even taken and edited off-line, it also prevents the data from becoming trapped in a single location, or becoming the responsibility of a sole 'gatekeeper'. Authorized AKDOT&PF users can create new site records and update existing ratings as changing conditions warrant.

In this section, basics of the TGIS AGOL geodatabases are described and discussed. Note that this section is not intended to be a full user's guide or provide training on general use of the AGOL system. It only provides highlights of key features of the database and brief instruction intended for users with at least an intermediate experience level with AGOL or GIS software programs. Tutorials on using AGOL can be found online[2] and will reflect the most recent program updates. To use some of the tools described in this guide, users may need to acquire an AGOL user name and password from the TGIS group, or work with TGIS to change their "role" in the organization, as different roles have access to different tools.

This appendix is organized as follows:

- Section 2: Individual Asset Geodatabases, which focuses on feature layers, definitions, and user permissions for the various asset types
- Section 3: Using the GAM Database, which focuses on the maps and apps that exhibit the data
- Section 4: Excel Workbooks for Detailed Ratings, which discusses methods to calculate rating data
- Section 5: Office-based Editing, which describes how authorized users can update the GAM geodatabases
- Section 6: Geodatabase Fields, which contains detailed information on field names, aliases, and how fields relate to rating categories.

2. INDIVIDUAL ASSET GEODATABASES

Each of the four asset classes (Rock Slopes, Unstable Soil and Embankment Slopes, Retaining Walls, and Material Sites) is subdivided into its own geodatabase hosted on AGOL. Additionally, the Geotechnical Event Tracker application is tied to a separate geodatabase specifically developed for storing geotechnical events. Web, desktop, and mobile apps can access AGOL hosted layers from anywhere on the Internet when the data owner grants permission. The geodatabases are separated into three types, the Hosted Feature Layer, a Feature Layer View, and the Service Definition. Each of these are required to view, edit (with proper permissions), and query the GAM layers.

[1] http://akdot.maps.arcgis.com/home/index.html - TGIS AGOL Base Website
[2] http://resources.arcgis.com/en/Tutorials/ - AGOL Tutorials

2.1 Hosted Feature Layers

Hosted feature layers support point, line, and polygon feature querying, visualization, and editing. Hosted feature layers are most appropriate for visualizing data on top of basemaps. In web apps, hosted feature layers are drawn by the browser and support interactive highlighting, queries, and pop-ups.

2.2 Feature Layer View

A hosted feature layer *view* is a portal with different permissions into the data and information accessed through a hosted feature layer. The hosted feature layer view is similar to a copy of a layer but is more powerful because it allows control for more than just how the layer is displayed. For example, the GAM feature layer views permit editing capabilities through specific Group permissions. AKDOT&PF needs to share data with the public and simultaneously allow members within the organization to keep that data up to date. Hosted feature layer views provide a direct way to do this. When publishing the hosted feature layer, it can be locked from editing for public facing sites. However, for members of the AKDOT&PF GAM group, editing is still enabled via an editing-enabled hosted feature layer *view* that references the original hosted feature layer. Because the two layers share the same data, as members edit the original hosted feature layer, the general public will see those changes immediately.

2.3 Service Definition

A service definition file contains information about service properties, capabilities, the service type, and attachments. These do not get added to maps, but rather support functionality of the associated Hosted Feature Layers. Table 1 below shows the current Service Definition links for each of the GAM program asset classes and the Event Tracker geodatabase. The table also includes details and links to the relevant geodatabase files for each of the GAM assets types and the Event Tracker.

Table 1: Asset Class Geodatabase Layers.

Item	Detail	Size on Disk (Dec. 2017)
Asset Class: Soil Slopes and Embankment Assets		
Name	Soil_Slope_and_Embankment_Assets	
Contains	Point locations, linear extents, site photographs (as attachments to the point layer)	
Feature Data Layer	http://akdot.maps.arcgis.com/home/item.html?id=1018357edeeb48e09ae0578dfd0b7cbf	2 MB
Editable View	Editable view for AKDOT&PF GAM Group Members. http://akdot.maps.arcgis.com/home/item.html?id=20a53ad400834720bec55d35113d60ad	0 MB
Service Definition	http://akdot.maps.arcgis.com/home/item.html?id=97f3334a5eb44a2b9a82172388859b86	6,154 MB
Asset Class: Rock Slopes		
Name	Rock_Slope_Assets	
Contains	Point locations, linear extents, site photographs (as attachments to the point layer)	
Feature Data Layer	http://akdot.maps.arcgis.com/home/item.html?id=e9e513aac1ab4e4686a933f3d8c51e3c	5 MB

Item	Detail	Size on Disk (Dec. 2017)
Editable View	Editable view for AKDOT&PF GAM Group Members. http://akdot.maps.arcgis.com/home/item.html?id=e645d16594074197a24fe8196385ca5f	
Service Definition	http://akdot.maps.arcgis.com/home/item.html?id=f2ff2bb8e58b415ab0f8289e2c79e55f	20,703 MB
Asset Class: Rated Retaining Walls		
Name	RatedRetainingWalls	
Contains	Point locations, linear extents, site photographs (as attachments to the point layer)	
Feature Data Layer	http://akdot.maps.arcgis.com/home/item.html?id=cfab6ec7a6a54e0c8f8d67724bfdd231	2 MB
Editable View	http://akdot.maps.arcgis.com/home/item.html?id=35a054b037b048b0ab4fc28a9b0efd8d	0 MB
Service Definition	http://akdot.maps.arcgis.com/home/item.html?id=095834986afb47d3a4368d2a29ef9314	5,443 MB
Asset Class: Retaining Wall Inventory		
Name	RetainingWallInventory	
Contains	Point locations, based on as-built plan sets	
Feature Data Layer	http://akdot.maps.arcgis.com/home/item.html?id=15c68596e5e74a97b7da0a8fb58b68e1	0.6 MB
Editable View	http://akdot.maps.arcgis.com/home/item.html?id=ae194e498e5f449194ed59e5c1c253d4	0 MB
Service Definition	http://akdot.maps.arcgis.com/home/item.html?id=d4ddd6d569ab4eacb135096d2899b174	0.1 MB
Asset Class: Material Sites		
Name	Material_Site_Assets	
Contains	Material Site Locations (points), valuable material sites, merged AHS and NHS highways, 5-mile haul buffers, and Maintenance Section service areas	
Feature Data Layer	http://akdot.maps.arcgis.com/home/item.html?id=17449075e7b24a4c89cefb40a8c3977c	28 MB
Editable View	http://akdot.maps.arcgis.com/home/item.html?id=d79bb6e7800c48048abe4588421f522e	0 MB
Service Definition	http://akdot.maps.arcgis.com/home/item.html?id=f9ef265b5b2a40cbb58d749248f9fc00	4 MB
Geotechnical Event Tracker Application and Geodatabase		
Data Entry Application	http://akdot.maps.arcgis.com/apps/GeoForm/index.html?appid=cb801e51e9f144b38eacc5fffca624af. Note that this is shared publically to encourage use by all interested AKDOT&PF staff, many of whom may not have an AGOL account.	0.06 MB
Data Edit Map	http://akdot.maps.arcgis.com/apps/Editor/index.html?appid=6cb963582be0497f87e3e5a896ce84ed Shared only with GAM Group Members	0.05 MB
Contains	Point Locations entered into the Geotechnical Event Tracker	
Feature Data Layer	http://akdot.maps.arcgis.com/home/item.html?id=6fee07a9de074f4ebd4b2b1b77ecc32e GAM_Event_Service	2 MB
Service Definition	http://akdot.maps.arcgis.com/home/item.html?id=1a851017ffb54ddf99e06636c1c8cc80	0.17 MB

2.4 GAM AGOL Group and User Permissions

User permissions for editing the geodatabases listed above are granted through membership to an AGOL Group created for editing and accessing GAM data. The AKDOT&PF TGIS AGOL Group is named ‘Geotechnical Asset Management (GAM) Program’ and is accessed via AKDOT AGOL[3]. Permission must be requested from and granted by TGIS following review by the manager administering the GAM Program, currently the Statewide Chief Engineering Geologist. Group membership is required for editing select GAM inventory and condition assessment layers described in the ‘Editable’ databases listed in the table above.

Membership in the Group will facilitate finding relevant GAM data, maps, and applications. Like much of AGOL, the Group is organized with tabs across the top of the page for Overview, Content, and Members. The default opening Overview tab is shown below (Figure 1). Clicking on the Content tab will list the layers, maps, apps, and other ancillary digital assets associated with the GAM Program. Items shared with the GAM Group can be sorted by a variety of parameters by clicking on the left ‘Refine Content’ list (Figure 2).

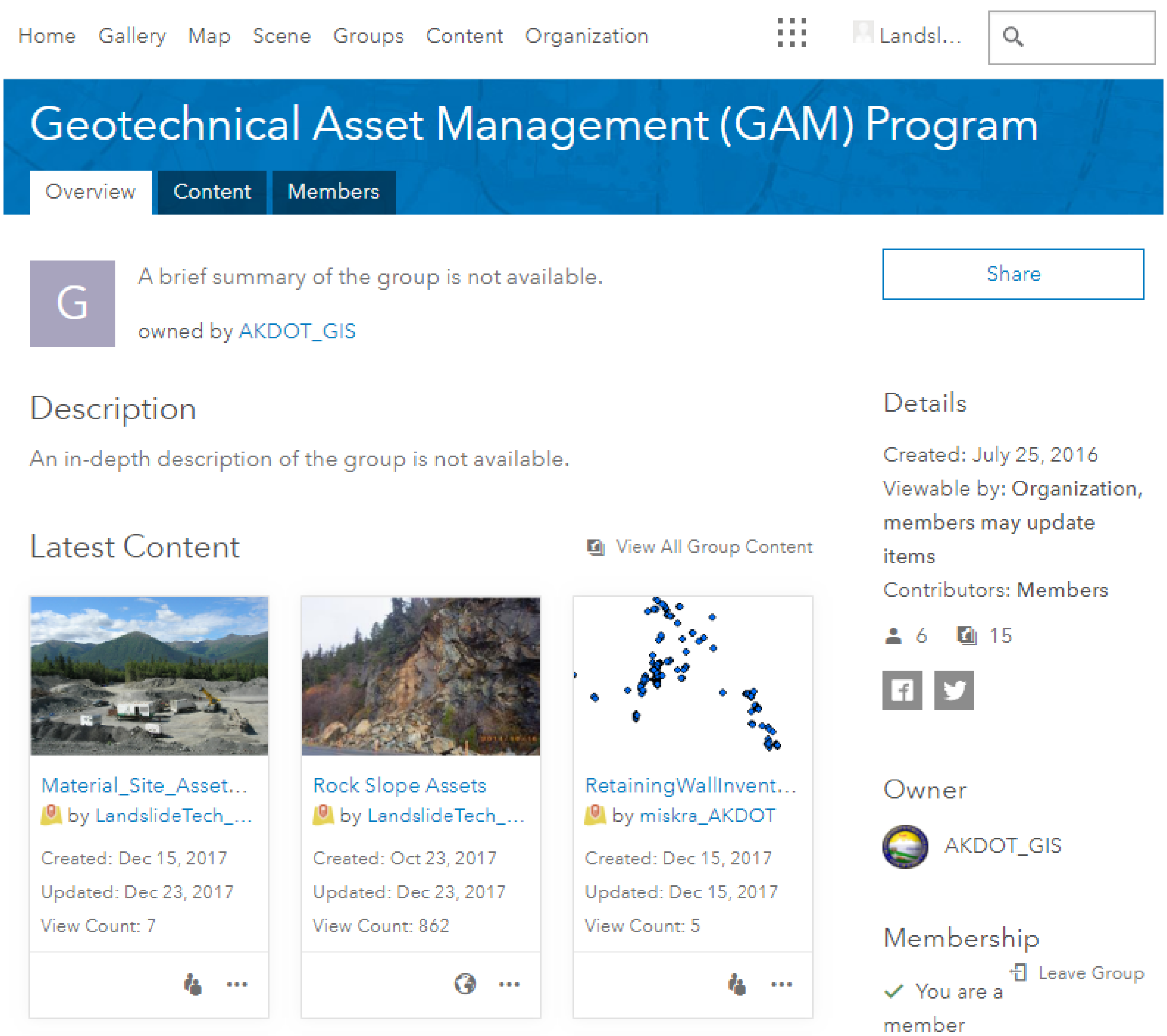


Figure 1: AGOL GAM Group View from a web browser.

[3] GAM Program Group http://akdot.maps.arcgis.com/home/group.html?id=c2dd635abd714928a100f5cdf31a0787#overview

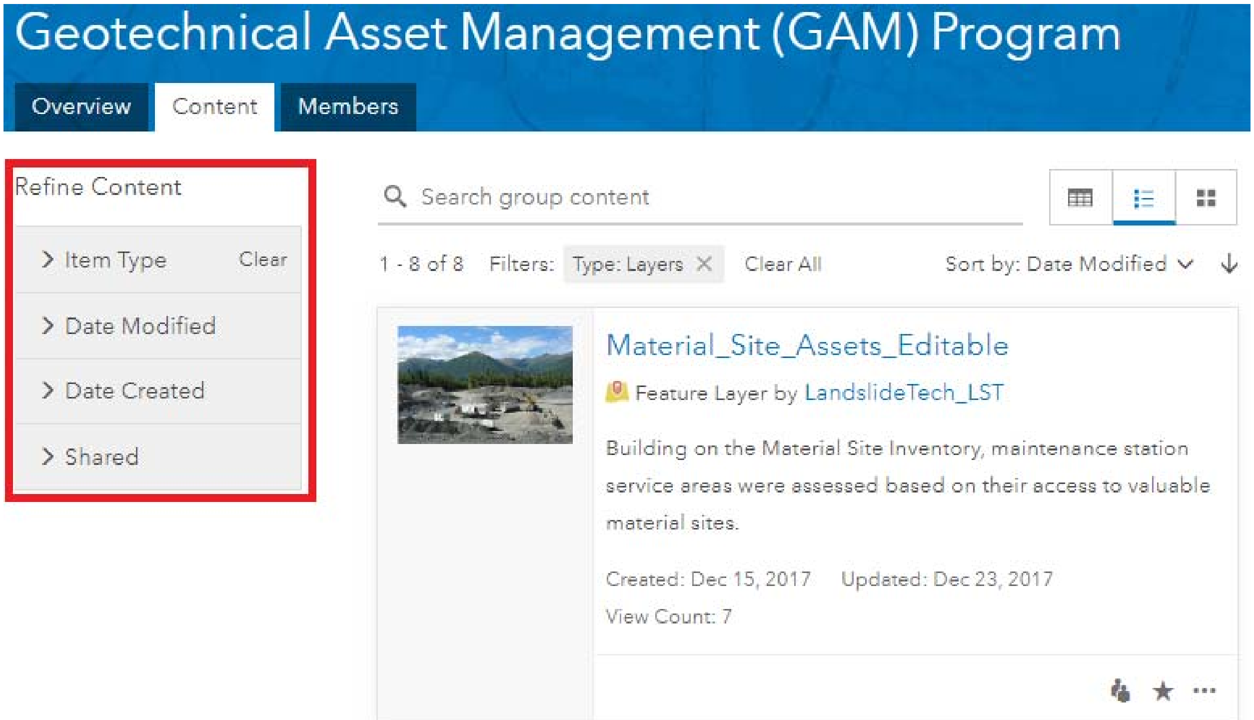


Figure 2: AGOL GAM Group content menu with available filtering criteria indicated with the red box.

3. USING THE GAM DATABASE

During inventory work for unstable slopes and retaining walls, a Microsoft Access database and ArcMap v 10.2 were used in the field. To improve ease of input and rapid field data collection and calculations, various datasets, such as AADT, milepoint locations of Mile Post markers, etc. were also incorporated into the Microsoft Access Database. The Material Site Inventory (MSI) program generated a series of Excel-based sheets and pdf reports. An ArcGIS geodatabase was also submitted to AKDOT&PF as a final deliverable. The database hosted on AGOL was created by compiling data from these various sources for use within an ArcGIS framework.

Following the field efforts, a separate data layer was created for each asset type in the GAM program. Taken collectively, they comprise the master geodatabase for use in a GIS environment. Layers created from the various inventory data sources were uploaded to the AGOL site, with the major layers listed in Table 1 in Section 2 above.

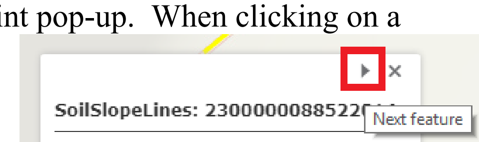
These AGOL layers are the primary method for interacting with the database so that all AKDOT&PF users have access to the same, up-to-date data. Standalone datasets, such as one for a particular Region, should be used only for specific projects and analytics, such as regional planning or relative prioritization within a particular highway segment. Extraction of the data in a variety of formats, such as shapefiles, file geodatabases, or tabular datasets is possible within the AGOL platform. Depending on a user's permissions, other tools within the AGOL platform permit filtering and data analysis.

The AGOL layers are available to view online, embed into other websites, take offline into the field using IPad or Android mobile devices, or opened in desktop GIS software such as ArcMap or ArcGIS Pro. The following sections describe the available interfaces.

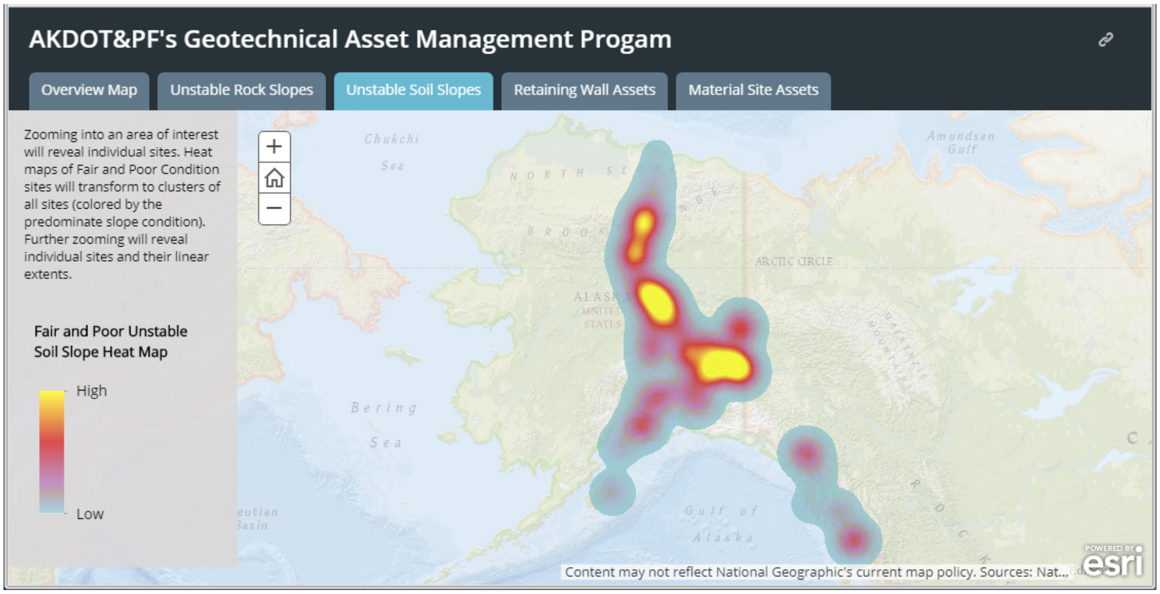
3.1 ArcGIS Online Database

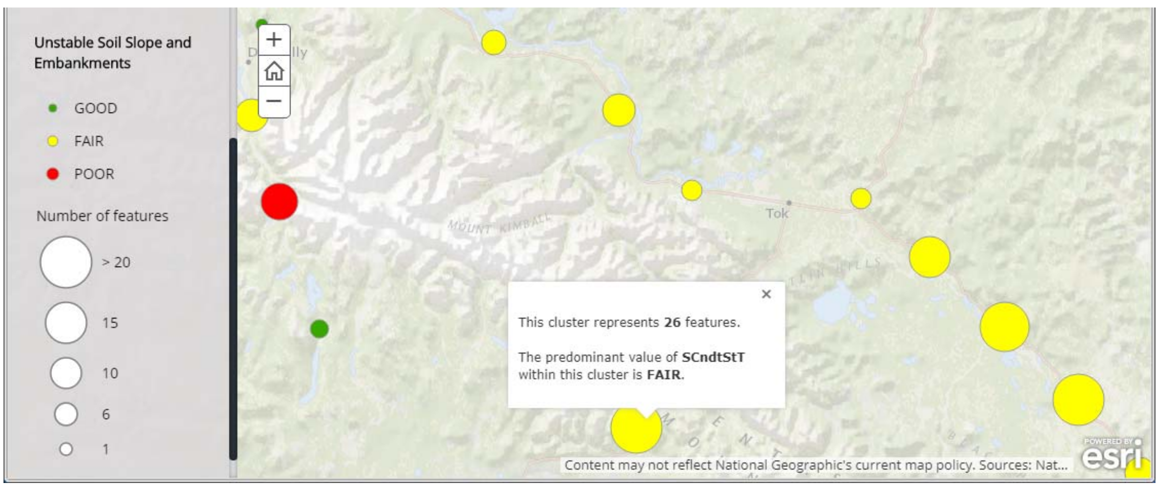
The most accessible method for viewing the GAM geodatabases is through AGOL. The database applications for rock slopes, unstable soil slopes and embankments, retaining walls, and material sites can be found directly within AGOL[4]. This interface is designed as the central public access to the AKDOT&PF Geotechnical Asset Management Program. Note that the tabs at the top permit viewing of each asset type interchangeably over the same geographic extent.

The AGOL map interface is interactive. As the user changes the map scale using the map controls or the mouse wheel, different visualizations of the same datasets appear as the user zooms in, then disappear as the user zooms back out. These maps use a variety of heat mapping, clustering, and when fully zoomed in, individual site locations and the linear site extents (Figure 3). Clicking on various tabs at the top permit viewing of each asset type. When fully zoomed in, point locations contain the full rating data formatted into a pop-up when clicked. Photos acquired of each site during the ratings are at the bottom point pop-up. When clicking on a point, AGOL often selects multiple features; use the arrow (indicated in red) at the top right of the pop-up to navigate.



[4] http://akdot.maps.arcgis.com/apps/MapSeries/index.html?appid=0be74f9ba168424eac48983da02e0250 - Direct link to GAM Program Application. Direct links to the underlying maps (for additional filtering and analysis capabilities) are http://www.arcgis.com/home/webmap/viewer.html?webmap=dc6b9c3925d341f4b0b5eb001e745c06 (rock slopes), http://www.arcgis.com/home/webmap/viewer.html?webmap=81ea598fbd3c414482471d8a41831ac8 (soil slopes), http://www.arcgis.com/home/webmap/viewer.html?webmap=d82ed83c9f7b444bb1d163906111e4c7 (retaining walls), and http://www.arcgis.com/home/webmap/viewer.html?webmap=a4920093a6d247f9b5a8f3f9273cb044 (material sites).

A) 

B) 

C) 

Figure 3: ArcGIS Online Opening Screen for Geotechnical Asset Program Interface, showing the unstable soil slope and embankment data. Views A, B, and C exhibit various heat mapping and grouping capabilities. Part A exhibits a heat map of at the furthest zoom. Part B exhibits clustering capabilities that change size and color based on the number of sites and their dominant condition, while C exhibits individual sites and their linear extents.

The maps contents and feature data layers and their visibility range are summarized in Table 2 (rock slopes, soil slopes and embankments, and retaining walls) and Table 3 (material sites). Data on each asset is accessible when zooming in and clicking on the point location. Photos are included for rock slope, unstable soil slope, and retaining wall assets.

The above interfaces are 'Apps', which use underlying 'Web Maps'. When using the Web Maps (see Footnote 4 for URL), the user can change the basemap type or add additional feature data layers such as STIP projects, additional GAM datasets, AADT overlays, and layers either created by AKDOT&PF or others that may facilitate specialized analyses. Adding these to the standalone map adds data only for that user session and does not change the map for other users. Additionally, pop-ups can be enlarged in the Web Map view for easier viewing, while they cannot be enlarged within Apps. The new altered map can be saved under a user's individual account when signed in.

Table 2: ArcGIS Online variable layer visibility for rock slopes, unstable soil slopes, and retaining walls.

Map Feature	Zoom Level Statewide	Region-wide	Intra-Region	Multi-Station	Intra-Station
Interactive Slope Heat Map	✓	✓	✓		
Route Data	✓	✓	✓	✓	✓
Mileposts			✓ (10 mile)	✓ (5 mile)	✓ (1 mile)
Individual Slope Points and Clusters		✓	✓	✓	
Individual Slope Linear Extents					✓

Table 3: ArcGIS Online variable layer visibility for material sites.

Map Feature	Zoom Level Statewide	Region-wide	Intra-Region	Multi-Station	Intra-Station
Individual Material Sites				✓	✓
Individual Valuable Material Sites		✓	✓	✓	✓
NHS and AHS Routes within 5 miles of a Valuable Material Site		✓	✓	✓	✓
NHS and AHS Routes		✓	✓	✓	✓
5-mile Buffer around Valuable Material Sites		✓	✓	✓	✓
Maintenance Station Service Area	✓	✓	✓	✓	✓

3.1.1 AGOL Analyses and Filtering

When opening any of the asset maps and selecting the content tab in the upper left, additional icons (Figure 4) appear which facilitate additional analysis and filtering of the rock slope database. The filtering tool icon ( ) permits isolating specific criteria on a statewide or local basis.

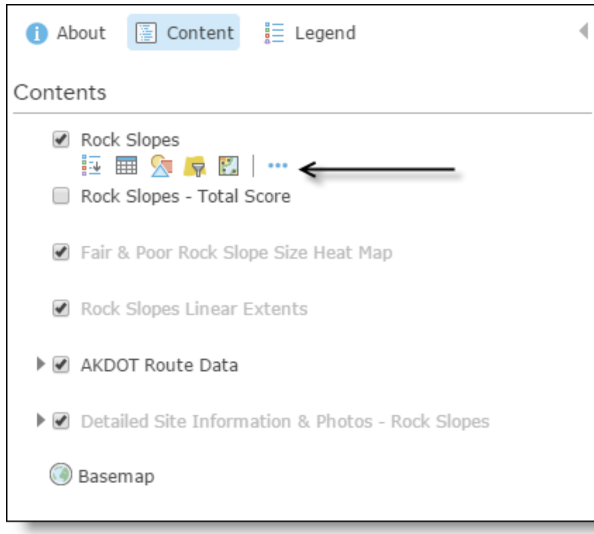


Figure 4: AGOL Content Tab with Additional Analysis and Filtering Icons Indicated.

For instance, if working with the rock slope map, adjustments can quickly be made so that the map displays all rock slopes in Condition State 3 (Fair) with Total Scores above 400 points to target a potential priority list of moderate condition sites with a high USMP score to prevent further deterioration to a Poor Condition. This filtering approach results in identification of 27 sites, concentrated on the Haines, Seward, and Glenn Highways with lesser concentrations on the Klondike and Tongass Highways (Figure 5). Other filtering examples for the rock slope map could include high risk ice fall candidate sites (poor ditch effectivness coupled with water on the slope and AADT greater than 3,000), or Fair and Poor Condition slopes with high AADTs, tall slopes, and poor geologic conditions, to identify high hazard sites with a potentially large impact.

Using the analysis tools (, available when signed into AGOL with an AKDOT&PF account with Publisher privileges), a variety of additional analysis tools become available. These include Summarization, Location, Pattern and Proximity Analysis, and Data Management Tools. While many of these tools are of limited use on linear systems such as a highway network, tools which enable buffering around assets and incorporation of other datasets, such as the Material Site Inventory, can serve Department Interests. For example, a buffer around STIP Projects involving Realignments, Fair and Poor Condition Rock Slopes, and an absence of good material sources nearby could identify where STIP-related rock excavation or rock cut expansion could improve traveler safety while also generating spoils that could be stockpiled for future use in other projects.

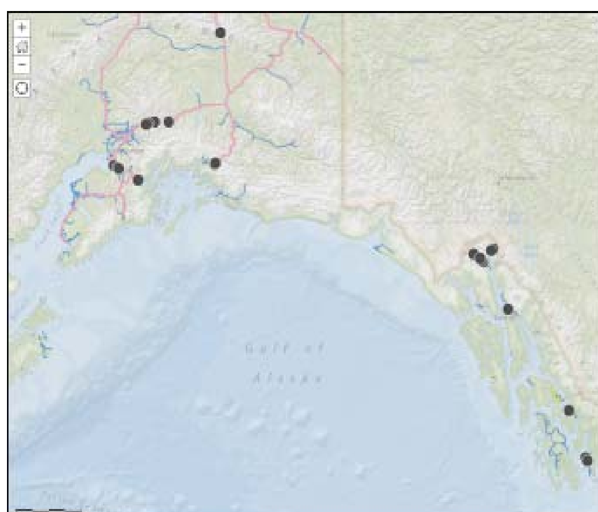


Figure 5: AGOL Filtering Example of Condition State 3 Slopes with USMP Scores Greater than 400 resulting in 27 identified sites.

3.1.2 Field Use

The AGOL-based GAM database is available for use in various Android™ or Apple iOS™ applications. The "ArcGIS" application for Android was tested with successful viewing of various maps created within the AGOL application. Users can log in via their AKDOT&PF AGOL organizational account (obtained through TGIS) within the application or from web browser-based applications. However, this requires internet access in the form of cell reception. Universal cell phone coverage along all highway routes is not currently available in Alaska, and users who plan to use the applications real-time in the field should be aware of this potential complication. Most data layers and maps have ‘Syncing’ enabled, which permits taking data and maps offline using ESRI’s ‘Collector’ Application. This application is found by searching ‘ESRI Collector’ in Apple’s iTunes or Google’s Play Store. Note that there is a process of downloading data and base maps while online prior to going into the field.

One application, shown in Figure 6, was created specifically for testing use with Android or iOS mobile devices, which utilizes the device’s web browser and cellular provider’s data services to access AGOL and provide the user with a rapid way to access the database while in the field. Using the device’s positioning services, the user can use the ‘locate’ button (appears as a gunsight icon) within the application which then automatically zooms into the user’s location to view the surrounding unstable slope sites. The application has similar functionality as the desktop-based version, with zoom and identify commands working as on the desktop version.

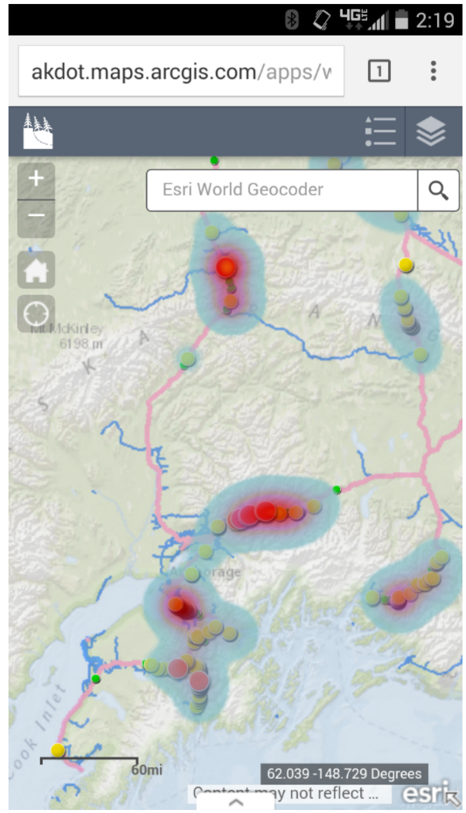
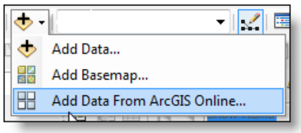
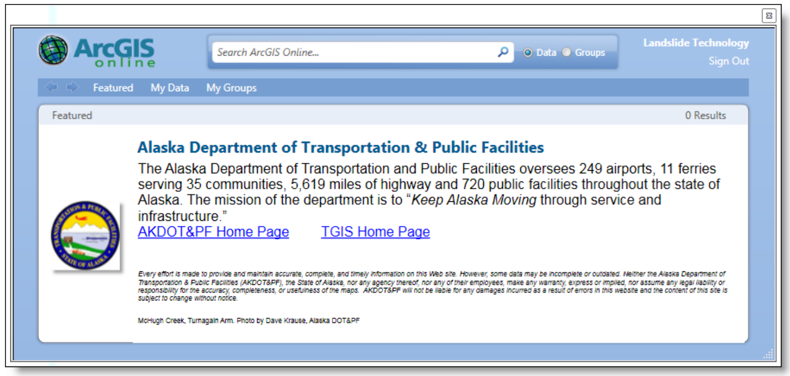


Figure 6: Screenshot and QR Code for loading the rock slope map on mobile devices.

3.1.3 Feature Data Layer Services for Desktop GIS

All data located on the AGOL servers is also available for direct inclusion into ArcMap and used with desktop GIS applications for more advanced mapping and analysis. A user with an AKDOT&PF AGOL account can add AGOL layers by first signing into ArcGIS using their AKDOT&PF account credentials from the *File: Sign-In* menu from ArcMap. After sign-in, the TGIS AGOL data is available from the standard *Add Data* menu item after selecting the *Add Data From ArcGIS Online…* menu item (Figure 7-A), then utilizing the resulting dialog for finding the relevant data layers (Figure 7-B). Data layers created for this program are tagged with “GAM” for simplified searches.





A. B.

Figure 7: Example Dialogs from ArcMap 10.2 to add hosted data onto Desktop GIS.

4. FIELD-BASED EDITING

One of AGOL's strengths is that any changes made to the individual asset layers, whether addition of new sites or edits to existing data, are immediately reflected in the GAM interface. However, AGOL and the Collector App are not able to automatically run calculations and populate fields based on values input into other fields. To simplify future rerating and rating of occasional new slopes, Excel-based worksheets were prepared to facilitate data collection and calculation of total Scores, Condition Indices and States, and initial Programmatic Cost Estimates for these asset types. These calculated values should then be added to the asset geodatabase via the Collector App, described in the next section.

The Excel workbooks were designed to run on both laptops and tablets that have Excel installed. The sheets prompt the user to enter site-specific information in the orange cells. Values in the gray and blue cells are calculated from measurements or rating values, or filled in from linked reference tables in other workbook sheets.

Individual Excel-based data collection worksheets were developed for each asset class (excluding material sites); these are shown in Appendices C, D, and E of the main report. When using an Excel data collection sheet, the rater fills in only the orange cells. Grey and blue cells are either filled in from the linked reference tables in other workbook sheets or calculated from measurements or rating values put into the orange cells. The sheet "Reference Tables" contains the tables necessary to populate various drop down options, the CDS route numbers, the AASHTO decision sight distance, and the estimated mitigation cost. The "Stations" sheet contains a table to help determine region, maintenance district, maintenance station, and CDS milepoint for a site. The sheet "New Site Information" tabulates all of the data from the Site Rating Calculator for easy input in AGOL. The sheet "RH" contains cross reference information for road name, CDS route number, and the new Road and Highway Route ID. This table is designed to work well with the Collector App, which is used to create new site records[5]. Except for the Site Rating Calculator, all sheets are locked, so that data cannot accidentally be changed. Within the Site Rating Calculator Excel sheet, all grey and blue cells are locked so that content can't be mistakenly altered.

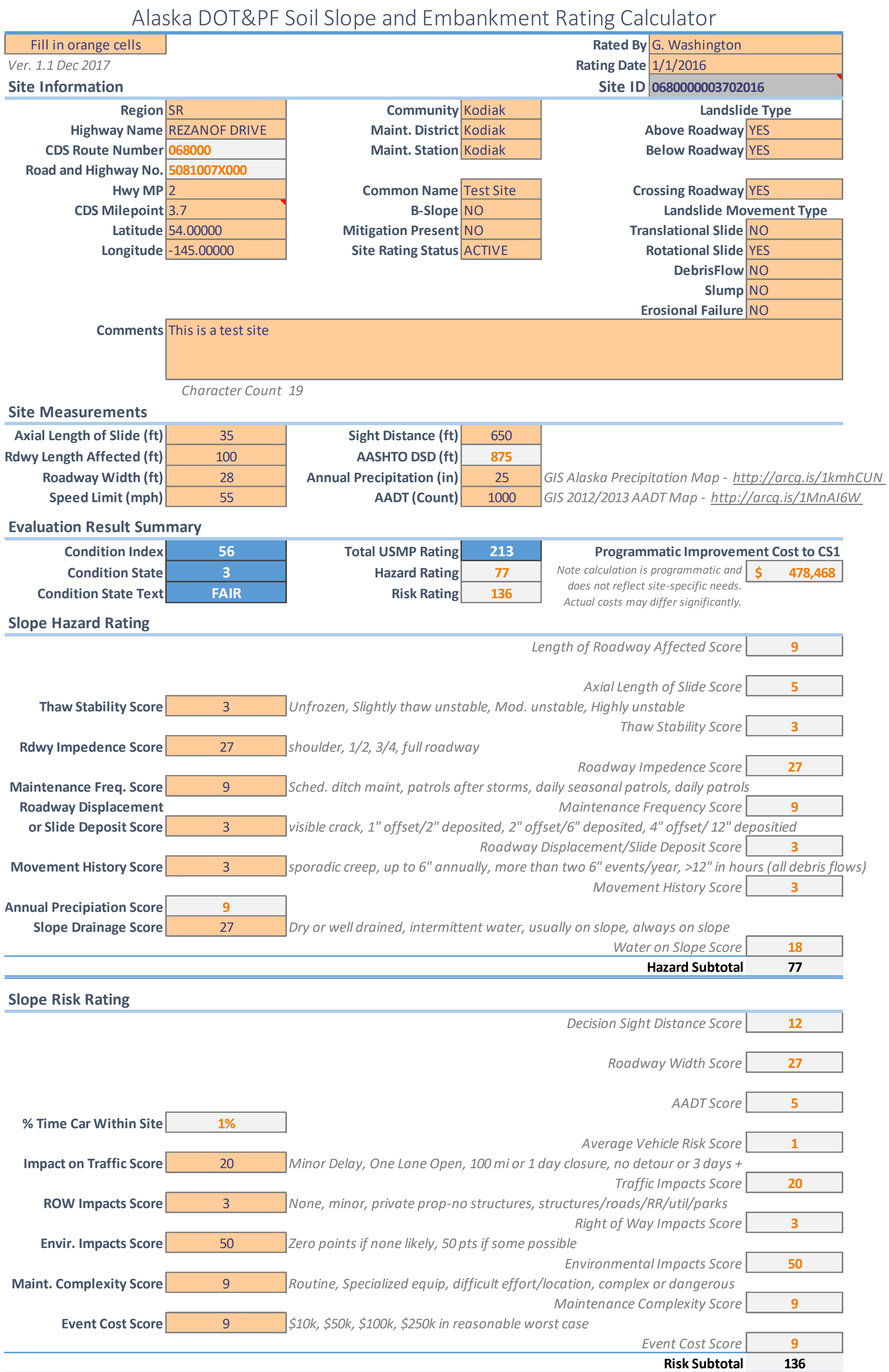
The programmatic costs applied in the worksheet are identical to those discussed in the main report's Section 6. As new project information or inflation rates are incorporated into the asset valuations, the costs referred to in this sheet should also be updated.

An example of the Excel "Site Rating Calculator" sheet for unstable soil slope and embankments, filled out with a rating for a new site (Figure 8), is shown on the following page.

In contrast to the other three geotechnical asset classes in the GAM Program, a condition re-rating application for the material site asset class was not developed. This outcome stems from several factors, including the unique aspects of the class, the sources of applicable data, the complexities of calculating Condition State for material sites, and functional relationships involving the MSI geodatabase. Material site condition state determination incorporates a concept of regional material availability, as well as material site-specific data. The Department anticipates undertaking a new material site inventory project that could differ markedly from the baseline inventory completed in 2015, and may involve a wider range of stakeholders. As of

[5] Excel Rating Sheets for Rock Slopes, Unstable Soil Slopes and Embankments, and Retaining Walls (AGOL GAM Group Membership Required).

2017, efforts are underway to greatly expand use of the MSI geodatabase to track material site use and status, capturing additional input from the Alaska Department of Natural Resources.



Alaska DOT&PF Soil Slope and Embankment Rating Calculator

Fill in orange cells

Ver. 1.1 Dec 2017

Rated By	G. Washington
Rating Date	1/1/2016
Site ID	0680000003702016

Site Information

Region	SR	Community	Kodiak	Landslide Type	
Highway Name	REZANOF DRIVE	Maint. District	Kodiak	Above Roadway	YES
CDS Route Number	068000	Maint. Station	Kodiak	Below Roadway	YES
Road and Highway No.	5081007X000				
Hwy MP	2	Common Name	Test Site	Crossing Roadway	YES
CDS Milepoint	3.7	B-Slope	NO	Landslide Movement Type	
Latitude	54.00000	Mitigation Present	NO	Translational Slide	NO
Longitude	-145.00000	Site Rating Status	ACTIVE	Rotational Slide	YES
				DebrisFlow	NO
				Slump	NO
				Erosional Failure	NO

Comments: This is a test site

Character Count 19

Site Measurements

Axial Length of Slide (ft)	35	Sight Distance (ft)	650	
Rdwy Length Affected (ft)	100	AASHTO DSD (ft)	875	
Roadway Width (ft)	28	Annual Precipitation (in)	25	*GIS Alaska Precipitation Map - http://arcg.is/1kmhCUN*
Speed Limit (mph)	55	AADT (Count)	1000	*GIS 2012/2013 AADT Map - http://arcg.is/1MnAI6W*

Evaluation Result Summary

Condition Index	56	Total USMP Rating	213	Programmatic Improvement Cost to CS1
Condition State	3	Hazard Rating	77	$ 478,468
Condition State Text	FAIR	Risk Rating	136	*Note calculation is programmatic and does not reflect site-specific needs. Actual costs may differ significantly.*

Slope Hazard Rating

			Length of Roadway Affected Score	9
			Axial Length of Slide Score	5
Thaw Stability Score	3	*Unfrozen, Slightly thaw unstable, Mod. unstable, Highly unstable*	*Thaw Stability Score*	3
Rdwy Impedence Score	27	*shoulder, 1/2, 3/4, full roadway*	*Roadway Impedence Score*	27
Maintenance Freq. Score	9	*Sched. ditch maint, patrols after storms, daily seasonal patrols, daily patrols*	*Maintenance Frequency Score*	9
Roadway Displacement or Slide Deposit Score	3	*visible crack, 1" offset/2" deposited, 2" offset/6" deposited, 4" offset/ 12" depositied*	*Roadway Displacement/Slide Deposit Score*	3
Movement History Score	3	*sporadic creep, up to 6" annually, more than two 6" events/year, >12" in hours (all debris flows)*	*Movement History Score*	3
Annual Precipiation Score	9			
Slope Drainage Score	27	*Dry or well drained, intermittent water, usually on slope, always on slope*	*Water on Slope Score*	18
			Hazard Subtotal	**77**

Slope Risk Rating

			Decision Sight Distance Score	12
			Roadway Width Score	27
			AADT Score	5
% Time Car Within Site	1%		*Average Vehicle Risk Score*	1
Impact on Traffic Score	20	*Minor Delay, One Lane Open, 100 mi or 1 day closure, no detour or 3 days +*	*Traffic Impacts Score*	20
ROW Impacts Score	3	*None, minor, private prop-no structures, structures/roads/RR/util/parks*	*Right of Way Impacts Score*	3
Envir. Impacts Score	50	*Zero points if none likely, 50 pts if some possible*	*Environmental Impacts Score*	50
Maint. Complexity Score	9	*Routine, Specialized equip, difficult effort/location, complex or dangerous*	*Maintenance Complexity Score*	9
Event Cost Score	9	*$10k, $50k, $100k, $250k in reasonable worst case*	*Event Cost Score*	9
			Risk Subtotal	**136**

Figure 8: Excel worksheet filled out for a sample unstable soil slope showing the site-specific rating, calculations, and summarization.

4.1 Field Work Maps and the Collector Application

Use of ESRI's Collector app is the recommended method to interface with digital versions of the GAM geodatabase when in the field. As of this writing, it is available through Apple's iTunes, Google Play Store, or the Microsoft Store for Windows 10 devices. It is not available for Windows 7 or Windows Mobile operating systems. Standalone GPS-capable and enabled devices (i.e., not approximate, cellular signal-derived location services) are required in order for the platform to properly function. In order to use the databases in the field, you need to have a TGIS AGOL account and membership with the GAM Group. Screenshots in this section are from the Android Collector Application, however, the iOS and Windows 10 interfaces are similar. General steps to use this application are outlined below.

4.1.1 Step 1: Open and Sign-In

Once the application has been downloaded and installed on your mobile device, open the application. If the user has not previously logged in using this device and application, he or she must sign in using the following settings:

Sign-In: https://akdot.maps.arcgis.com then tap 'Continue'. You'll then be prompted to sign in on the following screen (Figure 9), using the username and password assigned to you by TGIS.

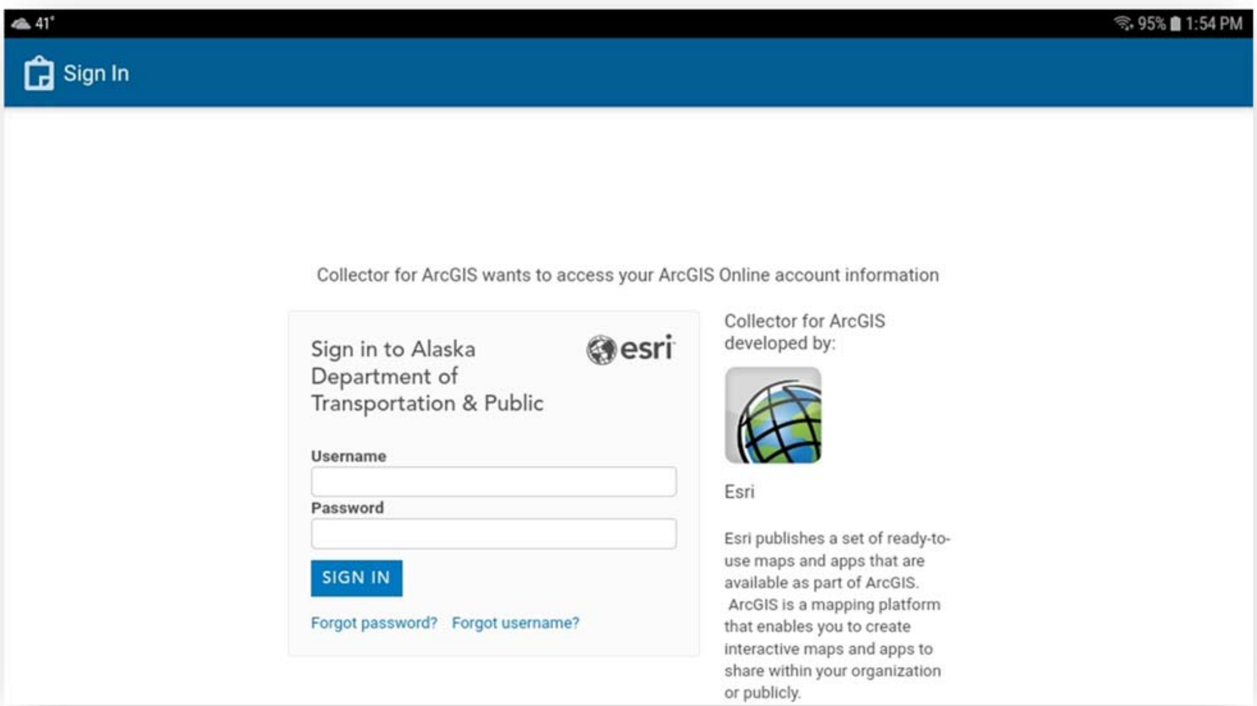


Figure 9: Collector Application Sign-In Screen.

One you sign in the first time, your information is stored in the device and you'll be automatically signed in for future sessions. If you have already created Web Maps in your AGOL account, a thumbnail tile listing of your maps will be shown (Figure 10). Maps for Collector do not need to be specifically made for it, rather all AGOL maps are available across platforms.

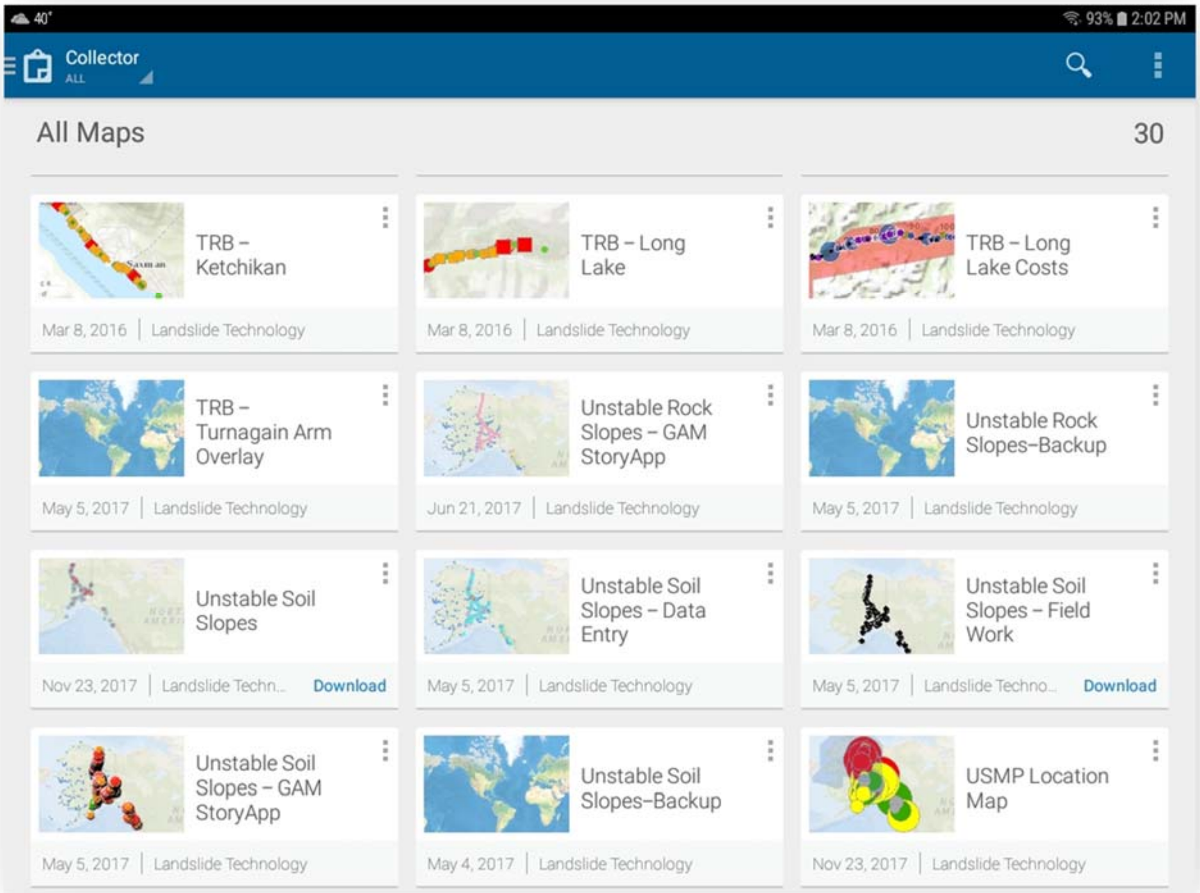


Figure 10: Collector Web Map Tile View. Maps from Landslide Technology's AGOL account shown for reference.

4.1.2 Step 2: Access the GAM Group Data

At the top left, tap the menu expansion icon (three lines to the left of the Collector icon in the Android App) and select the Geotechnical Asset Management (GAM) Program option. You need to be a Group member for this option to appear (Figure 11).

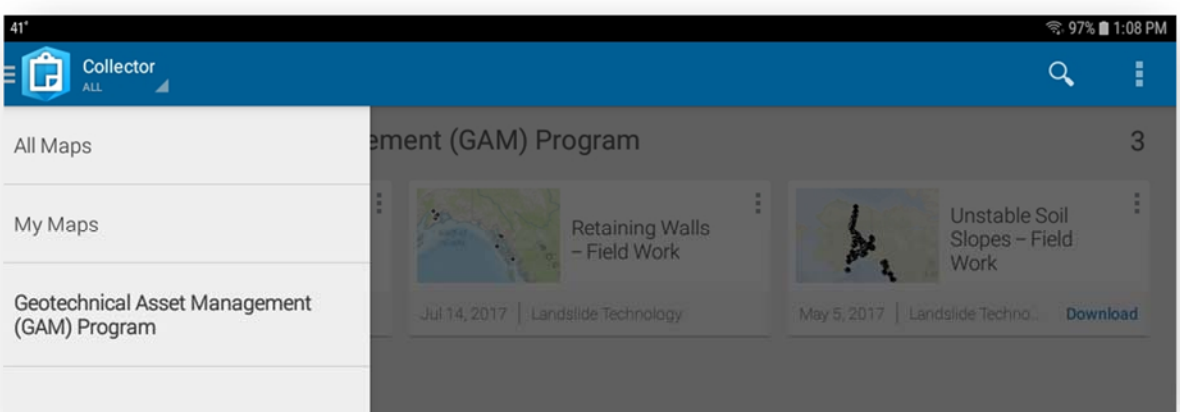


Figure 11: Accessing the GAM Group's data.

4.1.3 Step 3: Identifying GAM Content Ready to go Offline

In order to take maps and data offline, the data contained in the map must be configured for offline use. Select GAM Group maps have been configured for offline use by enabling 'Sync' settings in the data layers. Some data owners have not permitted Sync use or reversed permissions after initially enabling it, therefore adding only a few layers to each map will facilitate future offline capabilities. When a map is ready for offline use, the word 'Download' will appear next to it, such as highlighted in Figure 12, below. Tap the 'Download' text when ready to take it offline.

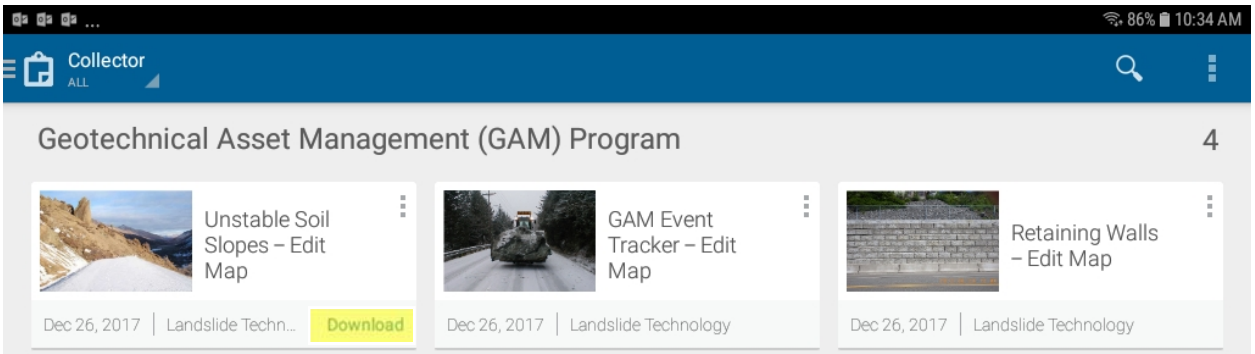


Figure 12: Collector map ready for offline use indicated by the highlighted 'Download' text.

4.1.4 Step 4: Downloading Content

Taking all available GAM and base map data offline would require terabytes of storage on each mobile device. Since this is not possible, ESRI has set up a two-step process for going offline. Once 'Download' has been tapped, the first window to appear is to choose the work area; the widest extent of data expected to be needed during the field outing. All base map and shape and attribute data (but not attachments) within this window will be downloaded.

The next screen will request the level of detail to download. Carefully note the storage required to download the base map, large areas with fine detail will quickly surpass the approximately 500 mb limit. If a user wishes to download a layer with different base map, on your desktop computer, open the Web Map of interest in your AGOL web browser, change the base map type, and then 'Save As' to the user's own account for later opening in Collector. This method can also add other syncable layers for offline use.

Once downloaded, the user can take the data offline within the work area and detail

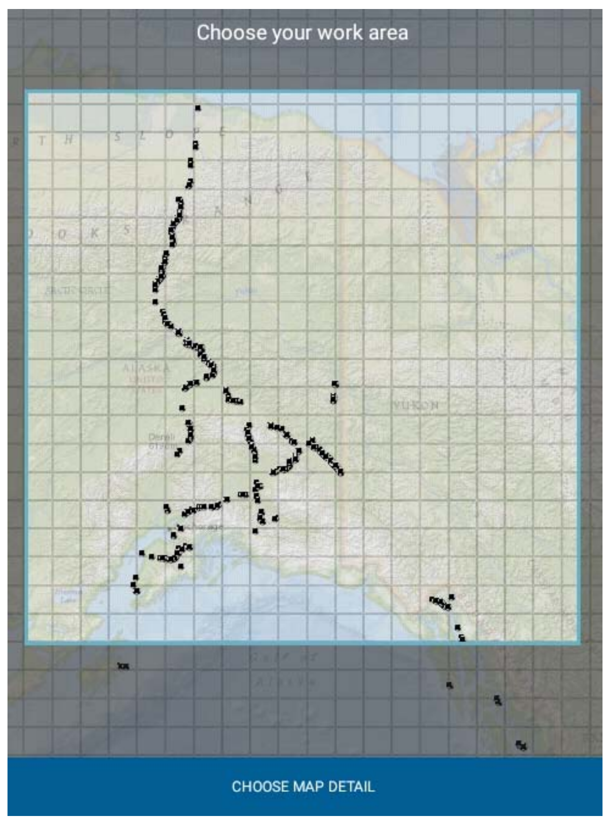


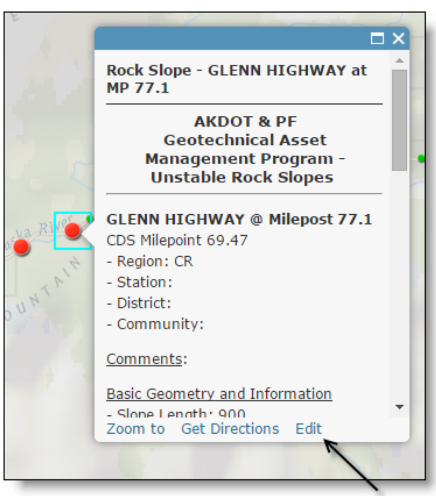
Figure 13: Choosing the extent of data download. Map detail selection process is similar.

downloaded. If a site is edited and/or attachments added, the word ‘Sync’ with a number indicating the number sites edited or added replaces ‘Download’. Once back online, tap ‘Sync’ to upload edits to AGOL. **Note that this overwrites the edited data.**

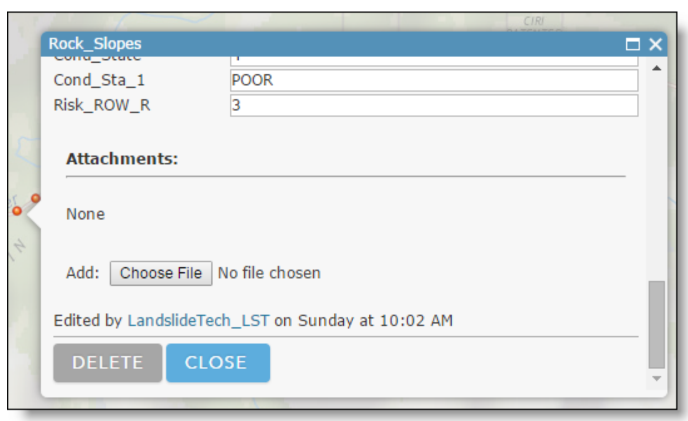
4.2 Adding Photographs and Digital Files to AGOL Database or Event Tracker

Site photographs should be collected during each evaluation or site visit. These files are stored on AGOL’s servers as attachments for each specific asset. If a site visit requires uploading new photos or a new site is added to the asset database, the following steps should be used to add site photos directly to the appropriate AGOL layer while online:

1. Log into the AGOL site with your AKDOT&PF AGOL account.
2. Zoom into and identify the site that files need to be associated with. Photos, PDFs, Office documents, compressed zip folders are among the supported attachment types.
3. Select the point associated with the site and locate the Edit link on the bottom (Figure 14-A). Note that the icons change when in edit view, though this will have no permanent effect on the map.
4. Scroll to the bottom of the pop-up window and locate Attachments Section and click the Choose File button (Figure 14Figure -B).
5. Navigate to and add the photo or other file to the site using the standard Windows file dialog box.
6. Click Ok or Open and the file will be added. It will now appear in the Attachments Section when a user opens the site information popup.
7. Close the AGOL pop-up window and deselect the Edit button in the upper left to return the map to its standard state (Figure 14-C).



A.



B.

C.

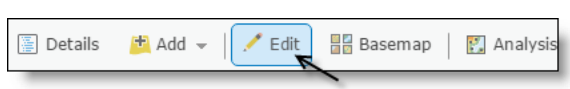


Figure 14: Adding Photos to the AGOL TGIS-hosted database for rock slopes, unstable soil slopes and embankments, or retaining walls through the appropriate asset point location layer.

5. OFFICE-BASED EDITING

Often, field conditions do not lend themselves to electronics and struggling with small electronic controls, adverse weather, poor lighting, or gloved hands. Field information may be taken with traditional pencil and paper then transcribed to the geodatabase within the dry confines of the office. The geodatabase can be edited directly within the AGOL environment when using the 'editable' layers indicated in Section 2, Table 1. Any changes made to the individual asset layers, whether addition of new sites or edits to existing data, are immediately reflected in the GAM interface. **All edits, both to position or to feature attributes, are permanent.** If an edit is made erroneously, a user will have to put the original value or position back in place. Edits made by authorized personnel to the 'editable' layer views are made to the underlying layer. The primary feature data layers are not directly editable, but only editable through the views.

To simplify future re-rating and also rating of new slopes and retaining walls, Excel-based worksheets were prepared to facilitate data collection and calculation of total Scores, Condition Indices and States, and initial Programmatic Cost Estimates for these asset types. These Excel-based worksheets are discussed in detail in this Appendix, Section 4.

Unlike the data for unstable slopes and retaining walls, the complete dataset in the MSI is not hosted on AGOL and is not live-linked to the Material Site Asset maps. The various material site reports and other documentation generated by R&M Consultants, Inc. of Anchorage and presented on the MSI website were used by R&M to create a database that could be used in GIS desktop applications or uploaded to AGOL. This is accessible through AKDOT&PF's Statewide Materials website, where it is used to generate the various material site maps[6]. However, because the MSI website and the geodatabase are not automatically linked, care will need to be taken in the future to ensure coordination in data editing.

As discussed in the introduction to Section 4, the Department anticipates that in the future the MSI geodatabase will be adapted for active tracking of material site use and status. In turn, use of that data for asset rating purposes is an aspect that will also need to be adapted.

5.1 Editing Existing Sites

As indicated above, edits to sites are permanent. In order to track change in performance over time, as indicated by rating and condition data, old data should be preserved rather than overwritten. The following steps should be taken. Note that these instructions take into account AKDOT's future migration to Windows 10, which is the only current desktop OS environment for Collector. Similar steps can be taken with the AGOL maps when open in a web browser. Familiarity with the Collector Application for Windows can be obtained through self-guided tutorials[7].

5.1.1 Step 1: Accessing the Maps

Once Collector for ArcGIS is downloaded and installed on your Windows 10 desktop[8], sign in using your AKDOT&PF AGOL account information provided to you by TGIS. If not already performed, this account needs to be associated with the Geotechnical Asset Management (GAM) Program AGOL group[3]. After signing in, a view of the user's individual maps is visible, similar

[6] http://www.dot.state.ak.us/stwddes/desmaterials/matsiteportal/materialsitemap.cfm
[7] https://doc.arcgis.com/en/collector/windows/collect-data/collect-tutorial.htm
[8] https://www.microsoft.com/store/productId/9WZDNCRDG7LK

to that shown in Figure 10. Select the Option in the upper left to display the editable maps shared with the GAM Group (Figure 15).

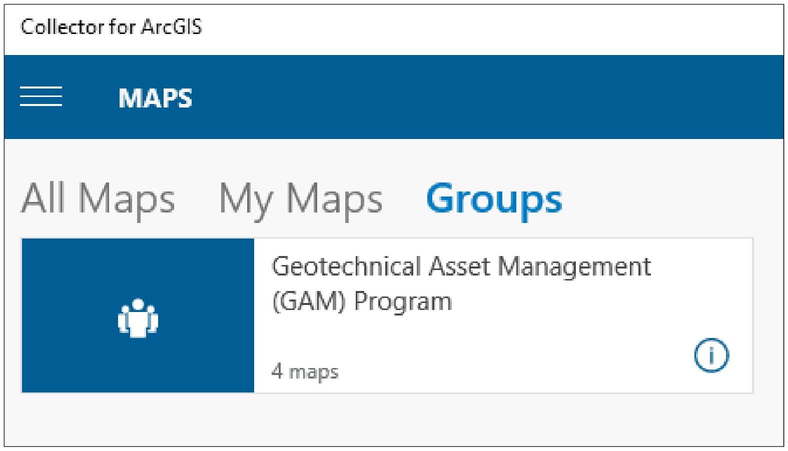


Figure 15: Selection of GAM Group content in the Windows 10 Collector for ArcGIS Application.

5.1.2 Step 2: Opening the Map

After accessing the GAM Group Maps, open the map containing the data needing editing. Currently, there are four maps, each containing data relevant to each asset class and data recorded in the Event Tracker (Figure 16). Note that these maps may change over time or additional maps may be added to the GAM Group.

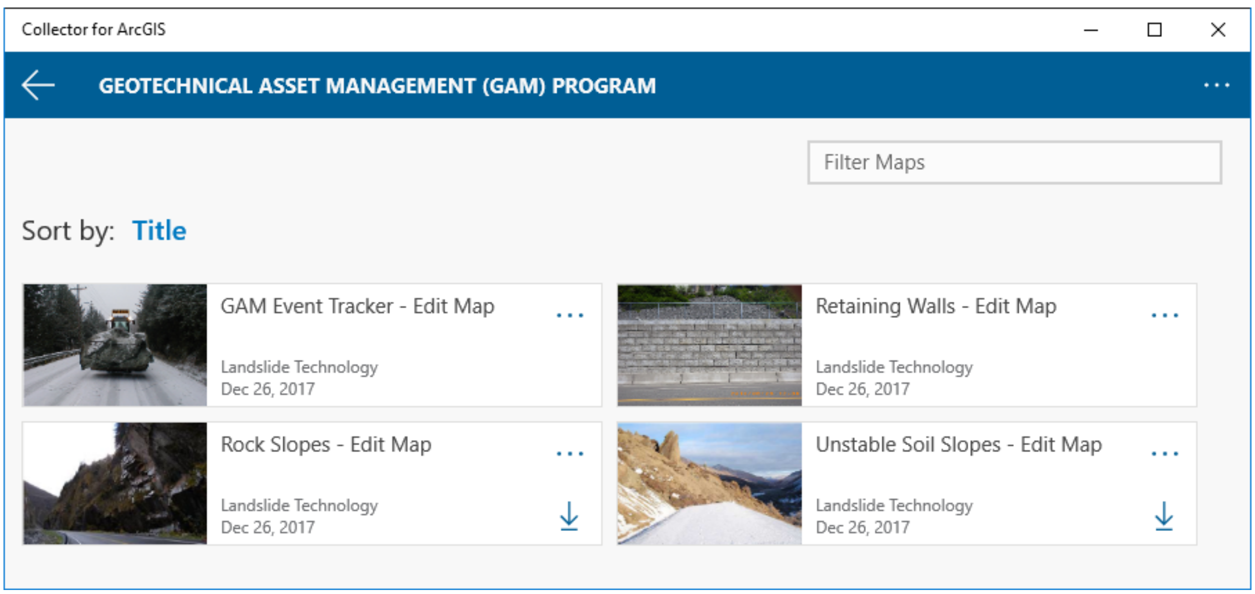


Figure 16: Maps configured for editing and shared with the GAM Group.

The map will open centered on your current location, typically based on your IP address when your device has no GPS capability (Figure 17). The 'Collect New' menu will be open with the option to add new features to the map available. Left-click and hold to rid the screen of the Collect menu and use the wheel to zoom and navigate to your area of interest. The Search icon also assists in navigation.

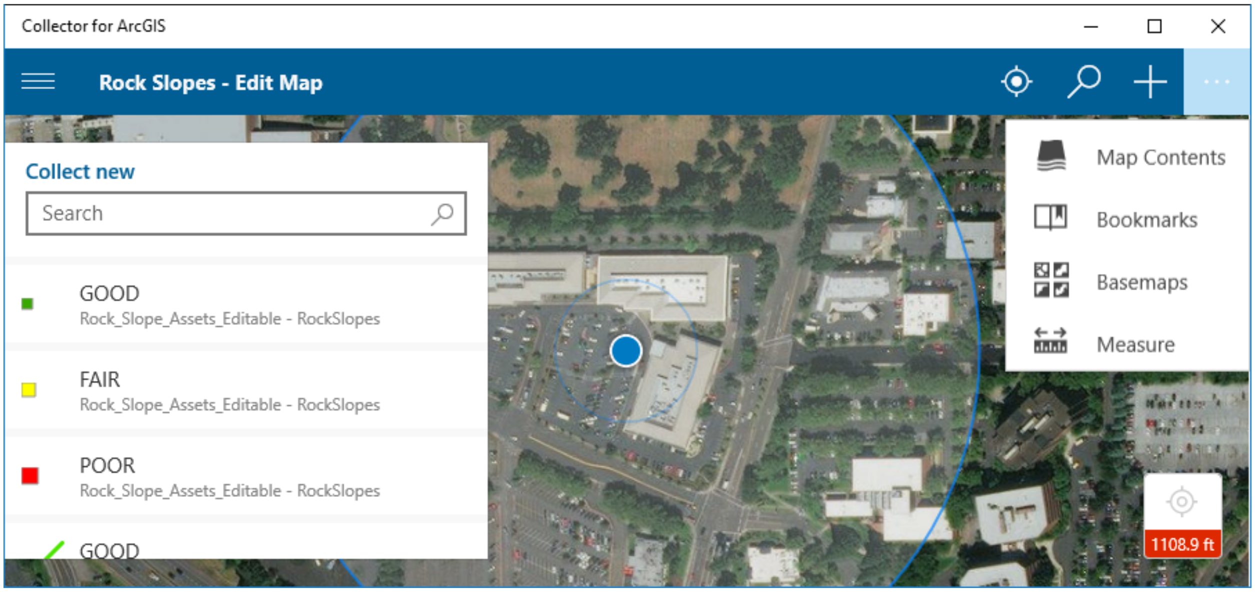


Figure 17: Rock Slope Edit map clicked, opens with the 'Collect New' menu open. The available tools shown on the right are accessible through the options menu. The blue dot and circle is the application's estimate of location. Left-clicking and holding drags the map and rids the view of the Collect New menu. Use the Map Contents menu item to switch layers off and on, as needed.

5.1.3 Step 3: Selecting a Site to Rerate

When new or additional information is available, when mitigation activities reduce hazard or risk, or a new slope is created, the modified slope should be rerated. When re-rating an existing site, it may be possible to copy much of the site information and rating category scores from the older data entry using the Collector Application.

To do this, first locate and navigate to the site needing updating. These steps presume that the Excel Rating Sheet has been completed for the new assessment. For example purposes here, a Poor Condition site in Ketchikan (Wolf Point) that may be mitigated is used as an example (Figure 18).

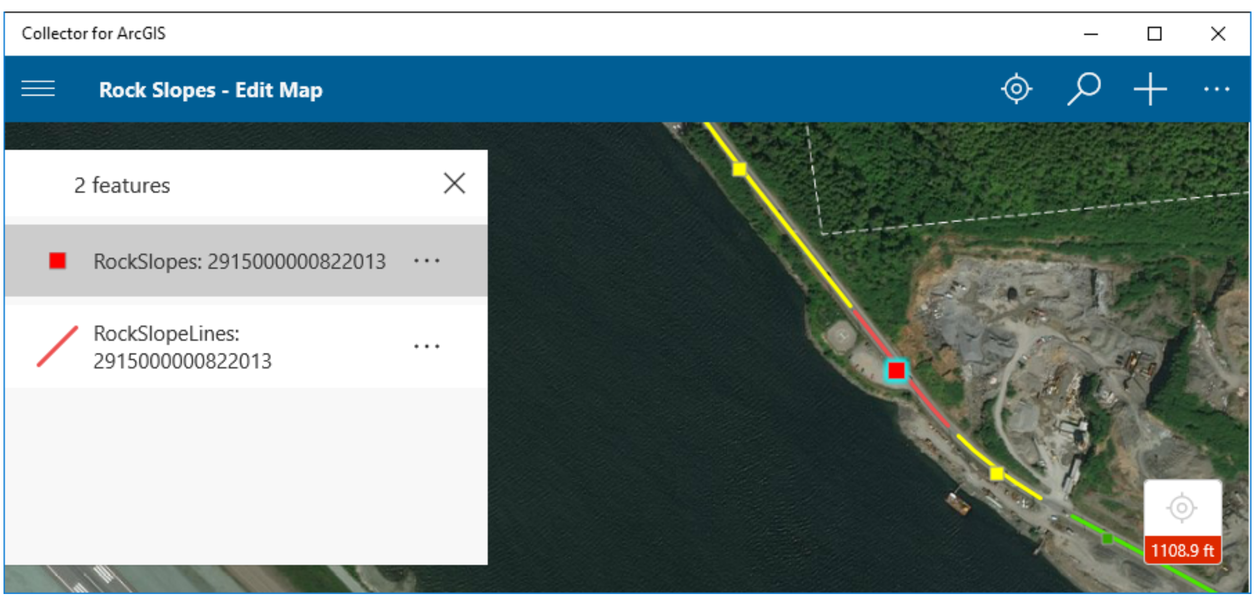


Figure 18: Selecting a rock slope site to rerate in Ketchikan.

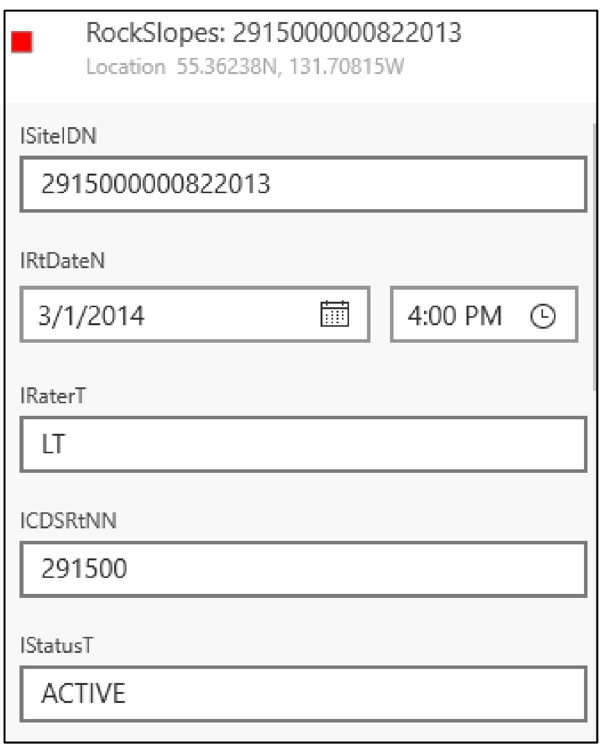
Clicking on the site brings up the various items that are in the vicinity of the cursor when clicked, here being the point location estimate and the linear extent of the rock slope, as shown on the left of the screen. Click on the point location, which contains all the assessment data; the lines only contain summary information. The left side of the screen now exhibits the formatted site information (Figure 19).

Confirm that the site needing editing was selected before progressing.

5.1.4 Step 4: Rerating - Archive Existing Site

It is important to save the old rating data for a variety of reasons. First, archive the existing site by clicking the edit icon:

A window with fields to replace appears:



Find the 'IStatusT' field. Here, it is the fifth field down. This field is used in analyses to only show active sites in the maps and analyses while still

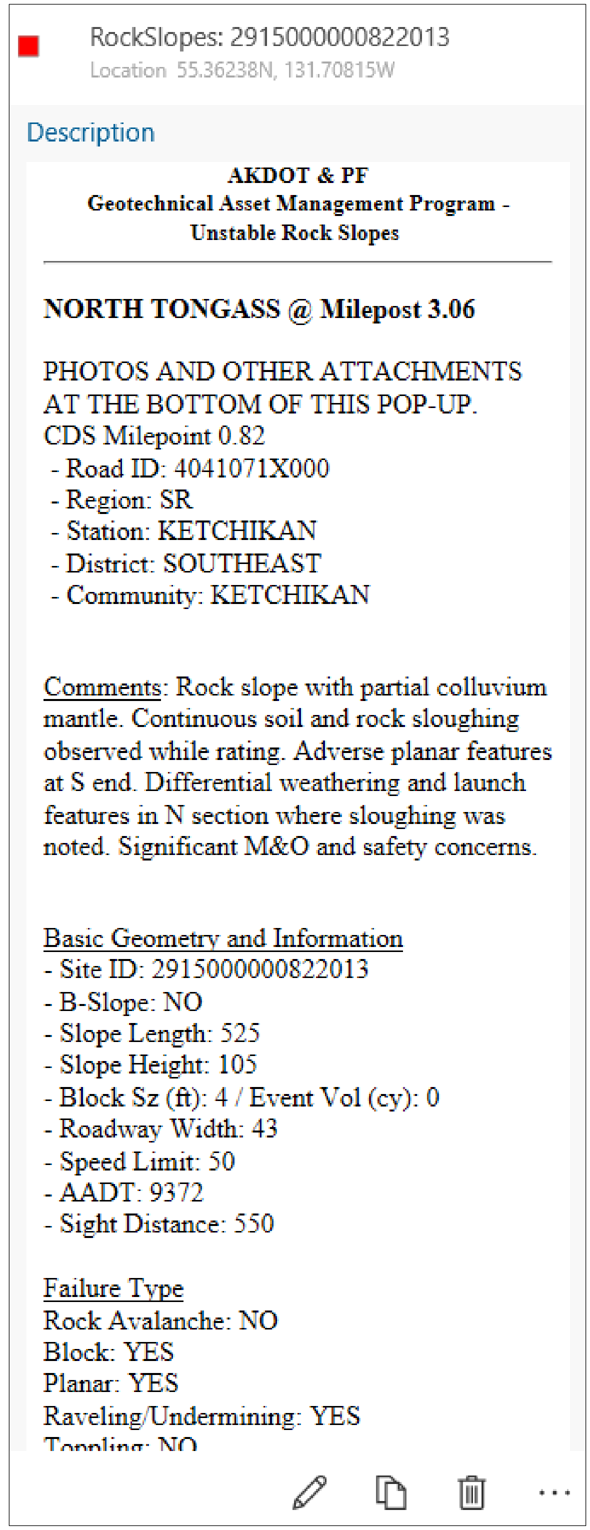


Figure 19: Site information shown after selecting the point data. Note icons at the bottom of the pop-up.

preserving older data. Change this text from 'ACTIVE' to 'ARCHIVE'. Click 'Submit' in the upper right.

Note the function of the following icons across the top of the application.

 Discards the current edits, reverts back to the previous version and closes the edit session.

 Settings menu for collecting data. No changes should be needed in a desktop environment.

 Undo edits once they are made to position or attribute

 Places the edited feature at your current position (likely your office)

Submits your edits to the AGOL server.

5.1.5 Step 5: Duplicate the Site for Reassessment

At the bottom of the information window, click on the duplicate icon:

Select the 'Like this one' option to start with the same attributes at the same location.

Note the red box in the image above corresponds to the Poor Condition slope and will change based on the asset type and duplicated site's Condition. The point location and attributes are copied to a new point. Change the 'IStatusT' field in this new point to ACTIVE and click the submit button. The new site is written to the AGOL server.

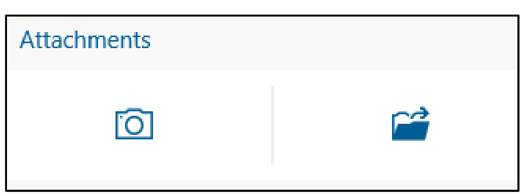
5.1.6 Step 6: Enter in the New Rating Information

At the bottom of a completed Excel rating sheet, there are fields that correspond to the geodatabase fields, an example shown below:

ISiteIDN	IRtDateN	IRaterT	ICDSRtNN	IStatusT	IRegionT	IHwyNamT
0674000243302016	1/1/2016	G. Washington	067400	ACTIVE	NR	CHINIAK HIGHWAY

Often, during a site rerate, only a few aspects may change, such as the event history or a lack of maintenance resulting in reduced ditch effectiveness. Review rerate information from the Excel sheet and carefully adjust the values in the new geodatabase site into the Collector window, field matching is illustrated in Figure 20, below.

Section 6 of this Appendix contains full details on the geodatabase fields, complete with a taxonomy of field names to assist with interpretation.



Note that previous photos are archived with the older point location. New photos current and relevant to the new rating should be attached to the database entry, available at the bottom of the edit dialog box, where you can take a photo with a device camera (left icon) or one contained in a folder (right icon):

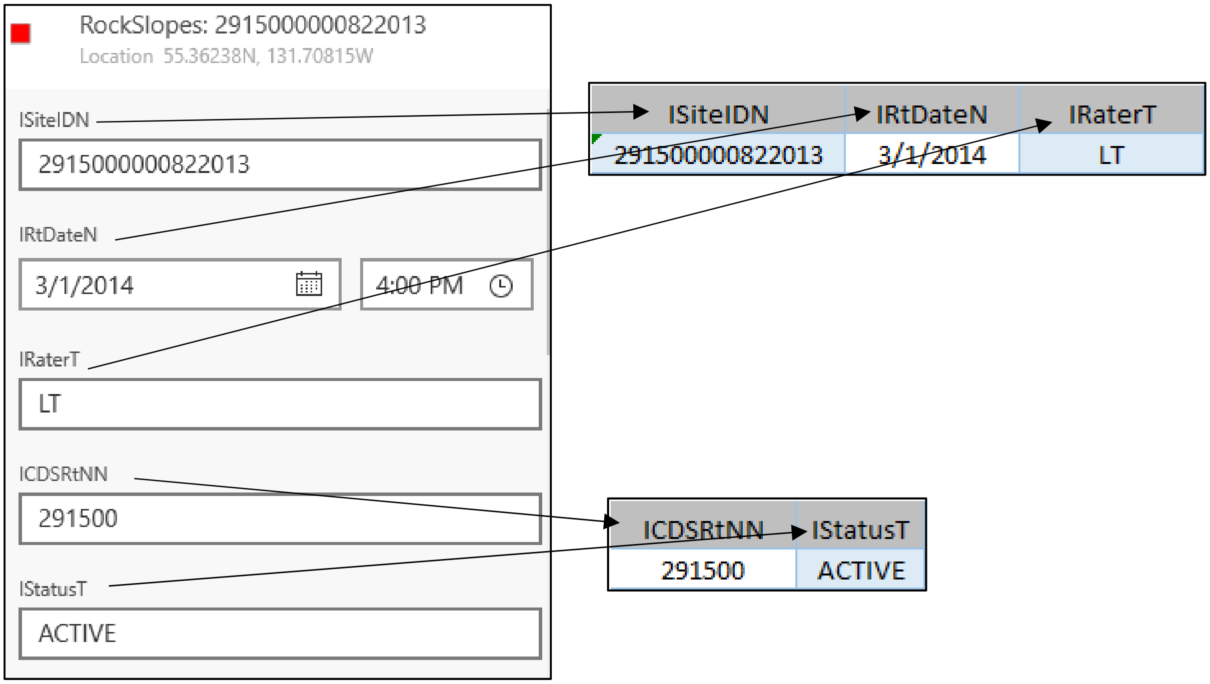


Figure 20: Example of field matching between the geodatabase edit dialog box and the Excel sheet.

5.1.7 Step 7: Edit the Summary Information in the Linear Extent Layer

After entering the complete information in the point layer, edit (don't duplicate) the existing linear extent layer to reflect the new assessment information (Figure 21).

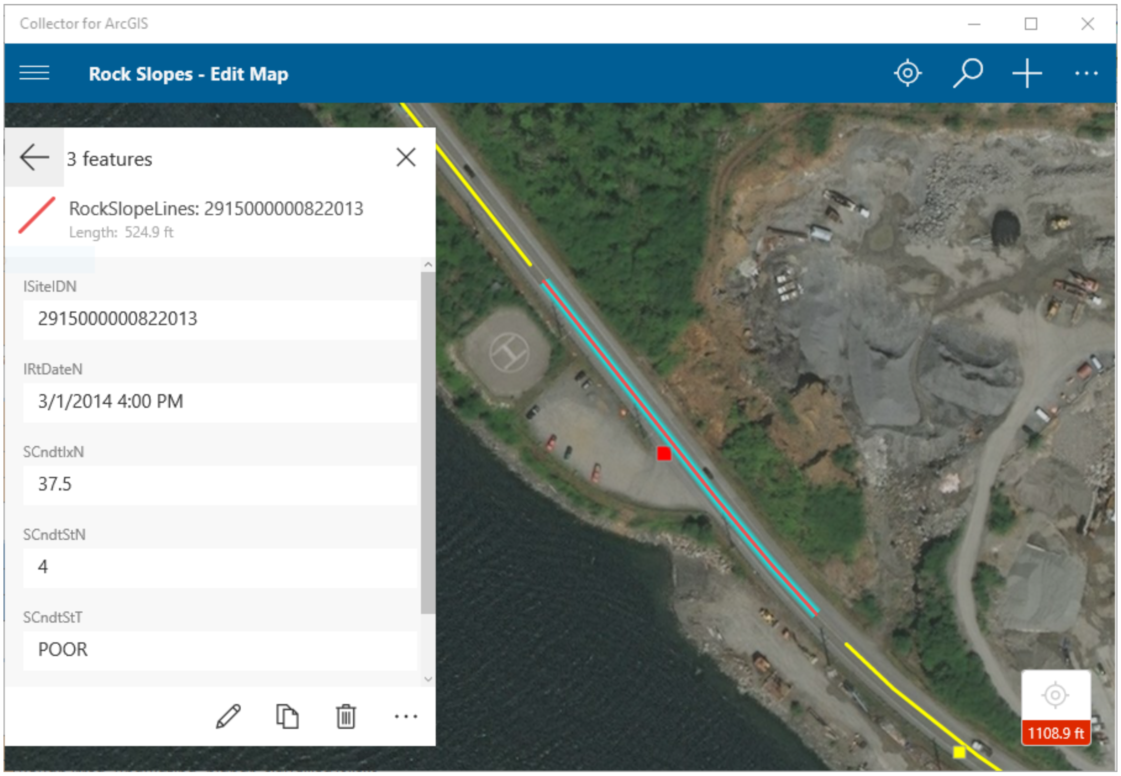


Figure 21: Editing linear extents following an updated rating.

The fields that should be edited are:

ISiteIDN: The site ID number should change based on the year of the rating, the last four digits.

IRtDateN: The date when the updated rating was performed.

SCndIxN: The new, updated Condition Index Number, from 100 (Good) to 0 (Failed)

ScndStN: The new, updated Condition State Number if the rating update resulted in a transitioned Condition State, from 1 to 5.

SCndStT: The GOOD, FAIR, or POOR Condition State, if changed by the updated rating.

Following this step, the geodatabase is updated to reflect new information. The changes will appear in all the maps and applications that access the geodatabases and across all platforms.

5.2 Correcting or Editing Information in Existing GAM Sites

The method used to correct incorrect site information or linear extents is essentially identical to that described in Section 5.1 above. However, if flawed information is being corrected, skip Steps 4 and 5. Do not archive or duplicate incorrect data.

5.3 Recording Geotechnical Events

5.3.1 Adding a New Event With the Geotechnical Event Geoform

"Geotechnical events", defined here as adverse events or acute hazardous situations occurring at geotechnical asset sites, occur regularly throughout the AKDOT&PF road system, spanning a wide array of situations. Tracking these events and the associated traffic delays, accident history, clean-up/repair and subcontracting costs will ensure the most up-to-date information is collected and factored into future evaluations, hazard analyses, and project planning. Ensuring a uniform and consistent entry of event information is crucial in providing quality information for utilization in the GAM program.

In order to meet this goal, a map[9] and associated web-based application[10] were developed in AGOL to track a variety of geotechnical events. The map and app build upon an earlier system (SALLy) that was devised and tested in the Southcoast Region. The final field list (Table 4) was refined with input from Department personnel to find the balance between the data required for future GAM evaluations and the information and time required to input a new site. The range of geotechnical events was made as wide as possible. The type category selection "Other" could apply to a rock block identified as potentially posing risk to transportation corridor function, for example.

In its current form, the Geoform collects the minimum information required to obtain event data that can be used in economic and risk-based valuations for the Department, something that is an integral part of GAM. When collecting data for a specific project, it may be necessary to contact regional personnel for additional information on a specific event.

Table 4: Geotechnical Event Tracker – Fields and options in the AGOL-hosted Geoform

DATA FIELDS	POSSIBLE CHOICES
Event Date	Enter the event date. If available, enter the event time.
Type of Event	Choose from: Rockfall; Debris Flow; Icefall; Retaining Wall Failure; Tree Fall; Flood Damage/Encroachment; Landslide and/or Embankment Failure; Snow Avalanche; Frost Heave; Other
Event Size	Choose from: Minor or routine; Moderate; Major; or a Catastrophic event
Accidents	Choose from: No Accident; Property Damage Only – One Vehicle; Property Damage Only – Two or More Vehicles; Minor or Moderate Injury Accident; Serious to Critical Injury Accident; Fatal Accident
Closure Duration	Choose from: Temporary slowdown under 30 minutes; Temporary slowdown between 30 minutes and 2 hours; Temporary slowdown over 2 hours; Closure under 1 hour; Closure between 1 and 6 hours; Closure between 6 and 24 hours; Closure between 24 and 72 hours; Closure between 72 hours and 1 week; Closure between 1 week and 1 month; Closure longer than 1 month
Resources Applied to Event Response	Choose from: M&O personnel & pickups only; M&O plus M&O heavy equipment; M&O plus other DOT resources; M&O, DOT, and outside resources; Government Emergency Declaration
Cost in Dollars	Enter total cost of event, including M&O costs, equipment rentals, and outside contractor/consultant costs
MMS Sequence Number (If Available)	MMS Sequence Number(s) associated with the event
Comment	Any additional information necessary. 2000 character maximum.
Attach Files	Attach photos, PDFs of news articles, or other files related to the event.

[9] http://akdot.maps.arcgis.com/home/webmap/viewer.html?webmap=ee1ad659cc89480a86584a3c90416465

[10] Geotechnical Event Tracker - GeoForm for event tracking and mapping.

When reporting an adverse geotechnical event through the application, users input information through a series of drop-downs, as shown in Figure 22. This makes the form easy for the initial user to complete and also ensures use of uniform terminology, which is critical when attempting to use a large data set in GAM calculations. Some fields, such as total cost, are not populated from a drop-down menu and should be filled out as accurately as possible based on input from M&O personnel. If available, the Maintenance Management System (MMS) sequence number can be added, which enables future users to dig deeper into the event cost breakdown. The attachment of electronic files, including event photos, PDF prints of news reports, or compressed plan sets, is also available through the geoform interface.

Because the geoform is integrated with the AGOL map, the user can place the event location directly on the map after entering event information, either by inputting Latitude/Longitude information or by dropping a pin in the correct location, as shown in Figure 23**Error! Reference source not found.**. Once the event is submitted, it is automatically included in the AGOL system. If necessary, users can log into the map and edit site location or event information at any time.

The Event Tracker Map and associated Geotechnical Event Tracker application are currently available to the general public, although Public use is not encouraged or advertised. This is to help encourage use by those in AKDOT that may not have an AGOL account.

Within the AGOL interface, the events entered through the Geoform can be viewed as they occur over time, creating a time-history of accumulated events and costs. A sample video of rockfall activity on the Seward Highway south of Anchorage between 2005 and 2015 has been prepared[11] and is hosted online. This 30 second video exhibits a deterioration of the rock slopes and exhibits the type of visualization and analysis possible when complete data is collected and historical data is mined.


1. Enter Information
EVENT DATE
TYPE OF EVENT
Select...
Select from the drop down menu
EVENT SIZE
Select...
Please select the size of the event. Please provide further details (size of the largest rock, volume of debris flow debris, icefall volume, etc.) in the comment field below.
ACCIDENTS
Select...
Select the level of accident occurrence, if any. Injury severity: Minor to moderate (lacerations & fractures), serious to severe (compound fractures to life-threatening) to fatalities.

Figure 22: The first entries in the Geotechnical Event Tracker Geoform. Note the use of drop-down menus to populate most fields.

5.3.1.1 Incorporating Historical Data into the Geotechnical Event Tracker

Historical information on Maintenance responses to certain geotechnical events are available in the MMS. This database houses the day-to-day activities for Department Maintenance and Operations (M&O) personnel and equipment, subdivided into Activity Codes that are associated with direct Department costs. One of the codes, “58645-ROCK&LANDSLIDE CLNUP”, is directly related to unstable slope events that require M&O response. Most or all of the “ROCK&LANDSLIDE CLNUP” codes are associated with a roadway and specific milepost or

[11] http://www.landslidetechnology.com/rockfall-GAM-DataTracking.htm

milepost range. MMS Activity entries[12] that are identifiable to a specific location can be entered into the Geotechnical Event Layer database. In general, only resource and cost information is available through the MMS. Information on road and traffic impacts or accident information are not included, but could possibly be obtained for more expensive events by contacting the M&O foreman responsible for responding to the event in question.

The geotechnical event application has a space for including the MMS sequence number, if available. This would allow users to search for the more detailed cost information located in the MMS. However, it is not anticipated that the MMS will be mined for current events once the geoform application is released within AKDOT&PF. New geotechnical events should be added through the application, so that all relevant information is collected upon entry creation.

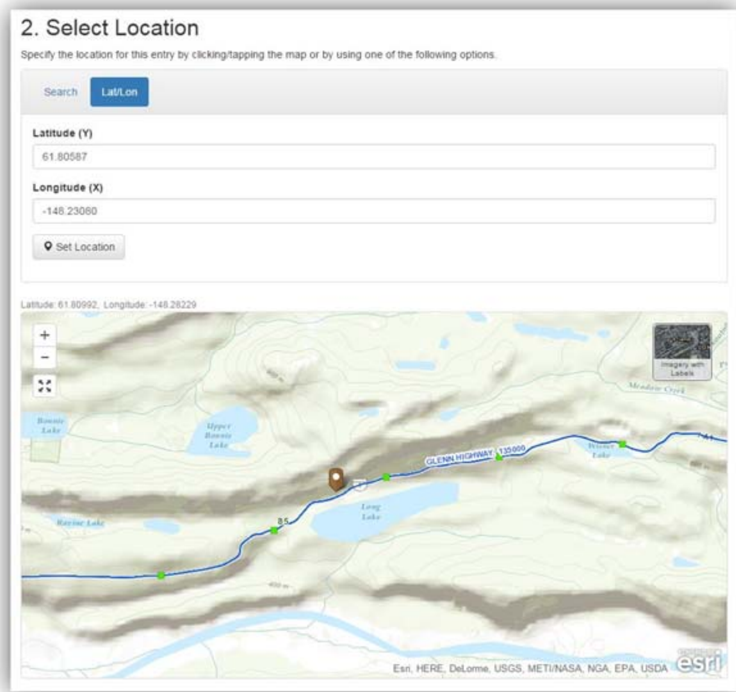


Figure 23: The Select Location interface in the Geotechnical Event Tracker Application. Users can input a location by typing in site coordinates or by manually dropping a pin at the correct location.

[12] https://mmsreports.dot.state.ak.us/moport - MMS dataport. Select "Cost by Activity Detail/Summation" from the "Cost Report" section of the site. Choose the Maintenance District of interest, date range, and "58645-ROCK&LANDSLIDE CLNUP" from the Activities list. Copy and paste the results into an Excel sheet for summarization.

6. GEODATABASE FIELDS

6.1 Common Prefixes and Suffixes

Geodatabase field name were formulated using a common set of prefixes and suffixes.

Prefix	Prefix Meaning
D	external data provided by AKDOT
E	estimate
I	information
M	measurement
S	scores
Suffix	**Suffix Meaning**
N	numerical entry
T	text entry

6.2 Rock Slope Shapefile Field Name Key

Shapefile Field Name	Field Name Translation	Rating Category Applied To
DAADTN	AADT	Annual Average Daily Traffic; Average Vehicle Risk
DSpdLmtN	Speed Limit	Average Vehicle Risk; Percent Decision Sight Distance
EImpCstN	Programmatic Improvement Cost to CS1	--
ESAreaN	Slope Area (sq ft)	Programmatic Improvement Cost
IAvlnchT	Rock Avalanche	--
IBlockT	Block Failure	--
IBSlopeT	B-Slope	--
ICDSMPN	CDS Milepoint (2 decimal places)	--
ICDSRtNN	CDS Route Number	--
ICmmntsT	Comments	--
ICmmntyT	Community	--
ICmnNamT	Common Name	--
IGeoChT	Geologic Character	Geologic Character
IHwyMPN	Highway Milepost (2 decimal places)	--
IHwyNamT	Highway Name	--
ILatN	Latitude (5 decimal places)	--
ILongN	Longitude (5 decimal places)	--
IMitgtnT	Mitigation Present	--
IMntDstT	Maintenance District	--
IMntStnT	Maintenance Station	--
IPlanarT	Planar Failure	--
IRaterT	Rater	--
IRavelT	Raveling/Undermining Failure	--
IRegionT	Region	--
IRtDateN	Rating Date	--

Shapefile Field Name	Field Name Translation	Rating Category Applied To
ISiteIDN	Site ID	--
IStatusT	Site Rating Status	--
IToppleT	Toppling Failure	--
IWedgeT	Wedge Failure	--
MBlckSzN	Block Size (ft)	Block Size or Event Volume
MEvntVlN	Volume per Event (cy)	Block Size or Event Volume
MRdWdthN	Roadway Width	Roadway Width
MSghtDiN	Sight Distance	Percent Decision Sight Distance
MSHeigtN	Slope Height	Slope Height
MSLengtN	Slope Length	Average Vehicle Risk
SAADTN	AADT Score	Risk Score
SAVRN	Average Vehicle Risk Score	Risk Score
SBSzEVlN	Block Size/Event Volume Score	Hazard Score
SC1JtFrN	Case 1 Joint Friction Score	Geologic Character
SC1StrN	Case 1 Structure Score	Geologic Character
SC2DfErN	Case 2 Differential Erosion Rate Score	Geologic Character
SC2FeatN	Case 2 Features Score	Geologic Character
SCndtIxN	Condition Index	Condition State Number/Text
SCndtStN	Condition State Number	Programmatic Improvement Cost
SCndtStT	Condition State Text	Programmatic Improvement Cost
SDitchEN	Ditch Effectiveness Score	Hazard Score
SDrainN	Slope Drainage Score	Water on Slope
SEnviroN	Environmental Impacts Score	Risk Score
SEvntCsN	Event Cost Score	Risk Score
SGeoChN	Geologic Character Score	Hazard Score
SHazardN	Hazard Score	Total USMP Score
SMntCmpN	Maintenance Complexity Score	Risk Score
SMntFrqN	Maintenance Frequency Score	Hazard Score
SPrecipN	Annual Precipitation Score	Water on Slope
SRdWdthN	Roadway Width Score	Risk Score
SRfHistN	Rockfall History Score	Hazard Score
SRiskN	Risk Score	Total USMP Score
SROWImpN	Right of Way Impacts Score	Risk Score
SSghtDiN	Percent Decision Sight Distance Score	Risk Score
SSHeigtN	Slope Height Score	Hazard Score
STrfImpN	Impact on Traffic Score	Risk Score
SUSMPRtN	Total USMP Score	--
SWaterN	Water on Slope Score	Hazard Score

6.3 Soil Slope Shapefile Field Name Key

Shapefile Field Name	Field Name Translation	Rating Category Applied To
DAADTN	Annual Average Daily Traffic (AADT)	Average Annual Daily Traffic; Average Vehicle Risk
DSpdLmtN	Speed Limit	Average Vehicle Risk; Percent Decision Sight Distance
EImpCstN	Programmatic Improvement Cost to CS1	--
IBSlopeT	B-Slope	--
ICDSMPN	CDS Milepoint (2 decimal places)	--
ICDSRtNN	CDS Route Number	--
ICmmntsT	Comments	--
ICmmntyT	Community	--
ICmnNamT	Common Name	--
IDebFlwT	Debris Flow	--
IErosnT	Erosional Failure	--
IHwyMPN	Highway Milepost (2 decimal places)	--
IHwyNamT	Highway Name	--
ILAbvRdT	Landslide Above Roadway	--
ILatN	Latitude (5 decimal places)	--
ILBlwRdT	Landslide Below Roadway	--
ILCrsRdT	Landslide Crossing Roadway	--
ILongN	Longitude (5 decimal places)	--
IMitgtnT	Mitigation Present	--
IMntDstT	Maintenance District	--
IMntStnT	Maintenance Station	--
IRaterT	Rater	--
IRegionT	Region	--
IRotatnT	Rotational Slide	--
IRtDateN	Rating Date	--
ISiteIDN	Site ID	--
ISlumpT	Slump	--
IStatusT	Site Rating Status	--
ITranslT	Translational Slide	--
MRdWdthN	Roadway Width	Roadway Width
MSAxHgtN	Axial Length of Slide	Axial Length of Slide
MSghtDiN	Sight Distance	Percent Decision Sight Distance
MSLengtN	Length of Roadway Affected	Length of Roadway Affected
SAADTN	AADT Score	Risk Score
SAVRN	Average Vehicle Risk Score	Risk Score
SCndtIxN	Condition Index	Condition State Number/Text
SCndtStN	Condition State Number	Programmatic Improvement Cost
SCndtStT	Condition State Text	Programmatic Improvement Cost
SDrainN	Slope Drainage Score	Water on Slope

Shapefile Field Name	Field Name Translation	Rating Category Applied To
SEnviroN	Environmental Impacts Score	Risk Score
SEvntCsN	Event Cost Score	Risk Score
SHazardN	Hazard Score	Total USMP Score
SMntCmpN	Maintenance Complexity Score	Risk Score
SMntFrqN	Maintenance Frequency Score	Hazard Score
SMvHistN	Movement History Score	Hazard Score
SPrecipN	Annual Precipitation Score	Water on Slope
SRdDispN	Road Displacement/Slide Deposit Score	Hazard Score
SRdImpdN	Roadway Impedance Score	Hazard Score
SRdWdthN	Roadway Width Score	Risk Score
SRiskN	Risk Score	Total USMP Score
SROWImpN	Right of Way Impacts Score	Risk Score
SSAxHtN	Axial Length of Slide Score	Hazard Score
SSghtDiN	Percent Decision Sight Distance Score	Risk Score
SSlLgthN	Length of Roadway Affected Score	Hazard Score
SThwStbN	Thaw Stability Score	Hazard Score
STrfImpN	Impact on Traffic Score	Risk Score
SUSMPRtN	Total USMP Score	--
SWaterN	Water on Slope Score	Hazard Score

6.4 Retaining Wall Shapefile Field Name Key

Shapefile Field Name	Field Name Translation	Rating Category Applied To
DAADTN	Annual Average Daily Traffic (AADT)	Annual Average Daily Traffic; Average Vehicle Risk
DSpdLmtN	Speed Limit (mph)	Average Vehicle Risk; Percent Decision Sight Distance
EImpCstN	Programmatic Improvement Cost to CS1	--
EWAreaN	Wall Area (sq ft)	Programmatic Improvement Cost
ICDSMPN	CDS Milepoint (2 decimal places)	--
ICDSRtNN	CDS Route Number	--
ICmmntsT	Comments	--
ICmmntyT	Community	--
IConstDN	Construction Date	--
IHwyMPN	Highway Milepost (2 decimal places)	--
IHwyNamT	Highway Name	--
ILatN	Latitude (5 decimal places)	--
ILongN	Longitude (5 decimal places)	--
IMntDstT	Maintenance District	--
IMntStnT	Maintenance Station	--
IOffsetT	Wall Offset	--
IProjNmN	State/Federal Project Number	--
IRaterT	Rater	--

Shapefile Field Name	Field Name Translation	Rating Category Applied To
IRegionT	Region	--
IRtDateN	Rating Date	--
ISiteIDN	Site ID	--
IStatusT	Site Rating Status	--
IWCatgrT	Wall Category	--
IWFunctT	Wall Function	--
IWTypeT	Wall Type	--
MRdWdthN	Roadway Width (ft)	Roadway Width
MSghtDiN	Sight Distance (ft)	Percent Decision Sight Distance
MWHeigtN	Wall Height (ft)	Wall Height
MWLengtN	Wall Length (ft)	Length of Roadway Affected
SAADTN	AADT Score	Risk Score
SAlignN	Vertical/Horizontal Alignment Score	Hazard Score
SAVRN	Average Vehicle Risk Score	Risk Score
SCndtIxN	Condition Index	Condition State Number/Text
SCndtStN	Condition State Number	Programmatic Improvement Cost
SCndtStT	Condition State Text	Programmatic Improvement Cost
SDrainN	Drainage System Score	Hazard Score
SEnviroN	Environmental Impacts Score	Risk Score
SEvntCsN	Event Cost Score	Risk Score
SFlrPrbN	Likelihood of Failure Score	Risk Score
SHazardN	Hazard Score	Total RWI Score
SMntCmpN	Maintenance Complexity Score	Risk Score
SMntFrqN	Maintenance Frequency Score	Hazard Score
SMvHistN	Movement History Score	Hazard Score
SOtherN	Critical Component Health Score	Hazard Score
SPercepN	Appearance/Public Perception Score	Total RWI Score
SPrecipN	Annual Precipitation Score	Hazard Score
SPubPerN	Public Perception Score	Appearance/Perception Score
SRdDispN	Displacement due to Wall Movement Score	Hazard Score
SRdImptN	Impact on Roadway Score	Risk Score
SRdWdthN	Roadway Width Score	Risk Score
SRiskN	Risk Score	Total RWI Score
SROWImpN	Right of Way Impacts Score	Risk Score
SSghtDiN	Percent Decision Sight Distance Score	Risk Score
STechApN	Technical Appearance Score	Appearance/Perception Score
STrfImpN	Impact on Traffic Score	Risk Score
SUSMPRtN	Total RWI Score	--
SWHeigtN	Wall Height Score	Hazard Score
SWLngthN	Wall Length Score	Hazard Score

6.5 Retaining Wall AKDOT As-Built Inventory Shapefile Fieldname Key

Shapefile Field Name	Field Name Translation	Rating Category Applied To
IDataScT	Data Source	--
IConstDN	Construction Date	--
IHwyNamT	Route Name	--
ICDSRtNN	CDS Route Number	--
ICDSMPN	Milepoint	--
IOffsetT	Offset	--
IRegionT	Region	--
IWFuncT	Wall Function	--
MMExpWHN	Maximum Exposed Wall Height (ft)	--
MMHeigtN	Maximum Wall Height (ft)	--
MWLengtN	Wall Length (ft)	--
IHypLnkT	E Docs Hyperlink	--
IOsetLRN	Offset Left or Right	--
IComntsT	Comments	--
IFedPrjT	Federal Project Number	--
ICreateT	Name of Point Creator	--
IDateT	Date of Point Creation	--
IEditT	Name of Point Editor	--
IDEditT	Date of Point Editing	--
IAKSASNN	AK DOT Project Number	--
IWCatgrT	Wall Category	--
IWCMtT	Wall Type Comments	--
IWTypeT	Wall Type	--
IInspecT	Inspection Report Link	--

6.6 Geotechnical Event Tracker Database Domain Key

Domains in the Geotechnical Event Tracker Database link integer codes (to the right the table below) to longer descriptions. When entering data into the tracker, a user will see the description below, but the integer will be entered into the geodatabase.

Domain Name	Description	Code
Accident	No Accident	0
	Property Damage Only, One Vehicle	1
	Property Damage Only, Two or More Vehicles	2
	Minor or Moderate Injury Accident	3
	Serious to Critical Injury Accident	4
	Fatal Accident	5
Duration of any Closure	None	0
	Temporary slowdown under 30 minutes	1
	Temporary slowdown between 30 minutes and 2 hours	2
	Temporary slowdown over 2 hours	3
	Closure under 1 hour	4
	Closure between 1 and 6 hours	5
	Closure between 6 and 24 hours	6
	Closure between 24 hours and 72 hours	7
	Closure between 72 hours and 1 week	8
	Closure between 1 week and 1 month	9
	Closure longer than 1 month	10
Event	Rockfall	0
	Landslide and/or Embankment Failure	1
	Debris Flow	2
	Frost Heave	3
	Snow Avalanche	4
	Icefall	5
	Retaining Wall Failure	6
	Tree Fall	7
	Flood Damage/Encroachment	8
	Other	9
Event Size	Minor or Routine Event (small size, volume, or rate)	0
	Moderate event	1
	Major event	2
	Catastrophic event (massive failures)	3
Response	M&O personnel and pickups only	0
	M&O plus M&O heavy equipment	1
	M&O plus other DOT resources	2
	M&O, DOT, and outside resources	3
	Government Emergency Declaration	4