MEMORANDUM

State of Alaska

Department of Transportation & Public Facilities
Design and Engineering Services – Central Region
HIGHWAY DESIGN

TO: Distribution (see below)

DATE: March 9, 2015

TELEPHONE NO: 269-0547
FAX NUMBER: 243-4409

FROM: Sean M. Baski, P.E.
Project Manager

SUBJECT: **Final DSR Transmittal**
SEWARD HWY: MP 17-22.5 REHABILITATION
0311(032)/53610

Attached for your records is the Final Design Study Report for the subject project.

DISTRIBUTION:
DOT&PF – Central Region

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SEWARD HWY: MP 17-22.5 REHABILITATION

Project No. 0311(032)/53610

DESIGN STUDY REPORT

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

CENTRAL REGION, DESIGN AND CONSTRUCTION
4111 AVIATION AVENUE
ANCHORAGE, ALASKA 99502

STATE OF ALASKA

DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
DESIGN AND ENGINEERING SERVICES – CENTRAL REGION

Design Study Report

For

Seward Hwy: MP 17-22.5 Rehabilitation

Project No.: 0311(032)/53610

Written By: Carol M. Larson

STATE OF ALASKA
49TH
KRISTEN E KEIFER
CE 13132
12/23/2014
REGISTERED PROFESSIONAL ENGINEER

Prepared By:

12/23/2014

Kristen E. Keifer, P.E. — Date
Project Engineer

Concur by:

12/23/14

Sean M. Baski, P.E. — Date
Project Manager

Concur by:

12/24/14

James E. Amundsen, P.E. — Date
Chief, Highway Design

Approved:

1/16/2015

Kenneth M. Morton, P.E. — Date
Preconstruction Engineer

NOTICE TO USERS

This report reflects the thinking and design decisions at the time of publication. Changes frequently occur during the evolution of the design process, so persons who may rely on information contained in this document should check with the Alaska Department of Transportation and Public Facilities for the most current design. Contact the Design Project Manager, Sean M. Baski, P.E., at 907-269-0547 for this information.

PLANNING CONSISTENCY

This document has been prepared by the Department of Transportation and Public Facilities according to currently acceptable design standards and Federal regulations, and with the input offered by the local government and public. The Department's Planning Section has reviewed and approved this report as being consistent with present community planning.

CERTIFICATION

We hereby certify that this document was prepared in accordance with Section 520.4.1 of the current edition of the Department's Highway Preconstruction Manual and CFR Title 23, Highway Section 771.111(h).

The Department has considered the project's social and economic effects upon the community, its impacts on the environment and its consistency with planning goals and objectives as approved by the local community. All records are on file with Central Region - Design and Engineering Services Division, Highway Design Section, 4111 Aviation Avenue, Anchorage, AK 99502.

1/16/2015		12/30/14	
Kenneth M. Morton, P.E. Preconstruction Engineer	Date	Jennifer W. Witt, AICP Chief, Planning & Administrative Services	Date

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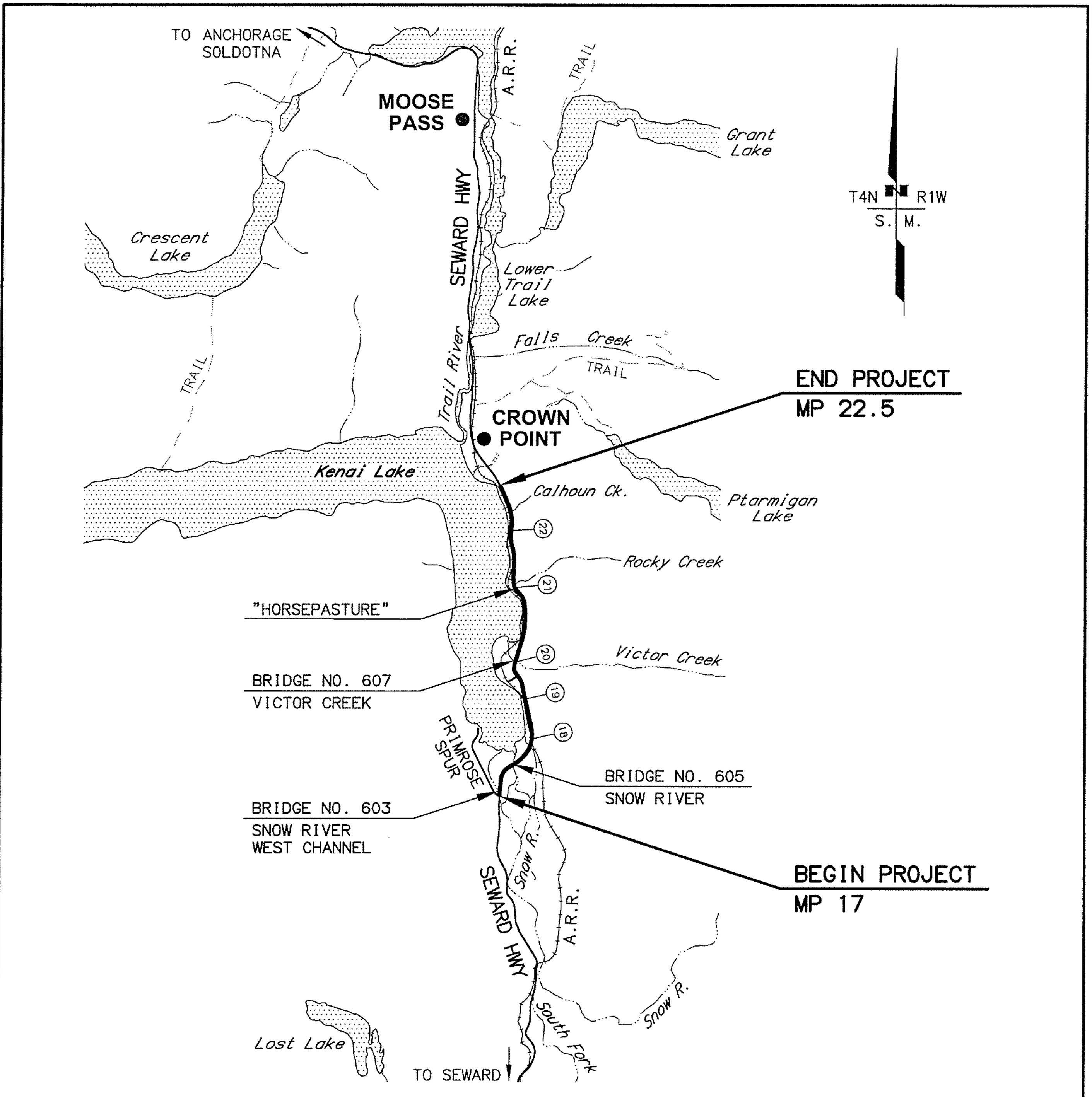
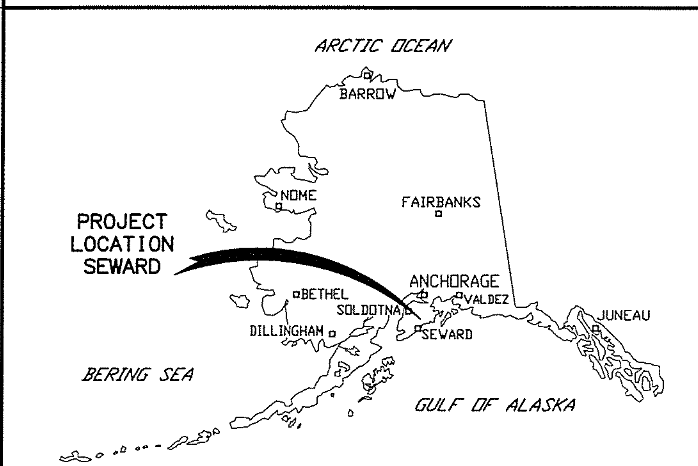
ADA	Americans with Disabilities Act
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ARR	Alaska Railroad
ARRC	Alaska Railroad Corporation
DOT&PF	Alaska Department of Transportation and Public Facilities
ESCP	Erosion and Sediment Control Plan
FHWA	Federal Highway Administration
HMCP	Hazardous Material Control Plan
HPCM	Alaska Highway Preconstruction Manual
ITS	Intelligent Transportation System
MAP-21	Moving Ahead for Progress in the 21st Century Act
M&O	Maintenance and Operations
MP	Milepost
MUTCD	Manual on Uniform Traffic Control Devices
NHS	National Highway System
PGDHS	A Policy on Geometric Design of Highways and Streets
SWPPP	Stormwater Pollution Prevention Plan
STRAHNET	Strategic Highway Network
TCE	Temporary Construction Easement

DRAWING LOCATION W:\Projects\Seward Hwy MP 17-22.5 Rehabilitation - 53610\Civ3D12\Exhibits\DSR\53610_DSR_Vicinity Map.dwg VIEW: DSR DRAFTED BY: VS/CL 12/12/2014





STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

FIGURE 1

SEWARD HWY: MP 17-22.5
REHABILITATION
PROJECT NO. 53610

LOCATION AND VICINITY MAP

1.0 PROJECT DESCRIPTION

1.1 Project Location and Description

The Alaska Department of Transportation and Public Facilities (DOT&PF) in cooperation with the Federal Highway Administration (FHWA) proposes to rehabilitate 5.5 miles of the Seward Highway between MP 17 and MP 22.5. The project will also replace the bridge at Victor Creek (Bridge No. 607) and rehabilitate two Snow River bridges (Bridge Nos. 603 and 605). The project is located approximately 110 road-miles south of Anchorage, and 17 miles north of Seward. Project location and vicinity maps are provided in Figure 1.

This project is included in the Statewide Transportation Improvement Program (STIP) and is a Federal-Aid project funded by the Moving Ahead for Progress in the 21st Century Act (MAP-21) administered by the Federal Highway Administration (FHWA). The current project is the second phase of a larger project, Seward Highway: MP 18-25.5 – Snow River to Trail River (Project No. NH-031-1(27)/53919). The first phase of the larger project rehabilitated the highway between MP 22.5 and MP 25.5 and replaced bridges at Ptarmigan Creek, Falls Creek, and Trail River near Crown Point (Seward Hwy: Trail RV, Falls CR & Ptarmigan Bridge Replacement - Project No. BR-NH-031-1(30)/52035).

1.2 Existing Facilities and Land Use

The Seward Highway provides the sole roadway connection to the City of Seward. The section of the Seward Highway south of its intersection with the Sterling Highway is classified as a Principal Arterial and is designated as a Non-Interstate NHS STRAHNET route by the FHWA.

The portion of the Seward Highway within the project area was originally constructed in 1952 and has a paved top width of 28 feet (two 12-foot lanes with 2-foot shoulders). The section across the Snow River between MP 17 to MP 18 was widened to a 40-foot top width (12-foot lanes and 8-foot shoulders) and realigned in 1964. The Snow River bridges were under construction when the Great Alaska Earthquake struck. Liquifaction of the alluvial foundation materials destroyed the new abutments and the bridge approaches; hence the roadway and bridges were subsequently reconstructed. The horizontal curve at MP 18 was again realigned in 1978 and a grade separated crossing for the Alaska Railroad at MP 18 was constructed (Bridge No. 606). Shortly after construction was completed, a landslide destroyed the new railroad overcrossing, which was replaced with a new Snow River Overhead (Bridge No 4001) in 1979. Except for resurfacing projects, the highway between MP 18 and MP 22.5 has not been upgraded since the original construction. The most recent resurfacing project was constructed in 2013 (Seward Highway MP 17.5-22.5 Pavement Preservation – Project No. NH-0311(33)/55256). The posted speed limit is 55 MPH.

The terrain in the vicinity of the project is generally mountainous, thickly wooded, and undeveloped adjacent to the highway. Above the tree line, slopes are bare rock and scree, or are covered in low alpine tundra or brush. The highway crosses the braided outwash channels of the Snow River close to its outlet into the south end of Kenai Lake, and then traverses the steep, rugged slopes of the Kenai Mountains along the east shore of the lake. Within most of the project, the Seward Highway parallels the Alaska Railroad (ARR), which runs along the eastern shore of the lake. The highway is located inland and above the railroad on the flanks of the mountains. Horizontal separation between the two facilities can be as small as 60 feet, while vertical separation ranges up to 100 feet. The existing grade-separated crossing (Snow River Overhead, Bridge No. 4001) is located 2,250 feet east of the eastern end of the Center Channel

Snow River Bridge.

The majority of the project is within the Chugach National Forest. A small enclave of private property including residences, recreational cabins, and small businesses are located along the highway near Victor Creek. Three additional private parcels as well as large tracts owned by the Alaska Department of Natural Resources (ADNR) are located adjacent to the highway near Rocky Creek. Access to the highway is stop controlled at Primrose Spur, the only active public approach within the project, though two other approaches are platted. The Victor Creek Trail, a historic hiking trail into the Chugach National Forest, is accessed from the Seward Highway at an unimproved trailhead located just north of the existing Victor Creek Bridge within existing DOT&PF Right-of-Way.

Utilities in the project area include overhead electric lines (transmission and distribution), fiber optic, and telephone lines. No illumination is provided within the project area, and there are no pedestrian/bicycle facilities beyond the existing shoulders and travel lanes.

The Seward Highway crosses the west channel and the main channel of the Snow River near the beginning of the project. Both Snow River bridges use prestressed concrete girder construction with reinforced concrete decks, and were constructed in 1965. The Snow River West Channel Bridge (No. 603) is 188 feet long with 30.1-foot wide decking. The Snow River Center Channel Bridge (No. 605) is 649 feet long with 30.1-foot wide decking. Snow River is catalogued as an anadromous stream and outfalls to the Kenai Lake with the ultimate receiving water being Cook Inlet.

Victor Creek crosses the Seward Highway at MP 20. The existing Victor Creek Bridge (No. 607) is a steel stringer bridge with a reinforced concrete deck. The bridge is 198 feet long with 24.2-foot wide decking. This bridge was constructed in 1952. Victor Creek is not listed as an anadromous stream and outfalls to Kenai Lake.

Drainage throughout the project area is provided through culverts and roadway ditches. Ditches tend to be undersized and need frequent maintenance due to rock fall debris. Culverts are subject to icing and deterioration due to the high debris loads in the steep mountain streams. The existing 10' x 10' concrete box culvert on Rocky Creek was installed in 1952 during the original construction of this segment of the highway. There is exposed rebar in the culvert's invert and one of the outlet wing walls has a widening crack at the joint with the main structure, caused by scour. The Seward Highway MP 17.5-22.5 Pavement Preservation Project (55256) installed riprap at the culvert outlet in 2013 to slow the deterioration of the wing wall.

Several active snow avalanche paths are located within the project area. The most active area is located just south of Rocky Creek, in an area known as the "Horsepasture." An existing avalanche gun mount is located adjacent to the highway south of the "Horsepasture."

There is an existing concrete retaining wall located at approximately MP 18.5 supporting the west side of the roadway embankment. The wall is approximately 100 feet in length and up to approximately 15 feet in height. This structure was constructed as part of the original highway project in 1952 but appears to still be in fair to good condition. A gabion retaining wall is located along the left side of the road at Calhoun Creek. This structure was installed in 1995 to mitigate embankment loss due to erosion below the existing guardrail.

1.3 Purpose and Need

This portion of the existing highway has deteriorated pavement, narrow shoulders, restricted sight distance, limited passing opportunities, narrow bridges, and inadequate ditches. The purpose of this project is to rehabilitate the project roadway, to provide passing opportunities, and to replace or rehabilitate deteriorated bridges.

2.0 DESIGN STANDARDS AND GUIDELINES

Design standards that apply to this project are contained in the following publications:

- A Policy on Geometric Design of Highways and Streets (PGDHS or "Green Book"), American Association of State Highway and Transportation Officials (AASHTO), 2001.

- Alaska Highway Preconstruction Manual (HPCM), State of Alaska, Department of Transportation and Public Facilities, 2005 (including all revisions thru December 2013)

- The Alaska Traffic Manual (ATM), consisting of the Manual on Uniform Traffic Control Devices (MUTCD), 2009 as amended, U.S. Department of Transportation, Federal Highway Administration (FHWA) and the Alaska Traffic Manual Supplement, 2012, State of Alaska, Department of Transportation and Public Facilities.

- AASHTO LRFD Bridge Design Specifications, 2012 Edition, with latest Interim Revisions.

- AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2nd Edition, with latest Interim Revisions.

Appendix A contains the project Design Criteria and Design Designation.

3.0 DISCUSSION OF ALTERNATIVES

3.1 First Alternative

The first alternative is the No-Build alternative. This alternative does not meet the purpose and need of the project. Though a recent pavement preservation project has temporarily improved the surfacing of the roadway, roadway geometrics and drainage remain substandard, and existing bridges will not be rehabilitated or replaced.

3.2 Second Alternative

The second alternative is to rehabilitate the roadway on the existing alignment without any widening. This alternative would include replacing the Victor Creek Bridge, and rehabilitating the Snow River Bridges. An existing horizontal curve near Victor Creek would be realigned to meet a 55 mph design speed, as recommended by the 3R analysis (refer to Appendix D). Culverts and guardrail would be replaced, and ditches improved where possible without significant cuts into the existing backslopes.

Though this alternative would meet some of the purpose and need for the Seward Highway, roadway geometrics in general would not be improved, except for flattening one horizontal curve. Passing opportunities would not be provided, clear zone would remain inadequate, and sight distance would not be improved. Roadway geometry would not be consistent with adjacent sections of the Seward Highway.

3.3 Third Alternative

The third alternative is to widen the roadway to 37 feet, including two 12-foot lanes and 6.5-foot paved shoulders; to provide slow vehicle turnouts where feasible and to improve the clear zone. As in the second alternative, the existing horizontal curve near Victor Creek would be realigned to meet a 55 mph design speed. In addition, minor geometric improvements to the alignment would be included to ensure superelevation transitions and sight distances meet the 55 mph design speed. Drainage would be improved by deepening and widening ditches and replacing culverts. Bridge rehabilitation at the Snow River Bridges and the replacement of the Victor Creek Bridge would be included. The existing concrete box culvert at Rocky Creek would also be replaced.

This alternative also includes raising a portion of the roadway near the "Horsepasture" approximately 30 feet above the natural terrain to provide avalanche mitigation. The proposed grade raise would require that approximately 2000 feet of highway be shifted up to 100 feet eastward to prevent encroachment of embankment material into the ARRC Right-of-Way. This alternative would require a realignment of a portion of the electrical transmission lines to the City of Seward and significant additional rock cuts beyond that required for the preferred alternative. The raised section of the roadway would also require an elaborate drainage system to prevent the impoundment of several small streams.

4.0 PREFERRED ALTERNATIVE

The preferred alternative includes all the geometric, bridge, and drainage improvements of the third alternative, with the exception of the "Horsepasture" grade raise and realignment. Instead, a smaller alignment shift is proposed in this area.

As with the third alternative, typical section geometry would be made consistent with adjacent sections of the Seward Highway. While the widening associated with this alternative would require extensive rock cuts, these impacts would be minimized as much as possible by staying close to the existing alignment. The proximity of the Alaska Railroad Corporation (ARRC) facilities and electrical transmission lines along the project corridor preclude other alignment alternatives.

Additional proposed improvements include construction of an avalanche berm as an avalanche mitigation measure in the "Horsepasture" area near Rocky Creek. Further evaluation associated with this improvement will be addressed as the design progresses.

5.0 TYPICAL SECTIONS

The highway typical section will consist of two 12-foot lanes with 6.5-foot paved shoulders for a total paved top width of 37 feet. Lanes will be 12 feet in width for the slow vehicle turnouts. Embankment foreslopes will generally be constructed at 4:1. In areas where guardrail is required, the slope will generally be 2:1. Ten-foot wide flat bottomed ditches will be constructed adjacent to rock cuts to provide for rockfall catchment. Rock cuts will be made at 0.5H:1V for the majority of the project, however 0.75H:1V is used in certain areas based on bedrock competency. The overburden depth varies throughout the project. A 5-foot bench is proposed at the top of the rock cuts. A 1.5:1 slope is proposed though the overburden. In areas where the slopes are required to be steeper than 1.5:1, a pinned wire mesh to stabilize steep soil slopes will be used. 4-foot wide flat bottomed ditches with 2:1 backslopes will be provided where rock cuts are not necessary.

The new bridge at Victor Creek will have a useable bridge width of 37 feet, matching that of the roadway typical section. Rehabilitation at the two Snow River Bridges will include reconstructing the bridge scuppers and raised curbs resulting in widening of the useable bridge widths to approximately 31 feet, resulting in two 12-foot lanes and 3.5-foot shoulders.

Rumble strips will be installed on the shoulders throughout the project except on bridges. Gaps will be provided for bicyclists to cross the milled rumble strips.

Typical sections are provided in Appendix B.

6.0 GENERAL HORIZONTAL AND VERTICAL ALIGNMENT

The horizontal and vertical alignments across the Snow River drainage area will match the existing alignment. Between MP 18 and MP 22.5, the existing horizontal curvature, constructed in 1952, has sections with extremely short curves, often with spiral segments, and inadequate tangent length between adjacent curves. The proposed shoulder widening will require that the horizontal alignment be shifted toward the mountain side (to the east) to lessen impacts to the ARRC facilities. The new alignment will largely parallel the existing alignment, but will smooth out and standardize the horizontal curvature to ensure adequate tangent lengths for superelevation transitions between adjacent curves.

The vertical alignment will generally follow the existing profile, with minor adjustments as necessary to better fit the terrain and to provide adequate sight distance.

The project includes two minor realignments:

- A realignment just south of Victor Creek will bring an existing horizontal curve up to 55 MPH design standards in accordance with the results of the 3R analysis prepared under Seward Highway: MP 18-25.5 – Snow River to Trail River (Project No. NH-031-1(27)/53919. Refer to Appendix D.

- The widening associated with construction of a slow vehicle turnout near the "Horsepasture" avalanche area will require realignment shift to lessen Right-of-Way impacts to the ARRC. The horizontal alignment will shift eastward approximately 45 feet.

Both horizontal and vertical alignments will meet 55 MPH design speed requirements.

Victor Creek Bridge will be constructed on the existing alignment. A temporary bridge will be required during construction of the new bridge.

7.0 EROSION AND SEDIMENT CONTROL

The project includes temporary and permanent measures to control or prevent erosion and sedimentation during and post project construction. The contractor will prepare a Storm Water Pollution Prevention Plan (SWPPP) prior to construction that follows the guidelines of the Erosion and Sediment Control Plan (ESCP) provided to the contractor. The contractor will submit the SWPPP for approval by the Department's Environmental Section. The contractor will conduct construction activities in accordance with the approved SWPPP. Temporary BMP's will remain in place until permanent erosion and sediment control measures are in place and soil is permanently stabilized.

8.0 DRAINAGE

All culverts within the project limits will be replaced and the ditches improved. Since the railroad is downstream of the highway, storm water runoff from the highway will be controlled and channelized into the existing railroad drainage structures. Roadway cross culverts less than 36" in diameter will be upsized to minimize icing potential and accommodate thaw wire installation, though existing drainage patterns will remain unchanged. Downstream impacts to the ARRC facilities will be coordinated with them.

A Hydrology and Hydraulics report was completed in support of bridge design for the Victor Creek Bridge by the Statewide Hydraulic Engineer and is available for reference. General highway drainage issues were discussed with local M&O personnel and field investigations were performed to identify needed improvements.

9.0 GEOTECHNICAL CONSIDERATIONS

Soils within the Snow River outwash plain consist of loose, thick alluvial and glacial deposits. These soils are subject to liquefaction during seismic events, as demonstrated by the failure of the new abutments of the main channel Snow River Bridge during the 1964 Great Alaska Earthquake. In the vicinity of Victor Creek, soils are alluvial gravelly sands and sandy gravels which did not exhibit liquefaction during the earthquake.

The bedrock within the project is typically comprised of thinly bedded phyllite, with argillite, and greywacke interbedded in varying proportions. Bedrock is overlain by organic silts, colluvium and/or glacial till. Overburden ranges from approximately 2 to 20 feet in thickness.

General soil and bedrock conditions within the project area, including station to station descriptions are included in the following reports:

- Seward Highway Milepost 18-25 - Final Geotechnical Recommendations, Memo Prepared by C. Boeckman for J. Dickenson, DOT&PF; January 31, 2002

- Geology Report – Seward Highway MP 18-25, Victor Creek Bridge No. 607, Project No. 53919, September 2003, Prepared by DOT&PF

- Final Structural Foundation Engineering Report, Victor Creek Bridge No. 607, Seward Highway MP 18 to 25, Alaska. September 2004, Prepared by Golder Associates, Inc.

- Geology Report – Seward Highway MP 18-25, Seward Highway Overhead (Snow River) Bridge No. 4001, Project No. 53919, September 2003, Prepared by DOT&PF

- Seward Highway Milepost 18-25. Project No. 53919; Geotechnical Recommendations, Prepared by C. Boeckman for J. Dickenson, DOT&PF; July 16, 2001.

A report documenting the avalanche hazards and evaluating mitigation measures for the project area is included in Appendix E:

- Avalanche Hazard Analysis, Seward Highway MP 18-23 (Snow River to Crown Point), Prepared for ADOT&PF by Arthur I. Mears, P.E. Inc, December, 2000.

10.0 ACCESS CONTROL FEATURES

Primrose Spur will remain a stop-controlled intersection. Future access to the highway will be controlled through driveway permits and future project evaluation. Reconstructed driveways will be constructed to current standards. Consolidation will be considered and addressed as the design progresses.

11.0 TRAFFIC ANALYSIS

The 2012 AADT for this segment of the Seward Highway was 1,930 vehicles per day. A 3R analysis was performed in accordance with the HPCM Section 1160.3 for the Seward Highway MP 18-25 Project, of which this project is a segment. As a result of the analysis, a horizontal curve near MP 20 will be improved to 55 mph standards. A summary of the 3R analysis results is provided in Appendix D.

12.0 SAFETY IMPROVEMENTS

The proposed improvements will enhance the safety and drivability of the roadway by widening shoulders, improving clear zone and sight distance, providing slow vehicle turnouts, adding pullouts, widening and resurfacing the existing Snow River Bridges, and replacing the existing bridge at Victor Creek. A horizontal curve near MP 20 will be realigned to 55 mph standards.

Existing guardrail will be replaced as part of this project, and new runs of guardrail installed where warranted. The length of need of existing installations will be reevaluated and adjusted where required. Rumble strips will be installed adjacent to the fog line.

An avalanche berm may be constructed upslope of the highway in the "Horsepasture" to mitigate the impact of small to intermediate sized avalanches in this area in accordance with recommendations from the avalanche hazard analysis (Appendix E).

13.0 RIGHT-OF-WAY REQUIREMENTS

Partial acquisitions will be required from an estimated 24 private parcels, including 2 businesses. Full acquisitions of three parcels may be required, including one occupied parcel, a parcel with a vacation cabin, and one unimproved (vacant) parcel. One relocation may be required.

Strip acquisitions approximately 30 to 100 feet in width are needed from the Chugach National Forest along much of the project length to accommodate the proposed roadway widening and rock cuts. A strip approximately 150 feet in width and 750 feet in length will be needed from an ADNR parcel for construction of the avalanche berm in the "Horsepasture" area.

All permanent work will be constructed within the Right-of-Way, easements, or permitted ARRC Right-of-Way. Temporary Construction Easements (TCEs) and Temporary Construction Permits (TCPs) will be required for constructing driveway approaches, detours, embankments and other facilities.

14.0 PEDESTRIAN AND BICYCLE FACILITIES

The project will be constructed in conformance with the Americans with Disabilities Act (ADA). The 6.5-foot wide paved shoulders will be available for bicycle and pedestrian usage. Improvements to the Victor Creek Trailhead will improve access to the trail by providing more parking spaces and minor amenities.

15.0 UTILITY RELOCATION AND COORDINATION

Utility companies with facilities in the project limits include the Alaska Railroad Corporation, AT&T, the City of Seward, and TelAlaska. Utilities will require relocation at select locations throughout the project, to address the following conflicts:

15.1 Alaska Railroad Corporation

The Alaska Railroad Corporation owns and operates a railway throughout the project area. Adjustments or relocation are not planned at this time. Some work on the roadway will take place in the ARRC Right-of-Way, which will require a permit. It was checked and confirmed that no railroad traffic control devices need to be brought up to standards in the project area. Drainage concerns associated with this projects improvements will be addressed as the design progresses.

15.2 AT&T

AT&T owns and operates a fiber optics facility that crosses the Seward Highway inside the railroad Right-of-Way. This facility is not anticipated to be in direct conflict and will be worked around and protected during roadway and railroad construction.

15.3 City of Seward

The City of Seward owns and operates aerial and underground transmission, distribution, and residential services throughout the project. The City of Seward will be required to relocate and install new poles to raise low wires, new guy poles with wires, and adjust existing down guys to accommodate fill slopes. Existing access trails used for servicing the distribution lines will need to be reconstructed and/or relocated as topography permits.

15.4 TelAlaska

TelAlaska owns and operates aerial and underground fiber optic and copper cable facilities throughout the project area. TelAlaska will also relocate existing aerial facilities throughout the project to accommodate driveway construction by either undergrounding the facilities or adjusting them up the poles if adequate room permits.

16.0 PRELIMINARY WORK ZONE TRAFFIC CONTROL

The HPCM, Section 1400.2 sets forth the criteria for determining if a project is to be classified as a "Significant Project" for purposes of determining the level of effort required in developing a Traffic Management Plan (TMP). This project meets the definition of "Significant" and therefore requires a Traffic Management Plan. The Traffic Management Plan (TMP) herein addresses delays and queuing times by limiting road closures to nighttime on weekdays only. Components of the TMP that are required include a Traffic Control Plan, Public Information Plan, and Transportation Operations Plan.

16.1 Traffic Control Plan (TCP)

The contractor will develop Traffic Control Plans during construction, to safely guide and protect the traveling public in work zones, in accordance with the Specifications. The TCP will include detours for the replacements of the Victor Creek Bridge and the concrete box culvert at Rocky Creek. The contractor will maintain two lanes of open traffic at most times while minimizing flagging delays.

16.2 Public Information Plan (PIP)

The DOT&PF in cooperation with the contractor will develop a public information plan to inform affected road users, the general public, area residents and businesses, and appropriate public entities of project scope, expected work zone impacts, closure details, and recommended action to avoid impacts and changing conditions during construction.

16.3 Transportation Operations Plan (TOP)

Coordination between the contractor and the ARRC will minimize the impacts to railroad traffic during blasting operations. No large construction projects are anticipated within the vicinity of this project site so cumulative traffic delay impacts are not anticipated.

17.0 STRUCTURAL SECTION AND PAVEMENT DESIGN

Pavement recommendations are being developed; however, based on other recent Seward Highway projects, preliminary recommended sections include the following:

- 2-inches of Hot Mix Asphalt, Type II; Class A
- 3-inches of Asphalt Treated Base (ATB)
- 2-inches of Aggregate Base Course, Grading D-1
- 36-inches of Selected Material, Type A

In the area between the beginning of project (near Primrose Spur) and east of the Snow River main channel bridge preliminary recommended section is:

- 2-inches of Hot Mix Asphalt, Type II; Class A
- 3-inches of Asphalt Treated Base (ATB)
- 2-inches of Aggregate Base Course, Grading D-1

Material sources for this project will be contractor supplied.

18.0 COST ESTIMATE

The project cost estimate is as follows:

Design	$	2,700,000
Utilities	$	700,000
Right-of-Way	$	500,000
Construction	$	57,000,000
Total	$	60,900,000

19.0 ENVIRONMENTAL COMMITMENTS AND CONSIDERATIONS

The proposed project meets the criteria for classification as a Categorical Exclusion (CE) per 23 CFR 771.117(d)(1 and 3), but does not meet the conditions outlined in the April 13, 2012 Programmatic Categorical Exclusion Agreement between the FHWA and the Alaska DOT&PF because it includes the use of properties protected by Section 4(f), 49U.S.C. 303 and requires acquisition of a parcel. The Categorical Exclusion (CE) for this project was approved by the FHWA on September 19, 2013. Two Section 4(f) De Minimus Impact Findings evaluating the project's effects on the USFS Victor Creek Trail and Victor Creek Trailhead were approved on September 18, 2013. These documents are provided in Appendix C.

Permits required for this project may include the following:

- U.S. Army Corp of Engineers (USACE) Section 404 Permit
- ADF&G Title 16 Fish Habitat Permit
- Kenai Peninsula Borough Conditional Use Permit
- Alaska Department of Environmental Conservation (ADEC) Letter of Non-Objection
- Eagle Permit

19.1 Hazardous Materials

The contractor will prepare a HMCP (Hazardous Material Control Plan) and submit it for approval by the Department's Environmental Section. The contractor shall conduct construction activities in accordance with the approved HMCP. If contaminated or hazardous materials are encountered during construction, all work in the vicinity of the contaminated site will be stopped until the Alaska Department of Environmental Conservation (ADEC) is contacted and a corrective action plan is approved by the ADEC and implemented.

19.2 Bald and Golden Eagles

If active bald or golden eagle nests are found within the project area, a primary zone of a minimum 330 feet will be maintained as an undisturbed habitat buffer around nesting eagles. If topography or vegetation does not provide an adequate screen or separation, the buffer will be extended to 0.25 mile, or a sufficient distance to screen the nest from human activities. Within the secondary zone (between 330 and 660 feet), no obtrusive facilities or major habitat modifications shall occur. If nesting occurs in sparse stands of trees, treeless areas, or where activities would occur within line-of-site of the nest, this buffer shall extend up to 0.5 miles. No blasting, logging, or other noisy, disturbing activities within the primary or secondary zones should occur during the nesting period (February 1 – August 31).

19.3 Migratory Birds

Clearing and grubbing are not permitted within the migratory bird window of May 1 to July 15, except as permitted by federal, state, and local laws and approved by the Project Engineer.

19.4 Invasive Plants

All construction equipment would be inspected and cleaned prior to entering and exiting the construction site to minimize spread of vegetative materials. Erosion and sediment control materials would be made from certified weed materials or locally produced products to minimize potential importation of new weed propagules from outside Alaska.

19.5 Air Quality

Air quality would be maintained through the use of best management practices such as watering, sweeping, stabilizing construction entrances/exits, and use of equipment emission control devices.

19.6 Noise

The contractor will make every reasonable effort to minimize construction noise through abatement measures such as proper maintenance of construction equipment.

19.7 Storm Water

The construction contractor will be required to prepare and implement a Storm Water Pollution Prevention Plan (SWPPP) that conforms to the DOT&PF Best Management Practices (BMPs) for Erosion and Sediment Control in accordance with the DOT&PF contract specifications. Appropriate erosion and siltation controls will be used and maintained during construction and all other exposed soils/fills will be permanently stabilized. An Erosion and Sediment Control Plan (ESCP) will be made available to the contractor to use as guidance in developing the SWPPP.

19.8 Public Notice

Advanced public notice of construction activities and potential traffic delays will be given to reduce construction impacts on local businesses, residents, and road travelers.

19.9 Historic Properties

If cultural, archaeological, or historic sites are discovered during project construction, all work that may impacts these resources would stop until DOT&PF consults with the State Historic Preservation Officer to determine the appropriate corrective action.

20.0 PRELIMINARY BRIDGE LAYOUT

The new bridge at Victor Creek will be 220 feet in length and will be a 2-span decked bulb-tee style bridge with hammerhead pier caps. Bridge improvements will include bridge railing with new bridge rail transitions to w-beam guardrail.

Rehabilitation at the two Snow River Bridges will include reconstructing the bridge scuppers and raised curbs, scarifying and resurfacing the existing bridge decks with a polyester concrete overlay, and replacing the existing bridge rail and bridge rail transitions.

21.0 EXCEPTIONS TO DESIGN STANDARDS

No exceptions to standards are required.

22.0 MAINTENANCE CONSIDERATIONS

Roadway widening will require additional effort for snow plowing in the project area, though the new flat-bottomed ditches will provide additional snow storage area. Guardrail installations beyond those existing will require revisions to current snow removal procedures. The addition of the avalanche berm at the "Horsepasture" may mitigate effects to the roadway facility from small to intermediate avalanches.

The effort required to maintain signs and striping within the project will increase due to the addition of pullouts and slow vehicle turnouts. Ongoing maintenance of the bridges will be less than that of the existing bridges.

Maintenance for the project roadway will be shared by the Seward and the Crown Point Alaska DOT&PF Maintenance Stations.

23.0 INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

No Automated Traffic Recorders are anticipated to be included in the project.

24.0 VALUE ENGINEERING

Department policy requires that all projects with a total estimated value equal to or greater than $40 million be considered for a VE analysis. Originally the project was part of a larger Seward Highway Improvements MP 18-25. The VE analysis was conducted in October 2001 and the full VE report can be found in the project files. Applicable excerpts are included in Appendix F.

APPENDIX A
APPROVED DESIGN CRITERIA AND DESIGN DESIGNATION

Project Design Criteria

Project Name:	Seward Highway: MP 17-22.5 Rehabilitation			
[ ] New Construction/Reconstruction*	[X] 3R	[ ] PM	[ ] Other:	
Project Number: 53610 / 0311(032)		[X] NHS	[ ] Non NHS	
Functional Classification:	Rural Principle Arterial - Other			**Source/Comments**
Design Year:	2023	Present ADT: (2008)	1780	Design Designations
Design Year ADT:	2070	Mid Design Period ADT: (2018)	1970	Design Designations
DHV:	415	Directional Split:	60/40	Design Designations
Percent Trucks:	16.4%	Equivalent Axle Loading:	421,303	Design Designations
Pavement Design Year:	2023	Design Vehicle:	WB-67	GB p. 18
Terrain:	Mountain	Number of Roadways:	1	
Design Speed:	55 MPH			PCM 1160.3.1, 3R Report
Width of Traveled Way:	Existing (24')			PCM 1160.3.2
Width of Shoulders:	Outside: 6.5'	Inside:	N/A	PCM 1160.3.2, CR-T-25.10
Cross Slope:	2%			PCM 1130.1.2
Superelevation Rate:	6%			PCM 1160.3.3, Fig. 1120-1
Minimum Radius of Curvature:	1065'			PCM 1160.3.3, GB Ex. 3-22
Minimum K-Value, Vertical Curves:	Crest: 114			PCM 1160.3.4, GB Ex 3-76
	Sag: 115			PCM 1160.3.4, GB Ex 3-79
Maximum Allowable Grade:	6%			PCM 1160.3.11, Fig 1120-1
Minimum Allowable Grade:	0%			PCM 1160.3.11, GB p. 242
Stopping Sight Distance:	495'			GB p. 112, p. 449
Lateral Offset to Obstruction:	1.5'			RDG Chapt. 10.0
Vertical Clearance:	20' 6" (Overhead Utilites)			PCM Table 1130 -1
Bridge Width:	37' Victor Ck; 30' Snow Rvr Bridges (Existing)			GB p. 451, PCM 1160.3.5
Bridge Structural Capacity:	HS-20 Victor Ck; HS-15 min Snow Rvr Bridges (Existing)			GB p. 451, PCM 1160.3.5
Min. Clear Zone:	24'			PCM Tbls. 1130-2, 1160-1
Passing Sight Distance:	1985'			GB p. 124, p. 449
Surface Treatment:	T/W: HMA	Shoulders:	HMA	
Side Slope Ratios:	Foreslopes: 4:1	Backslopes:	2:1	
Degree of Access Control:	Driveway Permits			
Median Treatment:	N/A			
Illumination:	N/A			
Curb Usage and Type:	N/A			
Bicycle Provisions:	Paved Shdrs			
Pedestrian Provisions:	Paved Shdrs			
Misc. Criteria:				

Proposed - Designer/Consultant: [signature] Date: 12/24/2013

Endorsed - Engineering Manager: [signature] Date: 12/30/13

Approved - Preconstruction Engineer: [signature] Date: 1/2/2014

*New Construction/Reconstruction: Shaded criteria are commonly referred to as the *FHWA 13 controlling criteria*. For NHS routes only, these criteria must meet the minimums established in the Green Book (*AASHTO A Policy on Geometric Design of Highway and Streets*). For all other routes, these criteria must meet the minimums established in the *Alaska Highway Preconstruction Manual*. Otherwise a Design Exception must be approved.

Design Criterion marked with a "#" do not need to meet minimums and have a Design Exception(s) and/or Design Waiver(s) approved. See the approved DSR for Design Exception/Design Waiver approval(s) and approved design criteria values.

DESIGN DESIGNATION

State Route Number: 130000 Route Name: Seward Hwy

Project Limits: MP 18 to MP 25.5 - Snow River Bridge to Trail River Bridge

State Project Number: 53919 Federal Aid Number: STP-031-1(27)

Project Description: 3R Project

Design Functional Classification:

☐ Urban Arterial ☒ Rural Arterial ☐ Major Collector ☐ Minor Collector ☐ Local

New Construction - Reconstruction: ☐ Rehabilitation (3R): ☒ Other ______

Project Design Life (years): 5 ☐ 10 ☒ 20 ☐ 25 ☐ Other ______

	Existing Year	Construction Year	Mid-Life Year	Future Year
	2008	2013	2018	2023
ADT	1,780	1,870	1,970	2,070
DHV	420	375	395	415
Peak Hour Factor	0.90	0.90	0.90	0.90
Directional Distribution	60/40	60/40	60/40	60/40
Percent Recreational Vehicles	NA	NA	NA	NA
Percent Commercial Trucks	16.4%	16.4%	16.4%	16.4%
Compound Growth Rate	1.00%	1.00%	1.00%	1.00%
Pedestrians (Number/Day)	NA	NA	NA	NA
Bicyclists (Number/Day)	NA	NA	NA	NA

Equivalent Axle Loads: 421,303

REVIEWED Howard Welker DATE 12-8-2010
Highway Data Manager

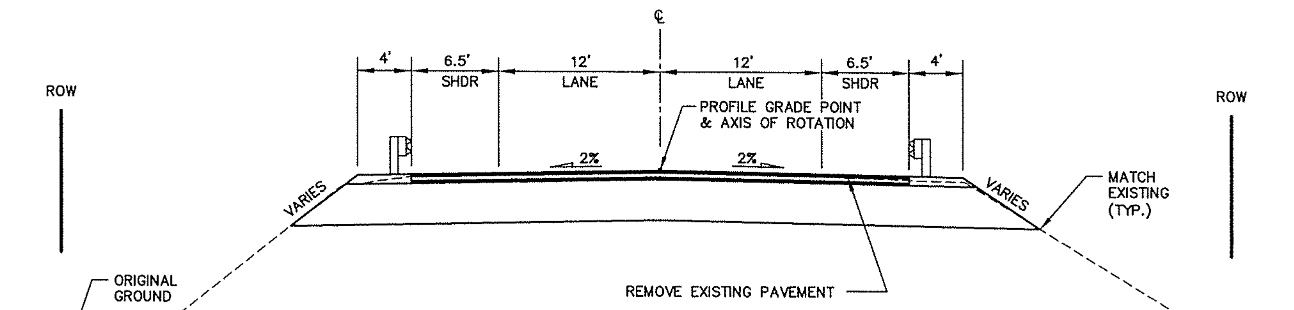
REVIEWED David Post DATE 1/6/2011
Area Planner

APPROVED [signature] DATE 1/10/2011
Regional Preconstruction Engineer

Figure 1100-1
Design Designation Form

APPENDIX B
TYPICAL SECTIONS

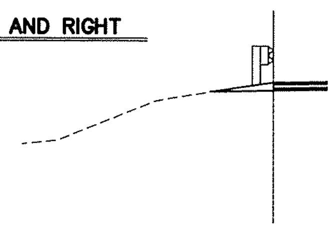
DRAWING LOCATION	W:\Projects\Seward Hwy MP 17-22.5 Rehabilitation - 53610\Civ3D12\Exhibits\DSR\53610_DSR_TypicalsPIH.dwg VIEW: DSR	DRAFTED BY	VS 1/28/2014

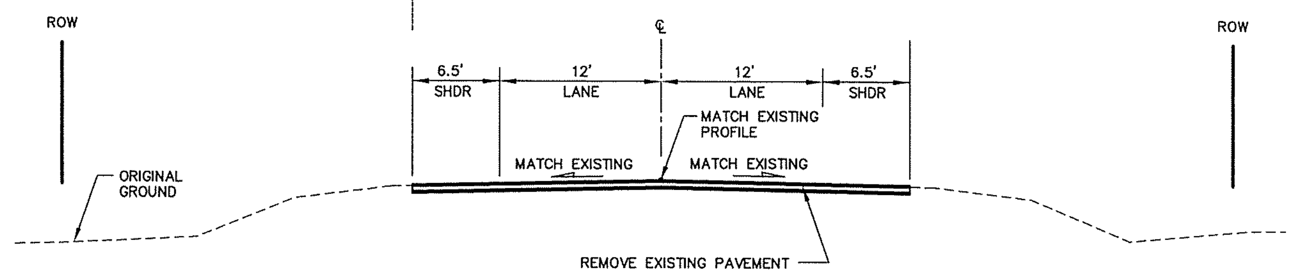


SEWARD HIGHWAY

CDS MP 17.65–18.07

GUARDRAIL LEFT AND RIGHT



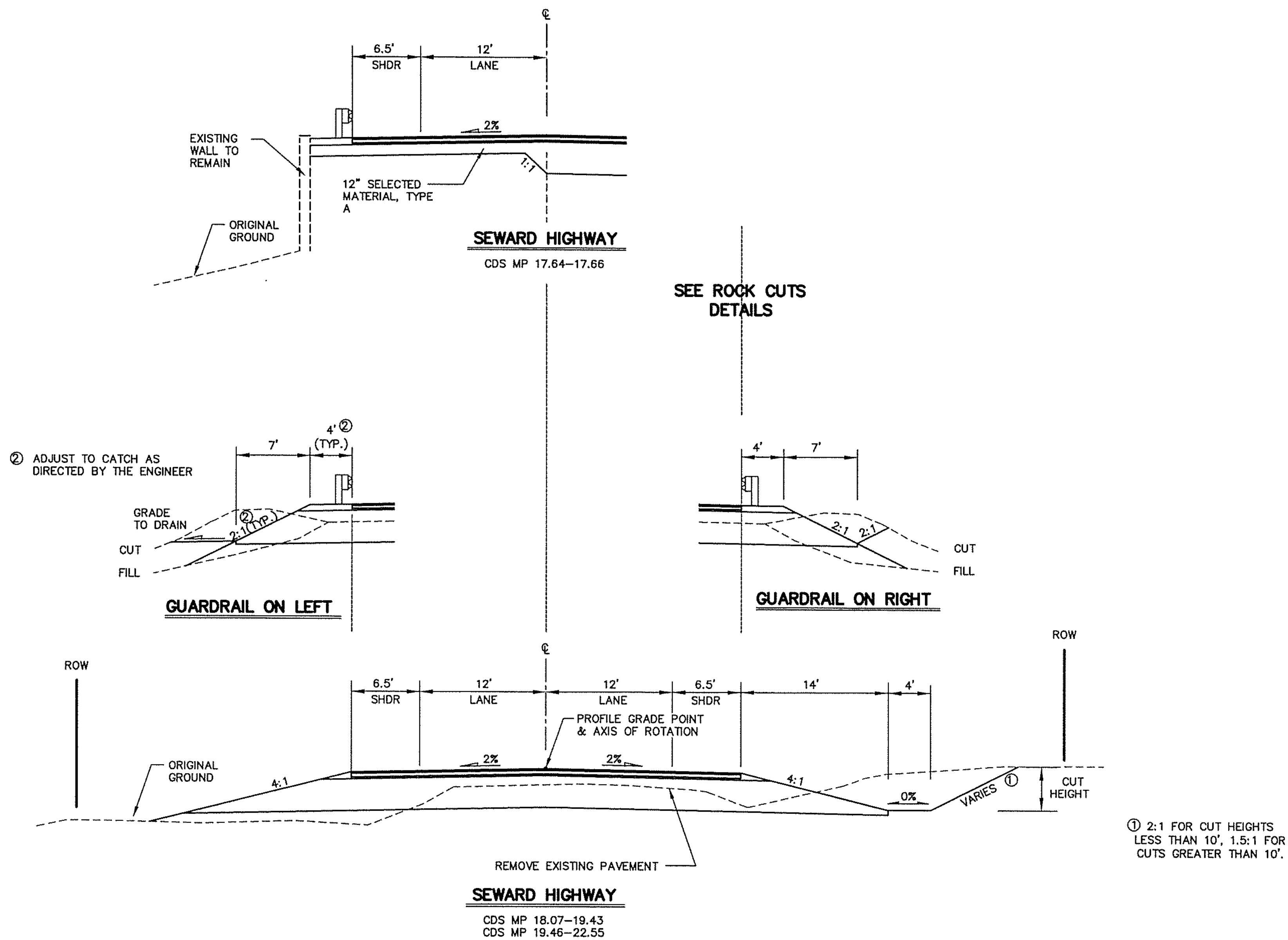


SEWARD HIGHWAY

CDS MP 16.94–16.99
CDS MP 17.01–17.52

SEWARD HWY: MP 17–22.5 REHABILITATIOIN – PROJECT NO. 53610
TYPICAL SECTIONS

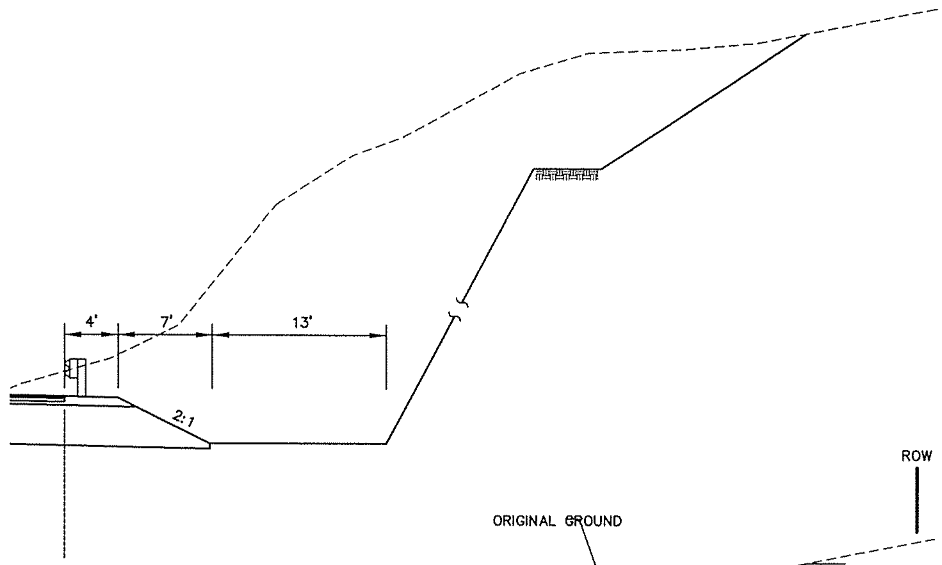
DRAWING LOCATION	W:\Projects\Seward Hwy MP 17-22.5 Rehabilitation - 53610\Civ3D12\Exhibits\DSR\53610_DSR_TypicalsPIH.dwg VIEW: DSR	DRAFTED BY	VS	1/28/2014



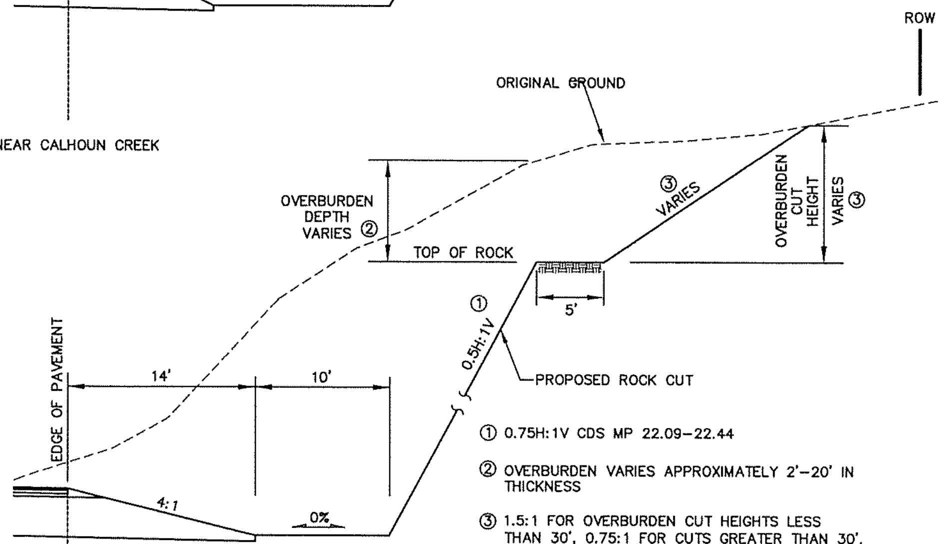
SEWARD HWY: MP 17–22.5 REHABILITATIOIN – PROJECT NO. 53610

TYPICAL SECTIONS

DRAWING LOCATION | W:\Projects\Seward Hwy MP 17-22.5 Rehabilitation - 53610\Civ3D12\Exhibits\DSR\53610_DSR_TypicalsPIH.dwg | VIEW: DSR | DRAFTED BY | VS | 1/28/2014



NEAR CALHOUN CREEK



ROCK CUT DETAILS

SEWARD HWY: MP 17-22.5 REHABILITATIOIN – PROJECT NO. 53610
TYPICAL SECTIONS

APPENDIX C
APPROVED ENVIRONMENTAL DOCUMENT

MEMORANDUM

State of Alaska

Department of Transportation and Public Facilities
Central Region Design and Engineering Services
Preliminary Design and Environmental

To:	Al Fletcher FHWA Field Operations Engineer	Date:	09/4/2013
From:	Brian Elliott BE Regional Environmental Manager	Project Name:	Seward Highway: MP 17-22.5 Rehabilitation
Subject:	Categorical Exclusion (CE)	Project No:	53610/FA-0311(032)

The subject project does not meet the criteria outlined in the September 2012 Memorandum of Understanding (MOU) between the Federal Highway Administration (FHWA) and the Alaska Department of Transportation and Public Facilities (DOT&PF) for the State Assumption of Responsibility for Categorical Exclusions and is not assignable to the DOT&PF in accordance with Section 326 of amended Chapter 3 of Title 23, United States Code (23 U.S.C. 326) because the project involves the horizontal realignment of a segment of roadway, an activity that is not included in the MOU.

The project meets the criteria for classification as a CE per 23 CFR 771.117(d)(1 and 3) but does not meet the conditions outlined in the April 13, 2012, Programmatic Categorical Exclusion Agreement between the DOT&PF and FHWA because it includes the use of properties protected by Section 4(f), 49 U.S.C. 303 and requires the acquisition of an entire parcel.

The CE Documentation Form is attached for your review and approval. Please return original signature page to this office and keep a copy for your file.

Enclosures: CE Documentation

cc: Sean Baski, P.E., Project Manager, Highway Design (w/ attachment)
Elysia Retzlaff, Environmental Team Leader, PD&E (w/o attachment)

State of Alaska
Department of Transportation & Public Facilities

CATEGORICAL EXCLUSION DOCUMENTATION FORM FOR FEDERAL HIGHWAY ADMINISTRATION PROJECTS

Project Name: Seward Highway: MP 17-22.5 Rehabilitation
Project Number (state/federal):53610/FA-0311(032)
Date: August 23, 2013
CE Designation: 23 CFR 771.117(d)(1)
23 CFR 771.117(d)(3)
List of Attachments:
Figure 1: Location and Vicinity Map
Figure 2a-b: Proposed Improvement Location Map
Figure 3: Typical Section
Figure 4: Typical Culvert Section
Appendix A: Section 106 Consultation
Appendix B: Section 4(f) Consultation
Appendix C: Public and Agency Coordination

I. Project Purpose and Need

The Alaska Department of Transportation and Public Facilities (DOT&PF), in cooperation with the Alaska Division of the Federal Highway Administration (FHWA), is proposing to rehabilitate the Seward Highway from milepost (MP) 17 to MP 22.5. The proposed project is located within Section 31, T 4 N, R 1 E; Sections 6, 7, 18, 19, and 30, T 3 N, R 1 E; and Section 25, T 3 N, R 1 W, Seward Meridian, on USGS Quad Map Seward B-7. Approximate GPS coordinates for the beginning of project are Latitude 60.3273°N, Longitude 149.3591°W (Figure 1).

Purpose and Need
The existing highway has deteriorated pavement, narrow shoulders, restricted sight distance, limited passing opportunities, narrow bridges, and inadequate drainage. The purpose of the proposed project is to improve the stated deficiencies, extend the service life of the roadway, and reduce maintenance costs.

II. Project Description

The proposed project would include the following:

- Resurface and widen the roadway to 36-feet
    - 12-foot lane widths and 6-foot shoulders
- Replace the Victor Creek Bridge
- Repair and resurface the concrete decks on the Snow River Bridges
- Provide passing and/or climbing lanes (~MP 19.5-20.5 northbound; MP 20-21.5 southbound); increasing width to 48-feet
- Realign a horizontal curve located just south of Victor Creek (~MP 18.5-19.5)
- Construct avalanche mitigation at MP 21, potentially involving:
    - Construction of a berm located uphill of the roadway or
    - Elevating the roadway approximately 30-feet

- Bring the clear zone in rock areas to current standards[1]
- Improve storm water drainage facilities, including replacement of cross culverts and a concrete box culvert at Rocky Creek
- Improve existing vehicle turnouts as needed
- Improve or replace guardrail, signing, and striping

[1] Clear zone – Area adjacent to traveled roadway where it is desirable to remove hazardous objects or conditions. Size of area is based on vehicle speed, traffic volume and geometric conditions of site.

III. Environmental Consequences

- For each yes, summarize the activity evaluated and the magnitude of the impact.
- For any consequence category with an asterisk (*), additional information must be attached such as an alternatives analysis, agency coordination or consultation, avoidance measures, public notices, or mitigation statement.
- Include direct and indirect impacts in each analysis.

A. Right-of-Way Impacts	N/A	YES	NO
1. Additional right-of-way required.		☒	☐
• Permanent easements required.	☐	☒	☐
• Estimated number of parcels: 3			
• Full or partial property acquisition required.	☐	☒	☐
• Estimated number of full parcels: 2			
• Estimated number of partial parcels: 22			
• Property transfer from state or federal agency required. *If yes, list agency in No. 4 below.*	☐	☒	☐
• Business or residential relocations required. *If yes, summarize the findings of the conceptual stage relocation study in No. 4 below and attach the conceptual stage relocation study.*	☐	☐*	☒
• Number of relocations: 0			
• Type of relocation: Residential: ☐ Business: ☐ Residential (Indicate number: N/A) Business (Indicate number: N/A)			
• Last-resort housing required.	☐	☐	☒
2. Will the project or activity have disproportionately high and adverse human health or environmental effects on minority populations and low-income populations as defined in E.O. 12898 (DOT Order 6640.23, December 1998)?		☐	☒
3. The project will involve use of ANILCA land that requires an ANILCA Tile XI approval. *If yes, the project is not assigned to the State per the 6004 MOU and the CE must be processed by FHWA.*		☐	☒

4. Summarize the right-of-way impacts, if any:

Twenty-four partial acquisitions are estimated for the proposed project; two from businesses and twenty-two from private residences. These acquisitions are required for widening the highway and will vary in width from 30 to 100 feet. Additionally, two full acquisitions, one parcel with a vacation cabin and one unimproved (vacant) parcel, will be required to accommodate highway realignment.

Between MP 20.4 and 21.5, partial acquisitions of state land owned by the Alaska Department of Natural Resources (DNR) will be required. Strip acquisitions approximately 30-100 feet wide will be required to accommodate highway widening. An additional strip near MP 21, approximately 150 feet wide by 2000 feet in length, will be required for highway realignment and avalanche mitigation. Strip acquisitions for highway widening are also needed along sections of the highway corridor currently owned by the Chugach National Forest.

No relocations are currently required. If any additional parcels are required and relocations determined to be necessary, all relocations will be done in accordance with the Uniform Relocation Assistance and Real Properties Acquisition Practices Act of 1971. No ANILCA lands are present in the project area. A detailed list of properties and easements that would be acquired will be developed during the design phase of the project.

U.S. 2010 Census data estimates a population of 34 individuals residing within the proposed project area. Of this population, 10% are classified as a minority; less than 10% are classified as low income. The proposed project will not have disproportionately high and adverse human health or environmental effects on minority populations and low-income populations as defined by Executive Order 12898.

B. Social and Cultural Impacts	N/A	YES	NO
1. The project will affect neighborhoods or community cohesion.		☐	☒
2. The project will affect travel patterns and accessibility (e.g. vehicular, commuter, bicycle, or pedestrian).		☐	☒
3. The project will affect school boundaries, recreation areas, churches, businesses, police and fire protection, etc.		☐	☒
4. The project will affect the elderly, handicapped, nondrivers, transit-dependent, minority and ethnic groups, or the economically disadvantaged.		☐	☒
5. There are unresolved project issues or concerns of a federally-recognized Indian Tribe [as defined in 36 CFR 800.16(m)]. *If yes, the project is not assigned to the State per the 6004 MOU and the CE must be processed by FHWA.*		☐	☒

6. Summarize the social and cultural impacts, if any:

The proposed project will provide a long-term benefit to both motorized and non-motorized members of the traveling public by improving travel conditions and safety in the project area. The project proposes to relocate the U.S. Forest Service Victor Creek Trailhead and construct a trailhead facility, including a parking area and new section of trail. The new trailhead and parking area would improve user safety through placement off the highway and provide increased vehicle storage capacity.

Adverse social or cultural impacts are not expected to occur from the proposed project, as travel patterns and accessibility will remain unchanged. Road users may be temporarily affected by traffic delays caused by construction activity. Refer to Section III, Part P for discussion of construction related traffic impacts.

C. Economic Impacts	N/A	YES	NO
1. The project will have adverse economic impacts on the regional and/or local economy, such as effects on development, tax revenues and public expenditures, employment opportunities, accessibility, and retail sales.		☐	☒
2. The project will adversely affect established businesses or business districts.		☐	☒

3. Summarize the economic impacts, if any:

The proposed project would provide a long-term economic benefit by improving the safety and efficiency of commercial traffic on the roadway. Several businesses are located along the proposed project area; however, the proposed project will not change access to these properties and no permanent adverse economic impacts are expected to occur. Refer to Section III, Part P for discussion of construction related economic impacts.

D. Land Use and Transportation Plans	N/A	YES	NO
1. Project is consistent with land use plan(s).	☐	☒	☐
a. Identify the land use plan(s) and date Kenai Peninsula Borough (KPB) Comprehensive Plan (2005)			
2. Project is consistent with transportation plan(s).	☐	☒	☐
a. Identify the transportation plan(s) and date. Kenai Peninsula Borough (KPB) Transportation Plan (2003); Alaska Statewide Long-Range Transportation Plan (LRTP): Let's Get Moving 2030 (2008); 2012-2015 Alaska Statewide Transportation Improvement Program (STIP)			
3. Project would induce adverse indirect and cumulative effects on land use or transportation. *If yes, attach analysis.*		☐	☒

4. Summarize how the project is consistent or inconsistent with the land use plan(s) and transportation plan(s):

The Seward Highway is a critical transportation link that serves local traffic and commuters as well as tourism, recreation, and commercial transportation. It is the only traffic carrier connecting Seward with other communities on the Kenai Peninsula and interior Alaska. The purpose and need for the project is consistent with the goals of all transportation and land use plans listed above. The proposed project is identified in the 2012 – 2015 STIP and is consistent with the project description contained therein. The KPB Transportation Plan lists a primary goal "to continue and improve maintenance and upgrading of Borough roads" and the LRTP includes "increase the safety of the transportation systems" and "system preservation" as some of the guiding policies for surface transportation systems in Alaska.

E. Impacts to Historic Properties	N/A	YES	NO
1. Does the project involve a road that is included on the "List of Roads Treated as Eligible" in the Alaska Historic Roads PA? *If yes, follow the Interim Guidance for Addressing Alaska Historic Roads.*		☐	☒
2. Does the project qualify as a listed activity that has no potential to cause effects to historic properties? *If yes, attach concurrence from the FHWA Area Engineer (non-assigned projects) or Statewide NEPA Manager for 6004-assigned projects.*		☐*	☒
a. Indicate the appropriate policy directive or memo that identifies the project as an action with no potential to cause effects to historic properties: ______			
3. Is a National Register of Historic Places listed or eligible property in the Area of Potential Effect?	☐	☒	☐

4. Date Consultation/Initiation Letters sent December 4, 2012 *Attach copies to this form.*

a. List consulting parties State Historic Preservation Officer, Qutekcak Native Tribe, Chugach National Forest, Kenai Peninsula Borough, Chugach Alaska Corporation, Chugachmiut

b. If no letters were sent, explain why not. *Attach "Section 106 Proceed Directly to Findings Worksheet", if applicable* ______

E. Impacts to Historic Properties

	N/A	YES	NO
5. Date "Finding of Effect" Letters sent August 5, 2013 *Attach copies to this form*			
a. State any changes to consulting parties ______			
6. List responding consulting parties, comment date, and summarize:			
7. Are there any unresolved issues with consulting parties?	☐	☐	☒
9. Will there be an adverse effect on a historic property?	☐	☐	☒

5. Date "Finding of Effect" Letters sent August 5, 2013 *Attach copies to this form*
   a. State any changes to consulting parties ______

6. List responding consulting parties, comment date, and summarize:
   State Historic Preservation Officer - Concurred with finding of no adverse affect on August 27, 2013.

   Sherry Nelson - Chugach National Forest, Seward District Archeologist - Concurred with FHWA finding of no adverse affect on July 8, 2013.

7. Are there any unresolved issues with consulting parties? ☐ ☐ ☒
   a. If yes, list ______

8. Date SHPO concurred with "Finding of Effect" ______ *Attach copy to this form.*

9. Will there be an adverse effect on a historic property? *If yes, attach correspondence (including response from ACHP) and signed MOA. If yes, Programmatic Agreements (PCEs) do not apply.* ☐ ☐ ☒

10. Summarize any effects to historic properties. *List affected sites (by AHRS number only) and any commitments or mitigative measures. Include any commitments or mitigative measures in Section VI.*
    The area potential effect (APE) consists of the road surface and generally extends up to 150 feet from the existing centerline where widening and vegetation clearing would occur. In the area where avalanche mitigation is proposed, the APE generally extends up to 300 feet uphill from the existing centerline. The APE also includes the first tier of properties to take into account any indirect effects from the proposed project.

    The Alaska Heritage Resources Survey (AHRS) database was reviewed by DOT&PF staff (4/3/2012 and 7/16/2013) to determine if any sites were identified within the APE. Table 1 presents all sites identified in AHRS records within the vicinity of the proposed project area or the area of potential effect.

Table 1: Identified AHRS sites within the Area of Potential Effect

AHRS Number	Site Name/Site Description	NRHP Eligibility
SEW – 00148	Seward-Moose Pass Trail	NDE*
SEW – 00598	Cabin and Log Garage	Not Eligible
SEW – 00602	Knopik Cabin and Garage	Not Eligible
SEW – 00600	Manson-Ostburg Garage	Not Eligible
SEW – 00840	Victor Creek Camp	Eligible
SEW – 01288	Victor Creek Bridge	NDE*
SEW – 01147	Victor Creek Trail	Eligible

*NDE - No determination of eligibility made

Several cultural resource surveys were conducted along the Seward Highway project corridor between 1993 and 2005. These reports include:

- Historical Properties Survey Seward Highway: MP 0 (Seward) to MP 36 (Sterling Highway Intersection (Stephen R. Braund & Associates with JG Haigh-Design, February 1993)

- Office of History and Archaeology (OHA) Archaeological Survey Unit – Short Report 2001-5, Archaeological Survey of Proposed Improvements to Seward Highway, MP 0-8 and 18-25 (DePew, March 2002)
- OHA Report Number 91, 2002 Archaeological Investigations and Historic Buildings Study along the Seward Highway, MP 18-25 (DePew and Buzzell, January 2003)
- Cultural Resource Evaluation of the Sather/Paulsteiner/Benoit Cabin (SEW-1136) at MP 21.5 of the Seward Highway: An Addendum to OHA Report Number 91 – Short Report 2004-8 (Thompson and DePew, January 2005)

OHA indicated that there was no clear evidence of the Seward-Moose Pass Trail (SEW-00148) within the APE; therefore no further evaluation of the trail was conducted for this project. The Victor Creek Camp (SEW-00840) archaeological site was determined eligible under criteria A & D in 2010 for its association with the Iditarod National Historic Trail and mining on the Kenai Peninsula. The Victor Creek Camp is located on the south side of the Victor Creek. The trailhead work would be conducted on the north side of the creek. Additionally, the temporary bridge replacement at Victor Creek will be adjacent to the existing bridge within the DOT&PF ROW and not extend to the archaeologically sensitive area. Therefore, the Victor Creek Camp will not be affected by the proposed project.

DOT&PF staff also searched the Kenai Peninsula Borough Parcel Viewer to determine if any properties with structures over 45 years in age were located in the project area. The search revealed no additional properties over 45 years in age.

FHWA has applied the November 2012 *Program Comment for Common Post-1945 Concrete and Steel Bridges* to this undertaking. The Program Comment is a national-level Section 106 compliance streamlining measure for certain types of bridges. Bridge #607 (SEW-01288), #603 and #605are a bridge type covered by this Program Comment. DOT&PF's cultural resources specialist has reviewed the undertaking, and none of the Program Comment's exclusions apply. As a result, Bridge #607 (SEW-01288), #603 and #605 require no further review under Section 106.

The proposed project would affect the Victor Creek Trail during construction, specifically, during replacement of the Victor Creek Bridge. A temporary bridge detour would be required, and the most viable option for its location is the east side of the existing bridge (upstream). A detour at this location would completely block access to the existing trailhead and require temporary use of a short section of the trail (approximately 50-75 feet) located within the DOT&PF right of way (ROW).

The temporary use would not adversely affect the Victor Creek Trail because the design, setting, feeling and characteristics that qualify the trail will not change. The physical alignment and layout will not be altered and the setting will remain the same as it would have been historically - that of a trail traveling along a glacier fed creek. The feeling of the site will also remain what it would have been historically, one of a transportation route through a prospecting and timber area. Access to the Iditarod Trail System and mining sites will not be restricted as the Victor Creek Trail will be accessible from a proposed new trailhead (see Appendix C). In addition, this temporary use would not adversely affect the Victor Creek Trail, as this portion of the trail has already experienced modifications due to the construction of the trailhead as well as the construction of the Seward Highway and Victor Creek Bridge. Therefore, the project will have no adverse impacts on the characteristics that qualify the Victor Creek Trail for inclusion in the National Register of Historic Places.

FHWA found no adverse effect on historic properties by the proposed project. The SHPO concurred with the finding of no adverse effect on August 27, 2013. Refer to Section VI for protocol if any historic properties are found during construction.

F. **Wetland Impacts**	N/A	YES	NO
1. Project affects wetlands as defined by the U.S. Army Corps of Engineers (USACE). *If yes, document public and agency coordination required per E.O. 11990, Protection of Wetlands.*		☐*	☒
2. Are the wetlands delineated in accordance with the *"Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Alaska Region (Version 2.0) Sept. 2007"?*	☐	☒	☐
3. Estimated area of wetland involvement (acres): N/A			
4. Estimated fill quantities (cubic yards): N/A			
5. Estimated dredge quantities (cubic yards): N/A			
6. Is a USACE authorization anticipated? *If yes, identify type*: NWP ☐ Individual ☐ General Permit ☐ Other ☐	☐	☐	☒
7. Wetlands Finding *Attach the following supporting documentation as appropriate:* • *Avoidance and Minimization Checklist, and Mitigation Statement* • *Wetlands Delineation.* • *Jurisdictional Determination.* • *Copies of public and resource agency letters received in response to the request for comments.*			
a. Are there practicable alternatives to the proposed construction in wetlands? *If yes, the project cannot be approved as proposed.*	☒	☐	☐
b. Does the project include all practicable measures to minimize harm to wetlands? *If no, the project cannot be approved as proposed.*	☒	☐	☐
c. Only practicable alternative: Based on the evaluation of avoidance and minimization alternatives, there are no practicable alternatives that would avoid the project's impacts on wetlands. The project includes all practicable measures to minimize harm to the affected wetlands as a result of construction. *If no, the project cannot be approved as proposed.*	☒	☐	☐

8. Summarize the wetlands impacts and mitigation, if any. *Include any commitments or mitigative measures in Section VI.*

The U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) (reviewed 2/7/2012) shows several freshwater forest/shrub wetlands located adjacent to the roadway between mileposts 17 -18. A wetland delineation performed by Hattenburg, Dilley & Linnell for DOT&PF in April 2013, confirms the information obtained from the USFWS NWI (on file in the Environmental Section). The proposed work located between MP 17-18 will be contained within the existing roadway embankment or road surface and will not involve the discharge of dredged or fill material into these wetlands. No adverse impacts to wetlands are expected to occur as a result of the proposed project.

G. Water Body Involvement

		N/A	YES	NO
1.	Project affects a water body.		☒	☐
2.	Project affects a navigable water body as defined by USCG, (i.e. Section 9).	☐	☐*	☒
3.	Project affects Waters of the U.S. as defined by the USACE, Section 404.	☐	☒*	☐
4.	Project affects Navigable Waters of the U.S. as defined by the USACE (Section 10)	☐	☐*	☒
5.	Project affects fish passage across a stream frequented by salmon or other fish(i.e. Title 16.05.841)	☐	☐	☒
6.	Project affects a cataloged anadromous fish stream, river or lake (i.e. Title 16.05.871).	☐	☐*	☒
7.	Project affects a designated Wild and Scenic River or land adjacent to a Wild and Scenic River. *If yes, the Regional Environmental Manager should consult with the Statewide NEPA Manager (assigned CEs) or FHWA Area Engineer and FHWA Environmental Program Manager (non-assigned CEs) to determine applicability of Section 4(f).*		☐	☒
8.	Proposed water body involvement: Bridge ☒ Culvert ☒ Embankment Fill ☐ Relocation ☐ Diversion ☒ Temporary ☒ Permanent ☐ Other ☐	☐		
9.	Type of stream or river habitat impacted: Spawning ☐ Rearing ☐ Pool ☐ Riffle ☐ Undercut bank ☐ Other ☐	☒		

10. Amount of fill below (cubic yards): OHW 11,000 MHW _____ HTL _____

11. Summarize the water body impacts and mitigation, if any. *Include any commitments or mitigative measures in Section VI.*

Waters of the U.S. in the project area include Snow River, Victor Creek, Rocky Creek, Kenai Lake, and numerous unnamed streams. All water bodies in the project area originate in the mountains on the east side of the highway and flow west under the Seward Highway into Kenai Lake. Kenai Lake, a traditional navigable water, parallels the west side of the Seward Highway for nearly the entire length of the project area.

Approximately 11,000 cubic yards of fill will be permanently placed below ordinary high water during replacement of the Victor Creek Bridge, Rocky Creek box culvert, and numerous cross culverts that transport the unnamed streams underneath the roadway. Bridge and culvert work is replacing existing structures; therefore fill amounts estimated above closely resemble existing conditions. Approximately 1600 cubic yards of new fill will be placed below ordinary high water during installation of riprap at Victor Creek and Rocky Creek. No fill material beyond what is necessary will be placed in waters of the U.S.

Small quantities of existing road embankment fill at Rocky Creek and three unnamed creeks will be removed, as well as the old abutments when the bridge at Victor Creek is replaced. Proposed culvert replacements may require temporary stream diversions during construction. All materials used for the diversions would be completely removed from creeks and streams upon completion of construction.

A U.S. Army Corps of Engineers (USACE) Section 404 permit will be obtained prior to construction. In 2005, the U.S. Coast Guard concurred with a determination by FHWA that the Victor Creek Bridge is exempt from a USCG Bridge Permit under Section 144(h) of Title 23, U.S. Code. The proposed project is not expected to have permanent adverse effects on waters of the U.S.

H. Fish and Wildlife

	N/A	YES	NO
1. Anadromous and resident fish habitat. *Any activity or project that is conducted below the ordinary high water mark of an anadromous stream, river, or lake requires a Fish Habitat Permit.*			
a. Database name(s) and date(s) queried: Atlas to the Catalog of Waters Important to the Spawning, Rearing or Migration of Anadromous Fishes, 2/7/2012			
b. Anadromous fish habitat present in project area.		☒*	☐
c. Resident fish habitat present in project area		☒*	☐
d. Adverse effect on spawning habitat.	☐	☐*	☒
e. Adverse effect on rearing habitat.	☐	☐*	☒
f. Adverse effect on migration corridors.	☐	☐*	☒
g. Adverse effect on subsistence species.	☐	☐*	☒
2. Essential Fish Habitat (EFH). *EFH includes any anadromous stream used by any of the five species of Pacific salmon for migration, spawning or rearing, as well as other coastal, nearshore and offshore areas as designated by NMFS.*			
a. Database name(s) and date(s) queried: Atlas to the Catalog of Waters Important to the Spawning, Rearing or Migration of Anadromous Fishes, 2/7/2012			
b. EFH present in project area		☒	☐
c. Project proposes construction in EFH. *If yes, describe EFH impacts in H.6.*	☐	☐	☒
d. Project may adversely affect EFH. *If yes, attach EFH Assessment.*	☐	☐*	☒
e. Project includes conservation recommendations proposed by NMFS. *If NMFS conservation recommendations are not adopted, formal notification must be made to NMFS. Summarize the final conservation measures in H.6 and list in Section VI.*	☐	☐	☒
3. Wildlife Resources:			
a. Project is in area of high wildlife/vehicle accidents.		☐	☒
b. Project would bisect migration corridors.		☐	☒
c. Project would segment habitat.		☐	☒
4. Bald and Golden Eagle Protection Act. *If yes to any below, consult with USFWS and attach documentation of consultation.*			
a. Eagle data source(s) and date(s) : N/A			
b. Project visible from an eagle nesting tree?		☐*	☐
c. Project within 330 feet of an eagle nesting tree?		☐*	☐
d. Project within 660 feet of an eagle nesting tree?		☐*	☐
e. Will the project require blasting or other activities that produce extreme loud noises within 1/2 a mile from an active nest?		☐*	☐
f. Is an eagle permit required?		☐*	☐
5. Is the project consistent with the Migratory Bird Treaty Act?		☒	☐

6. Summarize fish and wildlife impacts and mitigation, including timing windows, if any. *Include any commitments or mitigative measures in Section VI.*

Anadromous, Resident, and Essential Fish Habitat

Two water bodies supporting anadromous fishes are in the proposed project area; Snow River (AWC # 244-30-10010-2250) and Kenai Lake (AWC # 244-30-10010-0020). These water bodies are also considered EFH by the National Marine Fisheries Service. However, the proposed work does not involve any in-stream work or placement of fill or structures below ordinary high water in these water bodies. As such, adverse impacts to fish and habitat are not anticipated. Refer to Section III, Part P and Section VI for measures to protect water quality during construction.

Wildlife Resources

Vegetative clearing and rock cutting will be required in sections of the project area to accommodate widening of the highway. Though this will result in removal of some wildlife habitat, impacts to wildlife are likely to be minimal, as an abundance of similar habitat is adjacent to the project area.

The DOT&PF *Segments of Concern for Moose-Vehicle Collisions in the Central Region (2001-2005)* indicates the proposed project is not located in an area of high wildlife/vehicle accidents. Collisions are not expected to increase as travel patterns, roadway capacity and configuration will remain the same. Additionally, the proposed activities will occur along the existing alignment so there is no potential for further habitat segmentation or bisection of migration corridors. No adverse impacts to wildlife or wildlife habitat are expected to occur as a result of the proposed project.

Species with Greatest Conservation Need

A review of the ADF&G Wildlife Action Plan on June 3, 2013, indicated that several species listed as having the greatest conservation needs may be present or may pass through the project area. This list includes several species of fish, migratory birds, and mammals. The proposed project activities will occur along the existing alignment and are not expected to increase travel patterns, roadway capacity or configuration. As such, no adverse impacts to these species are expected to occur as a result of the proposed project.

Bald and Golden Eagle Protection Act

Suitable eagle nesting habitat exists adjacent to the proposed project corridor. One known eagle nest is within 200 feet of the project corridor near MP 17. Multiple site visits in 2013 indicate the nest is not currently active. Due to existing highway disturbance, permanent adverse impacts to eagles are not anticipated. Temporary noise impacts could occur during blasting and other construction activities. Prior to construction, a survey would be conducted to determine the presence of active nests, and if found, USFWS would be contacted for guidance on how to proceed.

Migratory Birds

Migratory bird species may pass through the proposed project area and could be affected by vegetation clearing activities. However, vegetation clearing would be minimal and would follow, to the maximum extent possible, the USFWS *Recommended Time Periods for Avoiding Vegetation Clearing in Alaska in Order to Protect Migratory Birds* advisory. If clearing during this time period is necessary the DOT&PF will consult with the USFWS for guidance on how to proceed.

I. Threatened and Endangered Species (T&E)

		N/A	YES	NO
1.	Database name(s) and date(s) queried: USFWS and ADF&G Threatened and Endangered Species Lists on August 5, 2013.			
2.	Listed threatened or endangered species present in the project area.		☐*	☒
3.	Threatened or endangered species migrate through the project area.		☐*	☒
4.	Designated critical habitat in the project area.		☐*	☒
5.	Proposed species present in project area.		☐*	☒
6.	Candidate species present in project area.		☐*	☒
7.	What is the effect determination for the project? *Select one.*			
	a. Project has no effect on listed or proposed T&E species or designated critical habitat.		☒	
	b. Project is not likely to adversely affect a listed or proposed T&E species or designated critical habitat. *Informal Section 7 consultation is required. Attach consultation documentation, including concurrence from the Federal agency, to this form.*		☐	
	c. Project is likely to adversely affect a listed or proposed T&E species or designated critical habitat. *If yes, consult the FHWA Area Engineer (non-assigned projects) or Statewide NEPA Manager for 6004-assigned projects.*		☐	

8. Summarize the findings of the consultation, conferencing, biological evaluation, or biological assessment and the opinion of the agency with jurisdiction, or state why no coordination was conducted. *Include any commitments or mitigative measures in Section VI.*

The USFWS and ADF&G threatened and endangered species lists identify the Kittlitz's Murrelet (*Brachyramphus brevirostris*), a candidate species, with ranges that include the proposed project corridor. The Kittlitz's Murrelet is typically found in coastal marine waters during the summer months. Because the proposed project is located approximately 15-miles from the nearest coastal area it is unlikely that this species would be encountered in the proposed project area. Additionally, the preferred summer nesting habitat for Murrelet is steep unvegetated mountainsides or slopes above timberline near glaciers and cirques, which are not present near the proposed project. Although possible, it is unlikely this species would be encountered within the project area. Adverse impacts to this species are not anticipated.

J. Invasive Species

		N/A	YES	NO
1.	Database name(s) and date(s) queried: Early Detection and Distribution (EDD) Mapping System of Invasive Species in Alaska and Alaska Exotic Plants Information Clearinghouse on June 12, 2013			
2.	Does the project include all practicable measures to minimize the introduction or spread invasive species, making the project consistent with E.O. 13112 (Invasive Species)? *If yes, list measures in J.3.*		☒	☐

3. Summarize invasive species impacts and minimization measures, if any. *Include any commitments or mitigative measures in Section VI.*

Multiple invasive plant species were identified in the vicinity of the proposed project area. The loss of native vegetation within the proposed project area during construction may allow for the introduction of new species or spread of these species. To minimize the risk of introducing or spreading invasive species, the DOT&PF will comply with all federal, state, and local laws and regulations regarding invasive species during construction of the proposed project. The area of ground disturbance will be kept to a minimum and certified weed-free seed will be used to re-establish native vegetation after construction.

K. Hazardous Waste	N/A	YES	NO
1. Database name(s) and date(s) queried: ADEC Contaminated Sites Mapper, 7/20/2013			
2. There are potentially contaminated sites within or adjacent to the existing and/or proposed ROW.		☐	☒
3. There are identified contaminated sites within or adjacent to the existing and/or proposed ROW.		☐	☒
4. Extensive excavation is proposed adjacent to, or within, a known hazardous waste site, or the potential for encountering hazardous waste during construction is high. *If yes, attach the hazardous waste investigation report and approved ADEC Corrective Action Plan.*		☐*	☒

5. Summarize the hazardous waste impacts and mitigation, if any. *Include any commitments or mitigative measures in Section VI.*
No contaminated releases, spills, or leaking underground storage tanks are located near the proposed project area. Refer to Section VI for protocol if any contaminated sites or hazardous materials are found during construction.

L. Air Quality (Conformity)	N/A	YES	NO
1. The project is located in an air quality maintenance area or nonattainment area (CO or PM-10 or PM-2.5). *If yes, indicate CO ☐ or PM-10 ☐ or PM-2.5 ☐, and complete the remainder of this section.*		☐	☒
2. The project is included in a conforming Long Range Transportation Plan (LRTP) and Transportation Improvement Program (TIP).	☒	☐	☐
a. List dates of FHWA/FTA conformity determination: ______			
3. The project is exempt from an air quality analysis per 40 CFR 93.126 (Table 2 and Exempt Projects). *If no, a project-level air quality conformity determination is required for CO nonattainment and maintenance areas, and a qualitative project-level analysis is required for both PM-2.5 and PM-10 nonattainment and maintenance areas.*	☒	☐	☐
4. Have there been a significant change in the scope or the design concept as described in the most recent conforming TIP and LRTP? *If yes, describe changes in L.8. In addition, the project must satisfy the conformity rule's requirements for projects not from a plan and TIP, or the plan and TIP must be modified to incorporate the revised project (including a new conformity analysis).*	☒	☐	☐
5. A CO project-level analysis was completed meeting the requirements of Section 93.123 of the conformity rule. The results satisfy the requirements of Section 93.116(a) for all areas or 93.116(b) for nonattainment areas. *Attach a copy of the analysis.*	☒	☐*	☐
6. A PM-2.5 project-level air quality analysis was completed meeting the requirements of Section 93.123 of the conformity rule. The results satisfy the requirements of Section 93.116. *Attach a copy of the analysis.*	☒	☐*	☐

L.	**<u>Air Quality (Conformity)</u>**	N/A	YES	NO
7.	A PM-10 project-level air quality analysis was completed meeting the requirements of Section 93.123 of the conformity rule. The results satisfy the requirements of Section 93.116. *Attach a copy of the analysis.*	☒	☐*	☐

8. Summarize air quality impacts, mitigation, and agency coordination, if any. *Include any commitments or mitigative measures in Section VI.*

A review of the U.S. Environmental Protection Agency Non-attainment Areas for Criteria Pollutants in Alaska on June 10, 2013, indicated that the proposed project is not within a non-attainment or maintenance area. The proposed project would not result in a permanent change in traffic patterns, volume, or any other factor that would cause a substantial change or increase in emissions along the project corridor. No adverse impacts to air quality are expected to occur as a result of the proposed project. Refer to Section III, Part P for discussion of construction related air quality impacts and Section VI for air quality environmental commitments and mitigation measures.

M.	**<u>Floodplain Impacts (23 CFR 650, Subpart A)</u>**	N/A	YES	NO
1.	Project encroaches into the base (100 year) flood plain in fresh or marine waters. Identify floodplain map source and date : <u>Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) 020012 2525A (effective May 1981), Reviewed 2/21/2012</u>		☐*	☒

If yes, attach documentation of public involvement conducted per E.O. 11988 and 23 CFR 650.109. Consult with the regional or Statewide Hydraulics/Hydrology expert. Attach the required location hydraulic study developed per 23 CFR 650.111. Answer questions M.1.a through d.

If no, skip to M.2.

		N/A	YES	NO
a.	Is there a longitudinal encroachment into the 100-year floodplain?	☒	☐*	☐
b.	Is there significant encroachment as defined by 23 CFR 650.105(q)? *If yes, the project cannot be approved as proposed without a finding that the proposed action is the "Only Practicable Alternative" as defined in 23 CFR 650.113. Attach the finding for approval.*	☒	☐*	☐
c.	Project encroaches into a regulatory floodway.	☒	☐*	☐
d.	The proposed action would increase the base flood elevation one-foot or greater.	☒	☐*	☐
2.	Project conforms to local flood hazard requirements.	☐	☒	☐
3.	Project is consistent with E.O. 11988 (Floodplain Protection). *If no, the project cannot be approved as proposed.*		☒	☐

4. Summarize floodplain impacts and mitigation, if any. *Include any commitments or mitigative measures in Section VI.*

According to the Federal Emergency Management Agency (FEMA), Flood Insurance Rate Map, the proposed project area is in Zone C, which has minimal flooding and Zone D, areas that have possible, but undetermined flood hazards. There are no regulatory floodplains or floodways within the proposed project area. Adverse impacts to floodplains are not anticipated.

	N/A	YES	NO
N. <u>Noise Impacts (23 CFR 772)</u>			
1. Does the project involve any of the following? *If yes, complete N.1.a. If no, a noise analysis is not required. Skip to section O.*		☐	☒

- Construction of highway on a new location.
- Substantial alteration in vertical or horizontal alignment as defined in 23 CFR 772.5.
- An increase in the number of through lanes.
- Addition of an auxiliary lane (except a turn lane).
- Addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange.
- Restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane.
- Addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot or toll plaza.

a. Identify below which category of land uses are adjacent: *A noise analysis is required if any lands in Categories A through E are identified, and the response to N.1 is 'yes'.*

	N/A	YES	NO
Category A: Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.	☒	☐	☐
Category B: Residential. *This includes undeveloped lands permitted for this category.*	☒	☐	☐
Category C (exterior): Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, daycare centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings. *This includes undeveloped lands permitted for this category.*	☒	☐	☐
Category D (interior): Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.	☒	☐	☐
Category E: Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not listed above. *This includes undeveloped lands permitted for this category.*	☒	☐	☐
2. Does the noise analysis identify a noise impact? *If yes, explain in N.3*		☐	☐

3. Summarize the findings of the attached noise analysis and noise abatement worksheet, if applicable:
The proposed project would not result in permanent change in traffic patterns, volume, or any other factor that would cause a substantial change or increase in noise along the project corridor. Horizontal alteration of the roadway will occur near MP 19.5, but is not considered substantial as defined by 23 CFR 227.5. As such, a traffic noise analysis is not required. Permanent noise impacts associated with the proposed project are not expected to occur. Temporary noise impacts could occur from blasting and other construction related activities. Refer to Section III, Part P for discussion of construction related noise impacts and Section VI for noise related environmental commitments and mitigation measures.

O. Water Quality Impacts

	N/A	YES	NO
1. Project would involve a public or private drinking water source. *If yes, explain in O.7*		☐	☒
2. Project would result in a discharge of storm water to a Water of the U.S. (per 40 CFR 230.3(s))		☒	☐
3. Project would discharge storm water into or affect an ADEC designated Impaired Waterbody. *If any of the Impaired Waterbodies have an approved or established Total Maximum Daily Load, describe project impacts in O.7*		☐	☒

a. List name(s), location(s), and pollutant(s) causing impairment:

______

4. Estimate the acreage of ground-disturbing activities that will result from the project? 75 acres

	N/A	YES	NO
5. Is there a municipal separate storm sewer system (MS4) APDES permit, or will runoff be mixed with discharges from an APDES permitted industrial facility?		☐	☒

a. If yes, list APDES permit number and type: N/A

	N/A	YES	NO
6. Would the project discharge storm water to a water body within a national park or state park; a national or state wildlife refuge? *If yes and Alaska Construction General Permit applies to the project, consultation with ADEC is required at least 30 days prior to planned start of construction activities.*		☐	☒

7. Summarize the water quality impacts and mitigation, if any. *Include any commitments or mitigative measures in Section VI.*

Storm water within the proposed project area sheet flows off the roadway and infiltrates into adjacent ground via roadside ditches and vegetation. Potential receiving water bodies include Snow River, Kenai Lake, Rocky Creek, Victor Creek, and several unnamed drainages. None of these water bodies are within a national or state park or wildlife refuge. None of the receiving water bodies are designated by ADEC as impaired and there are no MS4 facilities in the area.

The project proposes to widen the highway throughout the project corridor, increasing the amount of impervious surfaces. Increasing impervious surfaces could result in more storm water flowing off the roadway which in turn, could result in less water infiltrating adjacent ground, flowing instead into receiving water bodies. To prevent increased storm water reaching water bodies, the proposed project would improve storm water drainage facilities to accommodate the possible increase in storm water runoff. Drainage patterns in the proposed project area will not be altered. No long-term adverse impacts to water quality are expected to occur as a result of the proposed project. Refer to Section III, Part P for discussion of construction related water quality impacts.

P. Construction Impacts

	N/A	YES	NO
1. There will be temporary degradation of water quality.		☒	☐
2. There will be a temporary stream diversion.		☒	☐
3. There will be temporary degradation of air quality.		☒	☐
4. There will be temporary delays and detours of traffic.		☒	☐
5. There will be temporary impacts on businesses.		☒	☐
6. There will be temporary noise impacts.		☒	☐
7. There will be other construction impacts.		☐	☒

8. Summarize construction impacts and mitigation for each 'yes' above. *Include any commitments or mitigative measures in Section VI.*

Water Quality
Water quality degradation during construction may result from ground disturbance and sedimentation of storm water runoff. These impacts will be minimized through the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP) and use of Best Management Practices.

Air quality
The operation of construction equipment may lead to a temporary decrease in air quality because of increased airborne dust and emission-related particulate matter. Air quality impacts would be temporary and could be abated through watering disturbed surface areas and ensuring that construction equipment receives regular maintenance.

Traffic Impacts
Temporary traffic impacts may include delays or detours for road users. These impacts will be mitigated by providing advance notice to the public and creation of a traffic control plan.

Business Impacts
Businesses may be impacted by commercial and tourism traffic delays, however these impacts would be temporary and access would be maintained throughout construction.

Noise Impacts
Temporary noise impacts will result from the operation of heavy equipment, the presence of construction crews, and other associated construction activities. The proposed project is not anticipated to result in any permanent noise impacts. Noise from construction equipment can be minimized by maintaining their noise control devices.

Q. Section 4(f)/6(f)

	N/A	YES	NO
1. Section 4(f) (23 CFR 774)			
a. Does a Section 4(f) resource exist within the project area; or is the project adjacent to a Section 4(f) resource? *If yes, attach consultation with the Statewide NEPA Manager (assigned CEs) or FHWA Environmental Program Manager (non-assigned CEs) to determine applicability of Section 4(f)*		☒	☐
b. Does an exception listed in 23 CFR 774.13 apply to this project? *If yes, attach consultation with the Statewide NEPA Manager (assigned CEs) or FHWA Environmental Program Manager (non-assigned CEs), and documentation from the official with jurisdiction, if required.*	☐	☐	☒
c. Does the project result in the "use" of a Section 4(f) property? *"Use" includes a permanent incorporation of land, adverse temporary occupancy, or constructive use.*	☐	☒	☐
d. Has a *de minimis* impact finding been prepared for the project? *If yes, attach the finding.*	☐	☒	☐
e. Has a Programmatic Section 4(f) Evaluation been prepared for the project? *If yes, attach the evaluation.*	☐	☐	☒

Q. Section 4(f)/6(f)	N/A	YES	NO
f. Does the project require an Individual Section 4(f) Evaluation? *If yes, the project is not assigned to the State per the 6004 MOU and the CE must be processed by FHWA. Attach the evaluation.*	☐	☐	☒
2. Section 6(f) (36 CFR 59)			
a. Were funds from the Land and Water Conservation Fund Act (LWCFA) used for improvement to a property that will be affected by this project?	☐	☐	☒
b. Is the use of the property receiving LWCFA funds a "conversion of use" per Section 6(f) of the LWCFA? *Attach the correspondence received from the ADNR 6(f) Grants Administrator.*	☐	☐	☒

3. Summarize Section 4(f)/6(f) involvement, if any:
The proposed project would result in the temporary use of the Victor Creek Trail and Victor Creek Trailhead. FHWA determined the project will have *de minimis* impacts on each property and the officials with jurisdiction over each property have concurred in writing that the project will not adversely affect the activities, features and attributes that qualify the properties for protection under Section 4(f) (Appendix C).

IV. Permits and Authorizations	N/A	YES	NO
1. USACE, Section 404/10 *Includes Abbreviated Permit Process, Nationwide Permit, and General Permit*		☒	☐
2. Coast Guard, Section 9		☐	☒
3. ADF&G Fish Habitat Permit (Title 16.05.871 and Title 16.05.841)		☐	☒
4. Flood Hazard		☐	☒
5. ADEC Non-domestic Wastewater Plan Approval		☐	☐
6. ADEC 401		☒	☐
7. ADEC APDES		☒	☐
8. Noise		☐	☒
9. Eagle Permit		☐	☒
10. Other. *If yes, list below.*		☐	☒

V. Comments and Coordination	N/A	YES	NO
1. Public/agency involvement for project. *Required if protected resources are involved.*		☒	☐
2. Public Meetings. Date(s): N/A		☐	☒
3. Newspaper ads. *Attach certified affidavit of publication as an appendix.* Name of newspaper and date: Seward Phoenix and Peninsula Clarion 05/24/2013		☒	☐
4. Agency scoping letters. Date sent: May 15, 2012		☒	☐
5. Agency scoping meeting. Date of meeting: _____		☐	☒
6. Field review. Date: _____		☐	☒

7. Summarize comments and coordination efforts for this project. Discuss pertinent issues raised. *Attach correspondence that demonstrates coordination and that there are no unresolved issues.*

Consultation Efforts

On May 15, 2012, consultation was initiated with the following parties: U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, National Marine Fisheries Service, U.S. Environmental Protection Agency, U.S. Forest Service, U.S. Coast Guard, Alaska Department of Fish and Game, Alaska Department of Environmental Conservation, Alaska Department of Natural Resources, Alaska Railroad Corporation, Kenai Peninsula Borough, City of Seward, Chugach Alaska Corporation, Chugachmiut, and Qutekcak Native Tribe. Additional consultation was initiated with the U.S. Forest Service, Kenai Peninsula Borough; Chugach Alaska Corporation, Chugachmiut, and Qutekcak Native Tribe on December 4, 2012.

The proposed Victor Creek trailhead relocation was designed in consultation with recreation staff from the Chugach National Forest (CNF). On August 9th, 2012, DOT&PF met with CNF to discuss impacts to Victor Creek Trailhead and possible solutions for mitigation. The concept of relocating the trailhead to USFS lands was agreed to by all attendees at this meeting and design details determined in several subsequent discussions. All final design work for the new trailhead and access trail will be conducted in cooperation with CNF.

Coordination with the Public

A notice of intent to begin environmental and engineering studies was published in the *Peninsula Clarion* and *Seward Phoenix Log* on May 24, 2012, and posted on the State of Alaska public notice website (see Public Coordination Documentation). Several comments were received from residents in the project area. Pertinent issues raised include concern regarding the accident mitigation realignment south of Victor Creek; concern that increased noise levels may occur due to added passing lanes; concern that too many trees will be removed; and concern that realignment will damage a historic garage. The project manager has responded to these concerns and will continue to coordinate with the public and concerned residents throughout the design process.

A public notice for the proposed *de minimis* impact finding (see Section Q) was written in consultation with recreation staff from the CNF and published in the Anchorage Daily News and Seward Phoenix Log and posted on the State of Alaska public notice website (see Public Coordination Documentation) on March 21, 2013. No comments were received.

VI. Environmental Commitments and Mitigation Measures

List all environmental commitments and mitigation measures included in the project.

- If cultural, archaeological, or historical sites are discovered during construction, then all work that may impact these sites would stop. The SHPO would be consulted for guidance on how to proceed.
- If active Bald or Golden Eagle nests are found within 660 feet of the project area (primary and secondary protection zones), then construction activities would stop and the USFWS would be consulted for guidance on how to proceed.
- If contaminated or hazardous materials are encountered during construction, all work in the vicinity of the contaminated site would be stopped and ADEC would be consulted for guidance on how to proceed.
- The Contractor would be required to create a traffic control plan and provide advance notice to

the public of construction activities that will cause delays, require detours or affect access to adjacent properties.

- The Contractor would be required to prepare and implement a SWPPP in accordance with DOT&PF's contract specifications and the APDES Construction General Permit for storm water discharge in Alaska.
- The Contractor would be responsible for obtaining all necessary permits and clearances for material and disposal sites, and borrow or equipment storage areas, including compliance with the APDES CGP for storm water discharge.
- Vegetation clearing will follow the USFWS Recommended Time Periods for Avoiding Vegetation Clearing in Alaska in order to protect Migratory Birds unless the USFWS has been consulted to determine the most appropriate method to avoid impacts to nesting birds.
- Air quality BMP's such as watering, sweeping, maintaining construction exits, and equipment emission control devices would be used to maintain air quality.

VII. Environmental Documentation Approval

	N/A	YES	NO
1. Do any unusual circumstances exist, as described in 23 C.F.R. 771.117 (b)? *If yes, the CE Documentation form cannot be approved.*		☐	☒
2. Does this 6004 Program approval statement apply? "The State has determined that this project has no significant impact(s) on the environment and that there are no unusual circumstances as described in 23 CFR 771.117(b). As such, the project is categorically excluded from the requirements to prepare an environmental assessment or environmental impact statement under the National Environmental Policy Act. The State has been assigned, and hereby certifies that it has carried out, the responsibility to make this determination pursuant to Chapter 3 of title 23, United States Code, Section 326 and a Memorandum of Understanding dated September 20, 2012, executed between the FHWA and the State." *If no, the CE must be approved by FHWA.*		☐	☒
3. **For 6004 projects:** The project meets the criteria of the DOT&PF Programmatic Approval 2 authorized in the November 6, 2012 "CE Directive – Delegation of Approval Authority for Certain CEs under 6004 MOU". *If* yes, *the CE may be approved by the Regional Environmental. If no, the CE may be approved by a Statewide NEPA Manager.*	☒	☐	☐
4. **For non-assigned projects:** The project meets the criteria of the April 13, 2012 "Programmatic Categorical Exclusion for Use on Federal-Aid Highway Projects in Alaska" between FHWA and DOT&PF. *If yes, the CE may be approved by the Regional Environmental Manager. If no, the CE may be approved by FHWA Area Engineer.*	☐	☐	☒

VIII. Environmental Documentation Approval Signatures

Prepared by: ___[signature]___ Date: 9/5/13
[Sign] Environmental Impact Analyst

Elysia Retzlaff
[Print Name] Environmental Impact Analyst

Reviewed by: ___[signature]___ Date: 9/5/13
[Sign] Engineering Manager

SEAN BASKE
[Print Name] Engineering Manager

Approved by: Brian Elliott Date: 9/5/13
[Sign] Regional Environmental Manager

Brian Elliott
[Print Name] Regional Environmental Manager

Assigned CE
Approved by: ______________________ Date: ______
[Sign] DOT&PF Statewide NEPA Manager

____
[Print Name] DOT&PF Statewide NEPA Manager

Non-Assigned CE
Approved by: John Lohrey Date: 9/19/2013
[Sign] FHWA Area Engineer

John Lohrey
[Print Name] FHWA Area Engineer

APPENDIX D
3R ANALYSIS SUMMARY

MEMORANDUM

State of Alaska

Department of Transportation & Public Facilities
Design & Engineering Services
Highway Design Section

To: John Linnell, P.E.
Design Manager

Date: April 14th, 2011
Telephone No: 907-269-0565

Thru: Sean Baski, P.E.
Design Squad Leader

Subject: Seward Highway,
MP 18-25.5
3R Evaluation
53919
Summary of Report and Findings

From: Anna Bosin, P.E.
Designer

A 3R analysis of the subject project was performed using collision data from 1998 to 2007. This report includes the findings as outlined in Section 1160 of the Highway Preconstruction Manual (PCM). In addition, supporting documents used during the study are included in the appendices of the report.
A summary of the findings is as follows:

Lane and Shoulder Width
The existing lane width is 12' with 2' wide paved shoulders for a total paved top width of 28' for the entire project length. The actual collision rate is less than the predicted collision rate for the project length. Therefore, no changes to the lane and shoulder width are required to meet 3R analysis requirements.

Horizontal Curves
The existing horizontal alignment was examined for conformance with the current standards for a 55 MPH design speed. Curve #7 at STA 183+50 does not conform to current design standards. A cost analysis was conducted based on the collision data for this specific curve. The collision costs exceed the estimated project costs (costs to reconstruct the curve to current design standards), therefore the curve should be corrected.

Vertical Curves
The existing vertical alignment was examined for conformance with the current design standards for a 55 MPH design speed. Curve #11 (crest) at STA 271+40 was found not to conform to current design standards for stopping sight distance and the actual number of collisions exceeded the predicted number of collisions. A cost analysis was performed to compare collision costs to the estimated construction costs to reconstruct

curve 11 to current design standards. The collision costs did not meet the estimated construction costs, so the curve shall remain unchanged.

Although there is no defined 3R analysis for sag curves, an unusually high collection of collisions occurred at curve # 5 at station 173+00. This curve needs further review beyond the scope of the 3R analysis.

Bridges
Four bridges exist within the project limits. All four are longer than 100 FT and therefore are not included in 3R analysis. However, Ptarmigan Creek, Falls Creek, and Trail River Bridges are already slated for replacement under separate projects. The fourth bridge, Victor Creek, shall remain unchanged.

Side Slopes and Clear Zones
The same analysis is used under this section as used in Lane and Shoulder Analysis. No changes are required.

Pavement Edge Drops
The current project length has 2' wide paved shoulders. Field inspection revealed that there are minimal pavement edge drops. If repaved, shoulders will be regraded to remove any pavement edge drops.

Intersections
No collision anomalies at intersections occurred within the study period. In addition, none of the intersections are located within substandard curves; therefore the intersection geometry may remain.

Driveways
One driveway located at STA 184+50 is within substandard horizontal curve #7 and has a high occurrence of collisions. This driveway geometry should be evaluated when the curve is upgraded to meet 55MPH design speed which should also improve the stopping sight distance. No additional driveway anomalies were noted within the project limits.

Passing Sight Distance
Improvements of passing distances are not required within the context of 3R analysis.

Grades
All grades within the project limits meet AASHTO guidelines for rolling terrain.

Safety Mitigation
It is recommended that clearing to the ROW limits as well as ditch establishment in glaciating areas is added to the project scope where feasible. Additional field investigation is required to further define actual locations within the project area.

Moose-Vehicle Collisions

Although the PCM 3R analysis does not require evaluation of moose related collisions, a mile point breakdown of moose collisions was analyzed. The threshold for moose-vehicle collisions, as identified in the1995 Report *Moose-Vehicle Accidents on Alaska Roads,* was not met and therefore does not indicate any high level of moose collisions within the project limit.

If you have any questions, you may contact me at 269-0585.

The full Seward Highway MP 18-25.5 3R Report can be found with the project files.

APPENDIX E
AVALANCHE HAZARD ANALYSIS REPORT

AVALANCHE HAZARD ANALYSIS, SEWARD HIGHWAY

MP 18 – 23 (SNOW RIVER TO CROWN POINT)

Prepared For

Mr. John Dickenson
Alaska Department of Transportation & Public Facilities

Prepared By,

Arthur I. Mears, P.E., Inc.
Gunnison, Colorado
December, 2000

ARTHUR I. MEARS, P.E., INC.
Natural Hazards Consultants
555 County Road 16
Gunnison, Colorado 81230
Tel/Fax: 970-641-3236
artmears@rmii.com

December 19, 2000

Mr. John E. Dickenson, P.E.
Project Manager
Alaska Department of Transportation
and Public Facilities
P.O. Box 196900
Anchorage, AK 99516-6900

Dear Mr. Dickerson:

As we discussed last month, I have completed the attached report on snow avalanche hazard analysis and mitigation on the Snow River to Crown Point portion of the Seward Highway.

I enjoyed working with you and the staff on this project. Please contact me if you have any questions.

Sincerely,

Arthur I. Mears

Arthur I. Mears, P.E. (CO)
Avalanche-control engineer

Encl.

1 REPORT SUMMARY

The objective of this report is to quantify the snow avalanche hazard from stations 28+700 to 36+500 (approx. mileposts 18 – 22.8) of the Seward Highway and to provide mitigation recommendations where they are justified. The recently proposed reconstruction of the highway was considered in analysis.

The avalanche hazard was quantified by computation of the Avalanche-Hazard Index (AHI), a standard procedure that has been used throughout many mountain highways in Western North America. Avalanche frequency, depth and length of highway covered, potential consequences that would result as a result of impact, and winter average traffic volume are used to compute the AHI. The index thus obtained can be used to compare various highways and portions of highways with each other and, similarly can be used to compare relative hazard in individual avalanche paths. The AHI for this portion of highway is 18.1 which categorizes it as a "moderate hazard" highway with respect to avalanche hazard. For comparison, the Bird Flats portion of the Seward Highway has an AHI of 60, which ranks as a "high hazard."

The "Horse Pasture" avalanche (stations 33+380 to 33+580) has an AHI = 11.3 and thus accounts for approximately about 62% of the hazard on this portion of the highway. Two other avalanche paths (Andy Simons Face, stations 35+720 to 35+780) [AHI=2.15] and SP 7, stations 28+800 to 29+300 [AHI = 2.33]) are the next largest hazards. Six other relatively infrequent avalanches have a total AHI = 2.3.

Construction of a catching dam 10m (33 feet) high, with the height measured on the upslope face, can be built in the lower runout zone of the Horse Pasture. This dam would be 200m (660 feet long) and would have a volume of 42,000-45,000 m^3 (55,000-60,000 yd^3). This catching dam would not stop the larger-volume or fast-moving avalanches in the Horse Pasture, but would stop small-to-medium sized avalanches and reduce the hazard in this path by approximately 70% (a hazard-reduction factor of 0.3). Because the Horse Pasture by itself is a relatively dangerous avalanche we recommend this structure be built.

An avalanche shed is technically feasible for the Andy Simons Face but is nor justified because of the low AHI (2.15) and very high expense of a shed (roughly 3 – 4 million dollars). Avalanche path SP 7 can affect nearly 500m of the new alignment but since this alignment is to be on fill, which, according to plans will be 4m high at 28+800 (farthest from the avalanche) and 9m high at 29+300 (closest to the avalanche). Because only relatively unusual avalanches will affect the highway at this location, special mitigation in addition to the fill is not recommended.

The DOT&PF should continue to use and improve their avalanche forecasting and explosive control (AFEC) program on this portion of the highway. They should incorporate as much high-elevation (>700m) weather data as possible.

2 OBJECTIVES AND LIMITATIONS

As outlined in agreement number P12036 and my proposal which is attached to that agreement, this analysis and report have the following objectives:

a. Study of avalanche history in the milepost 18 to 23 area;
b. Application of runout-distance models to determine velocities, frequencies[1], and effects at the proposed alignment;
c. Quantification of avalanche hazard through computation of the avalanche-hazard index (AHI);
d. Comparison of the hazard to that on other highways; and
e. Discussion of avalanche mitigation.

This report also has the following limitations which must be understood by all those relying on the results and recommendations:

a. The mitigation discussed for the mp21 ("Horse Pasture") avalanche at station 33+500 will not prevent all avalanches from impacting the proposed highway; it is intended only to reduce the risk;
b. Structural avalanche mitigation techniques will reduce the overall risk but must be combined with an avalanche forecasting and explosive control (AFEC) program.

3 AVALANCHE TERRAIN, FREQUENCY AND DYNAMICS

3.1 Avalanche Terrain and Frequency

Several relatively large avalanches affect the study area and are shown schematically on Figure 3-1. In the northern section, paths "1" through "4B" begin on steep terrain on the west face of Andy Simons Mountain. Two of these paths (#2 or Andy Simons Face, and #4A or Horse Pasture) affect the highway at return periods of roughly 3 to 10 years, blocking it with deep snow. In the southern portion of the study area avalanches fall from the west face of Sheep Mountain. Paths 6 and 7 are known to have reached the highway (path 6 as recently as February, 2000), but have longer return periods.

The frequency data have been taken from DOT&PF records, discussion with maintenance personnel, previous study of this area by myself, and a report by the Alaska Mountain Safety Center (Fesler & Fredston, 1991). Avalanche path numbers and names used in this report are taken from this 1991 report.

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[1] We utilize an analysis of frequency/magnitude relationships in the Chugach Range (Hamre and McCarty [1996]), use of our database on extreme avalanche runouts in coastal Alaska, an updated avalanche-dynamics modeling procedure (Perla et. al., 1984, 2000), and a revised avalanche hazard indexing procedure (Schaerer, 1989).

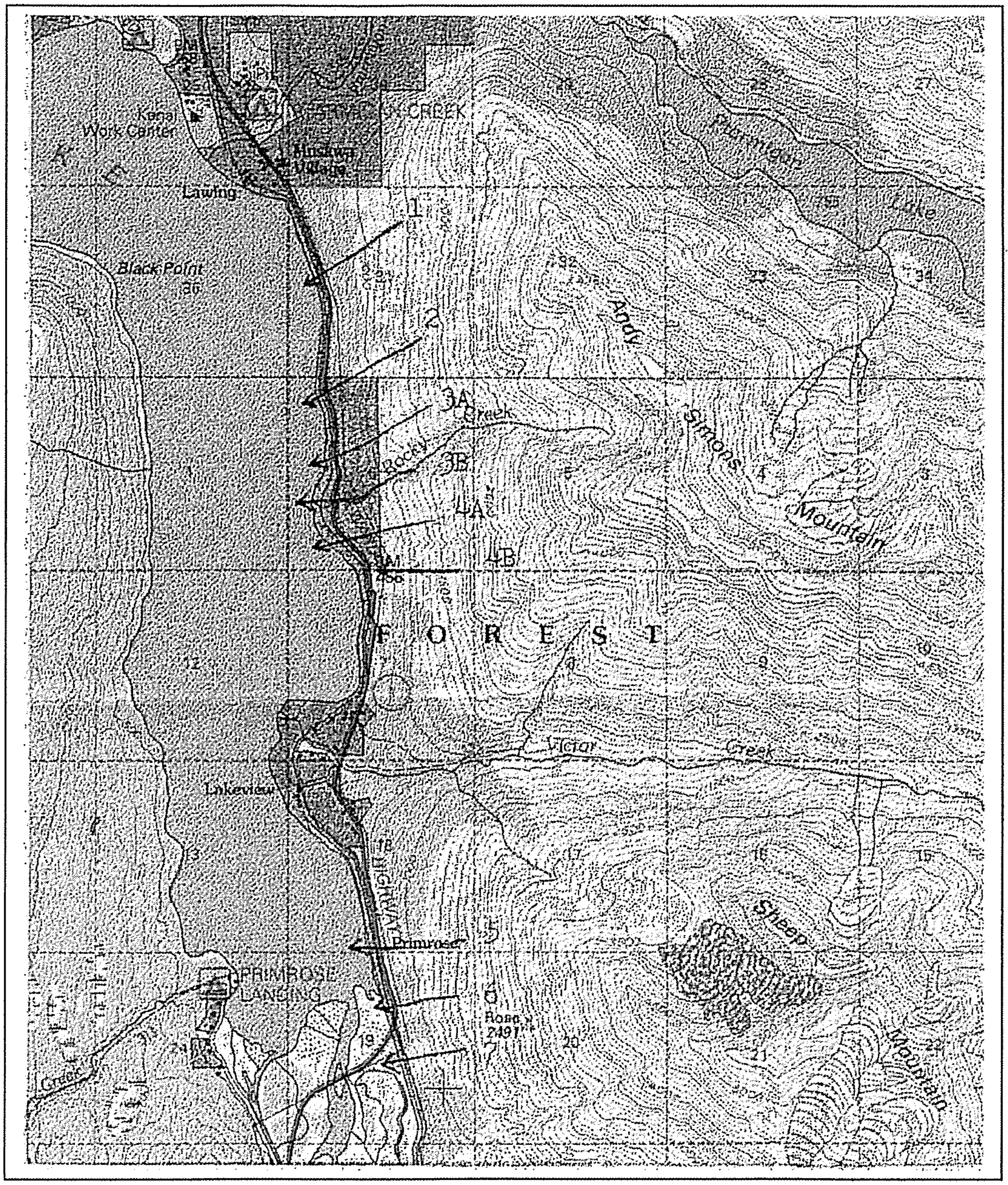

Figure 3-1. Overview of the milepost 18 (Snow River) to 23 (Crown Point) avalanche area.

The avalanche runout areas, where large avalanches decelerate, stop, and affect the highway, are shown in further detail on the aerial photos (Figures 3-2 to 3-4). The more frequent avalanche areas are clearly defined as downslope lineations through the forest. Some avalanches appear to stop before the highway is reached, but narrow "fingers" of snow extend through the forest to the highway, especially on the steeper terrain. Very rare and exceptionally large avalanches will also reach the highway after destroying the forest in some locations. These areas may not show field evidence of damage on the photos. Lòng-return-period events in forested paths will deposit deep vegetative and soil debris on the highway.

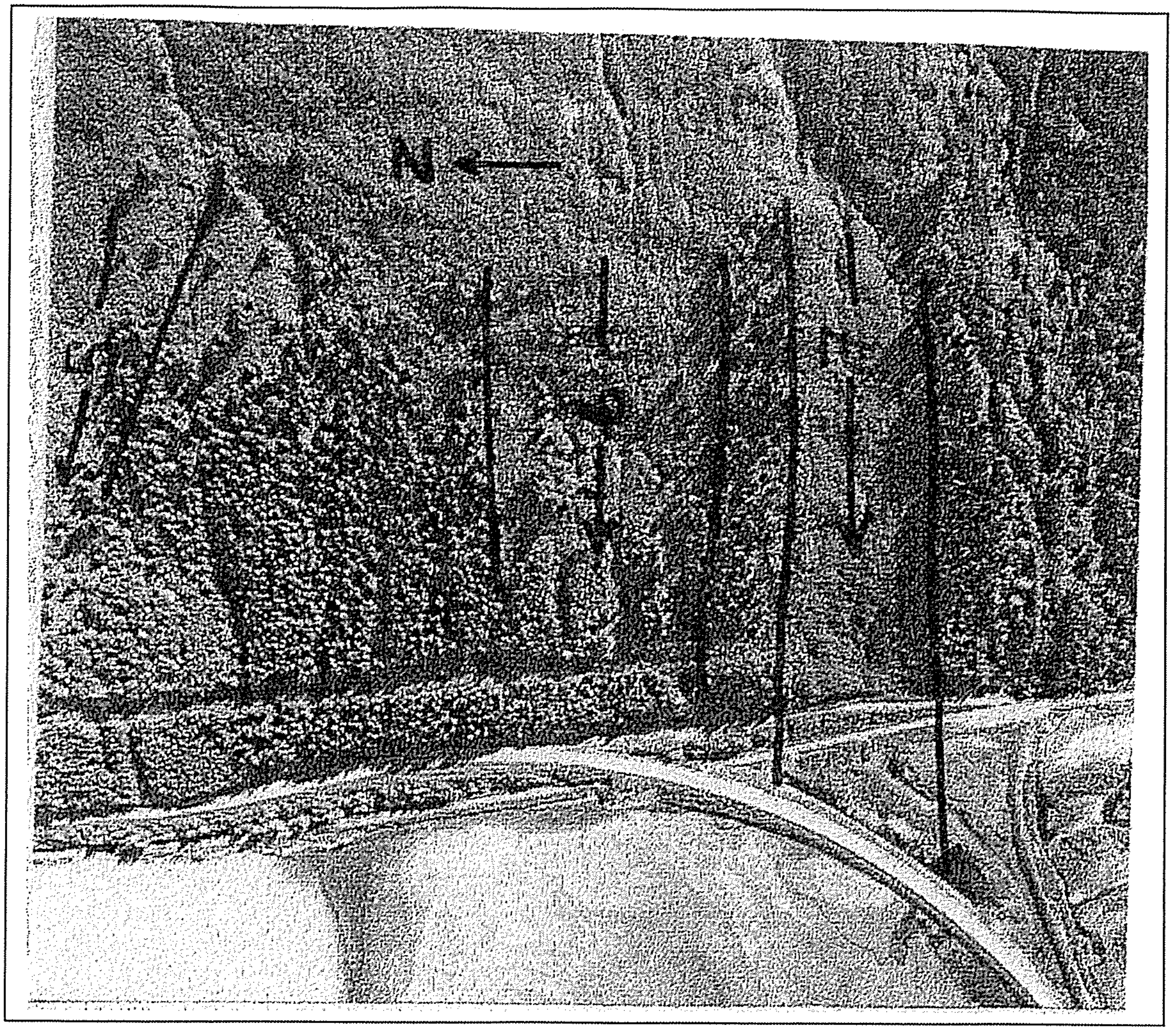

Figure 3-2. Avalanche paths affecting the existing highway at mileposts 18 – 19. The historical record indicates path 7 is the most frequent avalanche affecting the highway in this photo, however path 6 did reach the highway in February, 2000, blocking it with deep snow (see Appendix A).

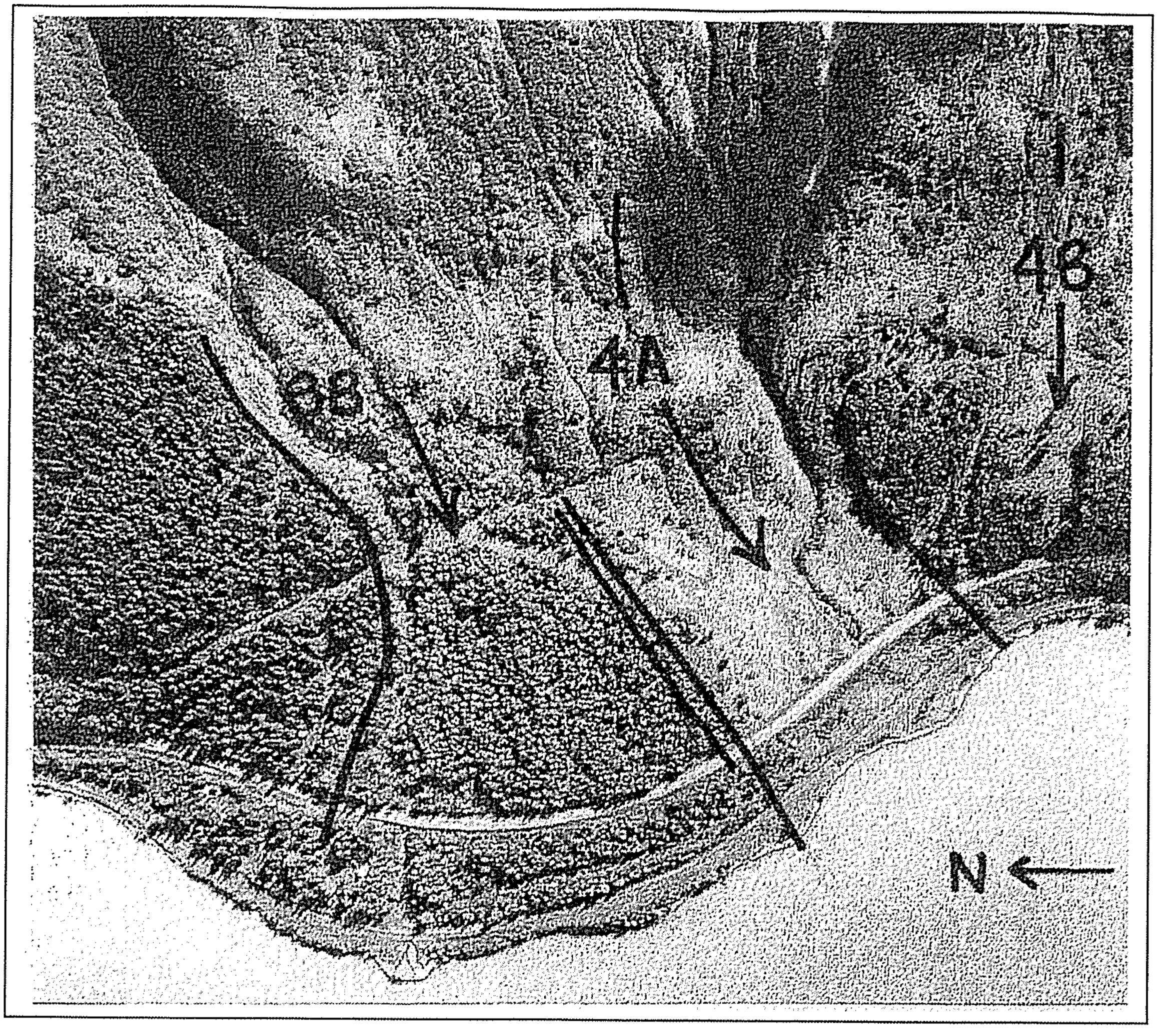

Figure 3-3. Avalanche paths in the mp 20.5 to 21.5 (Horse Pasture) area. Path 4A (Horse Pasture) is the most frequent avalanche in the study area, covering the highway with deep snow at average intervals of less than 5 years. The last major avalanche occurred in February, 2000 (see Appendix A). The lower runout of Path 4A is shown on the detailed topographic map in Section 5. Path 3B is confined to a narrow gully and can release large volumes of snow from a large basin high on the west side of Andy Simons Mountain. Large and rare events (return periods of approximately 100 years) can also spread across the northern part of the alluvial fan. The uniform and medium sizes of trees in the runout zone indicates this has occurred, but is not a frequent event.

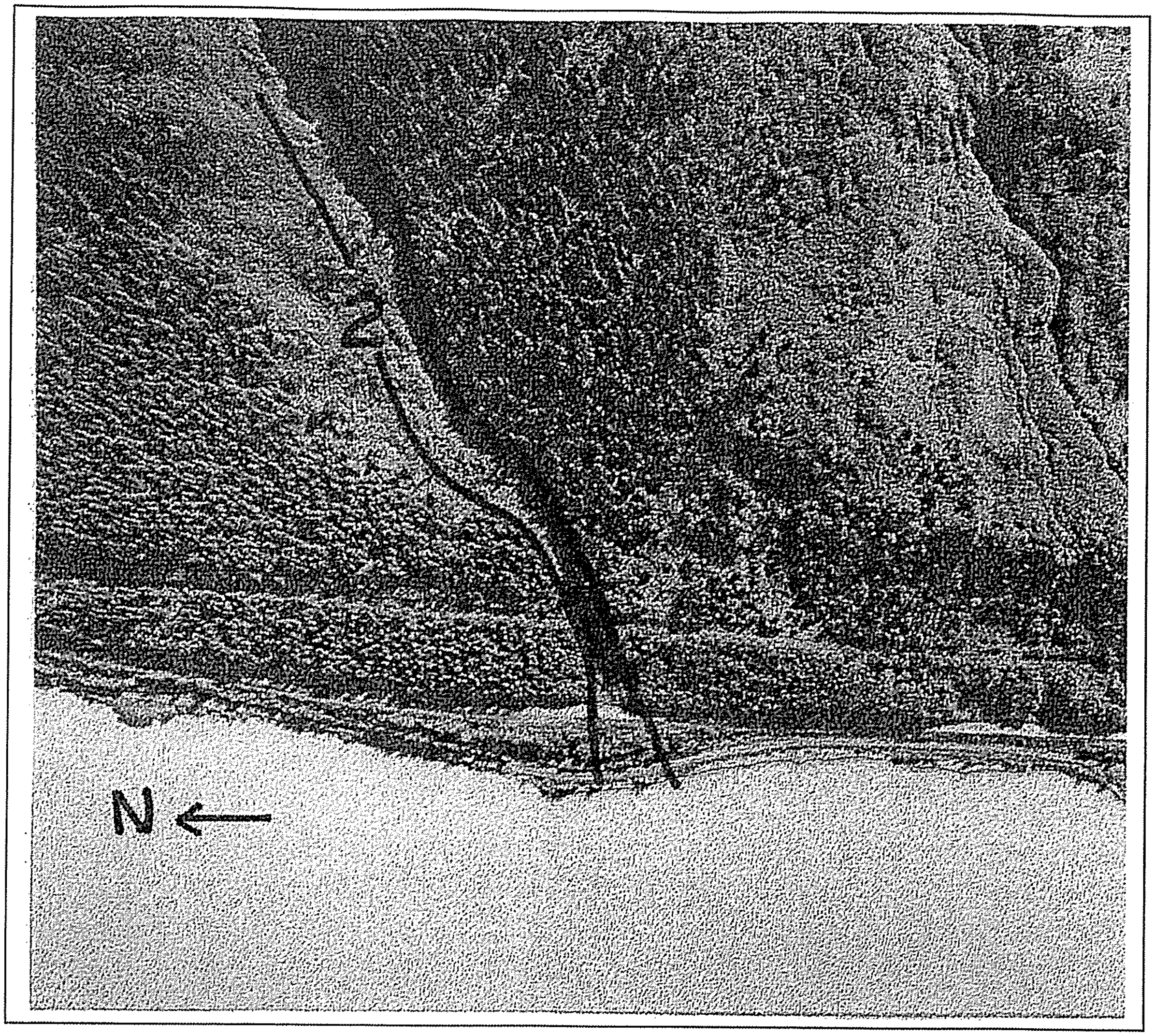

Figure 3-4. Avalanche path "2," the "Andy Simons Face," discharges down a deeply-encised gully and can block the approximately 60m (200 feet) of road with deep snow (see Appendix A). The last major avalanche in this path occurred in February, 2000.

Although Figures 3-2 through 3-4 are a good indication of the locations of typically large avalanches (return periods of 5-20 years), major events with return periods of approximately 100 years will exceed the boundaries indicated and run out into Kenai Lake at locations where this has not occurred historically. Major events in some large paths, such as path 4A (Horse Pasture) may travel 200 – 300m (650 – 1000 feet) into the lake. These rare, very large avalanches are not significant hazards to highway travel because of small probability of encounter with vehicles.

3.2 Avalanche Dynamics

Avalanche dynamics (including computation of velocities, velocity distributions, kinetic-energy density, flow thickness, and debris distribution) have been computed for the Horse Pasture (Path 4A), Andy Simons Face (Path 2), and SP 7 (at mile 18.3). Raw computer output from the avalanche-dynamics analysis has been provided in Appendix B.

The avalanche-dynamics analysis was conducted to:

- Compute the debris distribution for avalanches with return periods of approximately 10 years;
- Compute the avalanche velocity distributions; and
- Assess the feasibility of building avalanche defenses.

The procedures used for conducting the analysis were:

- Runout distances (positions of extreme distal margins of the avalanche debris) were computed by application of a statistical runout distance model which was derived from data on existing extreme avalanche runout in coastal Alaska;
- Runout distances for avalanches with return periods of 5-10 years (approximately) were determined from the historical record and from application of the methods of Hamre and McCarty (1996);
- Velocities, flow thickness and debris distributions were computed through application of a stochastic, 3-component, avalanche-dynamics model (Perla, et. al., 1984, with revisions in 2000).

General results of the analysis are:

a. Major avalanches, with return periods of approximately 100 years in avalanche paths SP 2 (Andy Simons Face), SP 4A (Horse Pasture), and SP 7 would be capable of running 200 – 300m (650 – 1000 feet) across a level surface at the position of Kenai Lake (for example, if the Lake were frozen).
b. Although avalanches with return periods of approximately 10 years do not reach nearly as far onto the flats, they are capable, similar to the avalanches of February, 2000 of blocking the highway.
c. Construction of a catching berm at the Horse Pasture is feasible (Section 5) and could be used to catch most of the debris from avalanches with return periods of 5-10 years.
d. Avalanches with return periods of approximately 10 years in path 7 can be mitigated by building the highway on a berm 5m high.

4 THE AVALANCHE HAZARD INDEX

4.1 Introduction

The avalanche-hazard index (AHI) is a numerical expression representing damage and loss potential resulting from interactions between snow avalanches and vehicles on a road (Schaerer, 1989). The concept was first developed in Canada (Avalanche task force, 1974) and has been applied at various locations in North America, Canada, and New Zealand: Armstrong, (1981); Mears and Newcomb (1989); Mears and Alaska Mountain Safety Center (1992); Mears, (1995); Mears and Glude (1995). Overall, the AHI hazard evaluation method has been applied to approximately 30-40 sections of highways exposed to avalanches in the United States, including the Bird Flats area.

As defined by Schaerer (1989) avalanche hazard is the expected frequency of damage and loss as the result of an interaction between an avalanche and objects or persons. Calculation of the hazard contains two elements: (a) the frequency (or probability) of an encounter, and (b) the nature and magnitude of the resulting damage from avalanches.

4.2 Damage Potential and Weighting the Consequences

The severity of the potential damage in the Bird Flats area is used to define three idealized classes of avalanches as follows:

Light Snow. Light-snow avalanches deposit less than 1m (3 feet) of snow on a highway and can stop vehicles by blocking the highway. Vehicles usually will not be seriously damaged but may, as a result of the light snow avalanche, be stuck in the snow and exposed to additional avalanches. All of the avalanche paths in the study area can produce light snow avalanches. **Light snow avalanches are assigned a weighting factor of 3.**

Deep snow. Flowing avalanches of deep snow deposit snow and debris to a depth of more than 1m (3 feet), could bury and push vehicles off the road and could severely damage a vehicle or kill occupants. On Bird Flats depths exceeding 3-6m (10-20feet) are probable. Such avalanches will always be associated with the larger-volume releases along Bird Flats, and are expected to reach the proposed alignment at return periods ranging from 5 to 10 years in various avalanche paths. Depths exceeding 10-15m (30-50 feet) have occurred. **Deep snow avalanches are assigned a weighting factor of 10.**

Plunging Snow. Plunging snow avalanches fall onto a road a high speeds after descending steep terrain or can push vehicles off the road onto the railroad or into Turnagain Arm. As with the deep snow avalanches, the plunging snow events will be common occurrences at Bird Flats expected at return periods of 5 to 10 years. **Plunging avalanches are assigned a weighting factor of 12.**

4.3 Avalanche Frequency and Width

Avalanche frequency and width (length of highway covered) has been estimated for each path separately for powder/air blast, deep snow, and plunging snow. Frequency is expressed as the average number (or fraction thereof) of occurrences of a given type of avalanche in each path per year. A "10-year" return period has an annual frequency of 1/10 or 0.10. The average annual width for each type of avalanche in each path is also estimated. Both frequency and width in each path are determined by highway records, historical data, and field evidence.

4.4 Calculating the AHI

The AHI is calculated by multiplying the encounter probabilities of moving and waiting vehicles being hit by various types of avalanches by the appropriate weighting factor ("1," "10," or "12") discussed in Section 4.2. The encounter probability,. P is calculated

$$P + P_M + P_W, \text{ where} \qquad (1)$$

P_M is the probability of a moving vehicle being hit by an avalanche and P_W is the probability of a waiting vehicle being hit by a second avalanche in the same path or by adjacent avalanches. When traffic volume is relatively high as on the Seward Highway long traffic queues can quickly develop under avalanche paths after a first avalanche blocks the highway. The probability of a waiting vehicle being reached by all types of avalanches is more than three times as large as for a moving vehicle (Table 4-1). The moving vehicle encounter probability, P_M is calculated

$$P_M = f\,(N,L,D,T,V), \text{ where} \qquad (2)$$

N is the average winter traffic volume[2], L is the average roadway length covered by avalanches of a given severity class, D is vehicle stopping distance, T is the annual probability of avalanches of a given class, and V is average vehicle speed (45mph is assumed during storms); V controls D. The calculation in (2) is repeated for each path and each class of avalanche in that path. The waiting encounter probability, P_W, is calculated

$$P_W = f\,(p_s, N, T) + 0.5\, f(p'_s, N,T), \text{ where} \qquad (3)$$

P_s is the probability of an avalanche in an adjacent path hitting stopped traffic during a waiting period assumed to be 0.5 hours before help arrives, N is the number of vehicles exposed, T is the annual probability of avalanches, and p'_s is the probability of a second avalanche in the path that caused the traffic blockage.

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[2] From DOT/PF data, an average traffic volume (ADT) of 5,162 vehicles per day is assumed for the November-May avalanche season, equal to approximately 3.6 vehicles per minute.

The avalanche hazard index (AHI) is calculated for *each path i*, as follows:

$$AHI_J = \Sigma\, W_J\, (PM_J + PW_J), \text{ where} \qquad (4)$$

The subscript "J" refers to the three classes of avalanches discussed in Section 4.2 which are assigned weighting factors 1, 10, and 12.

Finally a cumulative AHI_H is calculated for all of the avalanche paths along Bird Flats portion of the highway as follows:

$$AHI_H = \Sigma\, AHI_i, \text{ where} \qquad (5)$$

1 < or = i< or = n, and n is the number of paths on Bird Flats.

For purposes of calculations, each avalanche path (together with its neighboring paths) was assumed to be independent of other avalanches reaching the highway. Therefore, the same avalanche was assumed to hit both moving and waiting traffic each time it occurred after another avalanche had already blocked the road. It could be argued that the AHI could be made more realistic by taking into account that the traffic stops after one avalanche occurrence and that each avalanche can strike vehicles only once. However, this would not allow a comparison between individual paths which is one of the objectives of this analysis. Therefore, a simpler approach was adopted to calculate the index, similar to that used at other highway locations in the United States and Canada.

4.5 Results of the AHI-analysis for milepost 18-23

Table 4-1 indicates the encounter probabilities vehicles (P) and the AHI values for various avalanche paths.

Table 4-1. AHI-values for MP 18-23 Avalanche Paths

Path	Path Name	P	AHI
SP 1	SP 1	0.02	0.18
SP 2	Andy Simons	0.20	2.15
SP 3A	SP 3A	0.07	0.66
SP 3B	SP 3B	0.07	0.66
SP 4A	Horse Pasture	1.17	11.34
SP 4B	SP 4B	0.02	0.23
SP 5	SP 5	0.00	0.04
SP 6	SP 6	0.05	0.54
SP 7	SP 7	0.24	2.33
Total	All Avalanche Paths	1.79	18.12

The encounter probability values (P) in Table 4-1 are relative to each other and are not absolute. They assume the highway is open continuously during severe conditions and that all avalanches react independently and reach both moving and waiting vehicles. The AHI-values should be used to compare avalanche hazard between paths and to other highways in the United States, as discussed in Section 4.6.

4.6 Discussion of the AHI-Analysis

The following conclusions can be drawn from the analysis:

a. The total MP 18-23 AHI of 18.1 classifies this section of the Seward Highway as "low hazard;"
b. The major contributor to the hazard is in "Horse Pasture," with an AHI of 11.3 for that path alone; Andy Simons Face (AHI = 2.15) and SP 7 (AHI = 2.33) are the only other significant avalanche hazards.
c. The *encounter probability* values P calculated are higher than observed or expected because calculations assume the highway is open continuously during severe conditions, and that avalanches strike both moving and waiting vehicles; P should not be interpreted literally.
d. The encounter probability with a waiting vehicle is, however, 7.5 times as high as with a moving vehicle; this is realistic because most avalanche encounters are with waiting vehicles;
e. Similarly, the AHI value for waiting vehicles is 8.2 times higher than with moving vehicles.

Table 4-2 lists several highways in the United States with calculated AHI-values and the type of mitigation that is used to reduce avalanche hazard. Table 4-3 lists some individual avalanche paths, the AHI-value of that path, and mitigation that is used to reduce avalanche hazard.

Table 4-2. AHI-Values and Mitigation Used on Selected U.S. Highways

HIGHWAY	AHI-VALUE	MITIGATION TYPE
Bird Flats, AK[1]	60	B,C,D
Wolf Creek Pass, CO	54	B,C,D,E
Silverton-Gladstone, CO	49	B,C,D
Teton Pass[2], WY	46	B,C,D,E
Lizard Head Pass, CO	39	B,C,D
I-70 Tunnel Approaches, CO	27	B,C,D
McClure Pass, CO	25	B,C,D
Monarch Pass, CO	23	B,C,D
Thane Road, Juneau, AK	21	B,C
MP 18-23 Seward Highway	**18**	**B,D[3]**

1 *Additional structural avalanche mitigation is being considered*
2 *Fixed exploders (GAZ.EX) is installed in 2 avalanche starting zones.*
3 *Structural mitigation is being considered at some sites (this report).*

Table 4-3. AHI Values in Individual Avalanche Paths
On U.S. Highways and Mitigation Used

AVALANCHE PATH	AHI-VALUE	MITIGATION TYPE
5-Fingers (Seward Highway, AK)	21	B,C,D[1]
Big Slide (Monarch Pass, CO)	19	B,C,D
Snowslide Creek (Thane Rd., Juneau, AK)	15	B,C,D
Glory Bowl (Teton Pass, WY)	14	B,C,D,E
Straight Shot, (Seward Highway, AK)	11	B,C,D[1]
Horse Pasture (mp 18-23, Seward Hwy.)	**11**	**B,D**
Sneaky Pete (Seward Highway, AK)	10	B,C,D[1]
Dump (Seward Highway, AK)	7	B,C,D[1]
Dog Leg (Seward Highway, AK)	7	B,C,D[1]
Andy Simons Face (mp 18-23, Seward)	**2**	**B,D**
SP 7 (mp 18-23, Seward Highway)	**2**	**B,D**

1 Structural mitigation and possible highway alignment shift is being considered.

The mitigation types listed in the third column of Tables 4-2 and 4-3 are described below:

A. No mitigation is used
B. Observations are taken and advisories issued during periods of major snowpack instability
C. Daily observations are taken and analyzed by trained observers; highway closure is implemented and enforced at times
D. Closure and explosive control (when advised by trained observers) is done several times each typical winter
E. Special types of mitigation (structural control or other fixed installations) are in place or are planned (see notes).

The highway and avalanche path data summarized in Tables 4-2 and 4-3 are internally consistent because they were all done by one person (A. Mears), therefore they are comparable. Furthermore, the methods used to compute the avalanche hazard index are identical and the data reliability in each of the areas is of similar quality. The Department of Transportation reaction to the hazard on the *current* (i.e. 2000 alignment has not been considered in this analysis. However, moderately large avalanches, with estimated return periods of 10 years and longer will overrun the highway and railroad (see Figure 3-3).

Certain other United States Highways also have significant avalanche hazard, including Little Cottonwood Canyon, UT, Big Cottonwood Canyon, UT, Provo Canyon, UT, Snoqualmie Pass, WA , Richardson Highway, AK. Because hazard data on these roads are not readily available or may have been compiled by alternate methods, they are not used.

Strictly speaking, the overall hazard (and the results of the AHI-analysis) would be greater in the Snow River – Crown Point area than that specified in this report because avalanches affect the Alaska Railroad as well as the highway.

5 RECOMMENDATIONS AND MITIGATION

5.1 Introduction

Although avalanche hazard at mileposts 18-23 is "moderate," rather than "high," (such as on the Bird Flats section of the highway), certain problem areas exist, particularly at mp 21 (Horse Pasture). This path alone accounts for more than 60% of the hazard (see Table 4-2 and 4-3).

5.2 Mitigation at SP 4A (Horse Pasture, stations 33+380 to 33+580)

The runout zone (gently-sloping meadow) directly above the highway provides the opportunity for structural mitigation in the form of an earthen dam. This would utilize excess excavated material from highway construction. Calculations indicate that a dam 10m (33 feet) high, and approximately 200m (660 feet) long would stop approximately 90% of the avalanche debris *during 10-year return period* avalanches. Dam volume would be approximately 55,000 – 60,000 yd^3 (42,000 – 45,000m^3). Plan and cross section views are given on Figures 5-1 and 5-2. It is essential that the proposed location, length, and dam height are adhered to as closely as possible to that shown in Figures 5-1 and 5-2. In particular, the 10m height must be measured on the *uphill* side of the structure.

Approximately 10% of the avalanche debris would continue over the dam and across the highway even with the 10-year event. Powder blast, if that occurs in association with the avalanche, would also cross the highway. The larger (10-100 year events), because of increased speeds and flow thicknesses, will not be stopped by the dam. Overall, we estimate a hazard reduction at the Horse Pasture of approximately 70% as a result of the dam, thus reducing the hazard as measured by the AHI from 11.3 to 3.4.

5.3 Mitigation at SP 7 (Stations 28+800 to 29+300)

This area has an AHI = 2.3 with the proposed alignment. Additional structural mitigation is usually not required on avalanches with this hazard level unless valuable fixed facilities and/or prolonged exposure of persons is involved. The current and proposed alignment will be on fill varying in thickness from 4m at 28+800 to 9m at 29+200 according to current plans reviewed for this study. Avalanches will impact the Snow River floodplain directly east of this fill section, will deposit on the flats and can reach the proposed highway during 10-year events. However, hazard from the 10-year avalanche is small and extended periods of avalanche-debris cleanup will not be common. Larger avalanches with return periods of 10-100 years will bury the highway and necessitate more extensive cleanup operations, but overall risk to the public will be small because of the long return periods and minimal encounter probabilities with such rare events. Additional elevation increase of the highway is not recommended.

5.4 Mitigation at SP 2 (Andy Simons Face, stations 35+720 to 35+780)

This avalanche area has an AHI = 2.1. As with SP 7, additional structural mitigation is usually not required on avalanches with this hazard level unless valuable fixed facilities and/or prolonged exposure of persons is involved. The current and proposed highway are both exposed to avalanches that are confined to a shallow gully and can block about 60m (200 feet) of highway with debris up to several meters deep. Complete protection of this area could be achieved with a reinforced concrete avalanche shed built with fill on the uphill side to minimize avalanche deflection loads. Although beyond the scope of the current study, the structure could be designed primarily for static loads because these could be the design case. Assuming a deposit depth on a shed of 10m (33 feet) and a unit weight of avalanche debris of 500 kg/m^3 (31.2 lbs/ft^3), static normal loads would be approximately 49 kPa (1,025 lbs/ft^2). Assuming a shed width of 20m, a cost of $50,000/m, and a length of 70m, cost of a shed structure would be approximately $3,500,000 (say, 3 – 4 million dollars). Although avalanche loads are reasonable and a shed is technically feasible at this location, it would be unusual to build a shed at a location with such a relatively low avalanche risk.

5.5 Mitigation at other avalanche areas (mp 18-23)

In addition to the three avalanche areas discussed above, six additional avalanches can affect the alignment. However, as shown in Table 4-1, the *total* AHI for these other six paths is only 2.3. Because of the minimal hazard level, special types of structural mitigation is not recommended.

5.6 Changes to the AFEC program

The current AFEC (Avalanche Forecast and Explosive Control) program consists of forecasting for periods of snow instability, closing the highway, and delivering explosives by military weapons or occasionally by helicopter. Gun positions are currently near the Snow River (mp 18) for the southern area and between mp 21 and 22 for the northern area. Another possible gun position could be from the Victor Creek alluvial fan for the Horse Pasture area although this may be on private property. These appear to be good, easily accessible gun positions with good sights to the relevant starting zones. During periods of high avalanche danger, travel to the latter two positions from either the north or south would involve some exposure to avalanches with fairly long return periods, therefore access is not completely without risk although the risk seems acceptable compared to that assumed at numerous other areas.

An important element of any AFEC program is the "Avalanche Forecast" element. If remote, high-elevation (>700m or 2,300 feet) data are or become available, for example through National Resource Conservation Service (NRCS) "Snotel" sites, these data should be incorporated into the AFEC program.

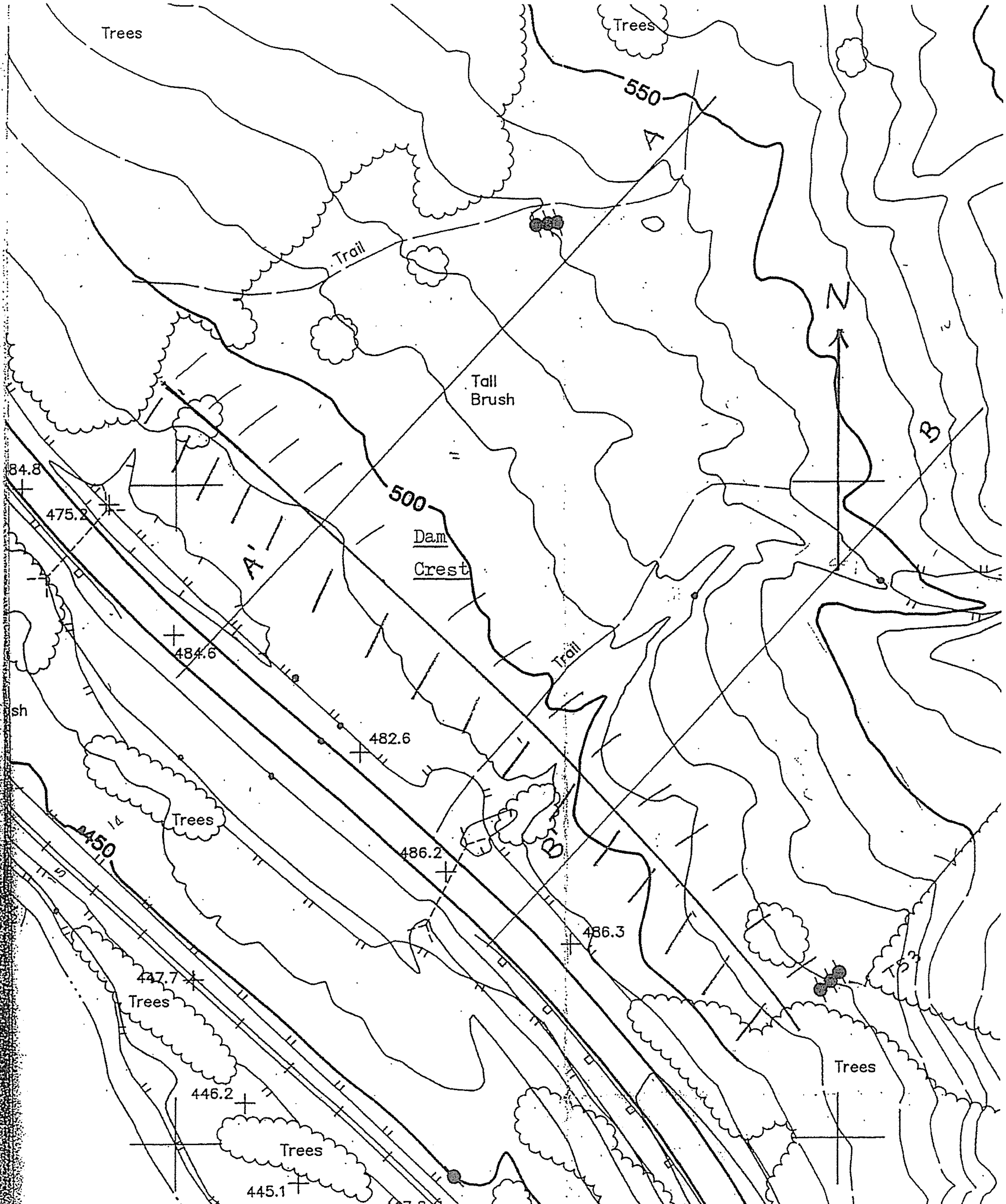

FIGURE 5-1. Map view of the Horse Pasture runout zone, showing the current highway, recommended location of the proposed dam crest, and sections A – A' and B – B' upon which Figure 5-2 is based. The dam would eliminate approximately 70% of the hazard at this site.

Scale: 1" = 100'; Contour interval = 10 feet

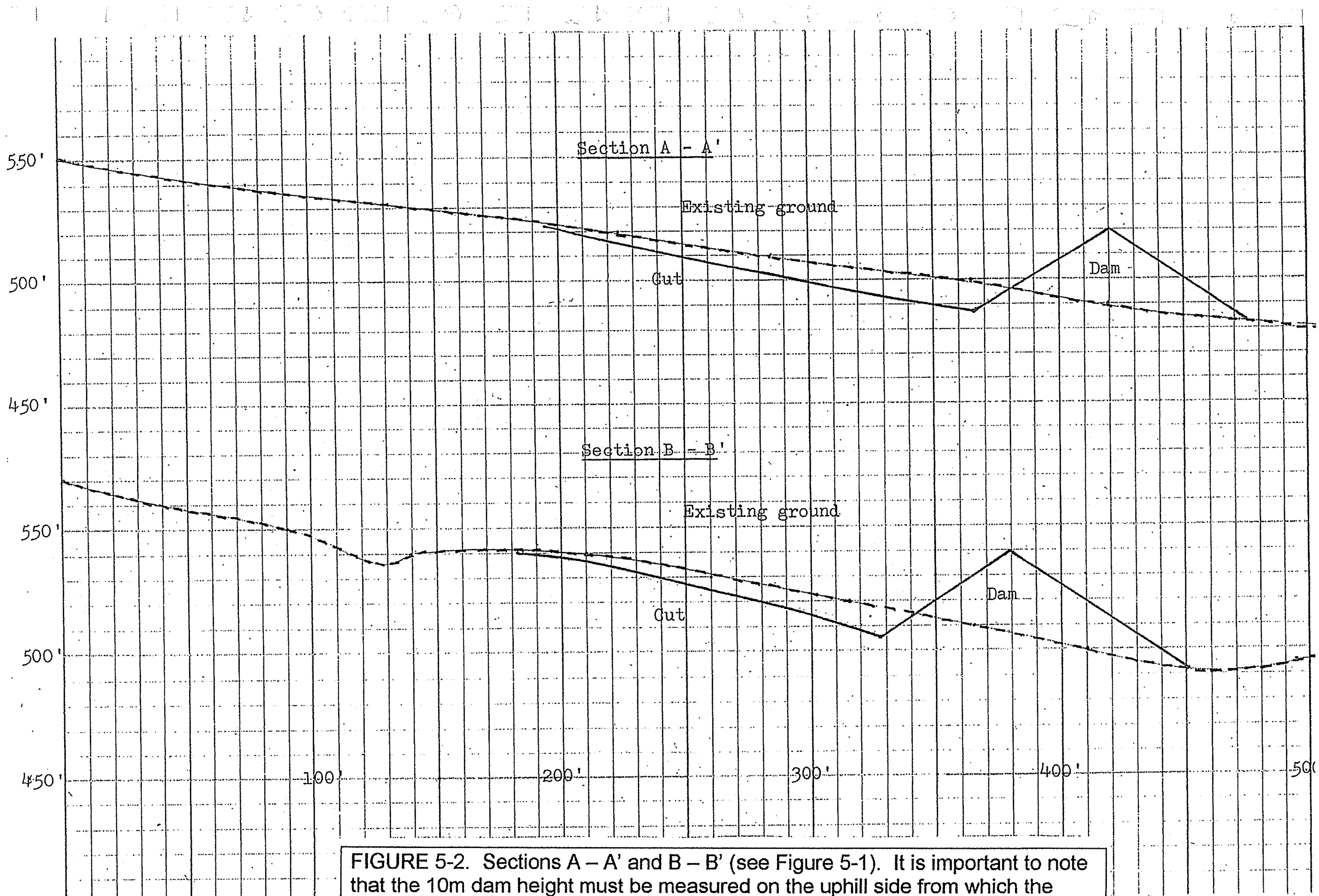

FIGURE 5-2. Sections A – A' and B – B' (see Figure 5-1). It is important to note that the 10m dam height must be measured on the uphill side from which the avalanche approaches. Estimated volume of this 200m-long structure is 42,000 – 45,000 m^3 (55,000 – 60,000 yd^3).

Scale: 1" = 50'

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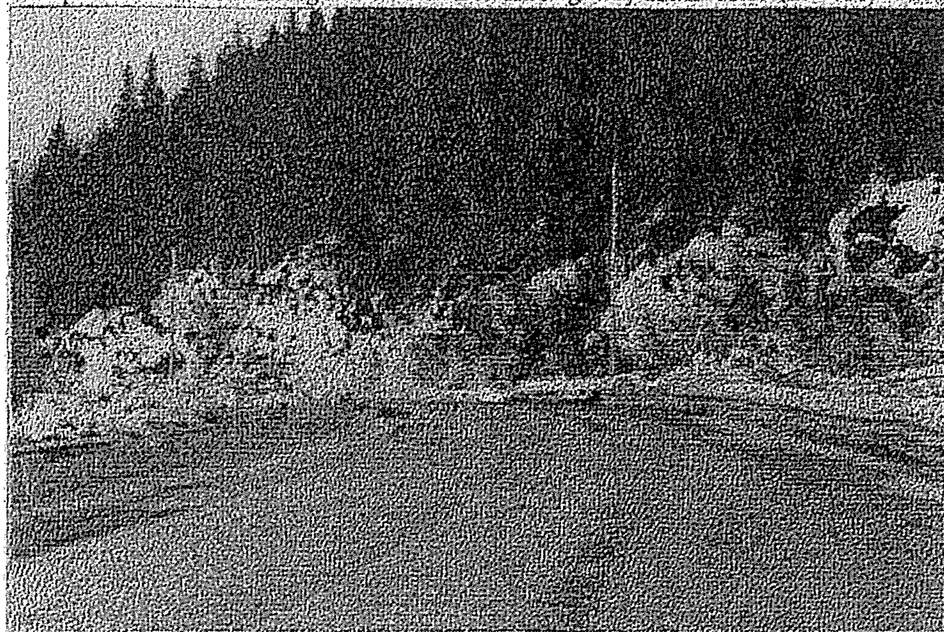
APPENDIX A – Photographs of avalanches that crossed the Seward Highway during Febuary, 2000. Labels on all photographs were provided by DOT&PF. Based on the historical record of avalanches, we assume these avalanches had return periods of approximately 10 years.

This picture was taken facing north east on the Seward Highway at MP 18.5 where highway goes over the railroad. Pictures were taken on Feb. 11, 2000.

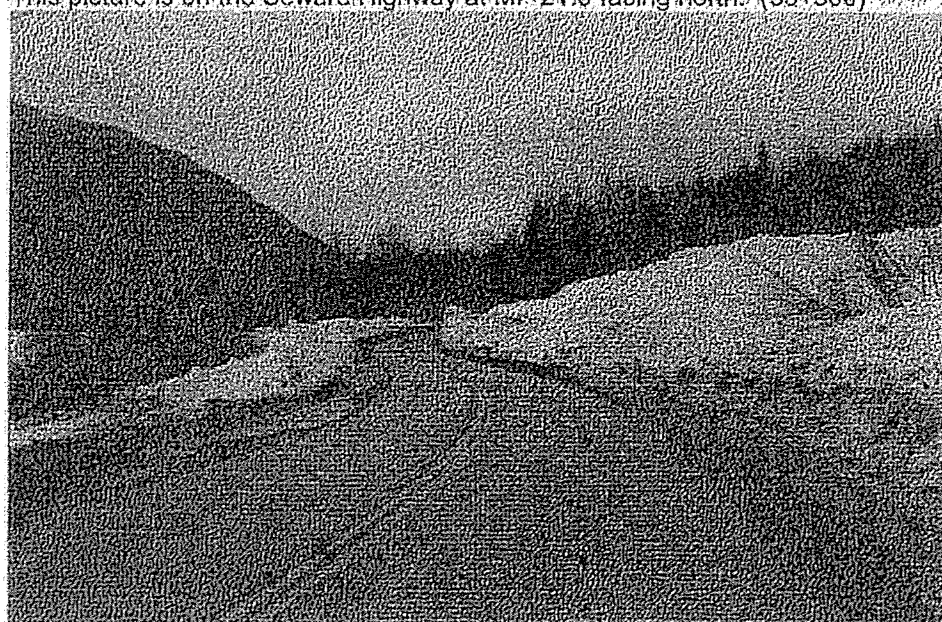
This picture was taken facing north on the Seward Highway at MP 18.5. (29+400)

Page 2 of 7

This picture was taken facing north on the Seward Highway at MP 18.5. (29+400)



This picture is on the Seward Highway at MP 21.0 facing north. (33+500)



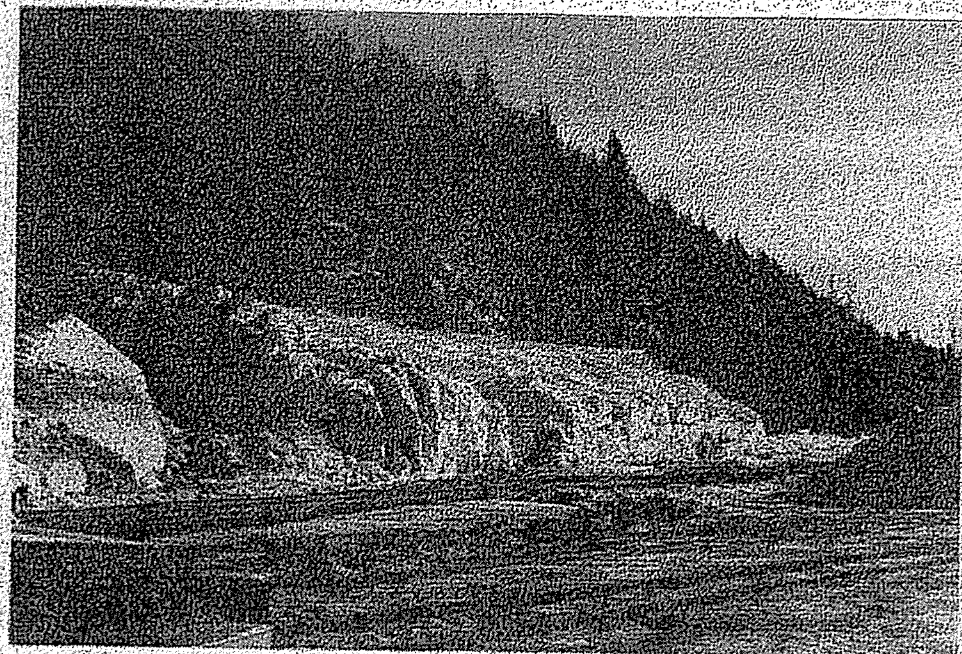
This picture was taken on Seward Highway at MP 21.8 facing south. Pictures were taken on Feb. 13, 2000 (34+800)

Looking south at the avalanche from a wide spot on west side of the road.

This picture was taken on Seward Highway at MP 21.8 facing south. (34+800)

Looking across the road at Kenai Lake

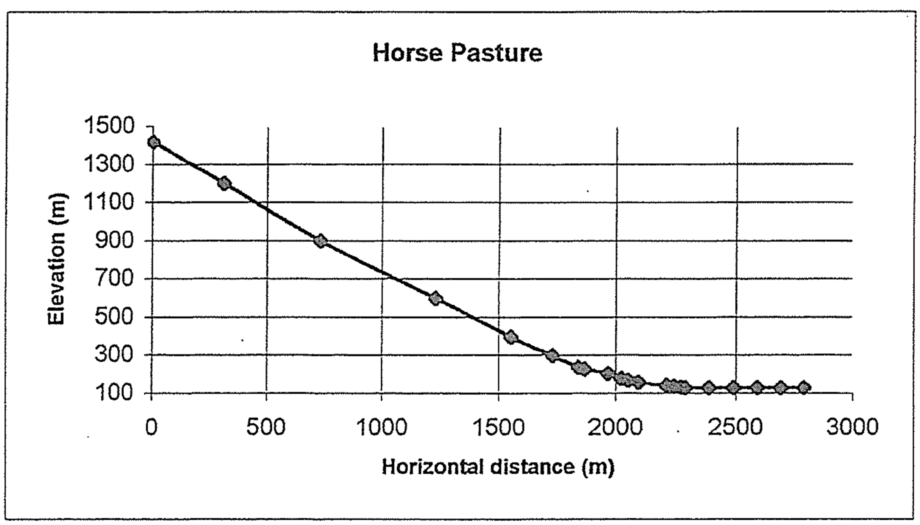
This picture was taken on Seward Highway at MP 21.8 facing south.(34+800)



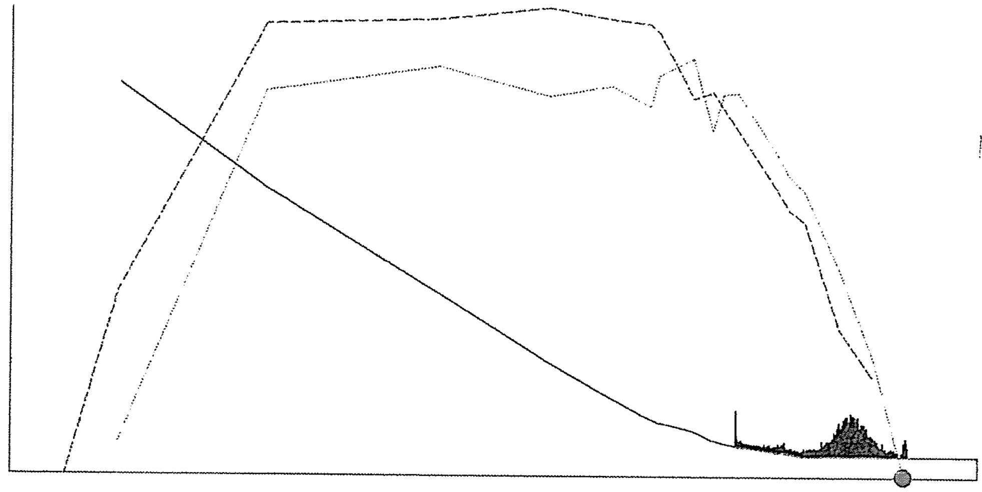
APPENDIX B. Raw data output from avalanche terrain profiles, avalanche-dynamics graphics, and avalanche-dynamics modeling. These data were used to assess the feasibility of structural defenses.

Avalanche Profile and x/y coordinates
Horse Pasture

Raw Data in feet		**Data in meters**		**Segment Data**			
X-feet	Y-feet	X-meters	Y-meters	L-meters	Ang - Deg	Sum L	Avg Angle
		0	1420			0.0	
		310	1200	380.1	35.4	380.1	35.4
		730	900	516.1	35.5	896.3	35.5
		1230	600	583.1	31.0	1479.4	33.7
		1550	400	377.4	32.0	1856.7	33.3
		1730	300	205.9	29.1	2062.6	32.9
		1840	240	125.3	28.6	2187.9	32.7
		1866	229	28.2	22.9	2216.2	32.5
		1966	207	102.4	12.4	2318.6	31.7
		2021	180	61.3	26.1	2379.8	31.5
		2052	171	32.3	16.2	2412.1	31.3
		2093	162	42.0	12.4	2454.1	31.0
		2209	146	117.1	7.9	2571.2	30.0
		2241	143	32.1	5.4	2603.3	29.7
		2270	137	29.6	11.7	2632.9	29.5
		2286	134	16.3	10.6	2649.2	29.4
		2386	134	100.0	0.0	2749.2	28.3
		2486	134	100.0	0.0	2849.2	27.4
		2586	134	100.0	0.0	2949.2	26.4
		2686	134	100.0	0.0	3049.2	25.6
		2786	134	100.0	0.0	3149.2	24.8



1900 particles start from top segment. 4454 particles deposited.



100 yr ret. per

c:\plk\horse pasture.txt
Path drops: 1285 m
Friction mu = 0.20
log M/D = 2.90
Random R = 0.200
Alpha = 26.5 degrees

● Front stops at X = 2571 m
.... Front speed (max = 43.5 m/s)
- - - - Mean speed (max = 48.7 m/s)
——— Deposition (not to scale)

Exit and view distributions
in your file c:\plk\results.txt

Please note: all v-variables are in meters/second.
Please note: all t-variables are in seconds.
Please note: NP is number of particles in packet.

AVALANCHE ENTERING SEGMENT	2
NUMBER OF PARTICLES MOVING	1900
NUMBER OF PARTICLES STOPPED	0
METERS TRAVELLED FROM START	380

vHIGH	26.34	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	3.00	1	0.53	2.98	3.32	31
vRANGE	23.34	2	2.98	5.43	6.06	72
vMEAN	19.16	3	5.43	7.88	9.29	113
vSTDEV	5.87	4	7.88	10.33	12.36	150
		5	10.33	12.78	15.23	187
tHIGH	25.03	6	12.78	15.23	17.85	218
tLOW	0.53	7	15.23	17.68	20.20	247
tRANGE	24.50	8	17.68	20.13	22.27	273
tMEAN	16.19	9	20.13	22.58	24.08	294
tSTDEV	5.99	10	22.58	25.03	25.65	315

AVALANCHE ENTERING SEGMENT	3
NUMBER OF PARTICLES MOVING	2416
NUMBER OF PARTICLES STOPPED	0
METERS TRAVELLED FROM START	896

vHIGH	58.66	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.86	1	17.54	19.62	39.90	49
vRANGE	55.80	2	19.62	21.69	40.75	185
vMEAN	46.90	3	21.69	23.77	41.04	490
vSTDEV	7.74	4	23.77	25.84	46.86	240
		5	25.84	27.92	49.59	203
tHIGH	38.29	6	27.92	29.99	49.63	231
tLOW	17.54	7	29.99	32.06	49.76	262
tRANGE	20.75	8	32.06	34.14	50.16	268
tMEAN	28.41	9	34.14	36.21	50.24	284
tSTDEV	5.41	10	36.21	38.29	49.91	204

AVALANCHE ENTERING SEGMENT	4
NUMBER OF PARTICLES MOVING	2999
NUMBER OF PARTICLES STOPPED	0
METERS TRAVELLED FROM START	1479

vHIGH	60.99	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.59	1	28.91	31.04	42.47	41
vRANGE	58.40	2	31.04	33.16	43.38	166
vMEAN	47.43	3	33.16	35.29	43.93	314
vSTDEV	8.29	4	35.29	37.41	44.89	618
		5	37.41	39.54	45.91	599
tHIGH	50.16	6	39.54	41.66	50.56	248
tLOW	28.91	7	41.66	43.79	50.94	288
tRANGE	21.25	8	43.79	45.91	51.29	275
tMEAN	39.67	9	45.91	48.04	51.30	285
tSTDEV	4.83	10	48.04	50.16	50.42	165

AVALANCHE ENTERING SEGMENT	5
NUMBER OF PARTICLES MOVING	3376
NUMBER OF PARTICLES STOPPED	0
METERS TRAVELLED FROM START	1856

vHIGH	62.22	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.66	1	35.69	37.93	39.47	35
vRANGE	59.57	2	37.93	40.17	42.83	158
vMEAN	48.69	3	40.17	42.40	44.43	327
vSTDEV	8.08	4	42.40	44.64	46.42	602
		5	44.64	46.87	48.42	904

tHIGH	58.06	6	46.87	49.11	50.90	355
tLOW	35.69	7	49.11	51.35	51.98	303
tRANGE	22.36	8	51.35	53.58	52.75	291
tMEAN	46.86	9	53.58	55.82	52.13	282
tSTDEV	4.62	10	55.82	58.06	51.43	119

AVALANCHE ENTERING SEGMENT 6
NUMBER OF PARTICLES MOVING 3582
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2062

vHIGH	63.12	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.47	1	39.60	41.86	40.57	33
vRANGE	60.65	2	41.86	44.12	42.99	148
vMEAN	47.49	3	44.12	46.38	43.77	315
vSTDEV	8.02	4	46.38	48.65	44.12	664
		5	48.65	50.91	47.68	1006
tHIGH	62.21	6	50.91	53.17	49.39	421
tLOW	39.60	7	53.17	55.43	50.89	307
tRANGE	22.61	8	55.43	57.69	51.10	298
tMEAN	50.86	9	57.69	59.95	50.76	280
tSTDEV	4.48	10	59.95	62.21	50.00	110

AVALANCHE ENTERING SEGMENT 7
NUMBER OF PARTICLES MOVING 3707
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2187

vHIGH	61.10	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.44	1	41.89	44.21	38.45	27
vRANGE	58.66	2	44.21	46.53	41.65	151
vMEAN	46.98	3	46.53	48.85	43.84	324
vSTDEV	7.86	4	48.85	51.17	44.54	648
		5	51.17	53.50	46.70	1132
tHIGH	65.10	6	53.50	55.82	48.78	444
tLOW	41.89	7	55.82	58.14	50.42	323
tRANGE	23.22	8	58.14	60.46	50.39	310
tMEAN	53.34	9	60.46	62.78	50.03	265
tSTDEV	4.41	10	62.78	65.10	48.98	83

AVALANCHE ENTERING SEGMENT 8
NUMBER OF PARTICLES MOVING 3735
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2215

vHIGH	59.64	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.01	1	42.42	44.76	41.65	24
vRANGE	57.64	2	44.76	47.10	41.42	149
vMEAN	46.09	3	47.10	49.44	41.97	334
vSTDEV	7.97	4	49.44	51.77	43.69	653
		5	51.77	54.11	45.90	1167
tHIGH	65.79	6	54.11	56.45	47.97	438
tLOW	42.42	7	56.45	58.78	49.61	326
tRANGE	23.37	8	58.78	61.12	49.55	316
tMEAN	53.92	9	61.12	63.46	49.05	260
tSTDEV	4.39	10	63.46	65.79	48.26	68

AVALANCHE ENTERING SEGMENT 9
NUMBER OF PARTICLES MOVING 3837
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2317

vHIGH	56.55	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	0.62	1	44.50	48.82	43.46	99
vRANGE	55.93	2	48.82	53.14	42.78	530
vMEAN	39.27	3	53.14	57.45	37.82	1954
vSTDEV	9.05	4	57.45	61.77	41.63	624

		5	61.77	66.09	41.17	534
tHIGH	87.67	6	66.09	70.40	27.83	60
tLOW	44.50	7	70.40	74.72	4.74	17
tRANGE	43.17	8	74.72	79.04	4.92	9
tMEAN	56.77	9	79.04	83.35	3.77	5
tSTDEV	4.73	10	83.35	87.67	3.82	5

AVALANCHE ENTERING SEGMENT 10
NUMBER OF PARTICLES MOVING 3898
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2378

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	55.75					
vLOW	2.26	1	45.74	50.51	35.93	162
vRANGE	53.49	2	50.51	55.28	42.66	680
vMEAN	39.98	3	55.28	60.06	39.16	1952
vSTDEV	7.64	4	60.06	64.83	42.32	695
		5	64.83	69.60	41.00	339
tHIGH	93.46	6	69.60	74.37	18.47	25
tLOW	45.74	7	74.37	79.14	17.50	23
tRANGE	47.71	8	79.14	83.91	17.27	11
tMEAN	58.31	9	83.91	88.68	18.03	6
tSTDEV	5.07	10	88.68	93.46	17.14	5

AVALANCHE ENTERING SEGMENT 11
NUMBER OF PARTICLES MOVING 3930
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2410

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	54.78					
vLOW	1.30	1	46.41	51.31	39.73	134
vRANGE	53.47	2	51.31	56.20	38.59	766
vMEAN	38.25	3	56.20	61.09	37.78	1957
vSTDEV	7.66	4	61.09	65.98	40.57	705
		5	65.98	70.87	39.29	295
tHIGH	95.34	6	70.87	75.77	18.49	26
tLOW	46.41	7	75.77	80.66	17.90	24
tRANGE	48.92	8	80.66	85.55	17.57	12
tMEAN	59.13	9	85.55	90.44	19.09	6
tSTDEV	5.13	10	90.44	95.34	17.11	5

AVALANCHE ENTERING SEGMENT 12
NUMBER OF PARTICLES MOVING 3972
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2452

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	51.18					
vLOW	0.61	1	47.37	52.40	39.91	138
vRANGE	50.57	2	52.40	57.43	37.96	790
vMEAN	36.04	3	57.43	62.46	35.21	1990
vSTDEV	8.03	4	62.46	67.49	37.66	733
		5	67.49	72.52	35.45	243
tHIGH	97.67	6	72.52	77.55	16.95	25
tLOW	47.37	7	77.55	82.58	17.14	27
tRANGE	50.30	8	82.58	87.61	17.87	15
tMEAN	60.39	9	87.61	92.64	18.30	6
tSTDEV	5.18	10	92.64	97.67	16.82	5

AVALANCHE ENTERING SEGMENT 13
NUMBER OF PARTICLES MOVING 3830
NUMBER OF PARTICLES STOPPED 259
METERS TRAVELLED FROM START 2569

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	45.26					
vLOW	3.36	1	50.37	56.00	33.47	161
vRANGE	41.90	2	56.00	61.64	32.41	995
vMEAN	29.78	3	61.64	67.27	28.85	1827

vSTDEV	6.15	4	67.27	72.90	30.32	710
		5	72.90	78.53	20.99	68
tHIGH	106.69	6	78.53	84.16	10.90	19
tLOW	50.37	7	84.16	89.80	10.72	25
tRANGE	56.32	8	89.80	95.43	10.40	14
tMEAN	64.06	9	95.43	101.06	10.24	6
tSTDEV	5.59	10	101.06	106.69	10.24	5

AVALANCHE ENTERING SEGMENT 14
NUMBER OF PARTICLES MOVING 3748
NUMBER OF PARTICLES STOPPED 373
METERS TRAVELLED FROM START 2601

vHIGH	43.08	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	1.69	1	51.29	56.96	31.38	154
vRANGE	41.39	2	56.96	62.64	30.10	975
vMEAN	27.78	3	62.64	68.31	26.76	1816
vSTDEV	5.62	4	68.31	73.98	27.83	710
		5	73.98	79.66	22.33	56
tHIGH	108.02	6	79.66	85.33	8.29	12
tLOW	51.29	7	85.33	91.00	8.78	10
tRANGE	56.73	8	91.00	96.68	9.12	8
tMEAN	64.90	9	96.68	102.35	8.97	4
tSTDEV	5.07	10	102.35	108.02	9.73	3

AVALANCHE ENTERING SEGMENT 15
NUMBER OF PARTICLES MOVING 3716
NUMBER OF PARTICLES STOPPED 435
METERS TRAVELLED FROM START 2631

vHIGH	40.66	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.19	1	52.20	58.06	30.28	161
vRANGE	38.46	2	58.06	63.93	29.10	1061
vMEAN	26.95	3	63.93	69.79	25.91	1752
vSTDEV	5.23	4	69.79	75.66	26.43	679
		5	75.66	81.52	20.63	40
tHIGH	110.85	6	81.52	87.39	11.11	5
tLOW	52.20	7	87.39	93.25	8.51	8
tRANGE	58.65	8	93.25	99.12	9.68	5
tMEAN	65.93	9	99.12	104.98	10.93	1
tSTDEV	4.99	10	104.98	110.85	7.50	4

AVALANCHE ENTERING SEGMENT 16
NUMBER OF PARTICLES MOVING 3704
NUMBER OF PARTICLES STOPPED 463
METERS TRAVELLED FROM START 2647

vHIGH	40.19	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	3.49	1	52.69	58.66	29.71	163
vRANGE	36.70	2	58.66	64.63	28.50	1109
vMEAN	26.40	3	64.63	70.59	25.35	1732
vSTDEV	5.12	4	70.59	76.56	25.58	654
		5	76.56	82.52	18.35	28
tHIGH	112.36	6	82.52	88.49	10.02	6
tLOW	52.69	7	88.49	94.46	8.81	5
tRANGE	59.66	8	94.46	100.42	12.17	3
tMEAN	66.49	9	100.42	106.39	7.35	2
tSTDEV	4.89	10	106.39	112.36	9.93	2

AVALANCHE ENTERING SEGMENT 17
NUMBER OF PARTICLES MOVING 2990
NUMBER OF PARTICLES STOPPED 1277
METERS TRAVELLED FROM START 2747

vHIGH	30.95	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	0.51	1	56.44	59.22	21.67	12
vRANGE	30.44	2	59.22	62.00	19.96	84

vMEAN	15.37	3	62.00	64.77	18.17	225
vSTDEV	5.09	4	64.77	67.55	17.20	403
		5	67.55	70.33	15.67	705
tHIGH	84.21	6	70.33	73.11	13.47	690
tLOW	56.44	7	73.11	75.88	14.61	428
tRANGE	27.77	8	75.88	78.66	15.54	284
tMEAN	70.73	9	78.66	81.44	13.24	130
tSTDEV	4.69	10	81.44	84.21	9.08	29

AVALANCHE ENTERING SEGMENT 18
NUMBER OF PARTICLES MOVING 306
NUMBER OF PARTICLES STOPPED 4061
METERS TRAVELLED FROM START 2847

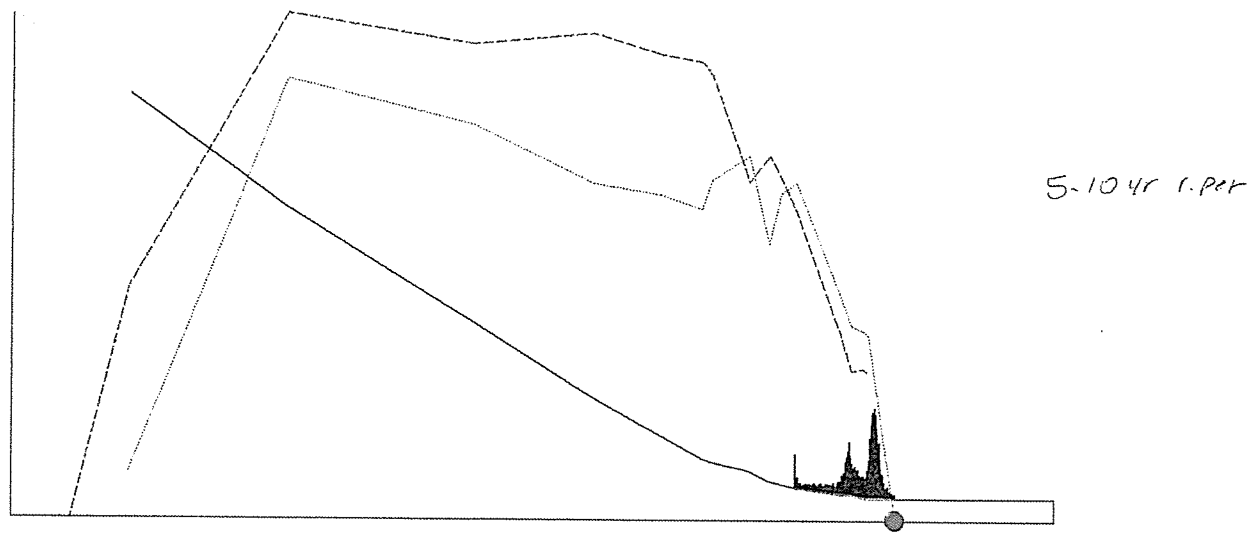
vHIGH	21.01	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	1.72	1	63.02	65.43	12.10	8
vRANGE	19.29	2	65.43	67.84	12.26	20
vMEAN	10.06	3	67.84	70.26	10.93	35
vSTDEV	3.69	4	70.26	72.67	10.16	51
		5	72.67	75.08	9.59	47
tHIGH	87.14	6	75.08	77.49	9.10	50
tLOW	63.02	7	77.49	79.91	10.49	41
tRANGE	24.13	8	79.91	82.32	9.95	29
tMEAN	74.77	9	82.32	84.73	9.03	19
tSTDEV	5.10	10	84.73	87.14	6.76	6

NUMBER OF PARTICLES MOVING 1
NUMBER OF PARTICLES STOPPED 4454
FASTEST PARTICLE SPEED AT FRONT 57.8 m/s
FASTEST PARTICLE SPEED (ANYWHERE) 64.8 m/s
ALPHA 26.5 degrees

MAX_DEPOSIT 2934 meters
MIN_DEPOSIT 2452 meters
RANGE_DEPOSIT 482 meters
MEAN_DEPOSIT 2759 meters
STD_DEV_DEPOSIT 89 meters

Packet	Max(m)	Min(m)	Particles
1	2500	2452	140
2	2548	2500	77
3	2597	2548	146
4	2645	2597	97
5	2693	2645	187
6	2741	2693	509
7	2789	2741	1474
8	2838	2789	1278
9	2886	2838	448
10	2934	2886	98

1900 particles start from top segment.   4241 particles deposited.



c:\plk\horse pasture.txt

Path drops: 1285 m

Friction mu = 0.20

log M/D = 2.60

Random R = 0.200

Alpha = 28.6 degrees

● Front stops at X = 2358 m

.............Front speed (max = 32.5 m/s)

- - - - - -Mean speed (max = 37.4 m/s)

————Deposition (not to scale)

Exit and view distributions
in your file c:\plk\results.txt

Please note: all v-variables are in meters/second.
Please note: all t-variables are in seconds.
Please note: NP is number of particles in packet.

AVALANCHE ENTERING SEGMENT 2
NUMBER OF PARTICLES MOVING 1900
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 380

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	21.93					
vLOW	3.00	1	0.53	3.17	3.43	35
vRANGE	18.93	2	3.17	5.81	6.38	82
vMEAN	17.08	3	5.81	8.45	9.62	126
vSTDEV	4.61	4	8.45	11.10	12.52	165
		5	11.10	13.74	14.98	197
tHIGH	26.94	6	13.74	16.38	17.01	224
tLOW	0.53	7	16.38	19.02	18.63	246
tRANGE	26.41	8	19.02	21.66	19.91	263
tMEAN	16.95	9	21.66	24.30	20.89	276
tSTDEV	6.54	10	24.30	26.94	21.63	286

AVALANCHE ENTERING SEGMENT 3
NUMBER OF PARTICLES MOVING 2416
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 896

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	46.33					
vLOW	2.86	1	19.46	21.81	32.52	69
vRANGE	43.47	2	21.81	24.15	33.14	330
vMEAN	37.43	3	24.15	26.49	35.30	431
vSTDEV	5.14	4	26.49	28.83	39.12	193
		5	28.83	31.17	39.11	215
tHIGH	42.88	6	31.17	33.52	39.10	239
tLOW	19.46	7	33.52	35.86	39.10	239
tRANGE	23.42	8	35.86	38.20	39.11	263
tMEAN	31.05	9	38.20	40.54	39.34	258
tSTDEV	6.35	10	40.54	42.88	38.89	179

AVALANCHE ENTERING SEGMENT 4
NUMBER OF PARTICLES MOVING 2999
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 1479

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	43.71					
vLOW	2.59	1	34.35	36.87	29.12	50
vRANGE	41.12	2	36.87	39.40	31.61	242
vMEAN	35.18	3	39.40	41.92	33.84	755
vSTDEV	4.68	4	41.92	44.45	35.40	568
		5	44.45	46.97	36.80	223
tHIGH	59.60	6	46.97	49.50	36.89	255
tLOW	34.35	7	49.50	52.02	36.68	273
tRANGE	25.25	8	52.02	54.55	36.56	278
tMEAN	45.82	9	54.55	57.07	36.67	261
tSTDEV	5.97	10	57.07	59.60	36.06	94

AVALANCHE ENTERING SEGMENT 5
NUMBER OF PARTICLES MOVING 3376
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 1856

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	44.18					
vLOW	2.66	1	43.60	46.28	24.84	36
vRANGE	41.52	2	46.28	48.96	30.05	216
vMEAN	35.99	3	48.96	51.65	35.05	796
vSTDEV	4.49	4	51.65	54.33	36.72	909
		5	54.33	57.01	37.19	244

		PACKET	tMIN	tMAX	vMEAN	NP
tHIGH	70.43	6	57.01	59.69	37.43	274
tLOW	43.60	7	59.69	62.38	37.18	279
tRANGE	26.83	8	62.38	65.06	37.31	305
tMEAN	55.50	9	65.06	67.74	37.15	257
tSTDEV	5.87	10	67.74	70.43	36.81	60

AVALANCHE ENTERING SEGMENT 6
NUMBER OF PARTICLES MOVING 3582
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2062

vHIGH	44.34	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.47	1	49.08	51.79	24.02	33
vRANGE	41.88	2	51.79	54.49	28.63	197
vMEAN	34.42	3	54.49	57.19	33.38	901
vSTDEV	4.35	4	57.19	59.90	35.13	1005
		5	59.90	62.60	35.49	257
tHIGH	76.12	6	62.60	65.30	35.79	279
tLOW	49.08	7	65.30	68.01	35.58	279
tRANGE	27.04	8	68.01	70.71	35.59	298
tMEAN	60.95	9	70.71	73.42	35.58	273
tSTDEV	5.79	10	73.42	76.12	35.44	60

AVALANCHE ENTERING SEGMENT 7
NUMBER OF PARTICLES MOVING 3707
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2187

vHIGH	41.76	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.44	1	52.44	55.17	22.93	31
vRANGE	39.32	2	55.17	57.91	28.08	184
vMEAN	33.83	3	57.91	60.65	32.78	926
vSTDEV	4.25	4	60.65	63.39	34.45	1102
		5	63.39	66.13	34.87	276
tHIGH	79.82	6	66.13	68.86	35.02	282
tLOW	52.44	7	68.86	71.60	34.93	277
tRANGE	27.38	8	71.60	74.34	35.05	308
tMEAN	64.38	9	74.34	77.08	35.05	270
tSTDEV	5.74	10	77.08	79.82	34.62	51

AVALANCHE ENTERING SEGMENT 8
NUMBER OF PARTICLES MOVING 3735
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2215

vHIGH	41.13	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.00	1	53.19	55.94	25.11	24
vRANGE	39.13	2	55.94	58.69	26.19	183
vMEAN	32.86	3	58.69	61.44	31.84	922
vSTDEV	4.34	4	61.44	64.19	33.46	1134
		5	64.19	66.94	33.81	282
tHIGH	80.68	6	66.94	69.69	34.11	283
tLOW	53.19	7	69.69	72.44	34.01	280
tRANGE	27.49	8	72.44	75.18	34.10	311
tMEAN	65.17	9	75.18	77.93	33.98	268
tSTDEV	5.72	10	77.93	80.68	33.49	48

AVALANCHE ENTERING SEGMENT 9
NUMBER OF PARTICLES MOVING 3837
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2317

vHIGH	33.40	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	0.62	1	56.39	60.57	26.86	51
vRANGE	32.78	2	60.57	64.74	25.78	771
vMEAN	24.98	3	64.74	68.91	24.73	1579
vSTDEV	5.01	4	68.91	73.09	24.84	454

		5	73.09	77.26	25.74	444
tHIGH	98.13	6	77.26	81.43	25.46	447
tLOW	56.39	7	81.43	85.61	18.87	72
tRANGE	41.73	8	85.61	89.78	4.64	9
tMEAN	69.14	9	89.78	93.95	4.06	8
tSTDEV	5.88	10	93.95	98.13	4.72	2

AVALANCHE ENTERING SEGMENT 10
NUMBER OF PARTICLES MOVING 3898
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2378

vHIGH	34.43	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.26	1	58.54	63.06	20.41	108
vRANGE	32.17	2	63.06	67.58	27.79	1076
vMEAN	26.90	3	67.58	72.10	26.68	1353
vSTDEV	3.71	4	72.10	76.61	27.18	484
		5	76.61	81.13	27.68	520
tHIGH	103.72	6	81.13	85.65	26.93	303
tLOW	58.54	7	85.65	90.17	18.48	29
tRANGE	45.18	8	90.17	94.69	16.82	14
tMEAN	71.42	9	94.69	99.20	16.42	9
tSTDEV	6.09	10	99.20	103.72	15.96	2

AVALANCHE ENTERING SEGMENT 11
NUMBER OF PARTICLES MOVING 3930
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2410

vHIGH	33.87	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	1.30	1	59.77	64.36	24.14	73
vRANGE	32.57	2	64.36	68.95	25.29	1225
vMEAN	25.25	3	68.95	73.55	25.11	1289
vSTDEV	3.80	4	73.55	78.14	25.76	492
		5	78.14	82.73	26.05	540
tHIGH	105.70	6	82.73	87.32	25.16	257
tLOW	59.77	7	87.32	91.92	18.18	28
tRANGE	45.93	8	91.92	96.51	16.54	15
tMEAN	72.63	9	96.51	101.10	16.43	8
tSTDEV	6.11	10	101.10	105.70	16.02	3

AVALANCHE ENTERING SEGMENT 12
NUMBER OF PARTICLES MOVING 3972
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2452

vHIGH	32.54	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	0.61	1	61.53	66.20	24.91	75
vRANGE	31.93	2	66.20	70.87	23.40	1294
vMEAN	22.77	3	70.87	75.54	22.16	1256
vSTDEV	4.10	4	75.54	80.21	22.52	532
		5	80.21	84.88	23.41	539
tHIGH	108.22	6	84.88	89.55	22.48	224
tLOW	61.53	7	89.55	94.22	16.26	23
tRANGE	46.69	8	94.22	98.89	15.38	17
tMEAN	74.48	9	98.89	103.55	15.15	8
tSTDEV	6.09	10	103.55	108.22	14.56	4

S = 418

AVALANCHE ENTERING SEGMENT 13
NUMBER OF PARTICLES MOVING 3671
NUMBER OF PARTICLES STOPPED 418
METERS TRAVELLED FROM START 2569

vHIGH	24.38	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	3.24	1	67.38	71.97	16.82	70
vRANGE	21.14	2	71.97	76.56	15.65	855
vMEAN	14.00	3	76.56	81.15	13.18	1394

S = 671

		PACKET	tMIN	tMAX	vMEAN	NP
vSTDEV	3.11	4	81.15	85.74	13.55	529
		5	85.74	90.34	14.13	495
tHIGH	113.30	6	90.34	94.93	13.50	298
tLOW	67.38	7	94.93	99.52	9.60	19
tRANGE	45.92	8	99.52	104.11	10.06	7
tMEAN	80.78	9	104.11	108.71	4.92	2
tSTDEV	5.87	10	108.71	113.30	7.25	2

AVALANCHE ENTERING SEGMENT 14
NUMBER OF PARTICLES MOVING 3032
NUMBER OF PARTICLES STOPPED 1089
METERS TRAVELLED FROM START 2601

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	21.68					
vLOW	0.61	1	69.27	72.85	14.38	29
vRANGE	21.07	2	72.85	76.42	13.19	230
vMEAN	11.04	3	76.42	79.99	11.99	916
vSTDEV	3.25	4	79.99	83.56	9.58	759
		5	83.56	87.13	10.87	339
tHIGH	104.99	6	87.13	90.70	11.15	318
tLOW	69.27	7	90.70	94.28	10.76	307
tRANGE	35.72	8	94.28	97.85	9.42	123
tMEAN	82.91	9	97.85	101.42	6.04	9
tSTDEV	5.84	10	101.42	104.99	9.58	2

S = 665

AVALANCHE ENTERING SEGMENT 15
NUMBER OF PARTICLES MOVING 2397
NUMBER OF PARTICLES STOPPED 1754
METERS TRAVELLED FROM START 2631

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	20.94					
vLOW	0.92	1	71.38	75.05	14.04	30
vRANGE	20.01	2	75.05	78.73	13.09	213
vMEAN	11.22	3	78.73	82.40	11.93	739
vSTDEV	2.81	4	82.40	86.08	10.14	549
		5	86.08	89.75	10.86	281
tHIGH	108.13	6	89.75	93.43	11.14	256
tLOW	71.38	7	93.43	97.10	10.77	254
tRANGE	36.75	8	97.10	100.78	9.14	70
tMEAN	85.15	9	100.78	104.45	5.68	3
tSTDEV	5.98	10	104.45	108.13	7.02	2

S = 240

AVALANCHE ENTERING SEGMENT 16
NUMBER OF PARTICLES MOVING 2173
NUMBER OF PARTICLES STOPPED 1994
METERS TRAVELLED FROM START 2647

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	21.19					
vLOW	0.71	1	72.69	76.44	13.77	33
vRANGE	20.48	2	76.44	80.19	12.72	235
vMEAN	10.90	3	80.19	83.93	11.30	696
vSTDEV	2.72	4	83.93	87.68	9.84	463
		5	87.68	91.43	10.76	258
tHIGH	110.16	6	91.43	95.17	10.90	231
tLOW	72.69	7	95.17	98.92	10.23	212
tRANGE	37.47	8	98.92	102.67	8.28	43
tMEAN	86.30	9	102.67	106.42	4.75	1
tSTDEV	5.99	10	106.42	110.16	6.60	1

S = 2,247

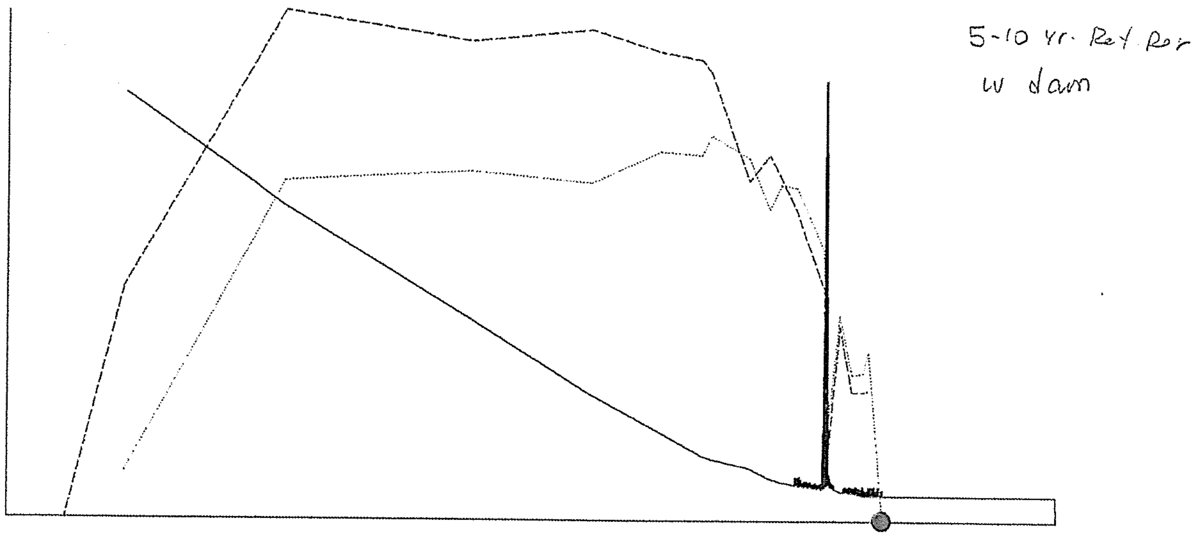
NUMBER OF PARTICLES MOVING 1
NUMBER OF PARTICLES STOPPED 4241
FASTEST PARTICLE SPEED AT FRONT 43.4 m/s
FASTEST PARTICLE SPEED (ANYWHERE) 46.7 m/s
ALPHA 28.6 degrees

MAX_DEPOSIT 2721 meters
MIN_DEPOSIT 2452 meters

RANGE_DEPOSIT 269 meters
MEAN_DEPOSIT 2630 meters
STD_DEV_DEPOSIT 52 meters

Packet	Max(m)	Min(m)	Particles
1	2479	2452	110
2	2506	2479	58
3	2533	2506	80
4	2560	2533	127
5	2587	2560	273
6	2613	2587	762
7	2640	2613	501
8	2667	2640	1230
9	2694	2667	1005
10	2721	2694	95

1900 particles start from top segment. 4212 particles deposited.



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Path drops: 1285 m

Friction mu = 0.20

log M/D = 2.60

Random R = 0.200

Alpha = 28.9 degrees

● Front stops at X = 2323 m

.... Front speed (max = 28.4 m/s)

- - - - Mean speed (max = 37.5 m/s)

——— Deposition (not to scale)

Exit and view distributions
in your file c:\plk\results.txt

Horse Pr... S-10 ... Down u=0.2 ln(...)=2.6 R=0.2

Please note: all v-variables are in meters/second.
Please note: all t-variables are in seconds.
Please note: NP is number of particles in packet.

AVALANCHE ENTERING SEGMENT 2
NUMBER OF PARTICLES MOVING 1900
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 380

vHIGH	21.93	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	3.00	1	0.53	3.17	3.43	35
vRANGE	18.93	2	3.17	5.81	6.38	82
vMEAN	17.08	3	5.81	8.45	9.62	126
vSTDEV	4.61	4	8.45	11.10	12.52	165
		5	11.10	13.74	14.98	197
tHIGH	26.94	6	13.74	16.38	17.01	224
tLOW	0.53	7	16.38	19.02	18.63	246
tRANGE	26.41	8	19.02	21.66	19.91	263
tMEAN	16.95	9	21.66	24.30	20.89	276
tSTDEV	6.54	10	24.30	26.94	21.63	286

Stopped = 0

AVALANCHE ENTERING SEGMENT 3
NUMBER OF PARTICLES MOVING 2416
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 896

vHIGH	44.75	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.86	1	18.84	21.24	29.00	48
vRANGE	41.89	2	21.24	23.65	32.34	271
vMEAN	37.50	3	23.65	26.06	35.71	470
vSTDEV	5.14	4	26.06	28.47	38.94	200
		5	28.47	30.87	39.14	215
tHIGH	42.91	6	30.87	33.28	38.99	236
tLOW	18.84	7	33.28	35.69	39.15	255
tRANGE	24.08	8	35.69	38.10	39.06	258
tMEAN	31.04	9	38.10	40.50	39.25	283
tSTDEV	6.40	10	40.50	42.91	39.34	180

Stopped = 0

AVALANCHE ENTERING SEGMENT 4
NUMBER OF PARTICLES MOVING 2999
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 1479

vHIGH	43.45	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.59	1	34.56	37.10	30.77	65
vRANGE	40.86	2	37.10	39.64	31.62	263
vMEAN	35.17	3	39.64	42.18	34.13	961
vSTDEV	4.66	4	42.18	44.73	35.78	338
		5	44.73	47.27	36.70	231
tHIGH	59.97	6	47.27	49.81	36.62	253
tLOW	34.56	7	49.81	52.35	36.52	277
tRANGE	25.41	8	52.35	54.89	36.88	279
tMEAN	45.80	9	54.89	57.43	36.58	271
tSTDEV	6.03	10	57.43	59.97	36.18	61

Stopped = 0

AVALANCHE ENTERING SEGMENT 5
NUMBER OF PARTICLES MOVING 3376
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 1856

vHIGH	44.84	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.66	1	44.54	47.11	31.05	63
vRANGE	42.19	2	47.11	49.67	31.41	279
vMEAN	35.98	3	49.67	52.24	35.48	1064
vSTDEV	4.51	4	52.24	54.81	36.51	591
		5	54.81	57.38	37.49	225

Stopped = 0

		PACKET	tMIN	tMAX	vMEAN	NP
tHIGH	70.22	6	57.38	59.95	37.15	263
tLOW	44.54	7	59.95	62.51	37.32	277
tRANGE	25.68	8	62.51	65.08	37.37	293
tMEAN	55.54	9	65.08	67.65	37.19	257
tSTDEV	5.86	10	67.65	70.22	36.79	64

AVALANCHE ENTERING SEGMENT 6
NUMBER OF PARTICLES MOVING 3582
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2062

vHIGH	42.64	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.47	1	50.42	53.00	30.64	72
vRANGE	40.17	2	53.00	55.59	31.24	278
vMEAN	34.36	3	55.59	58.17	33.75	1320
vSTDEV	4.35	4	58.17	60.75	34.89	555
		5	60.75	63.33	35.68	227
tHIGH	76.25	6	63.33	65.92	35.49	265
tLOW	50.42	7	65.92	68.50	35.57	280
tRANGE	25.83	8	68.50	71.08	35.57	297
tMEAN	61.07	9	71.08	73.67	35.72	238
tSTDEV	5.73	10	73.67	76.25	35.01	50

Stopped = 0

AVALANCHE ENTERING SEGMENT 7
NUMBER OF PARTICLES MOVING 3707
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2187

vHIGH	42.59	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.44	1	53.82	56.45	29.37	67
vRANGE	40.16	2	56.45	59.09	30.72	278
vMEAN	33.79	3	59.09	61.72	33.30	1371
vSTDEV	4.23	4	61.72	64.36	34.09	628
		5	64.36	66.99	34.92	246
tHIGH	80.16	6	66.99	69.62	34.92	262
tLOW	53.82	7	69.62	72.26	35.04	301
tRANGE	26.34	8	72.26	74.89	35.12	300
tMEAN	64.54	9	74.89	77.53	35.03	217
tSTDEV	5.65	10	77.53	80.16	34.04	37

Stopped = 0

AVALANCHE ENTERING SEGMENT 8
NUMBER OF PARTICLES MOVING 3735
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2215

vHIGH	42.65	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.00	1	54.62	57.26	30.57	62
vRANGE	40.65	2	57.26	59.90	28.99	285
vMEAN	32.82	3	59.90	62.54	32.37	1373
vSTDEV	4.35	4	62.54	65.18	33.07	652
		5	65.18	67.82	34.13	246
tHIGH	81.01	6	67.82	70.46	33.98	263
tLOW	54.62	7	70.46	73.10	34.17	298
tRANGE	26.39	8	73.10	75.74	34.12	307
tMEAN	65.35	9	75.74	78.38	34.05	214
tSTDEV	5.62	10	78.38	81.01	33.01	35

Stopped = 0

AVALANCHE ENTERING SEGMENT 9
NUMBER OF PARTICLES MOVING 3837
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2317

vHIGH	35.73	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	0.62	1	58.01	62.21	26.84	152
vRANGE	35.11	2	62.21	66.41	25.72	1619
vMEAN	24.99	3	66.41	70.61	23.69	790
vSTDEV	5.04	4	70.61	74.82	25.53	441

Stopped = 0

		5	74.82	79.02	25.72	495
tHIGH	100.03	6	79.02	83.22	24.36	290
tLOW	58.01	7	83.22	87.42	9.65	31
tRANGE	42.02	8	87.42	91.62	4.08	14
tMEAN	69.36	9	91.62	95.83	4.31	3
tSTDEV	5.89	10	95.83	100.03	3.95	2

AVALANCHE ENTERING SEGMENT 10
NUMBER OF PARTICLES MOVING 3898
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2378

vHIGH	35.55	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.26	1	60.13	64.71	24.44	218
vRANGE	33.29	2	64.71	69.29	27.50	1775
vMEAN	26.90	3	69.29	73.87	26.20	708
vSTDEV	3.71	4	73.87	78.45	27.40	505
		5	78.45	83.03	27.72	511
tHIGH	105.93	6	83.03	87.61	25.49	130
tLOW	60.13	7	87.61	92.19	16.84	30
tRANGE	45.80	8	92.19	96.77	16.41	14
tMEAN	71.67	9	96.77	101.35	16.52	5
tSTDEV	6.12	10	101.35	105.93	18.47	2

Stopped : 0

AVALANCHE ENTERING SEGMENT 11
NUMBER OF PARTICLES MOVING 3930
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2410

vHIGH	34.56	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	1.30	1	61.33	65.98	25.49	192
vRANGE	33.26	2	65.98	70.63	25.44	1846
vMEAN	25.30	3	70.63	75.27	24.77	717
vSTDEV	3.80	4	75.27	79.92	25.92	520
		5	79.92	84.57	26.09	500
tHIGH	107.80	6	84.57	89.21	23.58	102
tLOW	61.33	7	89.21	93.86	17.06	30
tRANGE	46.47	8	93.86	98.51	16.67	15
tMEAN	72.88	9	98.51	103.15	16.13	5
tSTDEV	6.14	10	103.15	107.80	17.56	3

Stopped : 0

AVALANCHE ENTERING SEGMENT 12
NUMBER OF PARTICLES MOVING 3972
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2452

vHIGH	32.09	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	0.61	1	62.93	67.71	24.54	188
vRANGE	31.48	2	67.71	72.49	23.31	1835
vMEAN	22.82	3	72.49	77.26	21.42	777
vSTDEV	4.08	4	77.26	82.04	22.98	561
		5	82.04	86.82	23.51	494
tHIGH	110.72	6	86.82	91.60	20.06	64
tLOW	62.93	7	91.60	96.38	15.96	31
tRANGE	47.79	8	96.38	101.16	15.31	15
tMEAN	74.73	9	101.16	105.94	15.14	6
tSTDEV	6.16	10	105.94	110.72	12.53	1

Stopped = 165.

AVALANCHE ENTERING SEGMENT 13
NUMBER OF PARTICLES MOVING 3880
NUMBER OF PARTICLES STOPPED 165
METERS TRAVELLED FROM START 2525

Upper Fan, 12m corn

vHIGH	27.36	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	1.50	1	66.17	71.34	19.13	213
vRANGE	25.86	2	71.34	76.51	17.74	1786
vMEAN	17.14	3	76.51	81.68	15.85	790

Stopped = 3722

vSTDEV	3.38	4	81.68	86.85	17.55	625
		5	86.85	92.02	16.79	376
tHIGH	117.88	6	92.02	97.20	11.88	36
tLOW	66.17	7	97.20	102.37	9.88	29
tRANGE	51.72	8	102.37	107.54	9.27	18
tMEAN	78.50	9	107.54	112.71	7.84	6
tSTDEV	6.40	10	112.71	117.88	8.02	1

AVALANCHE ENTERING SEGMENT 14
NUMBER OF PARTICLES MOVING 176
NUMBER OF PARTICLES STOPPED 3887
METERS TRAVELLED FROM START 2543

Lower Face · [illegible]

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	13.94					
vLOW	0.60	1	68.04	70.46	4.24	6
vRANGE	13.34	2	70.46	72.88	5.93	22
vMEAN	5.36	3	72.88	75.29	5.28	47
vSTDEV	2.52	4	75.29	77.71	5.06	21
		5	77.71	80.13	6.99	8
tHIGH	92.21	6	80.13	82.55	5.83	16
tLOW	68.04	7	82.55	84.96	4.89	14
tRANGE	24.17	8	84.96	87.38	5.25	19
tMEAN	78.87	9	87.38	89.80	5.54	17
tSTDEV	6.21	10	89.80	92.21	3.47	6

Stopped = 77

AVALANCHE ENTERING SEGMENT 15
NUMBER OF PARTICLES MOVING 132
NUMBER OF PARTICLES STOPPED 3964
METERS TRAVELLED FROM START 2576

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	18.08					
vLOW	8.81	1	70.76	73.44	14.66	2
vRANGE	9.26	2	73.44	76.11	14.91	15
vMEAN	14.03	3	76.11	78.79	14.17	33
vSTDEV	1.67	4	78.79	81.46	13.90	22
		5	81.46	84.14	14.48	11
tHIGH	97.52	6	84.14	86.82	14.11	7
tLOW	70.76	7	86.82	89.49	13.69	15
tRANGE	26.76	8	89.49	92.17	13.73	19
tMEAN	82.51	9	92.17	94.84	13.72	5
tSTDEV	6.18	10	94.84	97.52	11.03	3

Stopped = 53

AVALANCHE ENTERING SEGMENT 16
NUMBER OF PARTICLES MOVING 111
NUMBER OF PARTICLES STOPPED 4017
METERS TRAVELLED FROM START 2608

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	14.62					
vLOW	4.57	1	73.42	75.89	12.54	2
vRANGE	10.05	2	75.89	78.37	10.28	9
vMEAN	9.46	3	78.37	80.84	9.82	25
vSTDEV	1.98	4	80.84	83.31	8.77	25
		5	83.31	85.79	8.87	5
tHIGH	98.15	6	85.79	88.26	9.13	9
tLOW	73.42	7	88.26	90.73	10.67	7
tRANGE	24.73	8	90.73	93.21	9.81	13
tMEAN	84.80	9	93.21	95.68	8.66	12
tSTDEV	6.08	10	95.68	98.15	8.64	4

Stopped = 60

AVALANCHE ENTERING SEGMENT 17
NUMBER OF PARTICLES MOVING 81
NUMBER OF PARTICLES STOPPED 4077
METERS TRAVELLED FROM START 2638

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	14.38					
vLOW	1.94	1	76.11	78.65	12.13	2
vRANGE	12.44	2	78.65	81.19	10.66	10

vMEAN	9.42	3	81.19	83.73	9.64	16
vSTDEV	2.29	4	83.73	86.27	8.45	16
		5	86.27	88.80	8.83	4
tHIGH	101.50	6	88.80	91.34	9.27	7
tLOW	76.11	7	91.34	93.88	9.78	7
tRANGE	25.40	8	93.88	96.42	9.29	9
tMEAN	87.75	9	96.42	98.96	9.35	7
tSTDEV	6.32	10	98.96	101.50	8.37	3

Stopped = 33

AVALANCHE ENTERING SEGMENT 18
NUMBER OF PARTICLES MOVING 64
NUMBER OF PARTICLES STOPPED 4110
METERS TRAVELLED FROM START 2654

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	15.04					
vLOW	3.13	1	77.58	80.19	10.26	2
vRANGE	11.91	2	80.19	82.80	10.08	11
vMEAN	8.81	3	82.80	85.42	8.52	11
vSTDEV	2.35	4	85.42	88.03	7.55	14
		5	88.03	90.64	10.84	1
tHIGH	103.70	6	90.64	93.25	7.65	6
tLOW	77.58	7	93.25	95.86	11.04	6
tRANGE	26.12	8	95.86	98.48	9.93	7
tMEAN	89.01	9	98.48	101.09	7.52	4
tSTDEV	6.48	10	101.09	103.70	5.30	2

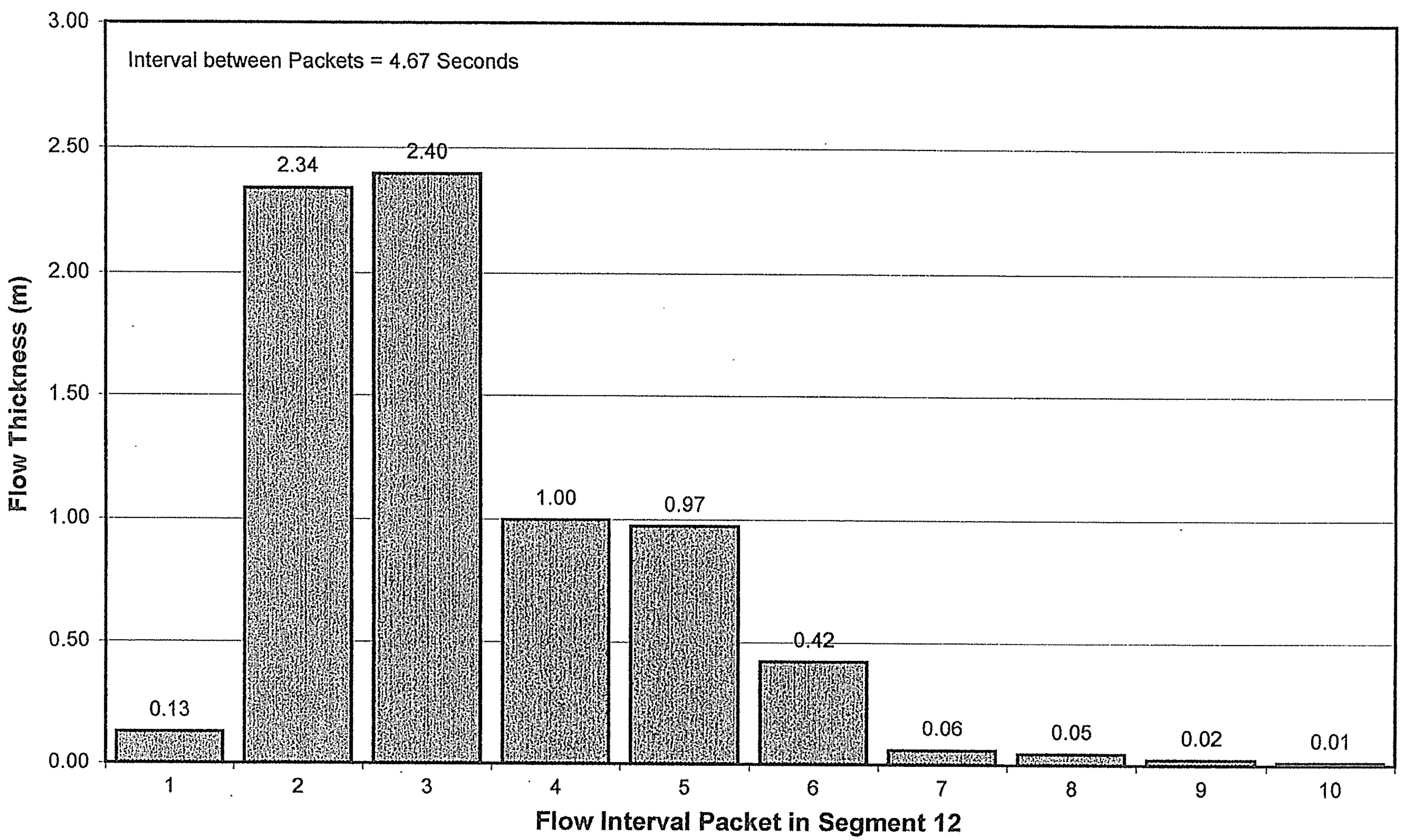
Stopped = 105 (in 41m)

NUMBER OF PARTICLES MOVING 1
NUMBER OF PARTICLES STOPPED 4215
FASTEST PARTICLE SPEED AT FRONT 41.2 m/s
FASTEST PARTICLE SPEED (ANYWHERE) 46.8 m/s
ALPHA 28.9 degrees

MAX_DEPOSIT 2695 meters
MIN_DEPOSIT 2452 meters
RANGE_DEPOSIT 243 meters
MEAN_DEPOSIT 2539 meters
STD_DEV_DEPOSIT 29 meters

Packet	Max(m)	Min(m)	Particles
1	2476	2452	81
2	2501	2476	45
3	2525	2501	39
4	2549	2525	3769
5	2574	2549	28
6	2598	2574	29
7	2622	2598	52
8	2646	2622	50
9	2671	2646	78
10	2695	2671	44

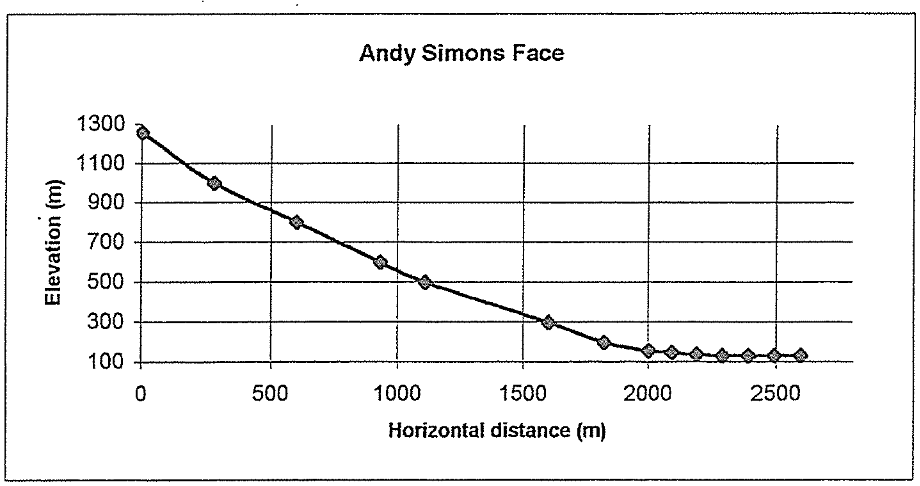
Horse Pasture Flow Thickness Distribution, Meadow Above Road



Avalanche Profile and x/y coordinates

Andy Simons

Raw Data in feet		Data in meters		Segment Data			
X-feet	Y-feet	X-meters	Y-meters	L-meters	Ang - Deg	Sum L	Avg Angle
		0	1260			0.0	
		280	1000	382.1	42.9	382.1	42.9
		600	800	377.4	32.0	759.5	37.5
		930	600	385.9	31.2	1145.3	35.4
		1110	500	205.9	29.1	1351.2	34.4
		1600	300	529.2	22.2	1880.5	31.0
		1820	200	241.7	24.4	2122.2	30.2
		2000	160	184.4	12.5	2306.5	28.8
		2090	150	90.6	6.3	2397.1	28.0
		2190	140	100.5	5.7	2497.6	27.1
		2290	134	100.2	3.4	2597.8	26.2
		2390	134	100.0	0.0	2697.8	25.2
		2490	134	100.0	0.0	2797.8	24.3
		2590	134	100.0	0.0	2897.8	23.5



Please note: all v-variables are in meters/second.
Please note: all t-variables are in seconds.
Please note: NP is number of particles in packet.

AVALANCHE ENTERING SEGMENT	2
NUMBER OF PARTICLES MOVING	1910
NUMBER OF PARTICLES STOPPED	0
METERS TRAVELLED FROM START	382

vHIGH	28.61	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	3.00	1	0.49	2.76	3.49	31
vRANGE	25.61	2	2.76	5.02	6.59	73
vMEAN	20.82	3	5.02	7.29	10.10	113
vSTDEV	6.38	4	7.29	9.55	13.45	152
		5	9.55	11.82	16.57	187
tHIGH	23.15	6	11.82	14.09	19.40	219
tLOW	0.49	7	14.09	16.35	21.95	249
tRANGE	22.66	8	16.35	18.62	24.20	274
tMEAN	14.97	9	18.62	20.89	26.16	296
tSTDEV	5.54	10	20.89	23.15	27.86	316

AVALANCHE ENTERING SEGMENT	3
NUMBER OF PARTICLES MOVING	2287
NUMBER OF PARTICLES STOPPED	0
METERS TRAVELLED FROM START	759

vHIGH	53.78	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.66	1	15.33	17.17	34.76	37
vRANGE	51.12	2	17.17	19.01	35.89	149
vMEAN	41.36	3	19.01	20.84	36.03	329
vSTDEV	6.70	4	20.84	22.68	38.38	324
		5	22.68	24.52	42.95	211
tHIGH	33.71	6	24.52	26.36	43.37	234
tLOW	15.33	7	26.36	28.20	43.93	256
tRANGE	18.38	8	28.20	30.04	44.14	264
tMEAN	25.26	9	30.04	31.87	44.66	288
tSTDEV	4.64	10	31.87	33.71	44.58	195

AVALANCHE ENTERING SEGMENT	4
NUMBER OF PARTICLES MOVING	2673
NUMBER OF PARTICLES STOPPED	0
METERS TRAVELLED FROM START	1145

vHIGH	58.49	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.61	1	23.58	25.46	39.76	30
vRANGE	55.88	2	25.46	27.34	41.79	135
vMEAN	45.64	3	27.34	29.22	41.94	285
vSTDEV	7.92	4	29.22	31.10	42.06	500
		5	31.10	32.98	44.27	493
tHIGH	42.37	6	32.98	34.85	48.83	259
tLOW	23.58	7	34.85	36.73	49.10	280
tRANGE	18.80	8	36.73	38.61	49.42	268
tMEAN	33.32	9	38.61	40.49	49.20	298
tSTDEV	4.23	10	40.49	42.37	48.41	125

AVALANCHE ENTERING SEGMENT	5
NUMBER OF PARTICLES MOVING	2879
NUMBER OF PARTICLES STOPPED	0
METERS TRAVELLED FROM START	1351

vHIGH	58.37	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.47	1	27.65	29.59	40.42	29
vRANGE	55.90	2	29.59	31.52	42.50	130
vMEAN	45.48	3	31.52	33.46	42.88	271
vSTDEV	8.08	4	33.46	35.39	42.52	444
		5	35.39	37.33	43.42	766

tHIGH	47.01	6	37.33	39.27	48.13	291
tLOW	27.65	7	39.27	41.20	49.09	288
tRANGE	19.35	8	41.20	43.14	49.20	288
tMEAN	37.56	9	43.14	45.07	49.09	297
tSTDEV	4.03	10	45.07	47.01	47.77	75

AVALANCHE ENTERING SEGMENT 6
NUMBER OF PARTICLES MOVING 3408
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 1880

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	52.05					
vLOW	1.94	1	39.06	41.17	36.97	25
vRANGE	50.11	2	41.17	43.29	37.76	122
vMEAN	38.17	3	43.29	45.40	38.02	236
vSTDEV	7.16	4	45.40	47.51	38.39	406
		5	47.51	49.63	38.43	639
tHIGH	60.19	6	49.63	51.74	37.34	777
tLOW	39.06	7	51.74	53.85	37.15	581
tRANGE	21.13	8	53.85	55.97	39.72	370
tMEAN	50.26	9	55.97	58.08	40.61	219
tSTDEV	3.80	10	58.08	60.19	38.12	33

AVALANCHE ENTERING SEGMENT 7
NUMBER OF PARTICLES MOVING 3650
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2122

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	53.49					
vLOW	2.13	1	44.26	46.52	33.61	22
vRANGE	51.36	2	46.52	48.78	35.91	110
vMEAN	38.94	3	48.78	51.04	37.53	265
vSTDEV	6.48	4	51.04	53.30	37.75	454
		5	53.30	55.56	39.37	653
tHIGH	66.86	6	55.56	57.82	39.47	808
tLOW	44.26	7	57.82	60.08	38.90	686
tRANGE	22.60	8	60.08	62.34	40.06	466
tMEAN	56.25	9	62.34	64.60	39.79	165
tSTDEV	3.94	10	64.60	66.86	39.11	21

AVALANCHE ENTERING SEGMENT 8
NUMBER OF PARTICLES MOVING 3834
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2306

Sneo
W = 60 m

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	44.33					
vLOW	0.65	1	48.63	54.15	34.05	139
vRANGE	43.68	2	54.15	59.68	33.31	843
vMEAN	30.01	3	59.68	65.20	30.04	1960
vSTDEV	7.59	4	65.20	70.73	29.76	747
		5	70.73	76.25	10.56	46
tHIGH	103.87	6	76.25	81.78	6.47	33
tLOW	48.63	7	81.78	87.30	6.69	31
tRANGE	55.24	8	87.30	92.82	6.40	24
tMEAN	62.60	9	92.82	98.35	6.10	8
tSTDEV	5.57	10	98.35	103.87	7.05	3

AVALANCHE ENTERING SEGMENT 9
NUMBER OF PARTICLES MOVING 3597
NUMBER OF PARTICLES STOPPED 328
METERS TRAVELLED FROM START 2397

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	40.90					
vLOW	1.22	1	51.30	53.95	30.61	17
vRANGE	39.68	2	53.95	56.60	28.57	88
vMEAN	25.07	3	56.60	59.25	28.04	241
vSTDEV	5.29	4	59.25	61.90	27.52	431

		5	61.90	64.55	26.81	695
tHIGH	77.81	6	64.55	67.20	24.69	865
tLOW	51.30	7	67.20	69.85	23.20	794
tRANGE	26.51	8	69.85	72.51	22.31	394
tMEAN	65.20	9	72.51	75.16	19.10	65
tSTDEV	4.17	10	75.16	77.81	12.90	7

AVALANCHE ENTERING SEGMENT 10
NUMBER OF PARTICLES MOVING 3343
NUMBER OF PARTICLES STOPPED 682
METERS TRAVELLED FROM START 2497

vHIGH	34.11	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	0.53	1	54.95	57.73	26.43	13
vRANGE	33.58	2	57.73	60.51	22.87	81
vMEAN	18.45	3	60.51	63.29	21.32	233
vSTDEV	4.96	4	63.29	66.07	20.85	409
		5	66.07	68.85	19.99	663
tHIGH	82.75	6	68.85	71.63	18.76	734
tLOW	54.95	7	71.63	74.41	16.92	680
tRANGE	27.81	8	74.41	77.19	14.86	414
tMEAN	69.66	9	77.19	79.97	11.38	104
tSTDEV	4.59	10	79.97	82.75	10.98	12

AVALANCHE ENTERING SEGMENT 11
NUMBER OF PARTICLES MOVING 1553
NUMBER OF PARTICLES STOPPED 2572
METERS TRAVELLED FROM START 2597

vHIGH	27.95	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	0.71	1	59.75	62.56	20.16	12
vRANGE	27.24	2	62.56	65.38	15.69	57
vMEAN	12.04	3	65.38	68.20	14.60	117
vSTDEV	4.29	4	68.20	71.02	13.42	230
		5	71.02	73.84	12.44	341
tHIGH	87.92	6	73.84	76.65	11.65	347
tLOW	59.75	7	76.65	79.47	10.73	257
tRANGE	28.18	8	79.47	82.29	9.58	147
tMEAN	73.91	9	82.29	85.11	7.07	39
tSTDEV	4.67	10	85.11	87.92	6.08	6

AVALANCHE ENTERING SEGMENT 12
NUMBER OF PARTICLES MOVING 27
NUMBER OF PARTICLES STOPPED 4198
METERS TRAVELLED FROM START 2697

vHIGH	17.59	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	3.98	1	65.04	66.68	17.42	2
vRANGE	13.62	2	66.68	68.31	10.08	1
vMEAN	9.70	3	68.31	69.95	12.60	1
vSTDEV	3.53	4	69.95	71.58	0.00	0
		5	71.58	73.22	6.99	4
tHIGH	81.39	6	73.22	74.85	13.06	1
tLOW	65.04	7	74.85	76.49	8.72	4
tRANGE	16.35	8	76.49	78.12	10.20	4
tMEAN	75.72	9	78.12	79.76	8.36	7
tSTDEV	4.54	10	79.76	81.39	9.66	3

NUMBER OF PARTICLES MOVING 1
NUMBER OF PARTICLES STOPPED 4294
FASTEST PARTICLE SPEED AT FRONT 52.1 m/s
FASTEST PARTICLE SPEED (ANYWHERE) 60.3 m/s
ALPHA 24.6 degrees

MAX_DEPOSIT 2766 meters
MIN_DEPOSIT 2306 meters
RANGE_DEPOSIT 460 meters

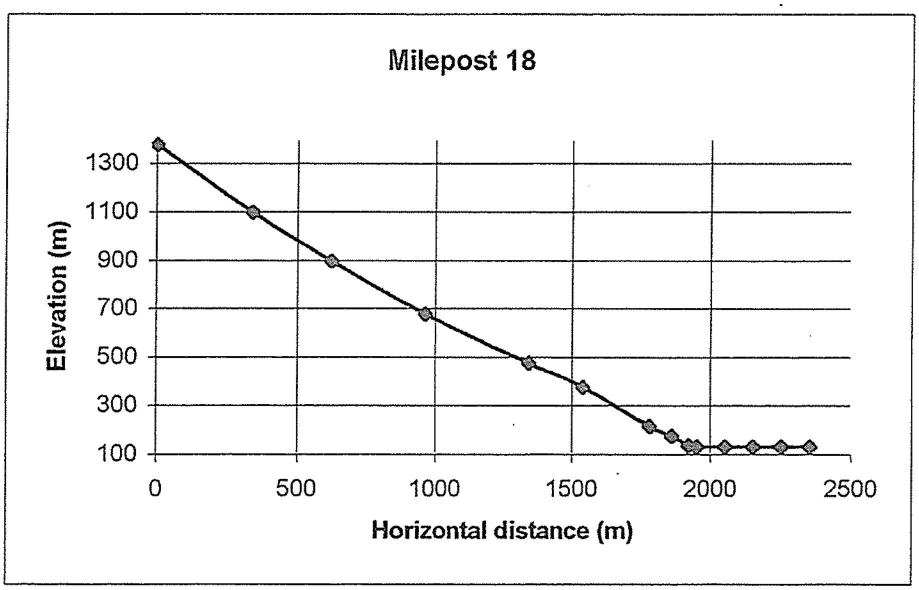
MEAN_DEPOSIT 2561 meters
STD_DEV_DEPOSIT 88 meters

Packet	Max(m)	Min(m)	Particles
1	2352	2306	232
2	2398	2352	103
3	2444	2398	144
4	2490	2444	167
5	2536	2490	499
6	2582	2536	1020
7	2628	2582	1317
8	2674	2628	638
9	2720	2674	119
10	2766	2720	55

Avalanche Profile and x/y coordinates

MP 18

Raw Data in feet		**Data in meters**		**Segment Data**				
X-feet	Y-feet	X-meters	Y-meters		L-meters	Ang - Deg	Sum L	Avg Angle
		0	1380				0.0	
		340	1100	1	440.5	39.5	440.5	39.5
		620	900	2	344.1	35.5	784.5	37.7
		960	680	3	405.0	32.9	1189.5	36.1
		1340	480	4	429.4	27.8	1618.9	33.9
		1540	380	5	223.6	26.6	1842.5	33.0
		1780	220	6	288.4	33.7	2131.0	33.1
		1860	180	7	89.4	26.6	2220.4	32.8
		1920	140	8	72.1	33.7	2292.5	32.9
		1950	135	9	30.4	9.5	2323.0	32.6
		2050	135	10	100.0	0.0	2423.0	31.3
		2150	135	11	100.0	0.0	2523.0	30.1
		2250	135	12	100.0	0.0	2623.0	29.0
		2350	135	13	100.0	0.0	2723.0	27.9



MP 18
Rel. per ≈ 6/50 yr
μ 0.2
log(M0) = 7.5?
ξ = 0.2

Please note: all v-variables are in meters/second.
Please note: all t-variables are in seconds.
Please note: NP is number of particles in packet.

AVALANCHE ENTERING SEGMENT 2
NUMBER OF PARTICLES MOVING 2202
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 440

vHIGH	21.50	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	3.00	1	0.51	3.40	3.82	44
vRANGE	18.50	2	3.40	6.30	7.43	105
vMEAN	17.56	3	6.30	9.20	11.07	160
vSTDEV	4.28	4	9.20	12.09	14.08	203
		5	12.09	14.99	16.42	238
tHIGH	29.47	6	14.99	17.88	18.17	263
tLOW	0.51	7	17.88	20.78	19.43	281
tRANGE	28.96	8	20.78	23.68	20.31	295
tMEAN	18.12	9	23.68	26.57	20.92	303
tSTDEV	7.23	10	26.57	29.47	21.34	310

AVALANCHE ENTERING SEGMENT 3
NUMBER OF PARTICLES MOVING 2546
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 784

vHIGH	40.15	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.86	1	15.29	17.88	29.27	94
vRANGE	37.29	2	17.88	20.47	29.56	433
vMEAN	33.37	3	20.47	23.06	34.01	204
vSTDEV	4.02	4	23.06	25.65	34.23	231
		5	25.65	28.24	34.43	251
tHIGH	41.19	6	28.24	30.83	34.43	256
tLOW	15.29	7	30.83	33.42	34.31	277
tRANGE	25.90	8	33.42	36.01	34.55	278
tMEAN	28.69	9	36.01	38.60	34.54	270
tSTDEV	7.18	10	38.60	41.19	34.46	252

AVALANCHE ENTERING SEGMENT 4
NUMBER OF PARTICLES MOVING 2951
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 1189

vHIGH	40.11	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.71	1	26.71	29.46	28.43	87
vRANGE	37.40	2	29.46	32.21	29.79	378
vMEAN	32.98	3	32.21	34.96	32.40	673
vSTDEV	3.98	4	34.96	37.72	34.21	249
		5	37.72	40.47	34.09	263
tHIGH	54.22	6	40.47	43.22	34.03	276
tLOW	26.71	7	43.22	45.97	34.22	293
tRANGE	27.51	8	45.97	48.72	34.18	295
tMEAN	39.57	9	48.72	51.47	34.01	293
tSTDEV	7.14	10	51.47	54.22	33.65	144

AVALANCHE ENTERING SEGMENT 5
NUMBER OF PARTICLES MOVING 3380
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 1618

vHIGH	38.09	PACKET	tMIN	tMAX	vMEAN	NP
vLOW	2.38	1	39.75	42.59	23.65	52
vRANGE	35.72	2	42.59	45.43	26.23	290
vMEAN	29.24	3	45.43	48.27	28.94	1093
vSTDEV	3.46	4	48.27	51.11	29.69	344
		5	51.11	53.94	30.23	277

tHIGH	68.14	6	53.94	56.78	30.15	274
tLOW	39.75	7	56.78	59.62	29.93	307
tRANGE	28.39	8	59.62	62.46	30.03	311
tMEAN	52.61	9	62.46	65.30	30.21	301
tSTDEV	6.96	10	65.30	68.14	29.68	131

AVALANCHE ENTERING SEGMENT 6
NUMBER OF PARTICLES MOVING 3604
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 1842

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	36.33					
vLOW	2.29	1	46.80	49.71	20.89	40
vRANGE	34.04	2	49.71	52.62	25.18	253
vMEAN	28.33	3	52.62	55.53	28.07	1162
vSTDEV	3.37	4	55.53	58.44	28.51	532
		5	58.44	61.36	29.27	271
tHIGH	75.91	6	61.36	64.27	29.08	283
tLOW	46.80	7	64.27	67.18	29.17	318
tRANGE	29.12	8	67.18	70.09	29.15	311
tMEAN	59.89	9	70.09	73.00	29.14	305
tSTDEV	6.90	10	73.00	75.91	28.78	129

AVALANCHE ENTERING SEGMENT 7
NUMBER OF PARTICLES MOVING 3892
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2130

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	39.53					
vLOW	2.76	1	55.60	58.57	21.40	47
vRANGE	36.78	2	58.57	61.54	29.26	444
vMEAN	33.04	3	61.54	64.51	33.69	1176
vSTDEV	3.47	4	64.51	67.48	33.43	611
		5	67.48	70.46	33.90	288
tHIGH	85.31	6	70.46	73.43	33.73	284
tLOW	55.60	7	73.43	76.40	33.74	323
tRANGE	29.71	8	76.40	79.37	33.83	321
tMEAN	68.33	9	79.37	82.34	33.84	287
tSTDEV	6.94	10	82.34	85.31	33.60	111

AVALANCHE ENTERING SEGMENT 8
NUMBER OF PARTICLES MOVING 3981
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2219

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	38.03					
vLOW	2.29	1	58.51	61.48	21.97	42
vRANGE	35.74	2	61.48	64.44	27.18	544
vMEAN	30.80	3	64.44	67.41	31.40	1219
vSTDEV	3.58	4	67.41	70.38	31.31	577
		5	70.38	73.34	31.70	284
tHIGH	88.17	6	73.34	76.31	31.61	289
tLOW	58.51	7	76.31	79.27	31.59	320
tRANGE	29.66	8	79.27	82.24	31.80	318
tMEAN	70.96	9	82.24	85.21	31.50	281
tSTDEV	6.90	10	85.21	88.17	31.34	107

AVALANCHE ENTERING SEGMENT 9
NUMBER OF PARTICLES MOVING 4053
NUMBER OF PARTICLES STOPPED 0
METERS TRAVELLED FROM START 2291

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	38.69					
vLOW	2.76	1	60.76	63.74	22.72	54
vRANGE	35.93	2	63.74	66.71	29.68	528
vMEAN	31.99	3	66.71	69.69	32.22	1297
vSTDEV	3.35	4	69.69	72.66	32.44	578

		5	72.66	75.63	32.74	289
tHIGH	90.50	6	75.63	78.61	32.67	285
tLOW	60.76	7	78.61	81.58	32.70	322
tRANGE	29.74	8	81.58	84.56	32.92	333
tMEAN	73.10	9	84.56	87.53	32.63	267
tSTDEV	6.88	10	87.53	90.50	32.28	100

AVALANCHE ENTERING SEGMENT 10
NUMBER OF PARTICLES MOVING 4037
NUMBER OF PARTICLES STOPPED 46
METERS TRAVELLED FROM START 2321

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	32.75					
vLOW	1.86	1	61.80	64.77	27.73	29
vRANGE	30.89	2	64.77	67.74	24.50	472
vMEAN	26.26	3	67.74	70.72	26.12	1344
vSTDEV	2.75	4	70.72	73.69	26.53	593
		5	73.69	76.66	26.81	289
tHIGH	91.52	6	76.66	79.63	26.75	283
tLOW	61.80	7	79.63	82.61	26.67	322
tRANGE	29.73	8	82.61	85.58	27.02	330
tMEAN	74.24	9	85.58	88.55	26.82	272
tSTDEV	6.83	10	88.55	91.52	26.26	103

AVALANCHE ENTERING SEGMENT 11 — *Impact on Sc. Fall*
NUMBER OF PARTICLES MOVING 2834
NUMBER OF PARTICLES STOPPED 1349
METERS TRAVELLED FROM START 2421

		PACKET	tMIN	tMAX	vMEAN	NP
vHIGH	18.85					
vLOW	0.10	1	67.25	70.28	12.01	25
vRANGE	18.75	2	70.28	73.32	11.60	242
vMEAN	9.79	3	73.32	76.36	10.03	865
vSTDEV	3.17	4	76.36	79.39	8.61	492
		5	79.39	82.43	9.71	218
tHIGH	97.62	6	82.43	85.47	9.68	229
tLOW	67.25	7	85.47	88.51	10.32	241
tRANGE	30.37	8	88.51	91.54	9.56	266
tMEAN	80.42	9	91.54	94.58	9.67	199
tSTDEV	6.88	10	94.58	97.62	7.40	57

NUMBER OF PARTICLES MOVING 1
NUMBER OF PARTICLES STOPPED 4255
FASTEST PARTICLE SPEED AT FRONT 38.1 m/s
FASTEST PARTICLE SPEED (ANYWHERE) 41.3 m/s
ALPHA 30.4 degrees

MAX_DEPOSIT 2493 meters
MIN_DEPOSIT 2291 meters
RANGE_DEPOSIT 202 meters
MEAN_DEPOSIT 2426 meters
STD_DEV_DEPOSIT 25 meters

Packet	Max(m)	Min(m)	Particles
1	2311	2291	31
2	2331	2311	33
3	2352	2331	39
4	2372	2352	63
5	2392	2372	87
6	2412	2392	526
7	2432	2412	1639
8	2453	2432	1398
9	2473	2453	368
10	2493	2473	71

APPENDIX F
VALUE ENGINEERING STUDY
SEWARD HIGHWAY IMPROVEMENTS MP 18-25

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION and PUBLIC FACILITIES

Seward Highway Improvements MP 18 to 25

VALUE ENGINEERING STUDY

October 2001

By
SOLUTIONS ENGINEERING & FACILITATING, INC.
9032 Gray Fox Drive
Evergreen, CO 8043

303-670-5620

TABLE OF CONTENTS

SECTION 1 - SUMMARY

SUMMARY

This Value Engineering (VE) Study generated fourteen proposals and fourtenn supplemental recommendations.

Caveats:

- Cost estimates made by the VE Team are intended to reflect relative values between alternatives. The estimated savings identified within each proposal are based upon comparison of the proposal to the design basis. Therefore, as is true with all cost estimates, the savings indicated are only approximate.
- Only potential savings are shown. As the proposals are implemented, additional costs or savings may result from redesign or modification.
- The proposed savings represent life cycle cost savings, not just initial (capital) savings. Future operations, maintenance, and periodic replacement costs are all calculated into the potential life cycle cost savings listed.
- Future estimated potential life cycle savings are presented on a present worth basis calculated as a 8 percent interest rate over a 20-year expected equipment life span for asphalt paving, 30 years for concrete paving and 75 years for bridges (I = 8% and N = 20, 30, or 75 years). The actual life cycle costs will vary as a function of equipment life span and the interest rate charged for capital financing.
- Some VE Proposals are mutually exclusive. Therefore, the potential savings are not the sum of all the VE Proposals presented.

PROPOSAL NO.	VE PROPOSAL DESCRIPTION	REVIEW BOARD COMMENTS
P01-014	Identify disposal site near the south end of the project. *Initial Est. Savings: $150,000* *Future Est. Savings: $0,000* *Total Est. Savings: $150,000*	Yes Accept.
P01-044	Consider a reduced or aggregate turf structural section for the Lawing Airport aircraft operating surfaces. *Initial Est. Savings: $100,000* *Future Est. Savings: $0,000* *Total Est. Savings: $100,000*	Accept reduced Agg Layer
P01-038	Reuse existing rail as new siding/mainline *Initial Est. Savings: $63,250* *Future Est. Savings: $0,000* *Total Est. Savings: $63,250*	Partially Accept - contact RR.
P01-003	Build a new box culvert next to the existing one at Rocky Creek and backfill the existing culvert with cellular concrete (foam grout) or flowable fill *Initial Est. Savings: $34,000* *Future Est. Savings: $0,000* *Total Est. Savings: $34,000*	Reject
P01-002	Rehabilitate existing box culvert in lieu of replacing it *Initial Est. Savings: $60,000* *Future Est. Savings: $0,000* *Total Est. Savings: $60,000*	Accept
P01-049	Delete Lower Trail Lake Road and provide driveways for access instead. *Initial Est. Savings: $1,600,000* *Future Est. Savings: $0,000* *Total Est. Savings: $1,600,000*	Reject
P01-027	Allow the contractor to use staged bridge construction as an alternative to detours at Victor Creek and Ptarmigan Creek bridges. *Initial Est. Savings: $300,000* *Future Est. Savings: $0,000* *Total Est. Savings: $300,000*	Accept
P03-012	Reposition the airport apron to reduce access road length. *Initial Est. Savings: $148,000* *Future Est. Savings: $0,000* *Total Est. Savings: $148,000*	Accept

PROPOSAL NO.	VE PROPOSAL DESCRIPTION	REVIEW BOARD COMMENTS
P01-004	Consider shifts in the alignment to weigh retaining wall (or slope reinforcement techniques) costs and impacts with excavation. *Initial Est. Savings: $220,000* *Future Est. Savings: $0,000* *Total Est. Savings: $220,000*	Accept
P01-015	Provide passing zones in lieu of passing lanes in physically constrained areas. *Initial Est. Savings: 590,000-$980,000* *Future Est. Savings: $0,000* *Total Est. Savings: 590,000-$980,000*	Reject
P05-002	Reduce highway shoulders and ditch section in costly (large cut) areas *Initial Est. Savings: $810,000* *Future Est. Savings: $0,000* *Total Est. Savings: $810,000*	Reject
P01-043	Eliminate asphalt concrete pavement on peripheral roadways including Lower Trail Lake Access Road, and Lawing Airport Road. *Initial Est. Savings: $43,600* *Future Est. Savings: $0,000* *Total Est. Savings: $43,600*	Reject
P01-016	Install a "Grade Separated Intersection" or a traditional at intersection in lieu of the proposed interchange at Crown Point. *Initial Est. Savings: 150,000 - $740,000* *Future Est. Savings: $0,000* *Total Est. Savings: 150,000 - $740,000*	Reject
P01-045	Upgrade the highway on the original alignment through Crown Point rather than construct an new alignment. *Initial Est. Savings: $3,800,000* *Future Est. Savings: $0,000* *Total Est. Savings: $3,800,000*	Accept

SECTION 2 - INTRODUCTION

INTRODUCTION

Value Engineering (VE) analysis identifies the high-cost areas of a project during the early design stages. The VE Study then determines less expensive alternative designs that can still be incorporated into the final design drawings and specifications without incurring large costs for redesign or major project delay. These VE proposals are substantiated with technical and economic analyses.

PROJECT DESCRIPTION

The project is a reconstruction of the existing two-lane arterial New Seward Highway, which is located 100 miles south of Anchorage and 18 miles north of Seward on the scenic Kenai Peninsula. The project terrain is mountainous, and much of the highway is cut into steep-sided slopes that lie between the mountains, Kenai Lake, and the railroad below. Where adjacent land is level, there is rural residential development and small tourist-oriented businesses. The Seward Highway is a National Scenic Highway. The proposed project will add passing lanes and widen highway shoulders, but will remain a two-lane highway. In the Crown Point community, the highway will be on a new alignment and old highway converted into a frontage road. This will require relocation of the railroad, and two existing bridges will be widened. Also, four highway bridges and one railroad bridge will be replaced. The largest bridge will be on curve, 120 meters long. Two arch pipe grade separations are proposed; one over railroad, another over a crossroad. The major cost items are excavation (rock and unclassified), retaining walls, bridges, railroad, and roadway surfacing. Most surplus excavation will be used to elevate the Crown Point airstrip. New rights-of-way will be required, mostly from the State-owned railroad and the State Department of Natural Resources. There will be other partial acquisitions from private owners. All other land in the project vicinity is the Chugach National Forest. Some utility relocation may be required. The construction cost estimate is $40,000,000.

ORGANIZATION

VE STUDY TEAM

The following individuals are members of the VE Team:

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THE REVIEW BOARD

The Review Board is comprised of the following representatives.

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The Review Board decided upon the status of the VE proposals one of four ways:

1. Accept the proposed alternative as it stands. This will require the design team to implement the accepted proposed alternative. Those individuals comprising the Review Board are expected to have this authority for their respective organization.

2. Accept the proposed alternative with modifications. This disposition is similar to item 1 but with some changes imposed by the Review Board.

3. Decline the proposed alternative altogether. This disposition is obvious but proper reasoning must be given for the final report.

4. Table the proposed alternative for further study or information gathering. This is the least desirable of the options since it delays progress; however, practicality sometimes deems it necessary. If a proposed alternative is tabled, it is wise to assign responsibilities to resolve the issue(s), assign a schedule for resolution, and set a decision tree.

METHOD OF THE VE STUDY

VE ANALYTICAL PROCESS

STEP	PROCEDURE INVOLVED
Information	The VE Team reviewed the existing design to identify basic functions where effectiveness could be improved or potential cost savings could be significant. These basic functions were organized into a Function Analysis Systems Technique (FAST) diagram. FAST diagrams serve as tools to help the VE Team visualize the functions that different portions of a project must perform. The FAST diagrams set priorities for analysis and for assessing the compatibility of alternatives with the total project design package.
Creative	The VE Team selected the basic functions for further analysis on the basis of cost and potential for improvement. Formal brainstorming sessions generated as many alternative methods as possible for achieving the selected basic functions.
Analysis	Analysis was performed by first passing or failing the brainstormed ideas, then combining or grouping similar ideas. The VE Team as a whole then discussed and recorded the relative advantages and disadvantages of each idea. The ideas surviving these discussions were selected as candidates for further development by individual team members.
Development	A detailed technical examination followed, including specific quantities, costs, and calculations for ideas shown to have potential for significant savings. An economic analysis of technically feasible alternatives was made. Ideas that passed the technical and economical analyses and, in the opinion of the VE Team should be incorporated into the design, were prepared as formal proposals.
Presentation & Report	All ideas, calculations, and cost analyses were recorded during the VE process and were compiled to provide support to this document.

SECTION 3 – VE PROPOSALS

VALUE ENGINEERING PROPOSAL NO. 01-003

SUMMARY PROPOSAL DESCRIPTION:

Build a new box culvert next to the existing one at Rocky Creek and backfill the existing culvert with cullular concrete (foam grout) or flowable fill

Estimated potential savings:

Initial:	$ 34,000
Future:	$ 0,000
Total:	$ 34,000

Discussion:

A new concrete box culvert could be built along side of the existing culvert . The new culvert box would be a three sided box using one wall of the existing box as the forth side. . The existing box would be backfilled with a cellular concrete or flowable fill to prevent settlement of the roadway with time.This would eliminate the cost of removing / demolishing the existing box.

Related Ideas:

Why not extend exist.?

EVALUATION
Idea Number: 01-003 Idea Description: Build new box culvert next to existing one & backfill existing culvert with cellular concrete
Advantages: 1. Saves costs and time to remove / demo existing culvert 2. Can increase size from 10ft X 10ft if required 3. New construction with longer service life 4. Traffic detouring for excavation of new box souldn't take any longer than demo of existing box per current design 5. Could do minor repairs and leave existing box open (not backfilled) plus build new box to provide addition capacity
Disadvantages: 1. Reroutes creek 2. Permitting issues 3. Existing box wall may be damaged
Risks: 1.
Conclusion: ☒ Propose this idea ☐ Propose this idea as a Supplemental Recommendation ☐ Do not propose this idea because

Calculations and/or Discussion:

Backfill existing box culvert w/ cellular Concrete

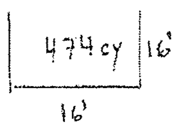
10' x 10' x 50' = 185 cy

Cellular Concrete 185 cy @ $150/cy — $27,750

Build Bulk heads Two @ $3500 each — $5,000

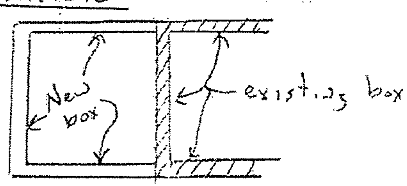
32,750

Excavate for New box



474 cy @ $18.33/cy — $8,689

Concrete



60 cy @ $800/cy — $48,000

Concrete for box east of highway From P.01-002 — $85,600

$175,039

New box at existing location From P.01-002 — Backfill existing — A

$208,811 − $175,039 = $33,772

VALUE ENGINEERING PROPOSAL NO. 01-002

SUMMARY PROPOSAL DESCRIPTION:

Rehabilitate existing box culvert in lieu of replacing it

Estimated potential savings:

Initial:	$ 60,000
Future:	$ 0,000
Total:	$ 60,000

Discussion:

The existing concrete box culvert at Sta 33+865, Rocky Creek, is schedule to be removed and a new concrete box culvert built at the existing location. Rather than removing and replacing the entire culvert as currently planned, repair the existing culvert invert. Also repair other concrete elements of the existing culvert as required.

Related Ideas:

EVALUATION
Idea Number: 01-002 Idea Description: Rehabilitate existing box culvert in lieu of replacing it
Advantages: 1. Save time and costs to remove existing box culvert 2. No lane closures required 3. No traffic control required
Disadvantages: 1. Existing size , 10ft X 10ft , of culvert is fixed
Risks: 1. Existing culvert may be found to be structurally unsound to allow for economical reuse
Conclusion: ☒ Propose this idea ☐ Propose this idea as a Supplemental Recommendation ☐ Do not propose this idea because

Calculations and/or Discussion:

Remove existing box culvert

Labor: - Flagman for 2 week
2 men x 80 hrs x $33.29/hr = $5,326.40

-- Opr
2 men x 80 hr x $39.37/hr 6,299.20

- Laborers
3 men x 80 hrs x $33.29/hr 7,989.60

Teamster
1 men x 80 hrs x $38.70/hr 3,096.00

Total Labor $22,711.00

Equipt: - Truck-dump 10 days @ $320/day $3,200

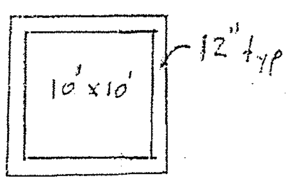
- Backhoe 10 days @ $750/day 7,500

- Loader 10 days @ 500/day 5000

Total Equipt 15,700

$38,411

New Concrete:



163 cy plus wingwalls 50 cy = 213 cy

213 cy @ $800/cy = $170,400

Total Cost $208,811

Repair existing box culvert

Clean and prep 3 weeks

- Labor : 3 men x 120 hrs x $33.29/hr =	$11,984
- Equip't : Misc @ 500/wk x 3 wks	1,500
	13,484

Concrete - invert only

10'w x 12" x 50'L = 20 cy

20 cy @ $1000/cy — $20,000

Misc repair - epoxy, etc — $30,000

New Concrete box east side of highway

107 cy @ $800/cy — 85600

149,084

Remove/Replace		Repair		Δ
$208,811	−	$149,084	=	$59,727

VALUE ENGINEERING PROPOSAL NO. 01-027

SUMMARY PROPOSAL DESCRIPTION:

OK

Allow the contractor to use staged bridge construction as an alternative to detours at Victor Creek and Ptarmigan Creek bridges.

Estimated potential savings:

Initial:	$ 300000
Future:	$ 0,000
Total:	$ 300000

Discussion:

Staged bridge construction may allow bridges to be constructed without detours. Staged construction would consist of the following sequence:

1. Shift traffic onto one lane of an existing bridge, using a traffic light to control traffic flows
2. Demolish half of the existing bridge
3. Construct half of the new structure
4. Shift traffic onto the new structure with traffic light control of flows
5. Demolish the remainder of the existing structure
6. Complete construction of the new structure

This process would only work in low traffic season (fall and winter)
It also typically works best if more than half of the existing structure can be preserved for one lane traffic.

Each detour has a total cost of approximately $300,000. As much as 50% of this $300,000 is potential savings that could be realized by deleting the detours and using staged construction.

Related Ideas:

Re-align the highway at bridge crossings to allow the existing bridge to be used in lieu of the detour.
This could be a full bridge width shift to eliminate the detour and eliminate any need for staged bridge construction. Trade-offs would be increased right-of-way impacts and increased environmental impacts.
The re-alignment could be a partial shift of half a bridge width. This would allow the existing bridge to be used in its entirety while half of the new bridge is being constructed. Single lane traffic would then be carried on the new structure while the existing bridge is removed and the new bridge constructed.

EVALUATION

Idea Number: 01-027

Idea Description: Allow the contractor to use staged bridge construction as an alternative to detours at Victor Creek and Ptarmigan Creek bridges.

Advantages:

1. Elilminate detours costs of install, remove, and revegetate.
2. Minimize impacts to streams and surrounding vegetation
3. Gives contractor an additional construction method option
4. May allow construction at times that would otherwise be prohibited due to fish concerns
5. Minimize right-of-way and permitting issues
6. May afford a way for the contractor to work effectively through the winter

Disadvantages:

1. Complicates bridge construction details
2. This option would only be viable in low traffic season (fall and winter)
3. Lowers traffic mobility
4. Complicates traffic control
5. May require the new bridge to be widened to accommodate the sequencing
6. May complicate removal of the existing structure

Risks:

1. Existing bridge stability and structurally adequacy in a partially demolished condition may limit this option. (This should be evaluated as a part of the bridge study report if this option is incorporated.)

Conclusion:

☒ Propose this idea
☐ Propose this idea as a Supplemental Recommendation
☐ Do not propose this idea because

Calculations and/or Discussion:

Detour Cost Estimate					
	[m]	[m]	[m]	[m^3]	
Description	wide	tall	Length	Volume	Totals
Unclassified Excavation	10	3.5	220	7700	
	Remove, haul, dispose [$/cm]			7.50	
	Credit for detour embankmant [$]			57,750	57,750
	[sm]	[$/sm]	[$/sm]	[$]	
	Area	Install	Remove	Credit	
Asphalt Paving	2200	8.00	2.00	22,000	22,000
Install and remove temporary bridge, signing, and rails				200,000	200,000
Total estimated Detour Cost					**$279,750**

VALUE ENGINEERING PROPOSAL NO. 01-004

SUMMARY PROPOSAL DESCRIPTION:

Consider shifts in the alignment to weigh retaining wall (or slope reinforcement techniques) costs and impacts with excavation.

Estimated potential savings:

Initial:	$ 220,000
Future:	$ 0,000
Total:	$ 220,000

Discussion:

The current alignment of the base case has been set to the existing vertical profile and shifted to accommodate horizontal constraints. No efforts to date have been made to weigh the costs of downslope retaining walls (or slope reinforcement techniques) versus excavation. The variables which should be considered include the slope height and material type which will be excavated along with the downslope fill heights which will be required.

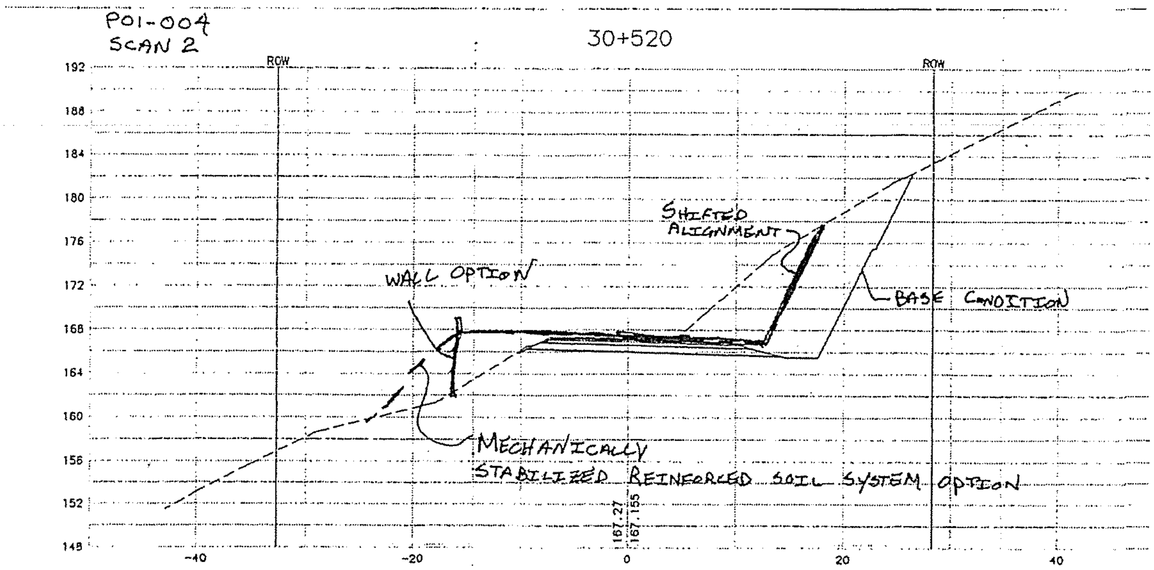
Related Ideas:

This proposal could be incororated into other proposals which narrow or shift the alignment including Proposal 05-002 which narrows the shoulders.

EVALUATION
Idea Number: 01-004 Idea Description: Consider shifts in the alignment to weigh retaining wall costs and impacts with excavation.
Advantages: 1. Better cut-fill balance will reduce haul.
Disadvantages: 1. Potential increase in maintanance. 2. Costruction could be complicated. 3. Walls could settle. 4. Additional testing would be required. 5. Steep slopes are dificult to vegitate.
Risks: 1.
Conclusion: ☒ Propose this idea ☐ Propose this idea as a Supplemental Recommendation ☐ Do not propose this idea because

Calculations and/or Discussion:

It is difficult to generalize the conditions and variables, which would weigh the costs of wall construction versus excavation. Due to the soil/rock conditions (which can be excavated and ripped without significant blasting) on this project, the costs to construct a wall would need to be offset by significant amounts of excavation. Assuming an average end area of excavation along the project alignment (applicable to this proposal) of about 100 m^2 at \$7.50/m^3 yields a cost of \$750 per linear meter of roadway for excavation. Assuming a cross section such as that at 30+520 where the existing uphill and down hill slopes are relatively equal, the downhill wall costs would need to be less (per linear meter along the alignment) than the uphill excavation. With an average downhill wall costs of \$600 m^2 the costs savings could never be recognized at a 45-degree slope angle. In many of the locations along the alignment however, the alignment could be shifted in part (to reduce the excavation) and a "Mechanically Reinforced Soil System" (MRSS) could be installed in lieu of a down hill wall. The MRSS is typically limited to 2-3 meters in height on a 45-degree slope angle. The all inclusive cost of such a system is approx. \$100 per m^2 of roadway surface. On the example presented below (Sta 30+520), the cost savings of excavation recognized by shifted alignment is approx. \$600 for each linear meter of road. The cost to construct the MRSS would be approx. \$500 per linear meter, netting a savings of apporx. \$100 per linear meter.



The table below summarizes potential locations along the alignment which cost savings may be recognized by incorporating MRSS:

Location of MRSS Begin Station	Location of MRSS End Station	Length (Meters)	Potential Cost Savings @ $100 Per Meter
29480	30760	1280	$128,000
32200	32620	420	$42,000
32800	32900	100	$10,000
33080	33120	40	$4,000
35400	35600	200	$20,000
36300	36500	200	$20,000
Total		2240	$224,000

Assumes an average cut height of 16 meters.

The total cost recognizes above may be high. Additional costs may be required which would lower the overall cost benefit. These costs may include but are not limited to:

- Additional design
- Testing
- Construction constraints and limitations
- Facing of the exposed slope

In addition to the direct cost savings of excavation, additional benefit to the project will be recognized by a more balanced earthwork cut and fill, thus reducing haul.

VALUE ENGINEERING PROPOSAL NO. 01-015

SUMMARY PROPOSAL DESCRIPTION:

Provide passing zones in lieu of passing lanes in physically constrained areas.

NO THANKS

Estimated potential savings:

Initial:	$ 590,000-$980,000
Future:	$ 0,000
Total:	$ 590,000-$980,000

Discussion:

This project is physically constrained by; the steep terrain, the railroad and lake Kenai at numerous locations along the alignment. The addition of a third lane to better accommodate passing opportunities will be expensive at many locations due to the height of adjacent cuts which will be required. If passing zones can be incorporated into the design in lieu of an additional lane, impacts and associated costs will be recognized.

Related Ideas:

EVALUATION
Idea Number: 01-015 Idea Description: Provide passing zones in lieu of passing lanes in constrained areas.
Advantages: 1. Reduce Costs 2. Could reduce the need for some of the planned improvments through the Crown Point area. 3. Reduces impacts to the surrounding environment.
Disadvantages: 1. Reduces Mobility. 2. Provides for less safety. 3. Not consistant with previous corridor improvments adjacent to this segment. 4. Does not move traffic away from Crown Point area.
Risks: 1.
Conclusion: ☒ Propose this idea ☐ Propose this idea as a Supplemental Recommendation ☐ Do not propose this idea because

Calculations and/or Discussion:

The traffic numbers for both the existing and design year (2024) do not necessarily warrant continuous passing opportunities and passing lanes.

	Count Year	Construction Year	Mid Life Year	Future Year
	1999	2004	2014	2024
ADT	1820	2060	2640	3370
DHV	390	450	570	730
Peak Hour Factor	0.09	0.09	0.09	0.09
Percent Commercial Trucks	3.00%	3.00%	3.00%	3.00%
Compounded Growth Rate	3.00%	3.00%	3.00%	3.00%

Source: Design Designation Study (May 9, 2001)

It is the current understanding that the DHV presented above is a seasonal peak, which would represent the worst case. The typical threshold for a lane of traffic traveling at a reasonable level of service in a rural area ranges from 1000 – 2000 DHV. Passing lanes are traditionally added to accommodate slower moving traffic and allow vehicles traveling at or near the speed limit to pass. The Seward Highway corridor has had a history of long queues behind slow moving vehicles. This can be attributed to the relatively higher than average; commercial truck, recreational vehicle and tourist vehicles on the roadway.

The proposed plan for this portion of the Seward Highway corridor incorporates over 5 miles of dedicated passing lanes on the project.

Approx limits of proposed passing lanes

Constrained Location Begin Station	Constrained Location End Station	Passing Lane	Length (Meters)	Length (Feet)	Length (Miles)
28850	30600	N.B. #1	1750	5740	1.09
37500	40000	N.B. #2	2500	8200	1.55
		Total N.B.	4250	13940	2.64
32400	36500	S.B. #1	4100	13448	2.55
Total			8350	27388	5.19

Locations along a corridor which can benefit from passing lanes are a function of total volume, vehicle mix (type of vehicles and drivers) and roadway grade. The volumes on this portion of the roadway are not high enough to warrant dedicated passing lanes based on volume alone. In some instances passing lanes can be warranted on safety rather than volume or mobility criteria. In cases where dedicated passing lanes are not warranted, passing zones are typically introduced. The passing zone still enables passing opportunity while not adding width to the roadway envelope. Passing zones are not as effective or as safe as a passing lane, but when strategically placed in conjunction with other passing zones or in combination with passing lanes can be a more cost effective measure.

The table below summarizes areas currently planed for passing lanes, which are physically constrained and may have significant reduction in costs if the dedicated passing lanes are removed and passing zones are substituted.

Cost savings of pavement

				Cost savings of pavement	
				Reduced Width	Potential Cost
Constrained Location	Constrained Location	Passing Lane	Length	of Pavement & Cut	Savings @ $25 *
Begin Station	End Station		(Meters)	(Meters)	Per m2
29480	30600	N.B. #1	1120	3.6	$100,800
32400	32620	S.B. #1	220	3.6	$19,800
32800	32900	S.B. #1	100	3.6	$9,000
33080	33120	S.B. #1	40	3.6	$3,600
35400	35600	S.B. #1	200	3.6	$18,000
36300	36500	S.B. #1	200	3.6	$18,000
Total			1880		$169,200

Cost savings of Excavation

				Cost savings of Excavation			
				Ave cut	Ave End Area	Total Cut	Potential Cost
Constrained Location	Constrained Location	Passing Lane	Length	Height		Volume Savings	Savings @ $7.5 *
Begin Station	End Station		(Meters)	(Meters)	(m2)	(m3)	Per m3
29480	30600	N.B. #1	1120	16	57.6	64512	$483,840
32400	32620	S.B. #1	220	16	57.6	12672	$95,040
32800	32900	S.B. #1	100	16	57.6	5760	$43,200
33080	33120	S.B. #1	40	16	57.6	2304	$17,280
35400	35600	S.B. #1	200	16	57.6	11520	$86,400
36300	36500	S.B. #1	200	16	57.6	11520	$86,400
Total			1880				$812,160

* Composit cost of pavment section per m2 of surface area

Total Cost Savings

				Total
				Cost
Constrained Location	Constrained Location	Passing Lane	Length	Savings
Begin Station	End Station		(Meters)	
29480	30600	N.B. #1	1120	$584,640
32400	32620	S.B. #1	220	$114,840
32800	32900	S.B. #1	100	$52,200
33080	33120	S.B. #1	40	$20,880
35400	35600	S.B. #1	200	$104,400
36300	36500	S.B. #1	200	$104,400
Total			1880	$981,360

Depending on the adjacent corridor improvements and a more detailed analysis, some or all of the passing lanes proposed may be eliminated. At a minimum, the northbound passing lane (NB#1 sta 29+480 to 30+600) should be considered which would leave one northbound and one southbound passing lane in this segment of the entire corridor. The cost for N.B. #1 is approx. $585,000. If all passing lanes are removed from this portion of the corridor an approx. total cost of up to $980,000 could be recognized.

Above improvements to mobility of a corridor that passing lanes can provide, safety can also be improved. Improved safety along with mobility need to be weighed in the final analysis.

VALUE ENGINEERING PROPOSAL NO. 05-002

SUMMARY PROPOSAL DESCRIPTION:

Reduce highway shoulders and ditch section in costly (large cut) areas

No THANKS

Estimated potential savings:

Initial:	$ 810,000
Future:	$ 0,000
Total:	$ 810,000

Discussion:

Reduce the highway shoulders from 1.8m to 0.6m in costly (large cut) construction areas. This will reduce excavation and pavement costs.

Related Ideas:

EVALUATION
Idea Number: 05-002 Idea Description: Reduce highway shoulders andditch section in costly (large cut) areas
Advantages: 1. Reduces the amount a total excavation 2. Reduces the amount a road construction (shoulder pavement) 3. Help reduce speeding in area
Disadvantages: 1. Less roadway emergency pull off provided 2. Reduces overall safety 3. Reduces sight distance 4. Not consistent with corridor improvements 5. Reduces shoulder passing opportunities
Risks: 1.
Conclusion: ☒ Propose this idea ☐ Propose this idea as a Supplemental Recommendation ☐ Do not propose this idea because

Calculations and/or Discussion:

Cost Savings of Pavement

			Cost savings of pavement	
			Reduced Width	Potential Cost
Constrained Location	Constrained Location	Length	of Pavement & Cut	Savings @ $25 *
Begin Station	End Station	(Meters)	(Meters)	Per M2
29480	30760	1280	2.5	$80,000
32200	32620	420	2.5	$26,250
32800	32900	100	2.5	$6,250
33080	33120	40	2.5	$2,500
35400	35600	200	2.5	$12,500
36300	36500	200	2.5	$12,500
Total		2240		$140,000

* Composit cost of pavment section per m2 of surface area

Cost Savings of Excavation

			Cost savings of Excavation			
			Ave cut	Ave End Area	Total Cut	Potential Cost
Constrained Location	Constrained Location	Length	Height		Volume Savings	Savings @ $7.5 *
Begin Station	End Station	(Meters)	(Meters)	(M2)	(M3)	Per M3
29480	30760	1280	16	40	51200	$384,000
32200	32620	420	16	40	16800	$126,000
32800	32900	100	16	40	4000	$30,000
33080	33120	40	16	40	1600	$12,000
35400	35600	200	16	40	8000	$60,000
36300	36500	200	16	40	8000	$60,000
Total		2240				$672,000

Total Cost Savings

			Total
			Cost
Constrained Location	Constrained Location	Length	Savings
Begin Station	End Station	(Meters)	
29480	30760	1280	$464,000
32200	32620	420	$152,250
32800	32900	100	$36,250
33080	33120	40	$14,500
35400	35600	200	$72,500
36300	36500	200	$72,500
Total		2240	$812,000

* Composit cost of pavment section per m2 of surface area

APPENDIX G
DESIGN MEMOS

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