Section 2

2005 Re-assessment of Unstable Slopes between MP 36 and MP 68 on I-90 Snoqualmie Pass

Introduction

Interstate 90 across Snoqualmie Pass is the most heavily used east-west crossing of the Cascade Mountains in Washington State. On average, 27,000 vehicles a day use the highway. On weekend travel dates, the count can climb as high as 58,000. The route is critical for commercial and freight movement – serving local, national and international markets and shippers --as well as for personal travel. Twenty-five percent of the customary weekday volume is generally made up of trucks.

Snoqualmie Pass is a very old travel corridor. The first real road over the Pass was built in 1916, largely following old Indian trails and wagon routes. The road was first paved in the 1920s as State Highway 10. In the 1950s the section from North Bend to Hyak (roughly between Mileposts 30 and 55) was widened to four lanes. In the late 1960s and early 1970s, many portions of the highway were realigned at considerable effort of engineering and construction to update the corridor to design standards for the interstate highway system.

Interstate 90 and the Geology of the Snoqualmie Pass Area

Areas through which I-90 has been built include, with widely varying rock types and conditions that have been shaped and altered by the ongoing mountain-building of the Cascade Range. Repeated glaciations over the last two million years and the ongoing processes of erosion and mass wasting driven by gravity have further shaped the rugged terrain.

Building today's I-90 alignments, engineers and contractors over the years have had to cut the roadway into the mountainous terrain. Slope hazards (apart from snow avalanches) on I-90 over Snoqualmie Pass are principally associated with these cut slopes and the fact that many of them have some degree of inherent geologically related instability in the face of gravity's inexorable effect on the rock itself.

Moreover, the cuts on I-90 were constructed at a time of relatively primitive engineering sophistication regarding the impacts and management of potentially adverse bedrock conditions. At that time, few tools and methods were available to characterize, analyze and design for them when the highway was built.

Additionally, many of the cuts were created using uncontrolled blasting methods that resulted in blast-induced damage to the finished cut slope. Fortunately, the most recent construction in the 1960s and 1970s largely relied on controlled blasting methods.

Due to the steep terrain traversed by the highway, a number of the cut slopes approach or exceed 100 feet in height above the highway. They are characterized by naturally occurring poor rock mass quality including planes of weakness in the rock ("discontinuities".) These factors add up to the risk of rock fall or even significant rock slides within the cut slopes along the corridor.

In the I-90 construction of the 1960s and 1970s, highway engineers sought to protect against rock fall by incorporating wide ditch catchment areas adjacent to the highway shoulders where small volume events would be captured. Since the mid-1990s, concrete barriers have also been placed along many of the rock fall ditches to improve their effectiveness in containing falling debris. Drivers can see these treatments at many locations along the corridor. Where slope heights and the volume of falling rock or debris are modest, these treatments have proved highly effective at mitigating the hazards of falling rock. They are not, however, provided at every slope location. Additionally, large volume slope failures can exceed the capability of the ditch/barrier systems and debris can enter the travel lanes. This was the case in the September and November 2005 rock slide events that occurred at two widely separated locations on the corridor.

Highway Improvements Plans for I-90 and Their Effect on Programming for Unstable Slope Mitigation in the Snoqualmie Pass Area

The initial statewide inventory of unstable slopes presenting hazards to state highways identified 28 slopes on I-90 between Mileposts 36 and 68. Twenty-six of those slopes are rock fall areas, while two slopes are potential landslides. Since 1995, nine of these slopes have been mitigated in the Unstable Slopes Preservation Sub-program (P3) at a cost of approximately $6.1 million dollars.

Meanwhile, the consideration of major highway improvements on I-90 east of the Snoqualmie Pass summit caused WSDOT in the late 1990s to extract 13 of the slopes located between Mileposts 55 to 70 from active consideration for mitigation in the Unstable Slopes Preservation Sub-program (P3). The proposed improvement project *I-90 Snoqualmie Pass East* would be expected either to stabilize these unstable slopes or re-align the highway away from the hazard. In 2005, the legislature provided major funding for construction of the first phase of that project, *Hyak to Lake Keechelus Dam* between Mileposts 55 and 60 with an expected construction commencement date of 2011.

The 2005 Reassessment Program

Due to the recent rockfall events at approximately Mileposts 50 and 58, WSDOT completed a detailed reassessment of unstable slopes on the Snoqualmie Pass corridor between Mileposts 36 and 68. The re-assessment has been performed by staff of WSDOT's Geotechnical Division who are experienced in geological hazard assessment [1].

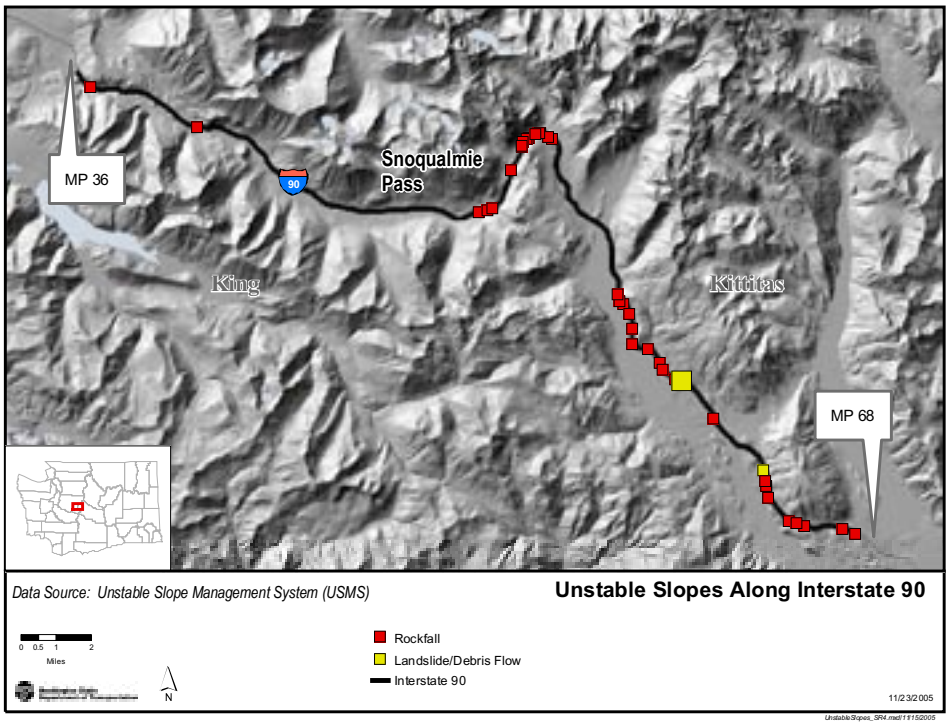
The assessment included field reviews and the reconsideration of information contained in the current inventory of the WSDOT Unstable Slopes Management Program and the gathering of other information.

(The field reviews were based on assessment of slope conditions made from the highway and did not include on-slope inspections. For a number of the higher slopes, vegetation and reduced viewing perspective limited visual assessment of detailed conditions.)

Based on the field reviews, the geotechnical assessment included:

- the defined slope limits;
- the nature and extent of the slope hazard(s);
- the slope hazard rating;
- evidence for slope distress or slope features (single blocks or masses of blocks) judged to be precarious;
- the potential volume of debris generated from such a slope failure; and,
- the expected/observed effectiveness of any ditch or other containment measures at the site to contain falling rock or debris.

[1] This work was performed by Tom Badger, WSDOT Assistant Chief Engineering Geologist and Steve Lowell, WSDOT Chief Engineering Geologist



Evidence for slope distress or precarious slope conditions included dilated fractures within a mass of blocks, especially those involving discontinuities (i.e., joints, bedding planes, faults) that were adversely oriented with respect to the highway, overhanging conditions, and extensively eroded zones bounding large blocks/boulders.

Once the geotechnical assessment was made, the slopes were jointly reviewed by the geotechnical experts with the highway maintenance workers who have personal knowledge of the historic activity of slope instability, effectiveness of the ditch catchment area, and accidents related to slope instability.

All information then was incorporated into the hazard ratings for each slope. This is consistent with the methodology used statewide for individual slopes routinely reassessed for developing the Unstable Slopes Preservation Sub-program (P3), as well as other corridor studies the WSDOT Geotechnical Division has completed for US 12 White Pass (2003) and SR 14 Columbia River Gorge (1999).

One of the important outcomes of the reassessment was to expand from 28 to 40 the separately identified and described unstable slope sites in the study area. Three slopes were added to the inventory. Otherwise, existing sites were subdivided to better represent the differing geologic or other risk conditions within a particular section of a previously identified slope.

The specific assessments (accompanied by photographs) for each of the 40 sites are provided on pages 18 to 57.

The current inventory of 40 slopes are presented in three separate tables.

Milepost 36 to 52

The first table includes 18 slopes west of the Snoqualmie Pass summit and outside the area of the forthcoming *I-90 Snoqualmie Pass East* project. This table includes three sites that have already received mitigation treatment under the Unstable Slopes Preservation Sub-program (P3). This includes the emergency stabilization work performed at the MP 50.29 to MP 50.34 site following the recent triple-fatality accident. This table also includes nine of the locations newly added by this reassessment. All the slopes in this table other than the slopes previously mitigated are regarded as "active" candidates for programming under the Unstable Slopes Preservation Sub-program (P3). Conceptual-level design has been performed for three of the sites.

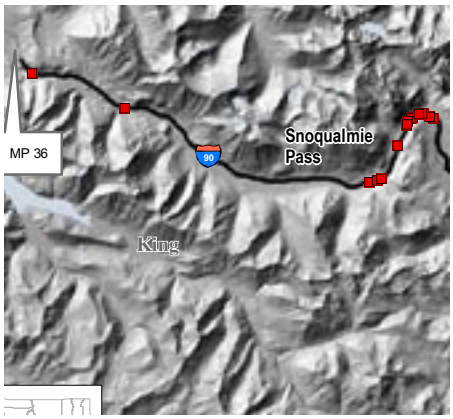


Table 2.1 Milepost 36 to 52, West of Snoqualmie Pass Summit

Slope No.	Begin	End	Side	Problem Description	USMS Rating	Revised Rating	Rating > 350	Rating Date	Miti-gated	Con-cept	Active
221	36.56	36.64	WB	Rockfall	69	75		5/17/02			X
227	39.95	40.17	WB	Rockfall	303	303		8/11/04		X	
228	48.77	48.92	EB	Rockfall	201	231		6/30/00			X
2960	48.91	48.96	WB	Rockfall		141		New			X
472	49.13	49.24	EB	Rockfall	273	219		5/14/02		X	
473	49.34	49.64	WB	Rockfall	276	297		5/17/02			X
2961	49.64	49.92	WB	Rockfall		207		New			X
2962	49.79	49.94	EB	Rockfall		285		New			X
2963	49.98	50.15	EB	Rockfall		231		New			X
2971	50.19	50.29	WB	Rockfall		381	•	New			X
2964	50.20	50.32	EB	Rockfall		285		New			X
2973	50.29	50.34	WB	Rockfall	273			8/13/00	X		
2586	50.32	50.58	EB	Rockfall	297	285		2/9/01		X	
2972	50.34	50.46	WB	Rockfall		381	•	New			X
2966	50.58	50.73	EB	Rockfall		273		New			X
2967	50.73	50.76	EB	Rockfall		135		New			X
605	51.30	51.57	EB	Rockfall	339			9/11/00	X		
1729	51.59	51.77	WB	Rockfall	279			8/13/00	X		

Milepost 57 to 61

The second table includes 13 slopes east of the Snoqualmie Pass summit generally in the vicinity of Lake Keechelus that are within the project limits (MP 55 to MP 60) of the forthcoming first phase *Hyak to Lake Keechelus Dam* of the *I-90 Snoqualmie East* project. This table includes five sites that have already received mitigation treatment under the Unstable Slopes Preservation Sub-program (P3).

The remaining sites on this table are treated as "deferred" for the purposes of the Unstable Slopes Preservation Sub-program (P3). These deferrals out of the on-going P3 program reflect the decision in the late 1990s described above that these sites would be held out to await their appropriate treatment within the *I-90 Snoqualmie East* project. This table, reflecting the results of the re-assessment, shows that three of these sites have been given ratings of 350 or higher under the Unstable Slopes Management Program rating process, indicating relatively high hazard – high risk slopes.

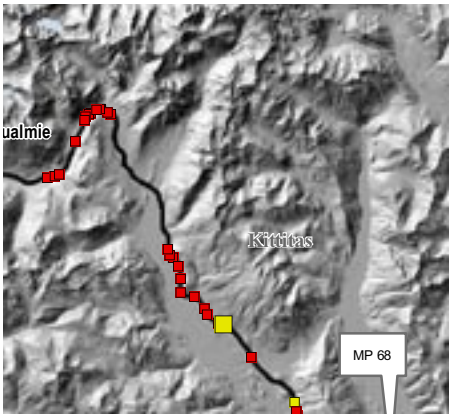


Table 2.2 Milepost 57 to 61, Lake Keechhelus Shoreline Vicinity

Slope No.	Begin	End	Side	Problem Description	USMS Rating	Revised Rating	Rating > 350	Rating Date	Miti-gated	Con-cept	Active
2965	57.35	57.64	WB	Rockfall		405	•	New			Deferred
1311	57.64	57.72	WB	Rockfall	411			3/11/98	X		
223	57.74	57.76	WB	Rockfall	318			9/19/95	X		
2968	57.88	58.00	WB	Rockfall		309		New			Deferred
1868	58.00	58.07	WB	Rockfall	303			12/8/97	X		
1867	58.15	58.38	WB	Rockfall	321	351	•	9/19/95			Deferred
2937	58.38	58.46	WB	Rockfall	321	375	•	4/6/05	X		
1864	58.61	59.08	WB	Rockfall	279	309		12/8/97			Deferred
222	59.08	59.16	WB	Rockfall	240			9/19/95	X		
2969	59.13	59.18	EB	Landslide		399	•	New			Deferred
1863	60.28	60.41	WB	Rockfall	273	81		12/8/97			Deferred
2970	60.67	60.75	WB	Rockfall		129		New			Deferred
1862	60.74	60.82	EB	Rockfall	357	255		12/8/97			Deferred

Milepost 64 to 68

The third table includes nine slopes east of the Snoqualmie Pass summit and generally to the east also of the Lake Keechelus vicinity and therefore within the project limits (MP 60 to MP 70) of the proposed future Phase 2 *Lake Keechelus Dam to Easton* portion of the *I-90 Snoqualmie Pass East* project. None of the sites in this table are new listings resulting from the re-assessment. One of the sites in this table has already received mitigation treatment under the Unstable Slopes Preservation Sub-program (P3)[2]. The other eight sites are treated as "deferred" for purposes of the P3 program for the same reason given for the deferred sites in the previous table. Three of these sites have been given ratings of 350 or higher under the Unstable Slopes Management Program – again indicating relatively high hazard, high risk slopes – and one, with a rating of 531, the highest in the corridor.

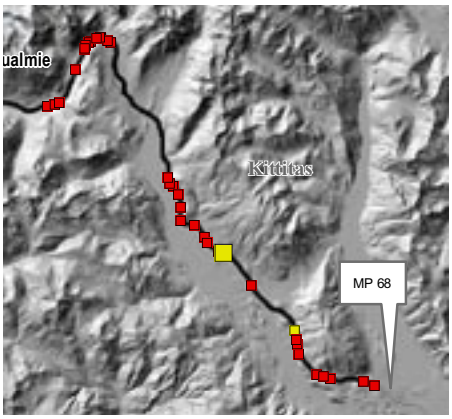


Table 2.3 Milepost 64 to 68, East of Lake Keechelus Dam

Slope No.	Begin	End	Side	Problem Description	USMS Rating	Revised Rating	Rating > 350	Rating Date	Miti-gated	Con-cept	Active
1747	64.45	64.55	EB	Settlement	399			9/19/95	X		
1752	64.76	64.89	WB	Rockfall	279	285		12/8/97			Deferred
1753	64.89	65.00	WB	Rockfall	273	285		9/19/95			Deferred
1757	65.20	65.25	WB	Rockfall	231	177		12/8/97			Deferred
1758	66.00	66.19	WB	Rockfall	333	531	•	12/8/97			Deferred
1759	66.27	66.31	WB	Rockfall	177	399	•	12/8/97			Deferred
1764	66.50	66.58	WB	Rockfall	249	369	•	12/8/97			Deferred
1765	67.60	67.67	EB	Rockfall	147	75		12/8/97			Deferred
1783	68.00	68.12	EB	Rockfall	195	285		6/30/00			Deferred

[2] This site (MP 64.45 – 64.55) constituted a landslide hazard and was mitigated by construction of a rock embankment at the toe of the landside in 1999.

Summary

The re-assessment identified eight unmitigated slopes that have a hazard rating greater than 350 points, representing relatively high hazard, high risk slopes. Seven of these are located within the *I-90 Snoqualmie Pass East* project. One has received extensive mitigation on an emergency basis following the recent rockslide. The other six are currently deferred for programming consideration; three of these six deferred slopes located on the west side of the pass are within the *Hyak to Lake Keechelus Dam* Phase 1 that is currently scheduled to commence construction in 2011. The remaining two slopes are located on the west side of the pass and are in active status within the Unstable Slope Preservation Sub-program (P3). All eight high hazard – high risk slopes were judged to have the potential for causing long duration highway impacts if they should be the sites of significant failure events. Slope assessments and photos of the 40 unstable slopes identified in Table 2.1 follow.

Conclusions and Recommendations

WSDOT has completed a re-assessment of the unstable slope hazards along Interstate 90 between Milepost 36 and Milepost 68 (Snoqualmie Pass).

The re-assessment included the following;

- Review of information in WSDOT's Unstable Slope Management Program on unstable sites in this corridor.
- Visual inspection of all sites, with updating as indicated on the information already in the Unstable Slope Management Program inventory.

In order to provide context for this new re-assessment, WSDOT also prepared for inclusion in this report:

- Information on unstable slope hazards along other problematic corridors in order to place the I-90 Snoqualmie Pass picture in a broader statewide perspective.
- Information on accident history on state highways from 1970 to 2005 to help understand the risks to highway users from unstable conditions based on knowledge of past experience.
- Information on major highway closures between 1985 and 2005 related to rockfalls and landslides, again, to help understand the risks of inconvenience and delay to highway users from conditions related to unstable slopes.
- Information on snow avalanche hazards on the I-90 corridor over Snoqualmie Pass and SR 2 over Sevens Pass. Avalanche hazards are another important concern related to slope hazards as they often affect highways and highway users.
- An independent assessment by Golder Associates, a nationally recognized engineering consulting firm specializing in geotechnical assessment and risk analysis, of the WSDOT Unstable Slope Management Program.

The conclusions and recommendations from this review are as follows:

Recommendation 1

Placed in the context of the many high hazard sites on several corridors around the state already included in the Unstable slopes Preservation Sub-program (P3), a number of the sites on the I-90 corridor should not be elevated to special priority over other higher-rated hazard sites elsewhere in the state at this time. This recommendation must be taken in full recognition that even expert geo-technical examination most often cannot predict slope failure nor guarantee against the possibility that injury to travelers or inconvenience and cost from highway closures might result at these sites.

Several sites, however, must be excepted from this general recommendation.

. Hazard high-risk sites west of Snoqualmie Pass Summit.

MP 50.19 to 50.29

MP 50.34 to 50.46

Recommendation 2

Two high hazard – high risk sites are located on westbound I-90 in the immediate area of the rockfall that occurred with tragic results in September 2005 near Milepost 50.3 (Westbound). These two sites are located within less than a quarter mile stretch of the highway at Milepost 50.19 to 50.29 (Westbound) and 50.34 to 50.46 on either side of the September 2005 event. Each has been assigned a rating value of 381.

These two sites will proceed to conceptual-level design and be included for future P3 programming consideration. Given their high hazard rating and high traffic volumes, it is anticipated that these slopes will become high priorities for future mitigation projects.

Recommendation 3

Three high hazard – high risk sites are located on I-90 near the shoreline of Lake Keechelus. Two of these sites are located on the westbound side of the highway at Milepost 57.35 to 57.64 and at Milepost 58.15 to 58.38 (immediately adjacent to the west to the November 2005 rockfall area) and one is a potential landslide area located on the eastbound stretch of I-90 at Milepost 59.13 to 59.18. These sites have been assigned rating values, respectively of 405, 383 and 399.

These three sites and four lesser rates sites also in the vicinity of the lake Keechelus shore have been removed from active consideration for mitigation in the Unstable Slopes Preservation Sub-program (P3) because of the expectation that they would be mitigated (or otherwise resolved) in the course of the *I-90 Snoqualmie Pass East* highway improvement project. (Seven sites in this stretch, including the site where the rockfall occurred in November 2005, have already been mitigated).

This stretch of the I-90 corridor is within the limits of Phase I of the improvement project, *Hyak to Lake Keechelus Dam*, now scheduled (see above) to enter construction in 2011. Accordingly, the recommendation to address these sites appears to present three choices:

- Await their treatment or other resolution through the *Hyak to Lake Keechelus Dam* highway improvement now scheduled to begin construction in 2011.
- Expedite their treatment or other resolution sooner than the existing *Hyak to Lake Keechelus Dam* improvement program as currently planned by expediting this project to an earlier construction start. This course will require a decision and direction to WSDOT that may affect the schedules of other projects elsewhere in the state that were designated and scheduled by the legislature in the 2005 session in connection with enactment of the 2005 Transportation Partnership Act project package.
- Proceed on an expedited schedule independently of the *Hyak to Lake Keechelus Dam* project with the object of supporting earlier resolution either through the Unstable Slopes Preservation Sub-program (P3) or with other funding support. This alternative accepts that expenditures for stabilization provide a short payback.

There are competing pro and con considerations to all three approaches and a clear need to be mindful of legislative direction. Because of the possibility, at least for now, that these sties might continue to be resolved in the Hyak to Lake Keechelus Dam construction program, WSDOT has not commenced mitigation designs for these sites. It should be noted that the highest of the hazard ratings for these three deterred sites is not as high as the rating for the site at Milepost 66.00 – 66.19, described in the next section, located to the east of the boundaries of the Hyak to Lake Keechelus Dam construction program.

Recommendation 4

Three high hazard – high risk sites are located on westbound I-90 to the east of Lake Keechelus. The sites are located within a stretch of just over half a miles at Milepost 66.00 to 66.19 (Westbound), Milepost 66.27 to 66.31 (westbound) and Milepost 66.50 to 66.58 (Westbound). These sites have been assigned rating values, respectively, of 531, 399 and 369.

These three sites, as well as three lesser rated sites within a mile and a quarter on the westbound direction and two lesser rated sites within a mile and a half on the eastbound direction, have been removed from active consideration for mitigation in the Unstable Slopes Preservation Sub-program (P3) because of the expectation that they would be mitigated (or otherwise resolved) in the course of the I-90 Snoqualmie Pass East highway improvement project.

This stretch of the I-90 corridor, however, is not within the limits of Phase I of that project, now scheduled (see above) to begin construction in 2011. Accordingly, in their current deferred status the prospect of near-term mitigation of these sites outside the P3 program is low.

The three high hazard rated sites on westbound I-90 between Mileposts 66.00 and 66.58 present a difficult situation. Their hazard is also associated with a high risk of substantial delay and inconvenience and economic cost in the event of a significant slope failure, to say nothing of potential risk of injury to users. A mitigation program will be a significant undertaking involving not only construction cost but interim lane closures or restrictions while mitigation work is performed in a very constrained physical location.

WSDOT believes that these three sites should be mitigated as soon as possible.

WSDOT is now proceeding with the engineering design of a mitigation program for these sites. The design work includes an engineering approach, a traffic management plan, a funding plan and a schedule plan. The schedule plan assumes the expedited permitting of the work can be performed with federal permitting agencies whose jurisdiction includes the area and its environmental considerations, especially the United States Forest Service. Assuming the success of the permitting approach, it is expected that the work could be put out for a construction contract to be performed at the very earliest in the early summer season of 2006 or, alternatively, in the late summer or fall. WSDOT's expectation is that funds for the program can be provided principally through access to approximately $ 5 million in federal STP flexible funds from SAFETEA-LU that have yet to be targeted for any other specific capital investment and for which the Legislature should appropriate expenditure authority for this purpose. Funds in addition to that amount (if needed up to a maximum estimated amount of about $7 million) would be secured by moving to future years currently scheduled projects at lower hazard/risk locations in such areas of the state as SR 203 at 26th Avenue NE near Duvall and on I-5 at the SR 526 Interchange in Everett.

Slope Scaling at Snoqualmie Pass

Recommendation 5

WSDOT's re-assessment of the unstable slope sites on the I-90 Corridor has caused it to consider the potential benefits of adding a mitigation tool to the approaches that have, to date, been taken in the Unstable Slopes Preservation Sub-program (P3). To date, the program has approached mitigation through projects that permanently stabilize a slope or provide a stabilization treatment expected to provide a long term (say, greater than 20 years) engineering solution. Other transportation agencies at the forefront of rockfall hazard mitigation, such as the British Columbia Ministry of Transportation and the Canadian Pacific Railway, have also devoted effort to ongoing rock slope scaling as a lesser, more expedient risk-management treatment than full-blown slope stabilization. These programs are intended to remove loose rock from slopes and in some cases install minor rock reinforcement. This is a hazard reduction strategy only. Today at WSDOT, rock scaling is occasionally performed within the on-going highway maintenance program. WSDOT intends, however,

now to incorporate this hazard reduction approach into the Unstable Slope Preservation Sub-program (P3). This technique would be applied on certain high hazard locations where it can suitably and safely be performed. However to avoid taking away from limited P3 funds and impacting stabilization projects of long-term/permanent objectives, additional funds will be needed to proceed with this risk-reduction strategy.

Recommendation 6

FY 2006 has seen an unusually large number of emergent and costly slope stabilization projects. These include the two rock slides on I-90 over Snoqualmie Pass that have led to this report. Other emergent unstable slope projects have recently arisen from the persistent wet weather that has afflicted much of the state. To date, about $8 million (more or less, estimates are still preliminary and incomplete and funding commitments are still verbal) are expected to be reimbursed from federal Emergency Relief funds. [1] Approximately $7 million (more or less, same caveat as to estimates) of additional work is expected to be required for other already identified unstable slopes. [2] To deal with this financial need, WSDOT recommends the Legislature authorize the issuance of $50 million in aggregate principal amount of emergency bonds to serve as a continuing standby financing facility for unavoidably necessary work to remedy emergent unstable slopes. The proceeds of the bonds should be appropriated to the purposes of the Unstable Slopes Preservation Program (P3). A similar approach was put in place in the 1990s to provide assured funding for this emergency purpose. The previous bonding authorization was exhausted in the 2003-05 biennium.

[1] The sites expected to be covered by this funding include:
I-90 Snoqualmie Pass at Denny Creek rockfall
SR 107 Slide
SR 105 Washaway Beach erosion
US 101 at MP 69.8 Settlement
SR 166 Slide 0.5 mile from SR 16
I-5 Slide at Nisqually

[2] The sites referred to here are
SR 11 Rockfall
SR 26 Sand Hollow culvert replacement
SR 539 Spring Creek culvert repair - Bellingham
I-90 Snoqualmie Pass at east end of snow shed
I-90 Snoqualmie Pass - additional slopes from MP 66.0 to 66.6
SR 508 Newaukum River settlement/erosion

MP 36.56 – 36.64
WB Left

SLOPE # – 221
PROBLEM TYPE – Rockfall
USMS RATING – 75
STATUS – Active

Cut slope constructed in volcanic bedrock with controlled blasting methods is up to 60 feet high and oriented at 0.25H:1V. The ditch is about 20 feet wide with an approximately 6H:1V in-slope. A chainlink fence near the edge of shoulder provides additional catchment capacity for rollout of small size debris. The rock mass contains some adversely oriented joints of low to moderate persistence resulting in potential planar and wedge failures with volumes of less than 10 cubic yards. No distress was observed in these features.

Maintenance was unaware of any rockfall debris reaching the roadway or rockfall-related accidents.

MP 39.95 – 40.17
WB Left

SLOPE # – 227
PROBLEM TYPE – Rockfall
USMS RATING – 303
STATUS – Conceptual

Natural/cut slope in volcanic rock varies from 75 to over 150 ft. in height and oriented from near vertical in the cut portion near the base of the slope to about 0.5H:1V overall. The rock mass contains some steep, adversely oriented joints of high persistence resulting in potential planar failures with volumes potentially exceeding 100s of cubic yards. Many large blocks are overhanging, but no significant strain was observed within these blocks/slabs. The existing ditch is approximately 20 wide measured from the edge of pavement to the rock face.

Because of the size of the overhanging blocks, failure would likely result in rock closing all westbound lanes.

Maintenance reported that rockfall debris only infrequently reached the shoulder and was not aware of any rockfall-related accidents.

MP 48.77 – 48.92
EB Right

SLOPE # – 228
PROBLEM TYPE – Rockfall
USMS RATING – 231
STATUS – Active

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 50 feet high and oriented at roughly 0.25H:1V. The ditch is about 20 feet wide with an approximately 6H:1V in-slope. The rock mass contains some steep, adversely oriented joints of high persistence resulting in potential planar failures with volumes of 10 to 20 cubic yards. One planar feature on the east end of about 20 cubic yards in volume is strained and detached from the rock slope; strain may be construction related. Another strained mass on the west end is overhung and bound beneath by a steep planar surface. Failures of this size could reach the outside traveled lane.

Maintenance reported that rockfall debris only infrequently reached the shoulder and was not aware of any rockfall-related accidents.

MP 48.91 – 48.96
WB Left

SLOPE # – 2960
PROBLEM TYPE – Rockfall
USMS RATING – 141
STATUS – Active

Cut slope constructed in granodiorite bedrock with controlled blasting methods is up to 80 feet high and oriented near vertical. The ditch is about 20 feet wide with an approximately 6H:1V in-slope. The rock cut exposed two large wedges greater than 500 cubic yards in volume that exhibit strain, mostly near the top, that may be construction related. Failures of this size could extend across most lanes. Other steep, adversely oriented joints of low to moderate persistence control small volume (< 10 cubic yards) toppling features. No evidence of recent activity was observed on the slope or in the ditch.

Maintenance reported that rockfall debris only infrequently reached the shoulder and was not aware of any rockfall-related accidents.

MP 49.13 – 49.24
EB Right

SLOPE # – 472
PROBLEM TYPE – Rockfall
USMS RATING – 219
STATUS – Conceptual

Cut slope constructed in strong meta-volcanic bedrock with uncontrolled blasting methods is up to 30 feet high and oriented about 0.5H:1V. The ditch is 20 to 24 feet wide with an approximately 6H:1V in-slope. The rock mass contains some steep, adversely oriented joints of low to moderate persistence resulting in potential planar failures and wedges with volumes of less than 50 cubic yards. No distress was observed in these features. Failures of these structurally controlled features could extend into the outside traveled lane. Some rock debris was observed in the ditch.

Maintenance reported that rockfall debris only infrequently reached the shoulder and was not aware of any rockfall-related accidents.

MP 49.34 – 49.64
WB Left

SLOPE # – 473
PROBLEM TYPE – Rockfall
USMS RATING – 297
STATUS – Active

Cut slope constructed in granodiorite bedrock with controlled blasting methods is up to 50 feet high and oriented near vertical. A steep natural bedrock slope above is draped with chainlink mesh. The ditch is about 18 feet wide with an approximately 6H:1V in-slope. The rock mass contains steep adversely oriented joints with moderate to high persistence controlling very large wedges greater than 500 cubic yards in volume and numerous small topple features typically less than 10 cubic yards in volume. Some of the topple features exhibit strain. No strain was observed in the large wedges. Failures of these large wedges could extend across most lanes, and failure of the topple features could reach the outside traveled lane.

Maintenance reported that rockfall debris only infrequently reached the shoulder and was not aware of any rockfall-related accidents.

MP 49.64 – 49.92
WB Left

SLOPE # – 2961
PROBLEM TYPE – Rockfall
USMS RATING – 207
STATUS – Active

Cut slope constructed in granodiorite bedrock with controlled blasting methods is up to 20 feet high and oriented near vertical. The ditch is about 30 feet wide with an approximately 6H:1V in-slope. The rock mass contains some adversely oriented joints of moderate to high persistence on the east end near the crest of the cut slope resulting in potential planar failures with volumes of less than 50 cubic yards. No distress was observed in these features. No evidence of recent activity was observed on the slope or in the ditch.

Maintenance was unaware of any rockfall debris reaching the roadway or rockfall-related accidents.

MP 49.79 – 49.94
EB Right

SLOPE # – 2962
PROBLEM TYPE – Rockfall
USMS RATING – 285
STATUS – Active

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 30 feet high and oriented between 0.5H:1V and 0.75H:1V. The ditch is 12 to 15 feet wide and 2 to 3 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. The rock mass contains mostly steep joints of moderate to high persistence controlling small volume (< 10 cubic yards) toppling features. Some moderately inclined joints control potential planar failures, some of which are of moderate to large volume (20 to 100 cubic yards) and exhibit minor strain or open joints. The ditch is effective in containing the frequent rockfalls at this site, but failure of the larger volume, structurally controlled features could extend into the outside traveled lane.

Maintenance reported that rockfall debris only infrequently reached the shoulder and was not aware of any rockfall-related accidents.

MP 49.98 – 50.15
EB Right

SLOPE # – 2963
PROBLEM TYPE – Rockfall
USMS RATING – 231
STATUS – Active

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 30 feet high and oriented between 0.5H:1V and 0.75H:1V. The ditch is 15 feet wide and 2 to 3 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. The rock mass contains some steep, adversely oriented joints of moderate to high persistence controlling small volume (< 10 cubic yards) planar features. Two of these features are located near the ditch, are bound by open fractures, and appear marginally stable. Toppling structure is also present, and one such feature on the east end is estimated to exceed 100 cubic yards in volume and exhibits some strain. The ditch is effective in containing the infrequent rockfalls at this site, but failure of larger volume, structurally controlled features could extend into the outside traveled lane.

Maintenance reported that rockfall debris only infrequently reached the shoulder and was not aware of any rockfall-related accidents.

MP 50.19 – 50.29
WB Left

SLOPE # – 2971
PROBLEM TYPE – Rockfall
USMS RATING – 381
STATUS – Active

Cut slope constructed in granodiorite bedrock with controlled blasting methods is up to 60 feet high and oriented near vertical. A steep natural slope above is mantled with bouldery colluvial and possibly glacial deposits and is draped with chainlink mesh. The ditch is about 30 feet wide with an approximately 6H:1V in-slope; a concrete barrier has been placed along the edge of shoulder to improve catchment area. The rock mass contains some adversely oriented joints of high persistence resulting in potential large volume (300 cubic yards) wedge failures within the cut slope and planar failures near the crest of the cut slope with volumes of up to about 50 cubic yards. Some of these planar features are bound by open joints, but none appeared significantly strained. Prior to the September 11th, 2005 failure immediately adjacent to this section.

Maintenance reported no rockfall reached the shoulder or traveled lanes, and the slope was moved from active to inactive status. Slope failures up to about 10 cubic yards in volume have previously occurred, but all have been effectively contained in the ditch.

This is the site, addressed in **Recommendation 2**, that is immediately west of the September 11, 2005 failure location.

MP 50.20 – 50.32
EB Right

SLOPE # – 2964
PROBLEM TYPE – Rockfall
USMS RATING – 285
STATUS – Active

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 30 feet high and oriented between 0.5H:1V and 0.75H:1V. The ditch is 12 to 15 feet wide and 2 to 3 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. A steep natural bedrock slope continues above the cut limits. The rock mass contains repeating, adversely oriented joints of moderate to high persistence controlling extensive planar features of small to large volume (< 10 cubic yards to > 100 cubic yards) in the western and middle portions. No significant strain was observed in these planar features. In addition, steep low to moderate persistence joints bound some toppling features on the east end. Failure of one such toppling feature within the last 10 years resulted in an overturned semi-truck. Remedial stabilization was performed in the immediate slope area. The ditch is effective in containing the frequent rockfalls at this site, but failure of the larger volume, structurally controlled features could extend into the outside traveled lanes.

Maintenance reported that rockfall debris only infrequently reached the shoulder.

MP 50.29 – 50.34
WB Left

SLOPE # – 2973
PROBLEM TYPE – Rockfall
USMS RATING – 273
STATUS – Mitigated

Large wedge failure involving up to 500 cubic yards occurred on September 11th, 2005 resulting in debris covering all three lanes and a single vehicle – triple fatality accident. In addition to the slope area from where the wedge failure initiated, similar wedge features in the adjacent slope areas were stabilized with slope scaling and rock anchors.

This is the site of the slope failure occuring on September 11, 2005.

MP 50.32 – 50.58
EB Right

SLOPE # – 2586
PROBLEM TYPE – Rockfall
USMS RATING – 285
STATUS – Conceptual

Cut slope in western and central portion constructed in volcanic bedrock with uncontrolled blasting methods is up to 60 feet high and oriented about 0.25H:1V. The ditch is 10 to 30 feet wide and 2 to 3 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. A steep natural bedrock slope continues above the cut limits. The rock mass contains some adversely oriented joints of moderate to high persistence controlling potential planar and wedge failures of small to medium volume (< 10 cubic yards to 50 cubic yards) in the western and middle portions. No significant strain was observed in these structurally controlled features. On the east end, an over steepened talus slope generates cobble- to small boulder-sized material that occasionally overtops the concrete barrier and reaches the shoulder The ditch is effective in containing the frequent rockfalls at this site, but failure of the larger volume, structurally controlled features could extend into the outside traveled lanes.

Maintenance reported that rockfall debris infrequently reached the shoulder; one rockfall-related accident is reported in the last 10 years.

MP 50.34 – 50.46
WB Left

SLOPE # – 2972
PROBLEM TYPE – Rockfall
USMS RATING – 381
STATUS – Active

Cut slope constructed in granodiorite bedrock with controlled blasting methods is up to 60 feet high and oriented near vertical. A steep natural slope above is mantled with bouldery colluvial and possibly glacial deposits and is draped with chainlink mesh. The ditch is about 30 feet wide with an approximately 6H:1V in-slope; a concrete barrier has been placed along the edge of shoulder to improve catchment area. The rock mass contains some adversely oriented joints of high persistence resulting in potential wedge failures within the cut slope and planar failures near the crest of the cut slope with volumes possibly exceeding several hundred cubic yards. Some of these planar features are bound by open joints, but no appeared significantly strained. Prior to the September 11th, 2005 failure immediately adjacent to this section.

Maintenance reported no rockfall reached the shoulder or traveled lanes, and the slope was moved from active to inactive status. Slope failures up to about 10 cubic yards in volume have previously occurred, but all have been effectively contained in the ditch.

This is the site, addressed in **Recommendation 2**, that is immediately east of the September 11, 2005 failure location.

MP 50.58 – 50.73
EB Right

SLOPE # – 2966
PROBLEM TYPE – Rockfall
USMS RATING – 273
STATUS – Active

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 40 feet high and oriented between 0.5H:1V and 0.75H:1V. The ditch is 20 to 30 feet wide and 3 to 4 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. The rock mass is highly fractured but also contains repeating, moderately to widely spaced joints of high persistence that dip steeply into the slope controlling extensive toppling features of small volume (< 10 cubic yards). Some toppling features exhibit strain, but the ditch appears to be of sufficient width to contain the potential debris volume. Raveling of single or a few blocks 6 to 18 inches in size also appears widespread. The ditch is effective in containing rockfalls at this site.

Maintenance was unaware of rockfall debris reaching the shoulder or traveled lanes or any rockfall-related accidents.

MP 50.73 – 50.76
EB Right

SLOPE # – 2967
PROBLEM TYPE – Rockfall
USMS RATING – 135
STATUS – Active

Over steepened cut slope constructed in cobble- to boulder sized colluvial/glacial deposits capped with coarse talus is up to 50 feet high and oriented about 1H:1V. The ditch is 12 to 15 feet wide and 2 to 3 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. Raveling of single or a few blocks 6 to 18 inches in size is mostly contained in the ditch, however, snow accumulation may lessen the effectiveness of the ditch during winter and spring.

Maintenance reported that rockfall debris only infrequently reached the shoulder and was unaware of any rockfall-related accidents.

MP 51.30 – 51.75
EB Right

SLOPE # – 605
PROBLEM TYPE – Rockfall
USMS RATING –339
STATUS – Mitigated

Rockfall hazards at this site were mitigated under two separate contracts in 1999 and 2000. The work consisted of excavating the eastern and western portions of the existing cut to improve slope stability and catchment area, reinforcing potentially unstable blocks with rock anchors, and replacing the existing draped chainlink mesh slope protection with both double twisted hexagonal mesh and cable nets.

MP 51.59 – 51.77
WB Left

SLOPE # – 1729
PROBLEM TYPE – Rockfall
USMS RATING – 279
STATUS – Mitigated

Rockfall hazards at this site were mitigated in 2002. The work consisted of reinforcing potentially unstable blocks with rock anchors, and draping the cut slope with wire mesh slope protection.

MP 57.35 – 57.64
WB Left

SLOPE # – 2965
PROBLEM TYPE – Rockfall
USMS RATING – 387
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 40 feet high and oriented at about 0.5H:1V. The bedrock portion of cut is mantled with colluvial/glacial deposits with cobble- to boulder-sized material that is locally over steepened. The ditch is 12 to 18 feet wide and 2 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. On the east end, the rock mass contains repeating, adversely oriented joints of moderate to high persistence controlling planar features of up to about 50 cubic yards in volume. Failure of one such feature resulted in a single vehicle – single fatality accident within the last 10 years. A precarious, highly fractured overhang remains in the slope from where this mass failed. In the central and western portions, low to moderate persistence joints bound other potential structurally controlled failures. Raveling of individual to a few blocks also occurs frequently in these portions of the slope. Some strain was observed in individual blocks. The ditch is effective in containing the frequent small-sized rockfalls at this site, but failure of the larger volume, structurally controlled features could extend to the median.

Maintenance reported that rockfall debris infrequently reached the shoulder.

This is one of the sites, included in the location of the Phase 1 *Hyak to Lake Keechelus* project that is addressed in **Recommendation 3**.

MP 57.64 – 57.72
WB Left

SLOPE # – 1311
PROBLEM TYPE – Rockfall
USMS RATING – 411
STATUS – Mitigated

Rockfall hazards at this site were mitigated in 1997. The work consisted of scaling loose rock from the slope and reinforcing potentially unstable blocks with rock anchors.

MP 57.74 – 57.76
WB Left

SLOPE # – 223
PROBLEM TYPE – Rockfall
USMS RATING – 318
STATUS – Mitigated

Rockfall hazards at this site were mitigated in 1997. The work consisted of scaling of loose rock from the slope and reinforcing potentially unstable blocks with rock anchors.

MP 57.88 – 58.00
WB Left

SLOPE # – 2968
PROBLEM TYPE – Rockfall
USMS RATING – 309
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 20 feet high and oriented at about 1H:1V. The bedrock portion of cut is mantled with colluvial/glacial deposits with cobble- to boulder-sized material that is over steepened but draped with chainlink slope protection. The ditch is 10 to 15 feet wide and 2 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. The rock mass contains repeating, adversely oriented joints of moderate to high persistence controlling planar features of up to about 30 cubic yards in volume. Raveling within the upper surficial deposits occurs frequently. Some strain was observed in a mass on the east end, but it may be construction-related as the potential failure mechanism was uncertain. The ditch is effective in containing the frequent small-sized rockfalls at this site, but failure of the larger volume, structurally controlled features could extend to the outside traveled lane.

Maintenance was unaware of rockfall overtopping the concrete barrier or of any rockfall-related accidents.

MP 58.00 – 58.07
WB Left

SLOPE # – 1868
PROBLEM TYPE – Rockfall
USMS RATING – 303
STATUS – Mitigated

Active raveling of the bouldery colluvial/glacial deposits has been mitigated by the replacement of the draped chainlink slope protection with double twisted hexagonal mesh in 1999. Since that time, some damage has occurred in the hexagonal mesh to larger volume surficial failures and large block sizes. Repair or replacement with cable nets is currently needed.

MP 58.15 – 58.38
WB Left

SLOPE # – 1867
PROBLEM TYPE – Rockfall
USMS RATING – 351
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 80 feet high and oriented at about 0.25H:1V. The ditch is 10 to 12 feet wide and 2 to 3 feet deep. The rock mass contains low to moderate persistence, closely spaced joints and some high persistence, near vertical oriented joints that control small volume (<10 cubic yards) toppling features. Raveling is prevalent in more highly fractured and highly weathered rock. Several overhangs are present near the slope crest in the middle portion of the cut slope. On the west end, adversely oriented joints of low to moderate persistence bound small volume planar features.

Maintenance reported that rockfall impacts both westbound lanes numerous times per year; no rockfall-related accidents are reported through this section.

This is the site is just west of the site of the rockfall event on November XX, 2005.

MP 58.38 – 58.46
WB Left

SLOPE # – 2937
PROBLEM TYPE – Rockfall
USMS RATING – 375
STATUS – Mitigated

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 90 feet high and oriented between about 0.25H:1V and 0.5H:1V. The ditch is 10 to 12 feet wide and 2 to 3 feet deep. The rock mass contains adversely oriented joints of high persistence controlling large volume (> 100 cubic yards) planar and wedge failures. The November 2005 rock slide is such a failure. Stabilization and removal of loose portions of the rock cut were recently completed throughout this 300 foot long section.

Maintenance reported that rockfall impacts both westbound lanes numerous times per year; two rockfall-related accidents are reported through this section.

This is the site of the site of the rockfall event on November XX, 2005.

MP 58.61 – 59.08
WB Left

SLOPE # – 1864
PROBLEM TYPE – Rockfall
USMS RATING – 309
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 90 feet high and oriented between about 0.5H:1V and 1H:1V. The ditch is 30 feet wide with an approximately 6H:1V in-slope. The lower portion of the rock mass contains adversely oriented joints of high persistence controlling large volume (> 100 cubic yards) planar and wedge failures. The upper portion and the western and eastern portions consist of highly weathered/altered bedrock that produces voluminous quantities of raveling type rockfall.

Maintenance reported that rockfall frequently reaches the shoulder and occasionally reaches the outside westbound lane; one rockfall-related accident is reported through this section.

MP 59.08 – 59.16
WB Left

SLOPE # – 222
PROBLEM TYPE – Rockfall
USMS RATING – 240
STATUS – Mitigated

Rockfall hazards at this site were mitigated in 1997. The work consisted of scaling loose rock from the slope and reinforcing potentially unstable blocks with rock anchors.

MP 59.13 – 59.18
EB Right

SLOPE # – 2969
PROBLEM TYPE – Landslide
USMS RATING – 399
STATUS – Deferred

Large rock embankment is about 80 feet high and oriented at about 1.3H:1V. Geotechnical borings confirm steeply sloping bedrock surface beneath the embankment. Embankment section failed catastrophically during initial construction in the late 1950s. Settlement in mostly the outside lane and shoulder is ongoing resulting in several inches of vertical and lesser horizontal displacements. Pavement patching on an annual basis and a recent overlay are required to maintain a safe driving surface. Situated on a horizontal curve.

Maintenance reports more than five accidents at this location believed to be due to unfavorable super-elevation and driving surface resulting from the settlement.

This is the site of the landslide location on the eastbound direction of I-90 that is addressed in **Recommendation 3** and is included within the boundary of the *Hyak to Lake Keechelus Dam* Phase 1 project.

MP 60.28 – 60.41
WB Left

SLOPE # – 1863
PROBLEM TYPE – Rockfall
USMS RATING – 81
STATUS – Deferred

Cut slope constructed in volcanic bedrock on the east end with uncontrolled blasting methods is up to 30 feet high and oriented between about 0.5H:1V. The western portion of the cut is also in volcanic bedrock, but it was constructed using controlled blasting methods oriented at 0.5H:1V. The middle portion of the cut is in glacial deposits with cobble- to boulder-size material. The ditch is 30 feet wide with an approximately 6H:1V in-slope. The western bedrock cut is in good condition and is not a significant source of rockfall. The middle portion of the cut is somewhat over steepened, and erosion and raveling of cobbles and boulders is occurring. The wide ditch mitigates rollout of this debris onto the roadway. The eastern bedrock cut contains some adversely oriented joints of low to moderate persistence that controls minor plane, wedge and toppling features with typical volumes of less than 10 cubic yards.

Maintenance reported that rockfall infrequently reaches the shoulder on the east end and was unaware of any rockfall-related accidents.

MP 60.67 – 60.75
WB Right

SLOPE # – 2970
PROBLEM TYPE – Rockfall
USMS RATING – 129
STATUS – Deferred

Cut slope constructed in volcanic bedrock with controlled blasting methods is up to 80 feet high and oriented at about 0.5H:1V. The ditch is 24 feet wide with an approximately 6H:1V in-slope. The eastern and upper portions of the rock mass is highly altered and contains adversely oriented joints of low to moderate persistence controlling small volume (10 to 20 cubic yards) planar features. On the west end, two high persistence joints form a large wedge that to date has not shown evidence of instability. Raveling in the upper portions of the cut slope, where typical block sizes range up to 3 to 4 feet, appears to occur occasionally.

Maintenance reported that rockfall infrequently reaches the shoulder and was unaware of any rockfall related accidents.

MP 60.74 – 60.82
EB Left & Right

SLOPE # – 1862
PROBLEM TYPE – Rockfall
USMS RATING – 255
STATUS – Deferred

Through-cut constructed in volcanic bedrock with uncontrolled blasting methods is up to 50 feet high and oriented at about 0.5H:1V (right) and 1H:1V (left). The right ditch is 20 feet wide and the left ditch is 10 feet wide; both have an approximately 6H:1V in-slope. The eastern rock mass is highly variable ranging from blocky and strong to highly altered and very weak. The rock mass contains adversely oriented, highly altered discontinuities of moderate to high persistence that control low to medium volume (10 to 50 cubic yard) planar features. The eastern portion of the left side cut slope has one mass up to 30 cubic yards in volume that exhibits strain and lies on an adversely oriented plane. The right side cut slope has experienced two planar failures of up to about 20 cubic yards in volume occurring on highly altered discontinuities; the recency of their occurrence is unknown. One overhang about 10 cubic yards in volume remains above one of these planar failures, however, it does not exhibit significant strain.

Maintenance reported that rockfall infrequently reaches the shoulder on the right and does several times per year on the left side. Maintenance was unaware of any rockfall related accidents.

MP 64.45 – 64.55
EB Right

SLOPE # – 1747
PROBLEM TYPE – Landslide
USMS RATING – 399
STATUS – Mitigated

Landslide hazards at this site were mitigated in 1999. The work consisted of constructing a rock buttress at the toe of the embankment. Maintenance reported that no subsequent roadway deformation has occurred.

MP 64.76 – 64.89
WB Left

SLOPE # – 1752
PROBLEM TYPE – Rockfall
USMS RATING – 285
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 60 feet high and oriented at about 1H:1V. The ditch is 15 feet wide with an approximately 6H:1V in-slope. The rock mass is typically highly fractured but does contain some large blocky fractured outcrops with block sizes up to about 3 feet in the upper portion of the cut. These blocky fractured outcrops contain some adversely oriented joints of low to moderate persistence controlling small to medium volume (10 to 20 cubic yards) planar and wedge features; none of these structurally controlled features exhibited significant strain. Raveling is the dominant source of rockfall in the highly fractured zones.

Maintenance reported that rockfall frequently reaches the shoulder but was unaware of any rockfall related accidents.

MP 64.89 – 65.00
WB Left

SLOPE # – 1753
PROBLEM TYPE – Rockfall
USMS RATING – 285
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 80 feet high and oriented at about 1H:1V with localized exposures from near vertical to 0.5H:1V. The ditch is 12 feet wide with an approximately 6H:1V in-slope. The rock mass is typically highly fractured with block sizes up to about 3 feet, but it does contain some large blocky fractured outcrops with adversely oriented joints of low to moderate persistence controlling small volume (10 to 20 cubic yards) planar and wedge features. None of these structurally controlled features exhibited significant strain. Raveling is the dominant source of rockfall in the highly fractured zones.

Maintenance reported that rockfall frequently reaches the shoulder but was unaware of any rockfall related accidents.

MP 65.20 – 65.25
WB Left

SLOPE # – 1757
PROBLEM TYPE – Rockfall
USMS RATING – 177
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 30 feet high and oriented at about 1H:1V with localized exposures from near vertical to 0.5H:1V. The ditch is 15 feet wide and 2 to 3 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. The rock mass is typically highly fractured with block sizes up to about 2 feet, but it does contain large blocky fractured outcrops with some adversely oriented joints of low to moderate persistence controlling small volume (10 to 20 cubic yards) planar and toppling features. One, several hundred cubic yard mass in the upper middle portion of the slope exhibits strain developing in an apparent toppling failure mode. Raveling is the dominant source of rockfall in the highly fractured zones.

Maintenance reported that rockfall infrequently reaches the shoulder and was unaware of any rockfall related accidents.

MP 66.00 – 66.19
WB Left

SLOPE # – 1758
PROBLEM TYPE – Rockfall
USMS RATING – 531
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is about 150 feet high and oriented at about 0.5H:1V. The ditch is 12 to 15 feet wide and 3 to 4 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. Rock mass conditions are highly variable. The rock mass is locally highly fractured, but it also contains extensive adversely oriented joints of low to high persistence controlling large volume (hundreds of cubic yards) planar, wedge and toppling features. Two moderate volume (up to 50 cubic yards) planar features show considerable strain. Although common throughout the cut slope, raveling is the dominant source of rockfall in the capping colluvial deposits and highly weathered zones near the slope crest and eastern portions of the cut. The ditch provides fair to limited catchment for smaller raveling type rockfalls and limited to no catchment for large volume slope failures.

Maintenance reported that rockfall frequently reaches the traveled lanes; no rockfall-related accidents have been reported through this section.

This is one of the high hazard sites addressed in **Recommendation 4** east of Lake Keechelus.

MP 66.27 – 66.31
WB Left

SLOPE # – 1759
PROBLEM TYPE – Rockfall
USMS RATING – 399
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods exceeds 100 feet in height and is oriented at about 0.5H:1V. The ditch is 12 feet wide and 2 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. Rock mass conditions are highly variable. The rock mass is locally highly fractured, but it also contains adversely oriented joints of low to high persistence controlling large volume (hundreds of cubic yards) planar, wedge and toppling features. Large volume, structurally controlled features dominantly have tight bounding discontinuities that do not exhibit strain. Raveling is the dominant source of rockfall in highly fractured zones. The ditch provides fair catchment for smaller raveling type rockfalls and limited to no catchment for large volume slope failures.

Maintenance reported that rockfall infrequently reaches the traveled lanes; no rockfall-related accidents have been reported through this section.

This is one of the high hazard sites addressed in **Recommendation 4** east of *Lake Keechelus*.

MP 66.50 – 66.58
WB Left

SLOPE # – 1764
PROBLEM TYPE – Rockfall
USMS RATING – 369
STATUS – Deferred

Cut slope constructed in volcanic bedrock with uncontrolled blasting methods is up to 50 feet in height and is oriented at about 1H:1V on the west end and about 0.5H:1V on the east end. The ditch is 12 feet wide and 3 feet deep; a concrete barrier has been placed along the edge of shoulder to improve catchment area. The rock mass is highly fractured in the western and middle portions of the cut; the eastern portion contains adversely oriented joints of moderate to high persistence controlling three large volume (hundreds of cubic yards) wedge features. The easternmost wedge exhibits considerable strain. Raveling is the dominant source of rockfall in highly fractured zones. The ditch provides good to fair catchment for smaller raveling type rockfalls and limited to none for large volume slope failures.

Maintenance reported that rockfall infrequently reaches the traveled lanes; no rockfall-related accidents have been reported through this section.

This is one of the high hazard sites addressed in **Recommendation 4** east of *Lake Keechelus*.

MP 67.60 – 67.67
EB Right

SLOPE # – 1765
PROBLEM TYPE – Rockfall
USMS RATING – 75
STATUS – Deferred

Cut slope constructed in volcanic and volcaniclastic bedrock with controlled blasting methods is up to 20 feet high and oriented at about 0. 5H:1V. The ditch is 18 feet wide with an approximately 6H:1V in-slope. Bedded volcaniclastic rocks dip steeply and are nearly coincident with the cut slope. The rock mass is locally highly fractured, but it also contains some adversely oriented joints of low to moderate persistence resulting in small volume (10 to 20 cubic yards) planar and wedge features. Raveling is the dominant source of rockfall in highly fractured zones.

Maintenance reported that rockfall infrequently reaches the shoulder and was unaware of any rockfall related accidents.

MP 68.00 – 68.12
EB Left

SLOPE # – 1783
PROBLEM TYPE – Rockfall
USMS RATING – 285
STATUS – Deferred

Cut slope constructed in volcanic and volcaniclastic bedrock with controlled blasting methods is up to 50 feet high and oriented at about 0. 5H:1V. The ditch is 18 feet wide with an approximately 6H:1V in-slope; a short section of concrete barrier has been placed on the edge of shoulder in the middle portion of the cut to improve catchment area. Bedded volcaniclastic rocks are exposed on the eastern half of the cut and dip steeply and are nearly coincident with the cut slope. The western portion of the rock mass is highly weathered/altered and produces much gravel-size debris that is effectively contained in the ditch. In the middle where the concrete barrier has been placed, the rock mass exhibits blocky fracture with typical block sizes up to 2 feet topple and ravel in several cubic yard events. The eastern half of the rock mass is locally highly fractured, but it also contains some adversely oriented joints of moderate to high persistence resulting in small to moderate volume (10 to 50 cubic yards) planar features. One such feature on east end shows considerable strain; failure of this mass could reach the shoulder and possibly the inside traveled lane.

Maintenance reported that rockfall infrequently reaches the shoulder and was unaware of any rockfall related accidents.