NOTICE OF AGENDA
PUBLIC MEETING
Canyon Springs Road Project
Ad Hoc Committee
Thursday, February 18, 2016 11:30AM
City Council Chambers
305 3rd Avenue East Twin Falls, ID 83301

Canyon Springs Road Project
Ad Hoc Committee Members:
Katie Breckenridge John Lezamiz Tony Mannen Dave McCullom Rick Novacek Jim Olson Linda Roberts
Todd Schwarz Jaime Tigue
Facilitator: Phil Kushlan
Staff: Troy Vitek, Lori Williamson

I. CALL MEETING TO ORDER:
1. Confirmation of quorum
2. Introduction of staff

II. CONSENT CALENDAR:
1. Approval of Minutes from the following meeting(s): January 21, 2016

III. ITEMS OF DISCUSSION:
1. Canyon Springs Road Project AD HOC Information Binder from JUB Engineering

IV. PUBLIC INPUT AND/OR ITEMS FROM THE COMMISSION/THE PUBLIC/CITY STAFF

V. UPCOMING MEETINGS:
Next public meeting to be scheduled for Thursday March 17, 2016

VI. ADJOURN MEETING:

Si desea esta información en español, llame Leila Sanches al (208) 735-7287
Any person(s) needing special accommodations to participate in the above noticed meeting should contact Lori Williamson at (208) 735-7248 at least two (2) working days before the meeting.

NOTICE OF Meeting Minutes
PUBLIC MEETING
Canyon Springs Road Project
Ad Hoc Committee
January 21, 2016 11:30AM
City Council Chambers
305 3rd Avenue East Twin Falls, ID 83301

Canyon Springs Road Project Ad Hoc Committee
Katie Breckenridge, John Lezamiz, Tony Mannen, Dave McCullom, Rick Novcek, Jim Olson, Linda Virgin Roberts, Todd Schwarz, Jamie Tigue

Facilitator: Phil Kushlan

MEMBER ATTENDANCE: Breckenridge, Lezamiz (via Telephone), Mannen, McCullom, Olson, Schwarz, Tigue
STAFF ATTENDANCE: Humble, Rothweiler, Strickland, Vitek, Williamson, Wonderlich
City Council Liaison: Barigar

CALL MEETING TO ORDER:

1. Confirmation of quorum: Meeting Facilitator Phil Kushlan called the meeting to order at 11:30 AM. He then confirmed there was a quorum present and proceeded with the meeting.
2. Introduction of committee members-Phil had the committee members introduce themselves and make a brief statement about what their interests are here.
3. Introduction of staff- Troy Vitek introduced himself as the project manager and Phil Kushlan as the facilitator, he also introduced Mike Woodworth from Strata and Brian Smith from JUB as the engineer for this project. Mayor Shawn Barigar introduced himself.

II. CONSENT CALENDAR:

1. Approval of Minutes from the following meeting(s): **There are no prior meeting minutes**

III. ITEMS OF DISCUSSION:

1. Open Meetings Act
2. City Policy of Transparency

IV. PUBLIC INPUT AND/OR ITEMS FROM THE COMMISSION/THE PUBLIC/CITY STAFF

V. UPCOMING MEETINGS:

Next public meeting to be scheduled for Thursday, February 18, 2016

VI. ADJOURN MEETING: Kushlan adjourned the meeting at 12:15pm

Si desea esta información en español, llame Leila Sanches al (208) 735-7287
Any person(s) needing special accommodations to participate in the above noticed meeting should contact Lisa A. Jones at (208) 735-7267 at least two (2) working days before the meeting.

Canyon Springs Road Project

AD HOC Committee Information Binder

J-U-B ENGINEERS, INC.

STRATA
A PROFESSIONAL SERVICES CORPORATION
Integrity from the Ground Up

March 25, 2014
File: TF14006A

Mr. Troy Vitek, P.E.
City of Twin Falls
P.O. Box 1907
Twin Falls, Idaho 83303

RE: **Conceptual Design (Draft)**
Canyon Springs Road
Twin Falls, Idaho

Dear Troy:

STRATA, A Professional Services Corporation (STRATA) is pleased to present this proposal to provide conceptual design for possible safety improvements to the existing Canyon Springs Road in Twin Falls, Idaho. The following paragraphs describe our project understanding, proposed scope of service, schedule, and fees. We prepared this proposal referencing our conversations with you, our previous project involvement, and our site visit on March 3, 2014.

PROJECT UNDERSTANDING

STRATA has previously been retained by the City of Twin Falls (City) to provide a rockfall evaluation for the Canyon Springs Road. Our previous evaluation identified several areas of the existing canyon wall above the Canyon Springs Road as a potential hazard to the existing roadway and public safety. The area of concern includes an approximate 2,200-foot length of the Canyon Springs Roadway in the Snake River Canyon.

Based on conversations with Mr. Troy Vitek, we understand the City wishes to evaluate possible remediation and/or relocation options to improve access and public safety. The primary goals which the City would like to achieve with a planned reconstruction or remediation for the Canyon Springs Roadway include improved safety, reduced rockfall risk, improved pedestrian access and improved drainage.

Based on our understanding of these goals, STRATA has subcontracted J-U-B Engineers (J-U-B) to assist with the conceptual design development of the roadway.

EXISTING CONDITIONS

Canyon Springs Road provides the only direct access for pedestrians, bicyclists, and vehicular traffic for existing City facilities and parks on the south side of the Snake River, west of the Perrine Bridge. The existing road has a relatively steep grade averaging approximately 10% from the top of the canyon rim to "flat" area at the base of the canyon.

The existing road also has two 180 degree "switchback" curves within the roadway alignment to provide the vertical grade transition while matching the existing canyon wall terrain. The roadway varies in width ranging from approximately 22 feet to 26 feet and there are currently no sidewalks or other pedestrian facilities within the roadway corridor.

Drainage along the roadway is handled with a roadside ditch on the uphill side of the road in addition to an existing half pipe CMP culvert "gutter" that runs approximately 2,000 feet in length along the upper section of the roadway (from the canyon rim to the first switchback curve). The upper section of roadway also has a concrete traffic barrier that extends approximately 2,250 linear feet.

The existing slope between the upper and lower sections of Canyon Springs Road is very steep ranging from 1.5 to 1.0 (horizontal to vertical) to near vertical several locations. Large boulders line several parts of the existing slope that appear to have come from the original roadway construction blasting that were discarded over the side of the roadway to form the new slope. Several of these boulders are more than 7 feet in diameter and there is limited buttress between the bottom of slope and edge of roadway.

In recent years, Canyon Springs Road has seen a significant increase in both vehicular and pedestrian traffic. Many pedestrians park at existing gravel lots located at either the top or bottom of the grade and then walk the roadway. As there are no sidewalks and limited shoulder areas, these pedestrians are required to walk down one of the vehicular travel lanes.

Rock fall from the existing near vertical rock cut canyon wall has also been an issue in recent years, particularly on the upper section of roadway. There is limited ditch / shoulder width between the roadway and the rock face to store any potential falling debris which then ultimately falls directly to the roadway surface below.

In addition, the City is undertaking a major construction project at their wastewater treatment plant located in the canyon that will add significant, heavy construction traffic during the duration of the project. The City is concerned that this additional construction traffic will create potential safety issues with pedestrians while also damaging the existing roadway structure that was not originally designed for this level of traffic.

As a result of these issues, the City has asked STRATA and J-U-B to complete a conceptual level review of potential solutions for improvements to the upper (2) sections of Canyon Springs Road (from the canyon rim to the 2nd switchback curve). In particular, the City requested solutions focus on three (3) specific areas of concern:

- Improving pedestrian access and safety
- Providing rock fall protection
- Improving the roadway horizontal alignment and structural section to accommodate the anticipated construction traffic impacts

ROCKFALL EVALUATION

To evaluate preliminary remediation designs, we reviewed our previous reports and data. Based on our previous geologic hazard evaluation, we identified 4 areas which, in our opinion, exhibited the highest risk associated with rockfall:

Table 1: Highest Rockfall Hazard Areas

Proposed Remediation Area	Location[1]	Rockfall Risk Category
1	STA 16+10 to 16+55	5
2	STA 17+75 to 18+25	4
3	STA 18+50 to 19+00	4
4	STA 19+75 to 20+25	4

As discussed in STRATA's March 23, 2009 report, the above areas exhibit, in our opinion, the highest rockfall risk (Category 4 or 5), with risk defined as a combination of likelihood of failure and consequences of failure. However, rockfall risk is not limited to the above areas, and failures which may result in injury, death, or damage to property may occur in areas other than those listed above.

We have reviewed and evaluated several remediation options to reduce the rockfall hazard along the existing Canyon Springs Road. Considering this, we have considered the following remediation options:

- **Blasting:** Blasting and creation of benches in the canyon face or catch ditches at the base of the rock wall was considered. However, considering space limitations, budget constraints, and the very high potential for damage of the roadway and sewer line related to blasting, as well as residential structures, this option was not considered feasible.

- **Rock Anchors and Shotcrete Facing:** This option consists of installation of rock anchors in identified unstable areas to provide increased long-term stability to the rock face. Rock anchors would be installed via drilling and grouting, and be post-tensioned to provide active restraint to the rock face. Shotcrete facing would be utilized to provide additional surficial stabilization and reduce the impact of freeze-thaw cycles. Primary advantages include substantial reduction in rockfall risk through increasing the stability of the rock face. Disadvantages include high relative cost.

- **Rockfall Mesh:** Rockfall mesh protection consists of installation of a high strength steel mesh which is anchored to the rock slope. The mesh transfers from the slope to rock anchors. Primary advantages include applicability for a wide range of geotechnical conditions, cost-effectiveness thanks to flexible nail spacing of up to 11 feet and quick installation and lower total project cost.

In addition to the above considerations, we also discussed land use and potential restrictions which could be enforced by the City. These include limitation or elimination of irrigation above the canyon, controlling concentrated runoff over the canyon rim, and providing safety warnings to motorists and pedestrians. While these considerations do not directly reduce rockfall hazard, the limitation of water introduction to the canyon face may reduce frequency of small rockfall events and providing safety warnings may increase public safety.

IMPROVEMENT ALTERNATIVES

Several improvement alternatives were identified and presented to City staff for conceptual level discussions. These discussions focused on construction viability, access, potential impacts to adjacent properties, traffic control during construction, overall benefits to the traveling public, and costs.

Alternative 1 – Widen upper section of roadway with at grade pedestrian improvements.

Initial discussions focused on additional rock excavation on the uphill side of the upper portion of roadway to provide additional horizontal roadway width for pedestrians, vehicles and rock fall storage. Fill improvements (i.e. widening to the downhill side) was not deemed feasible due to the additional fill material that would be required to be placed on a very steep and potentially unstable downhill slope.

The existing rock face walls extend more than 100 feet in height along a significant section of the upper roadway. This option required the paved roadway to be widened between 12 feet to 24 feet to accommodate the City's minimum 24 foot roadway width plus shoulders, pedestrian walkway, and traffic barrier. Additional horizontal width and rock removal would also be required to provide a catch and storage location for potential future rock fall. These improvements would result in more than 20 feet of rock excavation width which was cost prohibitive and would potentially impact the existing canyon rim trail and adjacent homes during drilling / blasting operations. As a result of these concerns, this option was deemed not feasible.

Alternative 2 – Install paved surface grade separated pedestrian improvements in conjunction with rockfall hazard reduction.

This alternative involves constructing a 12-foot-wide grade separated pathway for pedestrian use. The pathway "bench" would include an 8 foot wide paved walking surface installed at a maximum 10% running grade to generally match the adjacent roadway slope.

The bench would be installed in a "cut" section adjacent to the upper roadway section between the existing canyon rim parking lot and the first switchback curve and would be located up to 15' vertically below the adjacent roadway surface to accommodate the 10% maximum grade requirements. Pedestrians would then cross the roadway approximately 100 feet downhill of the first switchback curve to a new "fill" section pathway on the downhill side of the roadway which would extend to the 2nd switchback location. A typical section showing this proposed alternative is attached.

The primary advantage of this alternative is that "top down" construction could be used for the upper pathway section to potentially reduce traffic control impacts to the adjacent roadway. This alternative also does not require filling on top of the existing steep and potentially unstable downhill slope.

In existing rock cut areas, a vertical shotcrete wall fascia would be installed between the path and roadway. In areas of soil / boulder excavation, soil nailing would be used to stabilize the soil beneath the roadway in conjunction with a shotcrete fascia wall.

The lower section of pathway (between the 2 switchback curves) would be constructed on the downhill side of the roadway using mechanically stabilized earth (MSE) retaining walls. The downhill slopes on this section of roadway are not as steep and do not contain the unstable boulder fields observed on the uphill section. This approach would increase the overall stability of the construction in addition to reducing potential rock falling on pedestrians from the boulder field.

The roadway structural section would be reconstructed to meet City of Twin Falls Arterial standards (3" pavement, 17" compacted aggregate base). The roadway width would be improved to provide a minimum 24' wide driving surface with 2' paved shoulder (shy distance) to a traffic barrier. The roadway typical section would be revised from a "crown" to a "shed" section with storm water runoff diverted to a new drainage ditch adjacent to the roadway. Concrete catch basins would be installed at intermediate points along the length of the ditch and then piped across the roadway to rock lined outfall locations. Seepage from the adjacent rock face would be collected in a similar manner.

Rock fall protection would be achieved by rock bolting in conjunction with rockfall mesh or shotcrete facing. The rockfall mesh is preferred relative to shotcrete facing due to overall lower cost.

Due to the existing terrain limitations, the proposed pathway width and horizontal geometry would not meet AASHTO standards for bicycle pathway facilities and consequently bicycles would NOT be permitted on the pathway. "Share the Road" signing and striping would be added to the roadway to accommodate the bicycle traffic.

The proposed pathway would also not meet maximum 5% grade access criteria outlined in the Americans with Disabilities Act (ADA) for public pedestrian improvement projects. ADA does have provisions for projects deemed "structurally impracticable" due to the "unique characteristics of terrain that may prevent the incorporation of accessibility features". These provisions allow for steeper grades in situations with terrain similar to that facing Canyon Spring Road. However, as this provision is open to a degree of interpretation, it is recommended that the City's legal staff review this project for ADA compliance prior to moving forward with more formal design efforts.

The estimated construction cost for completing this alternative is **$5,327,955**. A summary of the quantities and unit costs used to develop this estimate are attached to this letter for reference.

Alternative 3 – Install "natural" surface grade separated pedestrian nature trail improvements.

This alternative is similar to Alternative 2 and involves constructing a 12' wide grade separated bench for pedestrian use. The bench would include an 8' wide natural or gravel walking surface with a grade that more closely matched the existing topography instead of attempting to match the maximum 10% grade of the adjacent roadway.

The trail would have an overall "average" slope from top to bottom of 10%, however, there would be several sections within the trail with grades of approximately 20%. This design approach is consistent with Federal Highways Administration (FHWA) recommendations for rural recreational trails in mountainous areas.

The advantage of this alternative is that it would significantly reduce excavation and rock removal quantities and costs for the pathway construction, particularly on the section between the canyon rim and the first switchback curve. The pathway would still be grade separated but not to the extent of Alternative 2. Costs for pathway paving would also be eliminated. Improvements for the lower section of pathway, roadway reconstruction, drainage, and rock fall protection outlined in Alternative 2 would be the same for this alternative.

As a result of the reduced rock removal, excavation, and paving, the estimated construction cost for Alternative 3 is **$4,827,803**. A summary of the quantities and unit costs used to develop this estimate are attached to this letter for reference.

LIMITATIONS

STRATA has provided this draft concept report for consideration by the City. However, the concepts outlined in this letter are preliminary and may require modification prior to construction. Further, STRATA's opinions of probable cost are made on the basis of experience and judgment, and STRATA cannot and does not guarantee that proposals, bids or actual total project or construction costs will not vary from opinions of probable cost prepared by STRATA and J-U-B. We appreciate the opportunity to be involved in this project, and look forward to continuing our relationship with the City of Twin Falls.

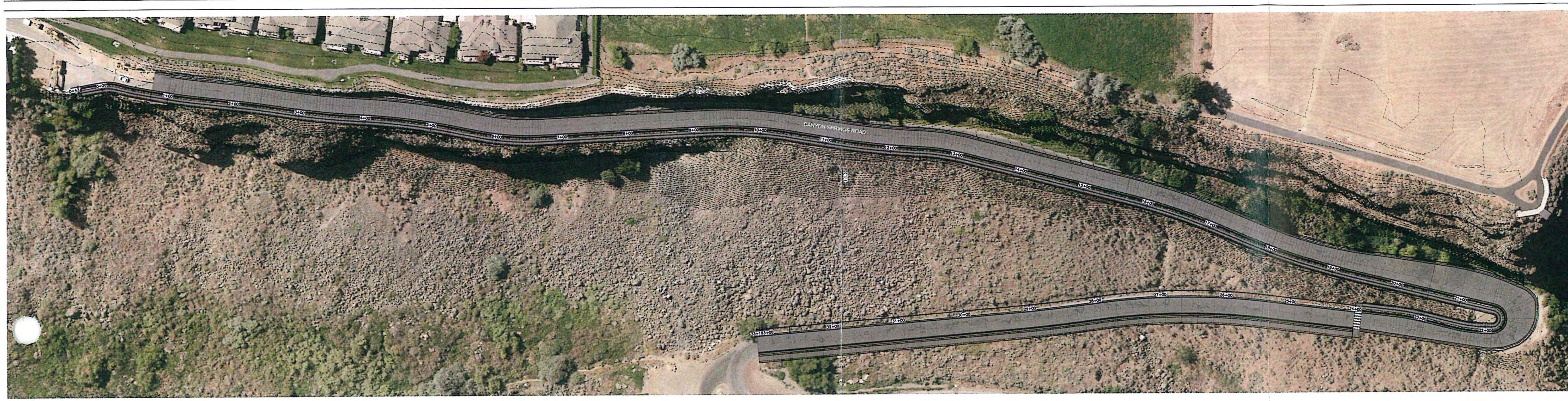
Sincerely,
STRATA, Inc.

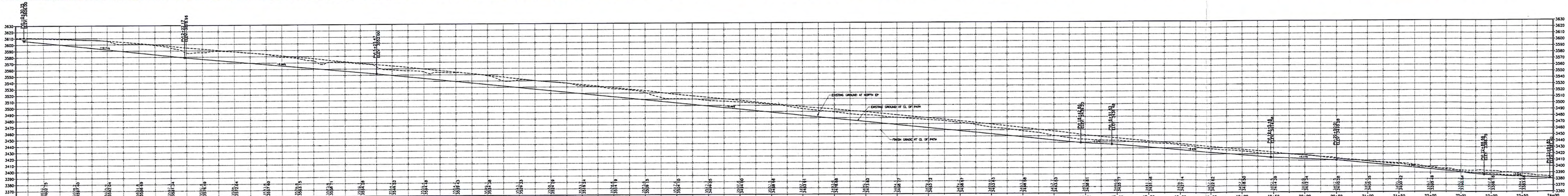
DRAFT

Michael G. Woodworth, P.E.
Engineering Manager

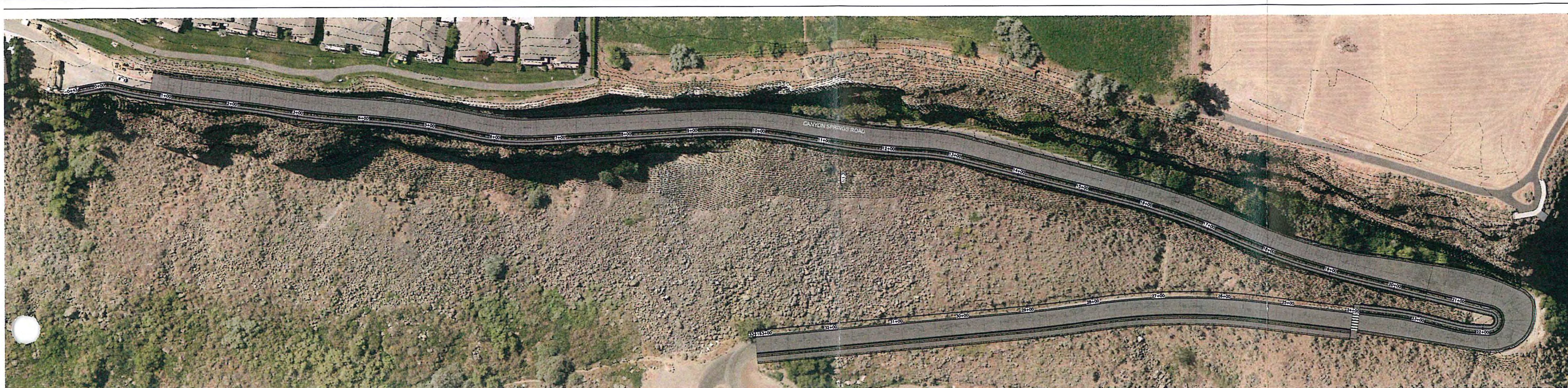
MGW/nm

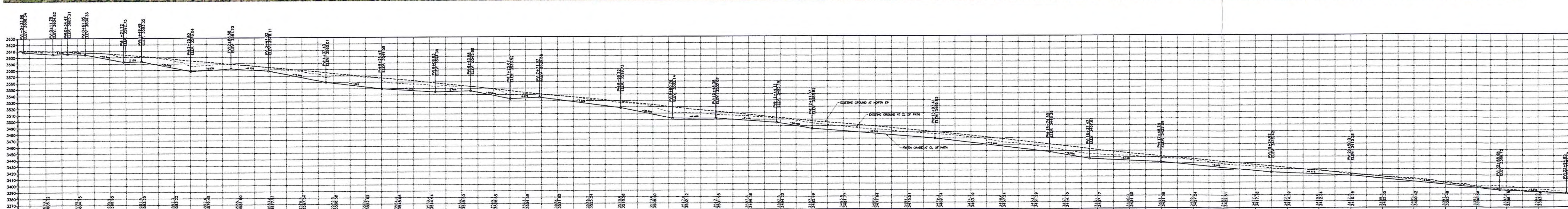
Attachments: Conceptual Design Plan and Profile
Typical Sections
Preliminary Cost Estimates



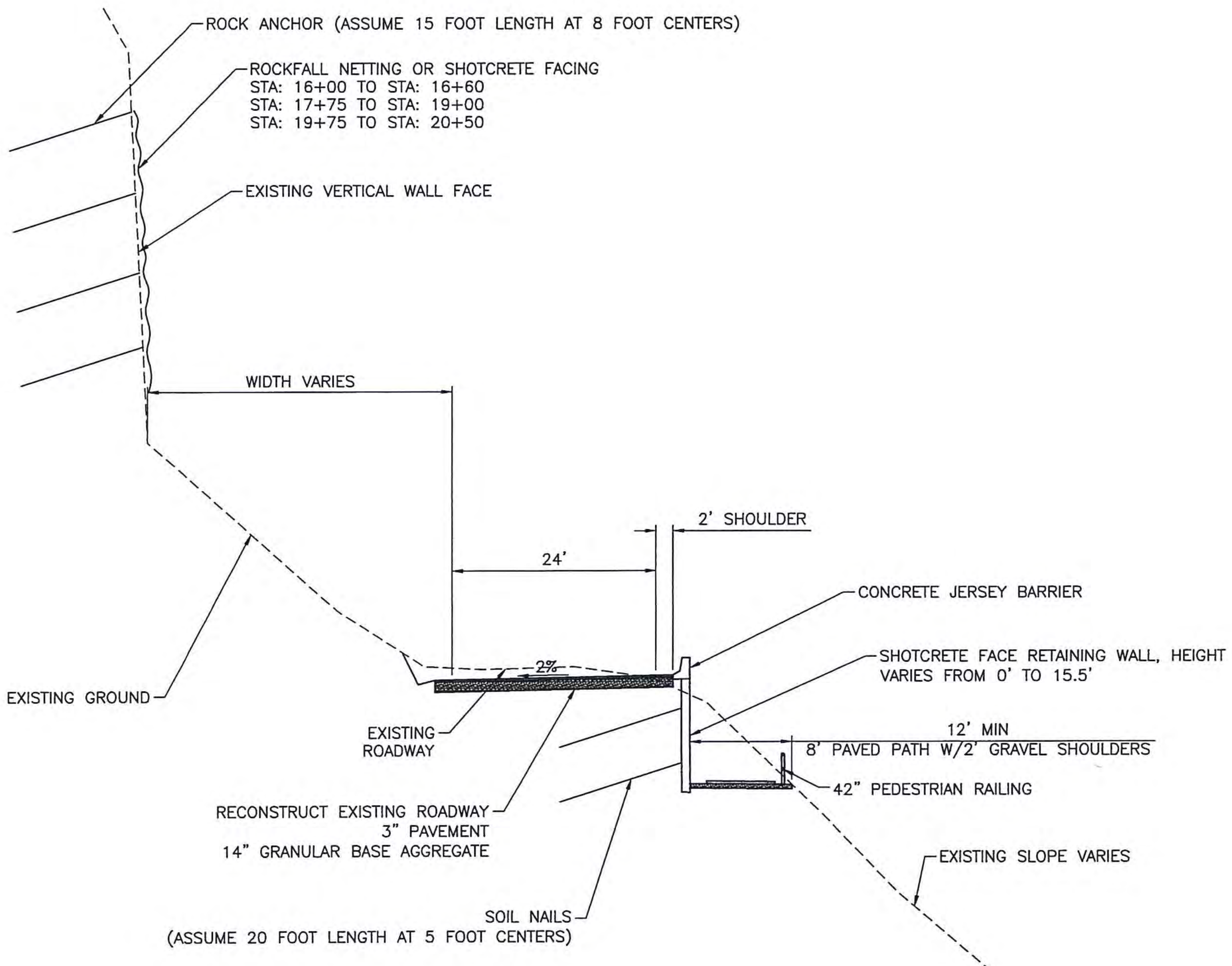


CITY OF TWIN FALLS
CANYON SPRINGS ROAD
IMPROVEMENTS - ALT 2
GRADE SEPARATED PAVED PATHWAY

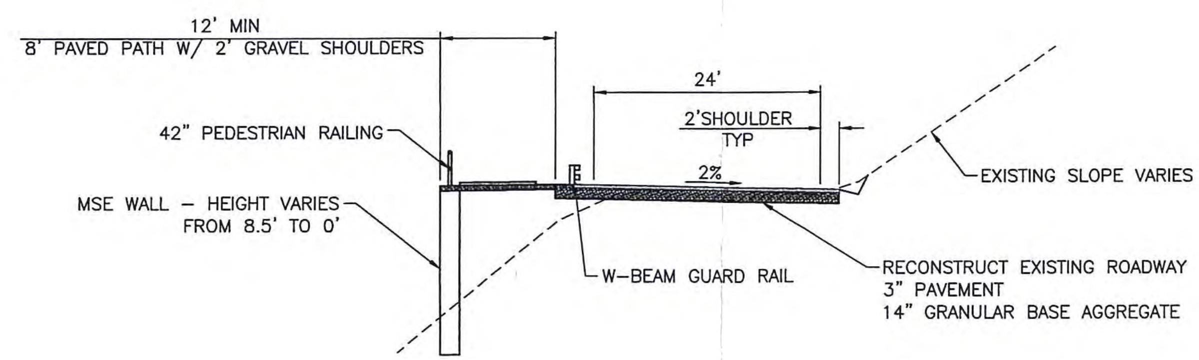




CITY OF TWIN FALLS
CANYON SPRINGS ROAD
IMPROVEMENTS - ALT 3
GRADE SEPARATED NATURE TRAIL



TYPICAL SECTION - STA: 0+00 TO STA: 24+00



TYPICAL SECTION - STA: 24+00 TO STA: 32+66

Date:3/25/2014 2:15 PM Plotted By: Shawn Dulin
Created:3/24/2014 F:\PROJECTS\JUB\10-14-036-STRATA-CANYON SPRING RD CONCEPTUAL EVAL\CADD\MODEL\SECTIONS.DWG

LAST UPDATED: 3/25/2014

JUB

CANYON SPRING DRIVE PATHWAY

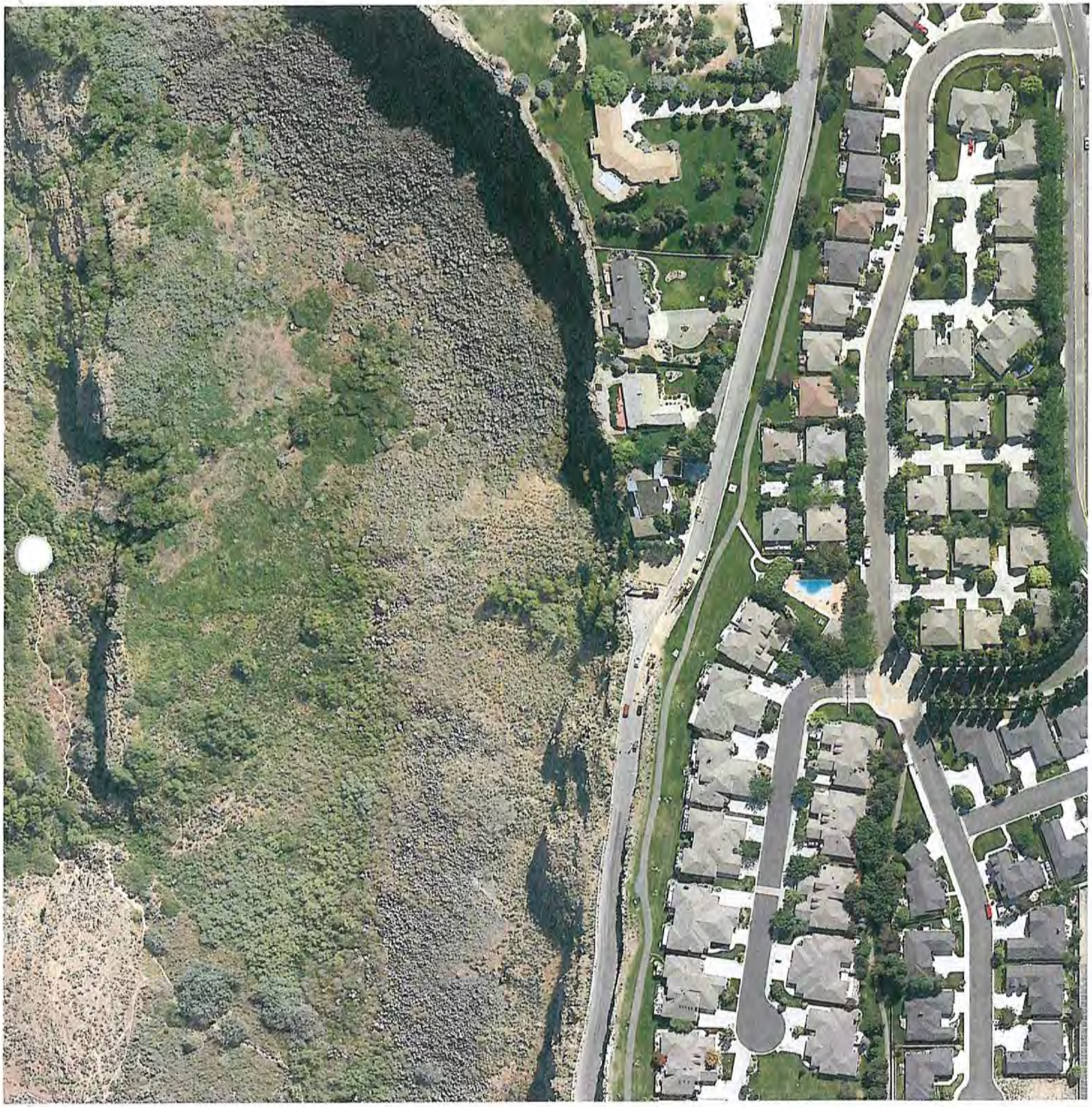
TYPICAL SECTIONS

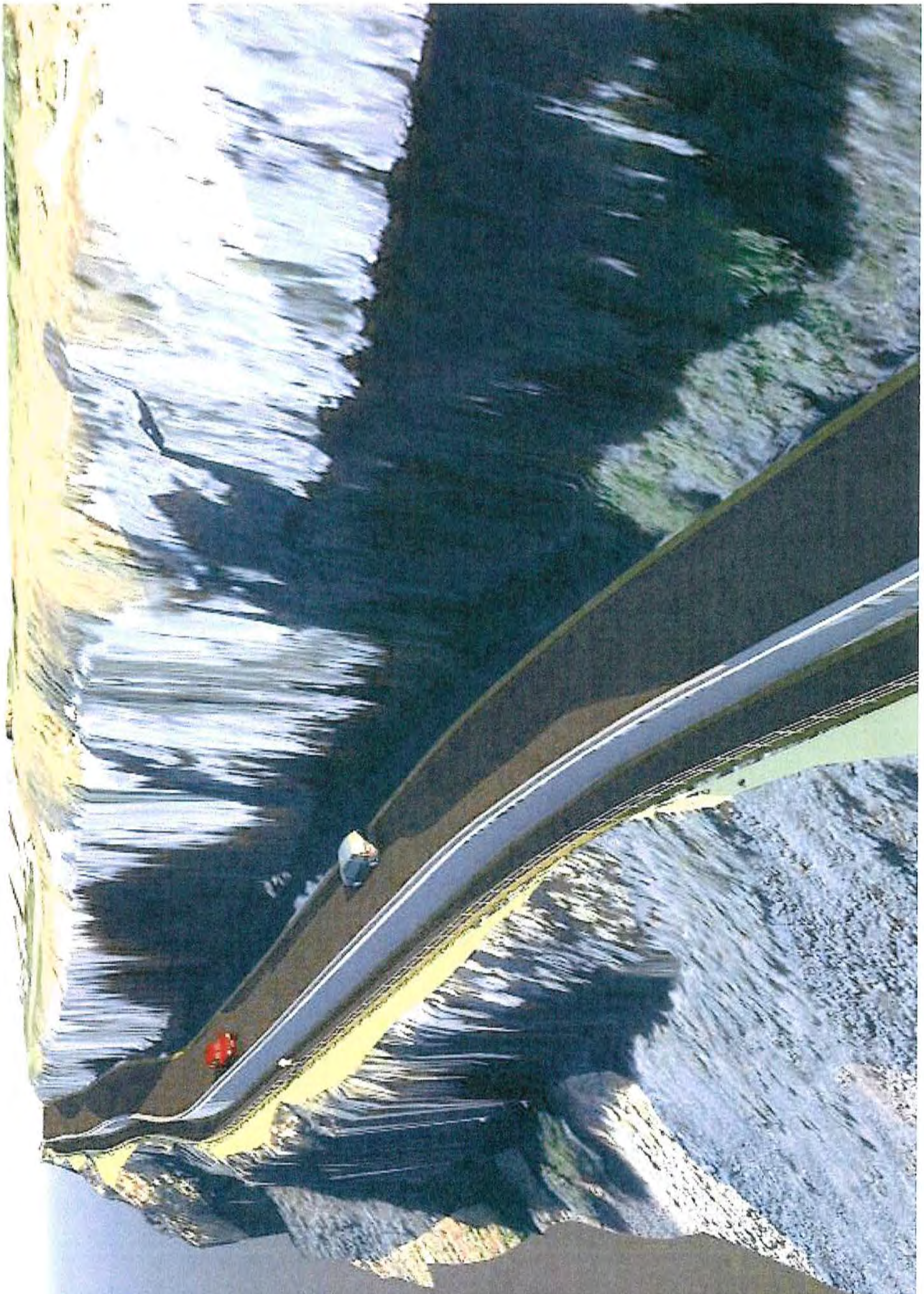
City of Twin Falls - Canyon Springs Roadway Conceptual Improvements
Alternate No. 2 - Grade Separated Paved Pathway (maximum 10% grade)
"DRAFT" Estimated Construction Costs

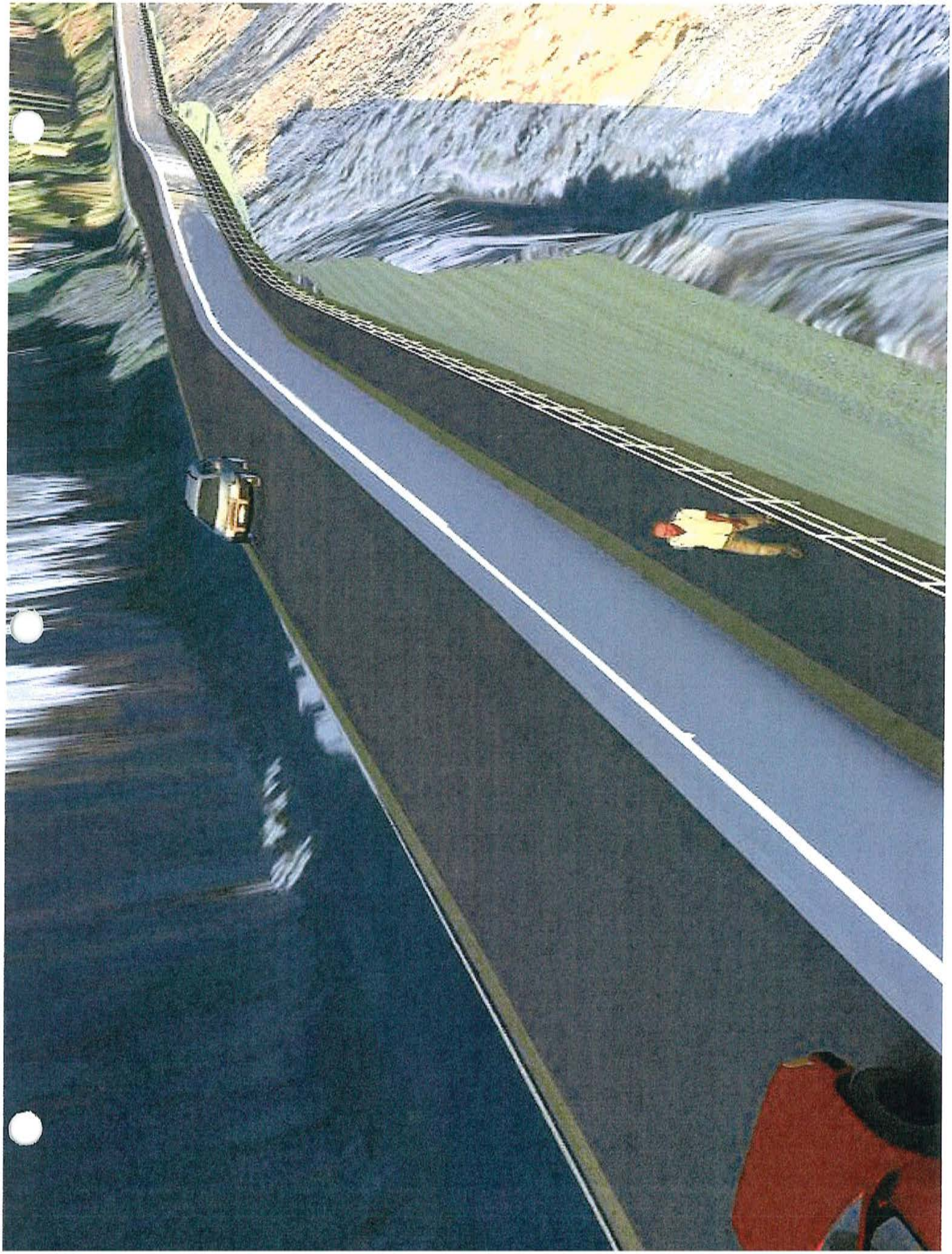
Item No.	Description	Quantity	Unit	Unit Cost	Total Cost
	Removal of Existing Concrete Railing	2,200	LF	$4.00	$8,800.00
	Rockfall Mesh Installation	18,500	SF	$25.00	$462,500.00
	Excavation	18,260	CY	$11.00	$200,860.00
	Granular Borrow Backfill	785	CY	$21.00	$16,485.00
	Blasting / Drill Holes	10,310	LF	$6.00	$61,860.00
	3/4" minus base aggregate	5,110	CY	$26.00	$132,860.00
	Plant Mix Pavement	2,230	TON	$85.00	$189,550.00
	18" Dia Culvert Pipe	500	LF	$40.00	$20,000.00
	Concrete Catch Basins	6	EA	$1,750.00	$10,500.00
	Adjust Manhole	4	EA	$800.00	$3,200.00
	PVC Conduit (Lighting)	3,400	LF	$5.00	$17,000.00
	Bike / Pedestrian Railing	3,200	LF	$85.00	$272,000.00
	MSE Retaining Wall	5,225	SF	$45.00	$235,125.00
	Shotcrete Wall Facing (Soil Nail Section)	14,200	SF	$70.00	$994,000.00
	Shotcrete Wall Facing (Rock Section)	14,030	SF	$35.00	$491,050.00
	Erosion and Sediment Control	1	LS	$90,000.00	$90,000.00
	Signage	1	LS	$3,000.00	$3,000.00
	Construction Traffic Control	1	LS	$95,000.00	$95,000.00
	W-Beam Guardrail	850	LF	$30.00	$25,500.00
	Concrete Traffic Railing	2,500	LF	$130.00	$325,000.00
	Mobilization 8%	1	LS	$292,343.20	$292,343.20
				Sub-Total:	$3,946,633.20
				15% Engineering:	$591,994.98
				20% Contingency:	$789,326.64
				Estimated Construction Total:	**$5,327,954.82**

City of Twin Falls - Canyon Springs Roadway Conceptual Improvements
Alternate No. 3 - Grade Separated Natural Trail (maximum 20% grade)
"DRAFT" Estimated Construction Costs

Item No.	Description	Quantity	Unit	Unit Cost	Total Cost
	Removal of Existing Concrete Railing	2,200	LF	$4.00	$8,800.00
	Rockfall Mesh Installation	18,500	SF	$25.00	$462,500.00
	Excavation	13,550	CY	$11.00	$149,050.00
	Granular Borrow Backfill	785	CY	$21.00	$16,485.00
	Blasting / Drill Holes	7,930	LF	$6.00	$47,580.00
	3/4" minus base aggregate	5,110	CY	$26.00	$132,860.00
	Plant Mix Pavement	1,850	TON	$85.00	$157,250.00
	18" Dia Culvert Pipe	500	LF	$40.00	$20,000.00
	Concrete Catch Basins	6	EA	$1,750.00	$10,500.00
	Adjust Manhole	4	EA	$800.00	$3,200.00
	PVC Conduit (Lighting)	3,400	LF	$5.00	$17,000.00
	Bike / Pedestrian Railing	3,200	LF	$85.00	$272,000.00
	MSE Retaining Wall	5,225	SF	$45.00	$235,125.00
	Shotcrete Wall Facing (Soil Nail Section)	13,000	SF	$70.00	$910,000.00
	Shotcrete Wall Facing (Rock Section)	9,440	SF	$35.00	$330,400.00
	Erosion and Sediment Control	1	LS	$90,000.00	$90,000.00
	Signage	1	LS	$3,000.00	$3,000.00
	Construction Traffic Control	1	LS	$95,000.00	$95,000.00
	W-Beam Guardrail	850	LF	$30.00	$25,500.00
	Concrete Traffic Railing	2,500	LF	$130.00	$325,000.00
	Mobilization 8%	1	LS	$264,900.00	$264,900.00
				Sub-Total:	$3,576,150.00
				15% Engineering:	$536,422.50
				20% Contingency:	$715,230.00
				Estimated Construction Total:	**$4,827,802.50**







STRATA
GEOTECHNICAL ENGINEERING & MATERIALS TESTING
Integrity from the Ground Up

January 8, 2010
File: TWICIT T09005B

Mr. Mike Trabert, P.E.
City of Twin Falls
324 Hansen St. East
Twin Falls, ID 83301

RE: **REPORT**
Rockfall Evaluation – Phase II Services
Canyon Springs Road
Twin Falls, Idaho

Dear Mr. Trabert:

STRATA, Inc. is pleased to present this rockfall evaluation for the Canyon Springs Road in Twin Falls, Idaho. Our geotechnical services were performed referencing our proposal dated December 3, 2008.

This report summarizes the results of our research, field evaluation, geologic reconnaissance, and remediation recommendations. Our geotechnical services were performed referencing conversations with you regarding the anticipated project approach. The findings and opinions presented herein are focused on our understanding of the site and geologic conditions. Other unforeseen site conditions not discussed herein may impact the project site. However, this report presents, in our opinion, the important risk factors that should be considered from a geotechnical and geologic standpoint. We have included visual aids with this report that can be used by you and other project team members.

We appreciate the opportunity to work with you on this project. We remain available to complete the next phase of services, as outlined in our original proposal. Please do not hesitate to contact us if you have any questions or comments.

Sincerely,
STRATA, Inc.

PROFESSIONAL ENGINEER REGISTERED 10830 1/8/10 STATE OF IDAHO MICHAEL G. WOODWORTH

Michael G. Woodworth, P.E.
Engineering Manager

MGW/sr

SUMMARY REPORT
Phase II Engineering Services
Rockfall Evaluation
Canyon Springs Roadway
Twin Falls, Idaho

INTRODUCTION

The purpose of this report is to present the findings from Phase II of STRATA's engineering services for the Canyon Springs Roadway rockfall evaluation project in Twin Falls, Idaho. Phase II of our engineering services function as a feasibility study, preliminary design concepts for slope remediation, and estimates of potential construction costs. This report includes remediation concepts and recommendations for the approximate 2,200-foot length of the Canyon Springs Road below the canyon wall. This report references our March 23, 2009 report which represents Phase I of our project involvement. We provided these Phase II engineering services referencing our December 3, 2008 Proposal presented to the City of Twin Falls.

DISCUSSION AND BACKGROUND

Existing Conditions

Based on conversations with Mr. Mike Trabert of the City of Twin Falls, we understand the existing canyon wall above the Canyon Springs Road has been identified as a potential hazard to the existing roadway and public safety. The area of concern identified by the City includes an approximate 2,200-foot length of the Canyon Springs Roadway in the Snake River Canyon. We understand the Canyon Springs Roadway has experienced previous rockfall events, resulting in a previous road closure and limiting access to the City of Twin Falls wastewater treatment plant. The rockfall events are likely related to isolated spalling, and ice jacking of basalt rock which forms the canyon walls, as well as larger block or wedge failures. We have been contracted with the City of Twin Falls to provide a geologic hazards evaluation to help understand risk associated with potential rockfall events and potential damage to property as well as safety of the public.

Geologic Setting

Rocks exposed within the Snake River Canyon in the Twin Falls area generally consist of late Tertiary Basalt overlain by limited near surface loess silt. In the project vicinity, the Snake River Canyon is approximately 450 to 475 feet from canyon rim on the south side to the river elevation. During the Bonneville flood, which occurred approximately 14,500 years ago, floodwaters filled and overtopped the present day canyon. Since the Bonneville flood, significant talus slopes have accumulated at the base of the canyon walls, which is indicative of periodic rockfall throughout the canyon.

Rockfall History

Based on our discussions with City personnel, we understand the Canyon Springs Road has experienced previous rockfall events which have been large enough to pose a potential public hazard and result in temporary road closure. Based on our discussions with Twin Falls City maintenance crews, we understand the Canyon Springs Road requires periodic rock removal, particularly during spring and winter months. Rockfall events which have occurred in the previous ten years range from several small events per year to a single large event which occurred in spring of 2003, which resulted in temporary road closure. To our knowledge, no injuries or damage to private property have occurred as a result of rockfall events.

PROJECT APPROACH

As discussed in our proposal dated December 3, 2008, this project consists of a risk-based evaluation of rockfall hazard along the existing Canyon Springs Road. We are contracted to accomplish our engineering services on a phased basis, with our Task 1 services consisting of a preliminary geologic evaluation to allow for identification and classification of rock fall hazards. Following completion of this task, Task 2 services include recommendations related to reducing rockfall hazard along the existing roadway. This report summarizes both our Task 1 and Task 2 services. To accomplish this evaluation, we performed the following:

1. Reviewed existing geologic and geotechnical reports for the general area to develop a preliminary indication of the subsurface conditions and previously identified geohazards at the project site.

2. Reviewed information collected by the City, specifically the information regarding previous rockfall events, as well as design documents related to existing residential development located near the canyon rim in the study area.

3. Performed field geologic mapping and reconnaissance on January 27, 2009, to identify potential unstable zones within the canyon wall and to categorize the risk factors associated with each identified unstable zone. We categorized potential rockfall hazards into a risk-based matrix, Plate 2, based on qualitative factors such as likelihood of failure, failure mechanism, and potential risk to public safety and property associated with each failure zone.

4. Prepared our Task 1 Report presenting our opinions and recommendations. This report includes a map showing locations of potential failure areas (Plate 1), annotated photographs (Appendix A), and a matrix of unstable zones (Plate 2).

5. Evaluated potential remediation options to reduce the rockfall hazard within the project area. Remediation options were discussed with the City regarding constructability, feasibility, and other factors.

6. Discussed remediation options with selected local contractors to provide preliminary construction cost estimates.

7. Prepared this final Summary Report.

LITERATURE REVIEW

STRATA reviewed literature available, which in our opinion, provides useful background information related to rockfall hazard and rock slope stability. Specific references reviewed in preparation of this report include:

- Rockfall Catchment Area Design Guide, dated November, 2001, Oregon Department of Transportation Research Group.
- Development and Implementation of the Idaho Highway Slope Instability and Management System (HiSIMS), dated June, 2003, National Institute for Advanced Transportation Technology, University of Idaho.

Review of the above publications provided background information related to risk assessment of rockfall hazard in rock slopes and impact to roadways and other transportation corridors. Further discussion of risk and rockfall assessment is provided in following sections of this report.

GEOLOGIC HAZARD EVALUATION (TASK 1 SERVICES)

General

Rock slope stability issues are common in vertical and near vertical fractured rock faces. Failures of rock slopes in competent rock, such as exists on the project site, occur along pre-existing rock fractures, and failure mechanisms include wedge failures, slab failures, toppling, and spalling. If fracture and joint patterns are relatively consistent in the overall rock mass, as may occur in sedimentary rock or faulted igneous rock, detailed fracture mapping and strength analysis can be a useful tool to predict failure mechanisms and risk of failure. However, in rock masses with randomly-oriented joints, joint set or fracture mapping is of limited value.

Considering the nature of the basalt rock on the project site and geologic history associated with basalt flows, in our opinion, the majority of fractures, within the basalt rock are a result of cooling of the basalt flow and subsequent cracking developed within the rock mass. With the exception of vertical or near vertical fractures which typically occur in basalt rock, these cooling fractures will be randomly oriented, and subsequently, failures of the rock mass will be controlled by the random fracture or joint pattern within the basalt rock.

Geologic Reconnaissance

As part of our scope of service, we have evaluated specific geologic conditions along the approximate 2,200-foot Canyon Springs Road alignment, as shown on Plate 1, Site Plan. We have utilized stationing along the roadway established through site survey by J-U-B Engineers as a reference for our geologic reconnaissance. Geologic reconnaissance and observation was accomplished by a licensed geotechnical engineer with geological engineering background. Specific observations made during our geologic reconnaissance are presented as Plate 2, Failure Zones and Risk Matrix. A general discussion of our observations is presented below, as referenced by station established by J-U-B Engineers.

Table 1. Summary of Site Observations

Station	Notes and Observations
11+00	West end of vertical face
11+00 – 12+50	Clean vertical face, very few fractures
12+50	Potential single boulder failure
13+90	Soil interbed noted below upper basalt
16+00 – 16+55	iUndermining of upper basalt, previous failures noted, high potential for future failure
21+00 – 31+50	Substantial seepage and ice from basalt face below approximate Elev 3505
22+00	End of blasted zone
22+00 – 31+50	Natural rock face, numerous potential individual failures
31+50	End of evaluation area

Note that the above stationing is provided on Plate 1 and is generally approximated in the field during our geologic reconnaissance.

General Rockfall Hazard Rating

Based on the Rockfall Hazard Rating System Implementation Manual developed by Federal Highway Administration, the Idaho Transportation Department (ITD) has developed a highway slope hazard rating system for highways in the state of Idaho. As applied to rock slopes, inputs for the rating system include both roadway and slope parameters. Based on the input parameters, a risk assessment for the roadway is provided. Details of the rating system are provided in Appendix B, and summarized in Table 2 below.

Table 2. ITD Rockfall Hazard Rating System

Input Parameter	Average Canyon Springs Road Condition	Score
Roadway Width	25 feet	27
Catch Ditch Effectiveness	No Catchment	81
Failure Frequency	1 – 3 per year	3
Impacted Road Length	>500 feet	81
Maintenance/Cleanup	Moderate; Some Loading and Hauling	9
Traffic Impact	Moderate	9
Average Daily Traffic	<200	3
Average Vehicle Risk	<25%	3
Percent Decision Sight Distance (PDSD)	80 – 99%	27
Potential For Major/Extreme Rockfall Event	Some Potential	9

Based on the above rating system, portions of the slope above the Canyon Springs Road range from a rating of approximately 252 out of a possible rating of 30 to 810. These ratings correspond to a moderate rockfall hazard. It is important to note that the risk to the public, as defined by the Idaho Rockfall Hazard Rating system is primarily reduced on the Canyon Springs Roadway as a result of relatively-low daily traffic.

Site Specific Rockfall Hazard Evaluation

In addition to the above generalized rockfall hazard rating system, we have also evaluated site specific potential rock failures for the Canyon Springs Road. In order to evaluate site specific rock failure potential, we created a site specific database of potential rockfall failure mechanisms, likelihood of failure, and risk to the public associated with a potential failure.

Based on our field observations and our knowledge of the site history, potential rock failures were divided into three categories based on the mechanism of failure. These failure mechanisms are defined below:

- Category I Failure - Single loose boulder/ multiple loose cobbles
- Category II Failure - Several loose boulders
- Category III Failure - Large wedge or column failure

An area categorized as a potential Category I failure can be seen on Photo 1 as a single boulder with a high likelihood of failure. Cobbles are defined as rocks with a diameter smaller than 10 inches and boulders are any rock larger than 10 inches in diameter. A typical potential Category II failure can be referenced on Photos 4 and 5. Photos 4 and 5 are of the area that has failed numerous times in the past and a failure consisting of approximately 2-foot diameter boulders occurred the day/night before our site visit on January 27, 2009. A previous wedge failure can be seen on Photo 9 that is approximately 100 feet wide and is likely the site of the 2003 failure that resulted in the closure of Canyon Springs Road.

In addition to identifying specific failure mechanisms, we also evaluated the potential likelihood of failure for each area, as well as the potential risk each failure presented to public safety and property. Specific classifications of failure mechanism and likelihood are presented as Plate 2.

Based on our observations and research, we further developed an inventory of the risk factors associated with potential rockfall events and identify potential hazardous areas, which in our opinion, may pose substantial risk to the public and property. Potential rock failures were divided into a total of six categories based on the the following criteria:

- Estimated failure type – Category I though Category III, as defined above.
- Estimated likelihood of failure – low, moderate, or high.
- Estimated consequences of failure – low or high.

In considering the potential risk associated with rockfall events, we utilized the following qualitative assessment matrix based on the above input parameters:

Table 3. Site Specific Rockfall Risk Matrix

Likelihood of Failure	Failure Mode			Consequence of Failure
	I	II	III	
High	3	4	5	High
	2	3	4	Low
Medium	2	3	3	High
	1	2	3	Low
Low	1	2	2	High
	0	1	2	Low

Based on the above matrix, risk categories vary from 0 to 5, with 5 being the highest risk. Note that for the lower risk categories (0 and 1) correspond primarily to small failures with low likelihood of failure and/or low consequence of failure. Moderate risk categories (2 and 3), correspond to relatively likely small failures or low probability large failures. The highest risk categories (4 and 5) correspond to large, Category II and III failures, with a high likelihood of occurrence, and a high consequence of failure. Based on our observations, Category 0 and 1 risk failures were typically identified as smaller cobbles and/or boulders that had a low likelihood of reaching the roadway, as seen on Photo 1. Category 2 and 3 risk failures are typically larger boulders that would have enough momentum to roll into the roadway and cause minor damage to the roadway and any passing vehicle, as seen on Photo 3. Category 4 and 5 failures will reach the pavement and have the potential to cause significant damage to the pavement surface, as seen on Photos 4 and 5. A passing vehicle could potentially suffer significant or catastrophic damage from Category 4 and 5 failures. Refer to Plate 2 for risk categories in each of the identified failure zones.

Discussion and Recommendations

Based on the above discussion, in our opinion, the overall risk associated with the existing condition of the canyon face can be assessed through a combination of the above factors. The areas of highest risk are areas with a combined high likelihood of failure and severe consequence of failure. Considering this, we have provided a matrix of overall risk for the canyon wall segments and presented this as Plate 2.

In our opinion, failures which are likely to occur are generally likely to be limited to areas within approximately 5 to 10 feet of the canyon rim. Therefore, risk of failures impacting structures above the canyon rim outside of this zone is low. However, the presence of development above the canyon rim, particularly with respect to stormwater and irrigation water management may adversely affect stability of the rock face.

As shown in the matrix, areas with highest risk correspond to areas which have been associated with previous failures. Further, the highest risk areas are concentrated in the portion of the alignment which has previously been blasted as part of the previous road construction. As such, we recommend remedial measures be evaluated and considered to reduce the rockfall risk in areas classified as Risk Category 2 or higher. We have evaluated potential remedial measures and discussed remedial options with the City. Our evaluation of remedial measures, recommendations, and construction cost estimates are presented in the following sections.

GEOLOGIC AND GEOTECHNICAL RECOMMENDATIONS (TASK 2 SERVICES)

Evaluation of Remediation Options

To evaluate preliminary remediation designs, we reviewed our previous Task 1 report with the City. Based on our discussions with City personnel, we understand remediation options have been elected to be limited to addressing rockfall risk categories 4 and 5 at this time. Based on our previous geologic hazard evaluation, we identified 4 areas which, in our opinion, exhibited the highest risk associated with rockfall:

Table 4: Highest Rockfall Hazard Areas		
Proposed Remediation Area	Location[1]	Rockfall Risk Category[2]
1	STA 16+10 to 16+55	5
2	STA 17+75 to 18+25	4
3	STA 18+50 to 19+00	4
4	STA 19+75 to 20+25	4

As discussed in our March 23, 2009 report, the above areas exhibit, in our opinion, the highest risk of failure (Category 4 or 5), with risk defined as a combination of likelihood of failure and consequences of failure. However, rockfall risk is not limited to the above areas, and failures which may result in injury, death, or damage to property may occur in areas other than those listed above.

We have reviewed and evaluated several remediation options to reduce the rockfall hazard along the existing Canyon Springs Road. Considering this, we have preliminarily evaluated the following remediation options:

- **Long Term Monitoring:** This option would consist of remote sensing, surveying, or periodic photographic documentation of the rock slope face. The purpose of this would be to identify areas which may exhibit change over the course of a season or year, and which would be good candidates for remediation options listed below. Advantages of this include relatively low cost and the ability to identify changes in the rock mass. Disadvantages of the monitoring program are that no inherent reduction in rockfall risk is realized and likely failure mechanisms are not likely to be identified through monitoring.

- **Rock Anchors and/or Shotcrete Facing:** This option consists of installation of rock anchors in identified unstable areas to provide increased long-term stability to the rock face. Rock anchors would be installed via drilling and grouting, and be post-tensioned to provide active restraint to the rock face. Shotcrete facing would be utilized to provide additional surficial stabilization and reduce the impact of freeze-thaw cycles. Primary advantages include substantial reduction in rockfall risk through increasing the stability of the rock face. Disadvantages include high relative cost.

- **Localized High Scaling:** High scaling, or removal of loose rock at the canyon face, could be accomplished with a lift or crane in areas up to approximate STA 21+00. Beyond this location, scaling would likely be accomplished from the top of the canyon wall. High scaling will reduce rockfall risk, particularly in areas of potentially small failures limited to isolated rocks. However, high scaling alone will not reduce rockfall risk in large areas which exhibit instability, such as noted above. Advantages of high scaling include moderate relative cost. Disadvantages include potential for damage to roadway from falling rock, and potential to destabilize additional areas of the canyon face during scaling operations.

- **Blasting:** Blasting and creation of benches in the canyon face or catch ditches at the base of the rock wall was also considered. However, considering space limitations, budget constraints, and the very high potential for damage of the roadway and sewer line related to blasting, this option was not considered feasible.

In addition to the above considerations, we also discussed land use and potential restrictions which could be enforced by the City. These include limitation or elimination of irrigation above the canyon, controlling concentrated runoff over the canyon rim, and providing safety warnings to motorists and pedestrians. While these considerations do not directly reduce rockfall hazard, the limitation of water introduction to the canyon face may reduce frequency of small rockfall events and providing safety warnings may increase public safety.

Recommended Remedial Measures

Based on our discussions with the City, we understand the City's preliminary goal is to reduce the existing rockfall hazard by implementing remediation efforts in areas which present the greatest overall risk to public safety and/or existing infrastructure. We note that the below remediation options attempt to satisfy this goal, but do not attempt to completely eliminate risk associated with rockfall hazards. Considering this, proposed remediation methods for each of the areas identified above are presented in Table 5, below:

Table 5: Proposed Rockfall Remediation

Proposed Remediation Area	Remediation Method
1	High Scaling, Rock Anchors and Shotcrete Facing
2	High Scaling and Rock Anchors
3	High Scaling and Rock Anchors
4	High Scaling and Rock Anchors

Specifics of each of the recommended remediation measures are discussed below:

<u>Rock Anchors</u>

Considering the random joint patterns and nature of the basalt rock, we recommend hollow core Spin-Lock mechanical rock anchors be used to stabilize the rock face in the proposed remediation areas listed above. Rock anchors could be installed at the rock face using a crane and lift basket and portable equipment.

We preliminarily anticipate rock anchors will consist of 1-inch diameter, galvanized, hollow core threaded bar, available from Williams Form or equivalent. Based on rock type, we anticipate a drill hole diameter of 1-5/8 inches will be required. The hollow core bar should be prestressed prior to grouting with prestressing up to the maximum recommended design load of 33 kips. We preliminarily estimate rock anchor lengths of approximately 15 feet, and spacing of approximately 5 to 8 feet on-center in the Remediation Areas 1 through 4.

In our opinion, spin-Lock rock anchors provide significant advantages for this application over traditional rock anchors due to ease of installation and the ability to tension the anchor prior to grout placement, which reduces the potential for grout cracking or movement at the rock face during grouting.

Shotcrete

We recommend shotcrete facing be applied in remediation area 1 to reduce the potential for moisture infiltration and freeze thaw cycles impacting the rock face. We preliminary anticipate shotcrete facing will be approximately 4 to 6 inches thick and reinforced with welded wire fabric. Shotcrete should be applied following installation of rock anchors.

High Scaling

We recommend localized high scaling be accomplished to remove loose rock which poses a rockfall hazard. Although high scaling will be required in remediation areas 1 through 4 prior to installation of rock anchors, we recommend high scaling be accomplished from approximate STA 12+50 to STA 21+00. The purpose of high scaling is to remove loose rock which is in imminent danger of falling. However, identification of the loose rock may not be possible until close-up inspection occurs during construction. We preliminarily recommend high scaling occur in areas identified in Plate 2 as potential type I and II failures from approximate STA 12+50 to 21+00. However, caution should be taken during scaling activities to reduce the potential for increasing rockfall hazard through undermining upper rock layers through removal of lower layers.

PRELIMINARY CONSTRUCTION COST ESTIMATES

To provide the cost estimates presented in subsequent sections, STRATA developed the remediation options discussed above and construction considerations such as slope geometry, materials and equipment required, accessibility, etc. We presented these preliminary design considerations to local contractors for their consideration and to assist STRATA in developing cost estimates. STRATA also reviewed construction schedules, material handling costs, equipment costs, etc. and we made modifications as necessary. We also estimated a contingency range for each construction cost estimate to account for construction aspects that may have high cost variability. It is difficult to predict costs such as steel, fuel, labor, etc. Given the above understanding, we present the following cost estimates for your consideration.

Final Design and Continuity Cost Estimates

A portion of the project costs to remediate the Canyon Springs rock slope will include final design and construction monitoring costs. We attempted to predict those costs by reviewing a scope of service to accomplish final geotechnical design, prepare plans and specifications construction monitoring. Additionally, construction observation and monitoring tasks presented below are independent of the selected remediation option. Our opinion is that this project will require full time observation to verify construction occurs as designed. Given the above understanding we propose the following minimum scope for construction monitoring, anchor testing and consultation during construction:

Table 6. Final Design and Construction Observation Tasks and Cost Estimates

Task	Estimated Cost
• Review City goals for construction • Prepare final plans and specifications for the remediation option • Interface with contractors	**$4,000 - $5,000**
• Provide geotechnical and civil engineering consulting during construction • Project management oversight during construction • Provide full-time construction observation by a materials testing technician or staff engineer • Provide project correspondence, reports, and final summary report	**$15,000 - $20,000**
Total Design and Construction Observation Estimate	**$20,000 - $25,000**

The above tasks are required to accomplish final geotechnical design. However, the following assumptions were made to prepare the cost estimates presented in above sections:

- STRATA will be retained to provide geotechnical design continuity through construction.
- Construction would occur over an approximate 30 day window.
- STRATA's engineer of record or designated representative would be on-site during construction. Good communication between the project and construction team can economize this project involvement.

Remediation Cost Estimates

We referenced the remediation concepts presented above to generate our assumptions and costs for the proposed construction. These cost estimates are not intended to represent a quote or bid from qualified contractors to construct the remediation construction. These fees exclude construction monitoring, design or permitting fees (if necessary) and any other costs not explicitly presented. Given the following assumptions and referencing our interaction with local contractors, Table 5 presents the construction cost estimates.

Table 7. Remediation Construction Tasks and Cost Estimates

Task	Estimated Cost
• Area 1 Remediation: High Scaling, Rock Anchors, Shotcrete Application	**$194,000**
• Areas 2 and 3 Remediation: High Scaling and Rock Anchors	**$81,150**
• Area 4 Remediation: High Scaling and Rock Anchors	**$137,500**
Total Construction Estimate	**$412,650** **+ Contingency**

The above construction cost estimates include the following assumptions:

- Construction would occur over an approximate 30 day window.
- The City will secure access on private property above the slope from STA 17+50 to STA 21+00.
- Contractor can mobilize and accomplish construction for the four remediation areas noted above concurrently.
- A total of 83 rock anchors have been assumed.
- A total of 145 man-hours of high scaling has been assumed.
- A 40-ton crane will be required for construction in area 4. A total of 40 hours of crane rental has been assumed.

If the above assumptions are not possible, additional fees may be incurred. We recommend the City of Twin Falls consider inclusion of a contingency factor for the construction costs from 10 to 20 percent for planning purposes. This contingency increase likely covers any costs associated with installation of additional rock anchors, identification of previously unknown hazards, or other unknown conditions which may occur during construction. This would result in a total engineer's estimate of probable construction costs of about $475,000 to $520,000 (including design and construction consultation). Detailed construction cost estimates are presented in Appendix C.

The above assumed cost associated with remediation is based on estimates of manpower and equipment required. Note that contractor availability at the time of bidding or other unforeseen events may substantially impact anticipated costs. Further, costs noted above do not include engineering observation or other consulting services which would be required during construction.

Summary of Assumptions

The assumptions presented above were required to develop construction cost estimates. However, for final design and construction, there exists significant considerations that must be addressed and accounted for. We provide the following aspects to present special considerations that are either included or excluded in the above construction cost estimates. These aspects are generally independent of the remediation option and will allow the City to evaluate additional construction costs that may or may not be anticipated.

- The roadway will be closed intermittently during construction, but not through the duration of construction.
- The contractor will provide complete as-built drawings of the construction.
- The contractor will be provided an area to stage equipment, materials, etc. within ¼-mile of the project site.
- Remediation construction excludes an erosion and sediment control plan or SWPPP. These services can be provided as an additional service.
- The remediation construction will not require environmental cleanup.

SUMMARY OF FINDINGS

Discussion and Limitations

This report presents an evaluation of feasibility of the above preliminary remediation concepts and presents approximate construction cost estimates. However, this feasibility study is limited in scope and extent such that only very rough cost estimates are provided. No preliminary construction cost estimate can be relied upon for final construction budgeting and planning. Further, the above cost estimates will be subject to significant fluctuation associated with labor and material cost depending on final design. The intent of the above presentation is to simply provide a tool to evaluate potential construction costs to assist planning. We do not authorize use of this report to develop final construction budgets.

In addition to the above considerations, we specifically note that geotechnical design and geotechnical-related remediation options require field modifications, judgment and experience from the engineer of record. Subsurface conditions, especially in situations where heterogeneous conditions exist such as within the basalt rock face, have the potential to vary and will impact construction schedules and costs. Our assumptions and cost estimates presented above are based on geologic reconnaissance and observations. The findings and opinions discussed herein require judgment, anticipation, and ultimately understanding on the part of the design team with respect to unanticipated conditions. In summary, geotechnical follow-up during construction is a critical part of the design and construction process.

CLOSING

Acknowledgment of Scope of Service Limitations

The information contained in this report is preliminary and is based on limited engineering analyses and preliminary project concepts. A specific and detailed geotechnical analysis of final remediation design has not been performed.
Accordingly, this document must only be used as a planning tool and is not authorized by STRATA to be used for construction.

Additional Recommended Services

As discussed in this report, additional geotechnical engineering analysis and design will be required during final design of the proposed project. We recommend STRATA provide project geotechnical continuity through preliminary planning, providing final design engineering, preparing of construction drawings and specifications and providing construction engineering consultation and monitoring.

Further, the areas recommended for remediation in this report reflect, in our opinion, areas of highest risk associated with rockfall, and were selected for remediation with input from the City. However, other areas also present a rockfall hazard which have not been recommended for remediation in this report. We recommend the City allocate ongoing budget items for continued remediation of other areas along the Canyon Springs Road. Specifically, we recommend the City consider the following areas in addition to those recommended above:

- Soil interbed from STA 14+00 to STA 16+00.
- Numerous potential failures from STA 12+80 to 14+30.
- Area of undermining from STA 14+80 to 15+35.
- All other areas identified as Risk Category 3 or higher.

Evaluation Limitations

This report has been prepared to evaluate the feasibility of remediation options for the existing Canyon Springs Roadway in Twin Falls, Idaho. Our services consist of professional opinions and recommendations made in accordance with generally accepted geotechnical engineering principles and practices. This acknowledgment is in lieu of express or implied warranties.

STRATA conducted our preliminary services in accordance with the generally accepted standard of care that exists for geotechnical or geologic engineering consultants at the time of this evaluation in southern Idaho. Please be aware that retention of our services does not provide a guarantee that the proposed project is without risk on the part of the stakeholders.

The results and opinions generated from geologic reconnaissance and analyses are based on information acquired during the authorized scope of service. It is possible that variations at the property could exist beyond points observed during the course of our services. The passage of time must also be considered and it is important that the City recognize that due to natural occurrences or direct or indirect human interventions at a site or distant from it, actual conditions may change quickly.

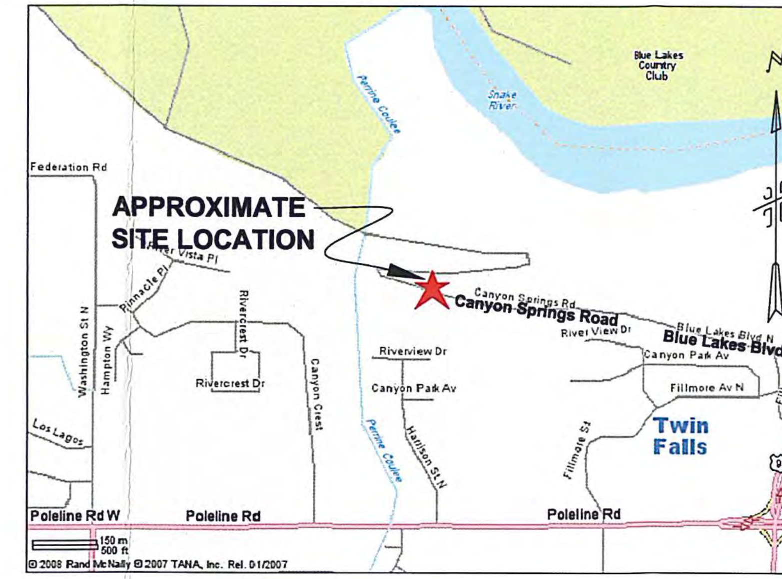
We have presented recommended a proposed scope of engineering services to provide final design and remediation. These services are, in our opinion, critical and necessary to the success of the project. If we do not perform the additional recommended services, we cannot be responsible for related planning, design and construction errors or omissions at the project.

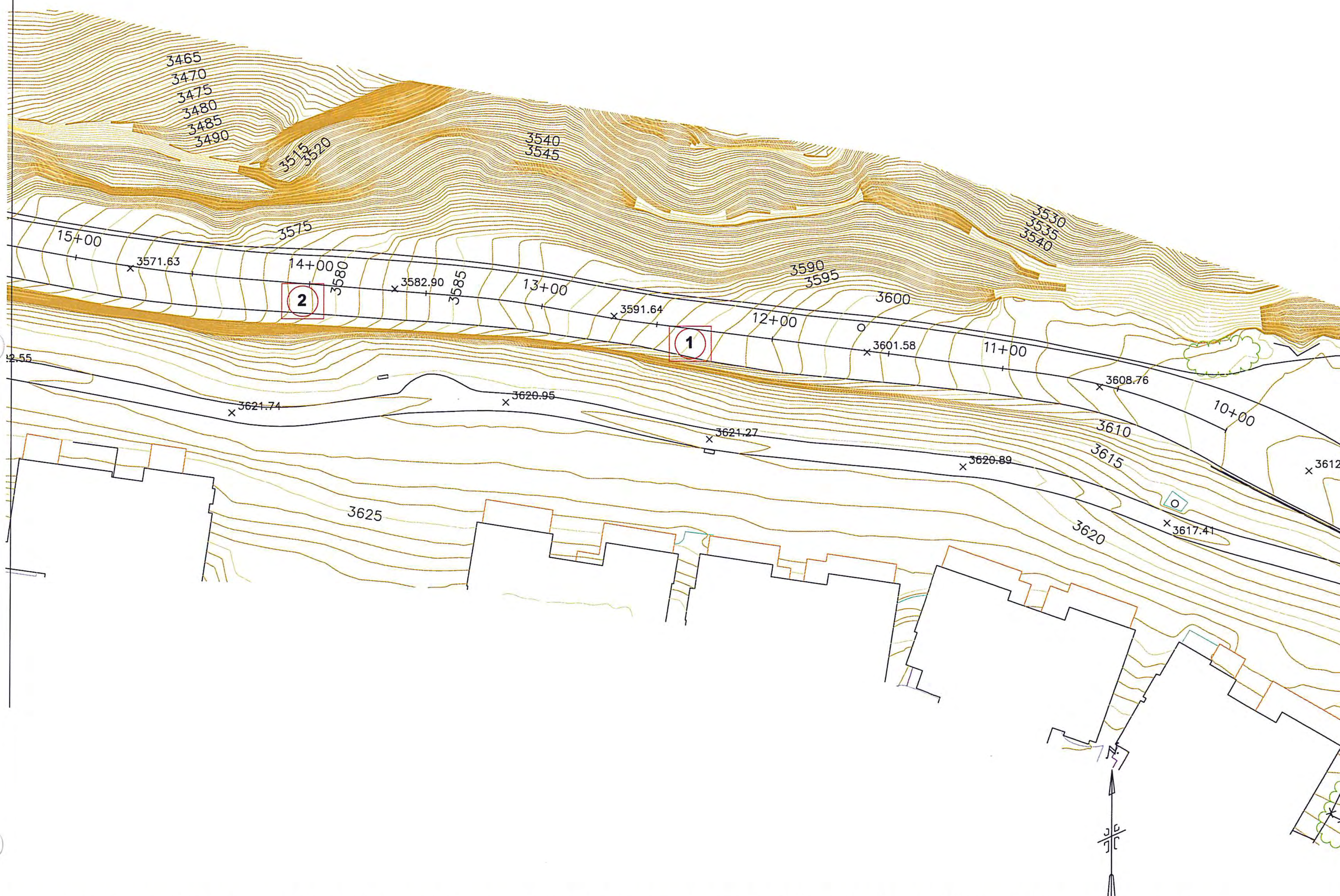
We appreciate the opportunity to assist the City of Twin Falls on this project. If you have any questions, please contact us.

The following plates and appendices accompany and complete this report.

Plate 1:	Site Plan
Plate 2:	Failure Zones and Risk Matrix
Appendix A:	Photographic Documentation
Appendix B:	ITD Rockfall Hazard Evaluation
Appendix C:	Detailed Construction Cost Estimate

VICINITY MAP
NOT TO SCALE





LEGEND

1 — Photo Number and Approximate Location, Refer to Appendix A.

11+00 10+00 — Stationing Established by JUB Engineers.

Vegetation

Edge of Pavement

N.

0 25 50 100

SCALE: 1 inch = 50 ft

SITE PLAN
CANYON SPRING ROAD
Rockfall Evaluation
Twin Falls, Idaho

STRATA
GEOTECHNICAL ENGINEERING & MATERIALS TESTING
Integrity from the Ground Up

TWICIT T09005A | PLATE: 1 Sheet 1

THIS PLAN COMPRISES A PORTION OF STRATA'S REPORT AND THE TEXT OF THE REPORT CONTAINS ESSENTIAL INFORMATION: BEFORE UTILIZING THIS PLAN FOR ANY PURPOSE WHATSOEVER, THE REPORT SHOULD BE READ COMPLETELY. THIS PLAN IS INTENDED TO HELP VISUALIZE THE INFORMATION PROVIDED IN THE REPORT. THESE LOCATIONS AND INFORMATION WERE ADDED TO EXISTING PLANS OF THE SITE PREVIOUSLY PREPARED BY OTHERS AND NO CHECK OF ACCURACY, CURRENCY, APPROPRIATENESS, ETC., OF INFORMATION PROVIDED BY OTHERS WAS PERFORMED, SINCE SUCH CHECKS WERE NOT PART OF STRATA'S SCOPE OF SERVICES.

Reference: Site Plan From JUB Engineers, Dated: 2008.

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MATCHLINE SHEET - 3

LEGEND

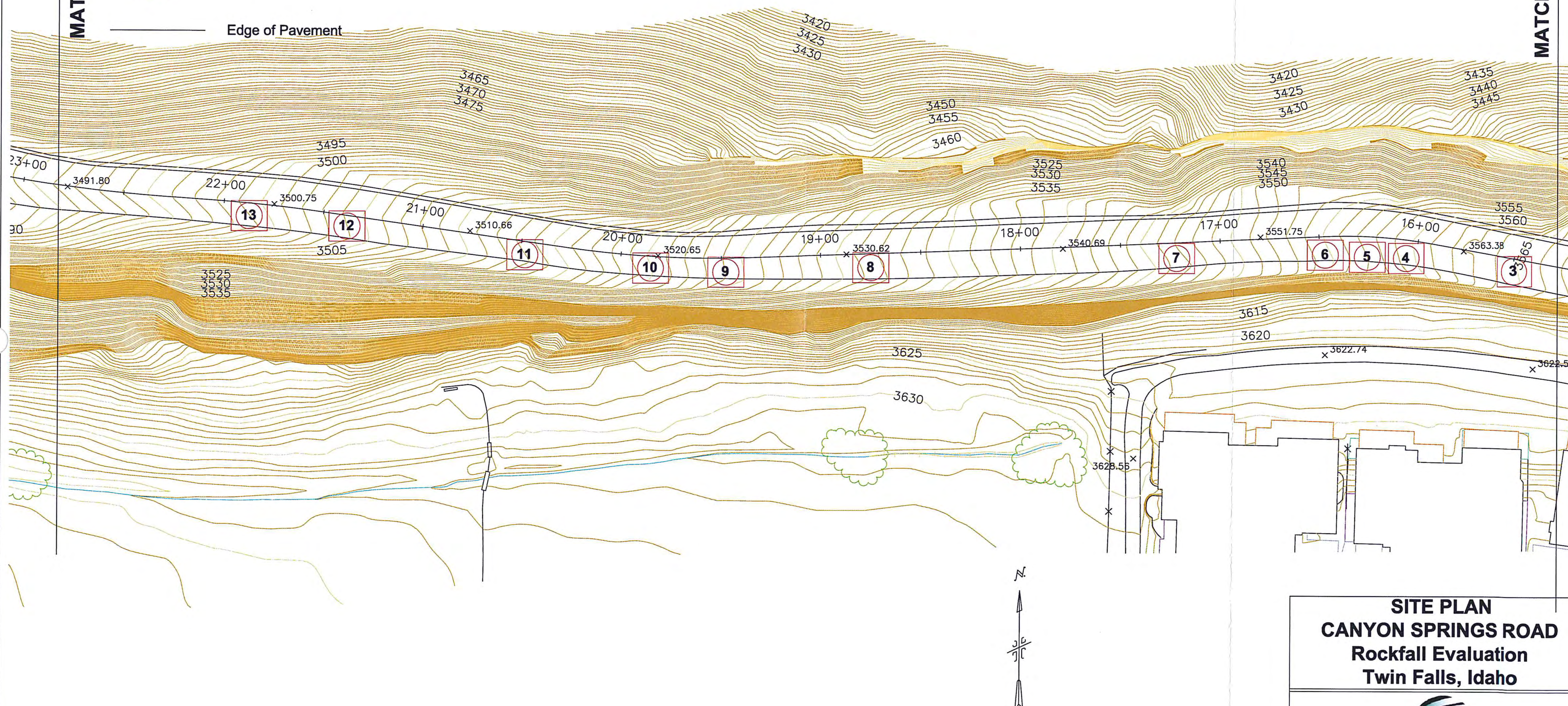
[1] Photo Number and Approximate Location, Refer to Appendix A.

11+00 — 10+00 Stationing Established by JUB Engineers.

Vegetation

Edge of Pavement

MATCHLINE SHEET - 1



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SCALE: 1 inch = 50 ft

SITE PLAN
CANYON SPRINGS ROAD
Rockfall Evaluation
Twin Falls, Idaho

STRATA
GEOTECHNICAL ENGINEERING & MATERIALS TESTING
Integrity from the Ground Up

TWICIT T09005A	PLATE: 1 Sheet 2

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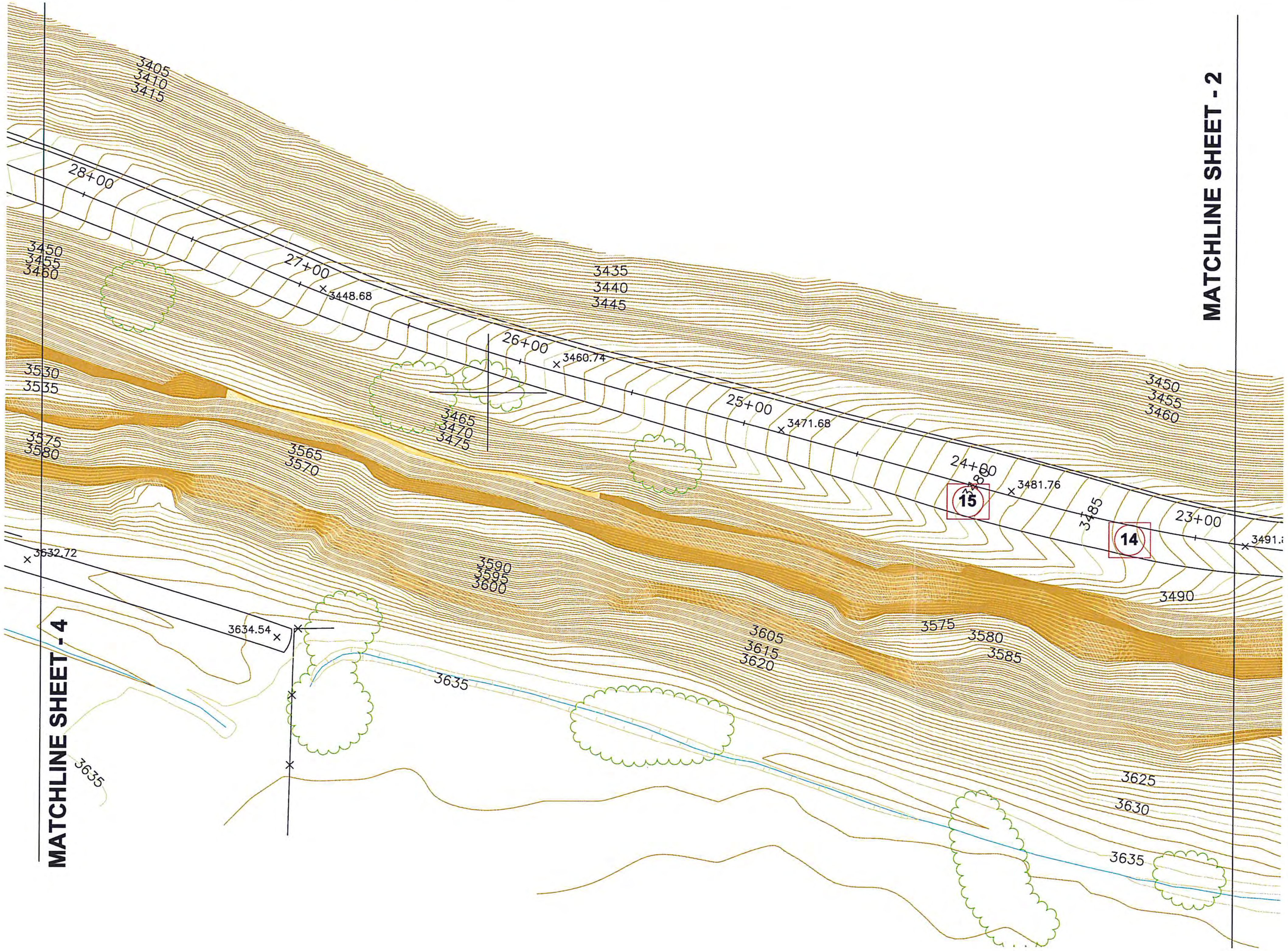

LEGEND

- (1) Photo Number and Approximate Location, Refer to Appendix A.
- 11+00 — 10+00 Stationing Established by JUB Engineers.
- Vegetation
- Edge of Pavement

N

0 25 50 100

SCALE: 1 inch = 50 ft

SITE PLAN
CANYON SPRINGS ROAD
Rockfall Evaluation
Twin Falls, Idaho

STRATA
GEOTECHNICAL ENGINEERING & MATERIALS TESTING
Integrity from the Ground Up

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Reference: Site Plan From JUB Engineers, Dated: 2008.

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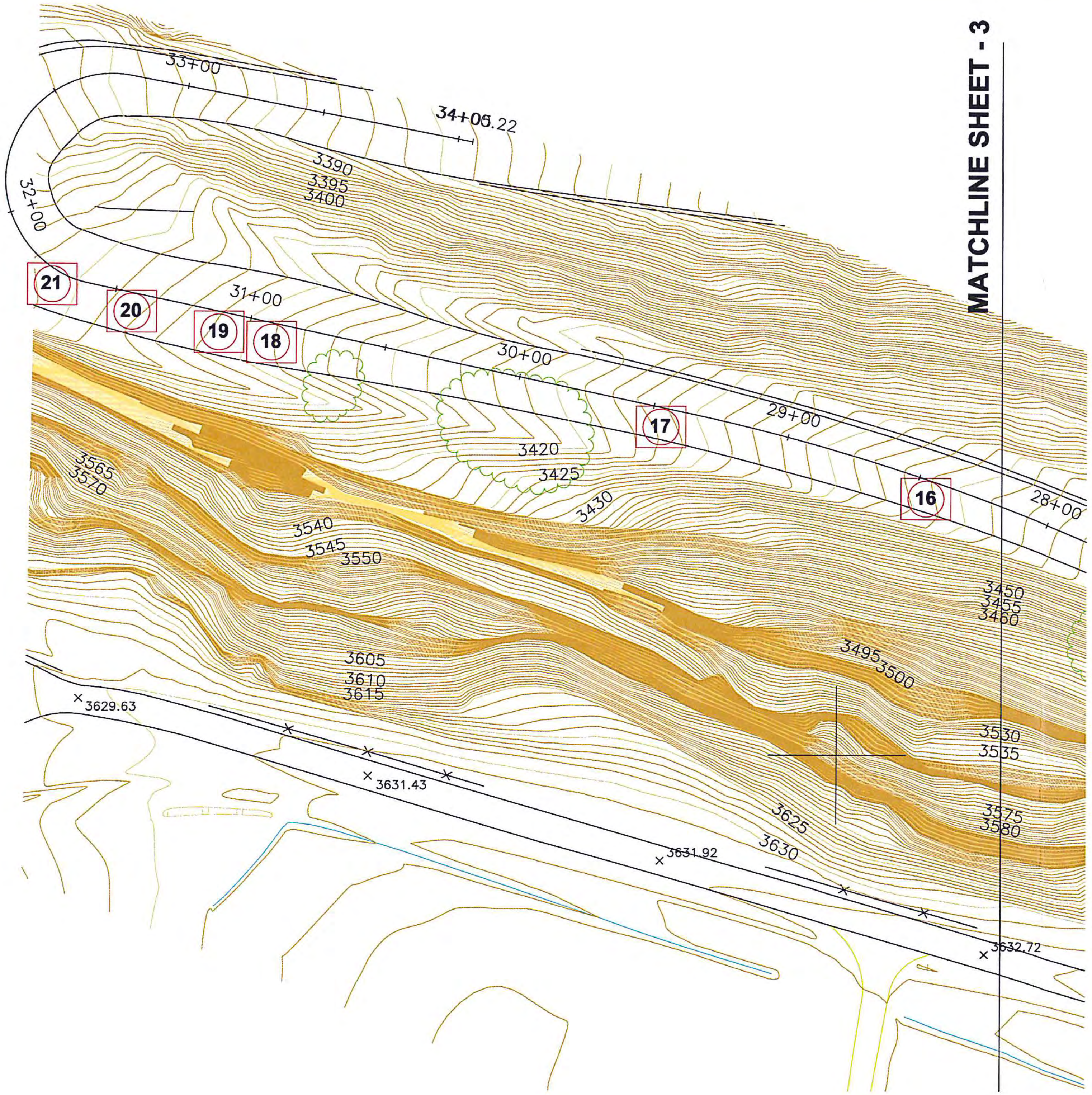

LEGEND

Symbol	Description
1	Photo Number and Approximate Location, Refer to Appendix A.
11+00 — 10+00	Stationing Established by JUB Engineers.
(cloud symbol)	Vegetation
(line)	Edge of Pavement

N.

0 25 50 100

SCALE: 1 inch = 50 ft

SITE PLAN
CANYON SPRINGS ROAD
Rockfall Evaluation
Twin Falls, Idaho

STRATA
GEOTECHNICAL ENGINEERING & MATERIALS TESTING
Integrity from the Ground Up

TWICIT T09005A	PLATE: 1 Sheet 4

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Reference: Site Plan From JUB Engineers, Dated: 2008.

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Station/Zone of Interest	Failure Type & Likelihood of Failure	Risk Category	Comments
STA 10+00 to 12+50	I- Low	0	Vertical face, very few fractures
STA 12+50	I- High	2	
STA 12+80	I & II- Moderate	3	Soil and loose rock
STA 13+00	I- High & III- Moderate	3	
STA 13+40	I- High & III- Moderate	3	
STA 13+90 to 16+00	Soil Interbed Seperates Upper and Lower Bench		
STA 14+30	I- High	3	
STA 14+45 to 14+80	II- Moderate & III- Low	2	
STA 14+80 to 15+35	II & III- Moderate to High	3	Significant undermining
STA 15+60	II- Moderate to High	2	
STA 16+00 to 16+10	II- High	3	Upper Bench, Rock below interbed at STA 6+00
STA 16+10 to 16+55*	II- High & III- Moderate	5	Failure occurred 1/25/09, significant undermining
STA 16+60 to 16+75	II- Moderate	3	Upper Bench
STA 16+82	I- Moderate	2	Upper Bench
STA 17+00 to 17+75	I- Moderate to Low	1	Top of Upper Bench
STA 17+15 to 17+30	I & II- Moderate	2	Lower Bench
STA 17+30 to 17+65	III- Low	2	Upper Bench
STA 17+75 to 18+25*	II- Moderate to High	4	Upper Bench
STA 18+50 to 19+00*	II- High & III- Moderate	4	Upper Bench, Manhole 8+68
STA 18+80 to 18+95	I- Low to Moderate	1	Lower Bench, Seepage observed at 8+95
STA 19+00	I- Low to Moderate	2	Top of Upper Bench
STA 19+30 to 19+95	I- Low to Moderate	2	Upper Bench, 2003 failure at the top
STA 19+75 to 20+25*	III- Moderate to High	4	Upper Bench
STA 20+10 to 21+95	I- Low to Moderate	2	Middle Bench
STA 20+45 to 21+55	II- Moderate to High	3	Upper Bench
STA 20+65 to 20+90	II- Moderate	3	Upper Bench
STA 21+00 to 21+80	II- Low to Moderate	2	Middle Bench
STA 21+00 to 21+80	I- Low to Moderate	1	Upper Bench
STA 21+80 PLUS	I & II- Low to Moderate	2	End of upper bench sloped in the past by blasting
STA 21+80 to 22+25	II- High & III- Moderate	3	Middle Bench
STA 22+40 to 22+50	II- High	3	Middle Bench seepage observed
STA 23+20 to 23+50	II- Moderate & III- Low	3	Middle Bench Manhole 13+19
STA 23+75 to 24+80	II- High	3	Upper and Middle Bench
STA 25+00 to 27+40	I & II- Moderate to High	2	Upper and Middle Bench
STA 26+15 to 26+35	II- Moderate	1	Lower Bench
STA 26+90 to 27+10	II & III- Moderate	3	Upper Bench
STA 27+00 to 28+00	II- Moderate to High	3	Upper Bench
STA 28+00 to 29+10	II & III- Moderate & I- High	3	Upper and Middle Bench
STA 29+00 to 29+50	II- Moderate	2	Upper and Middle Bench
STA 29+50 to 29+55	I- High	3	Upper Bench
STA 29+80 to 30+50	II- Moderate	2	Entire Face
STA 30+70 to 31+25	II & III- Moderate	3	Entire Face
STA 31+00 to 31+10	II- High	3	Overhang, Lower Face
STA 31+30 to 31+45	II- Moderate	2	Lower Face
STA 31+55 to 32+00	II- Moderate to High	3	Upper and Middle Face

Likelihood of Failure		Failure Mode I	Failure Mode II	Failure Mode III	Consequence of Failure
High		3	4	5	High
		2	3	4	Low
Medium		2	3	3	High
		1	2	3	Low
Low		1	2	2	High
		0	1	2	Low

Failure Categories	
I	Single loose boulder/ multiple loose cobbles
II	Several loose boulders
III	Large wedge or column failure

* Area of Concern

Failures Zones and Risk Matrix
Canyon Springs Road
Twin Falls, Idaho

STRATA

TWICIT T09005A | Plate 2

APPENDIX A

Photo 1 – View at Station 12+50 of approximately 3-foot diameter boulder with a high risk of falling.

Photo 2 – View from Station 13+90 facing west of soil interbed separating flows. Significant undercutting has occurred in the soil interbed.

Photo 3 – View of Interbed at STA 15+60

Photo 4 – View of interbed undercutting the rock face at STA 16+10 to 16+55.

Photo 5 – View of entire rock face at STA 16+10 to 16+55.

Photo 6 – View of lower rock face at STA 16+90

Photo 7 – View of rock outcropping at STA 17+30 to 17+65

Photo 8 – View of upper rock face with numerous past failures at STA 18+50 to 19+00

Photo 12 – View of middle bench at STA 21+00 to 21+80

Photo 13 – View of end of past drill and blasting at STA 21+80

Photo 14 – View of rock outcropping at STA 23+20 to 23+50

Photo 15 – View of rock outcropping at STA 23+75 to 24+80

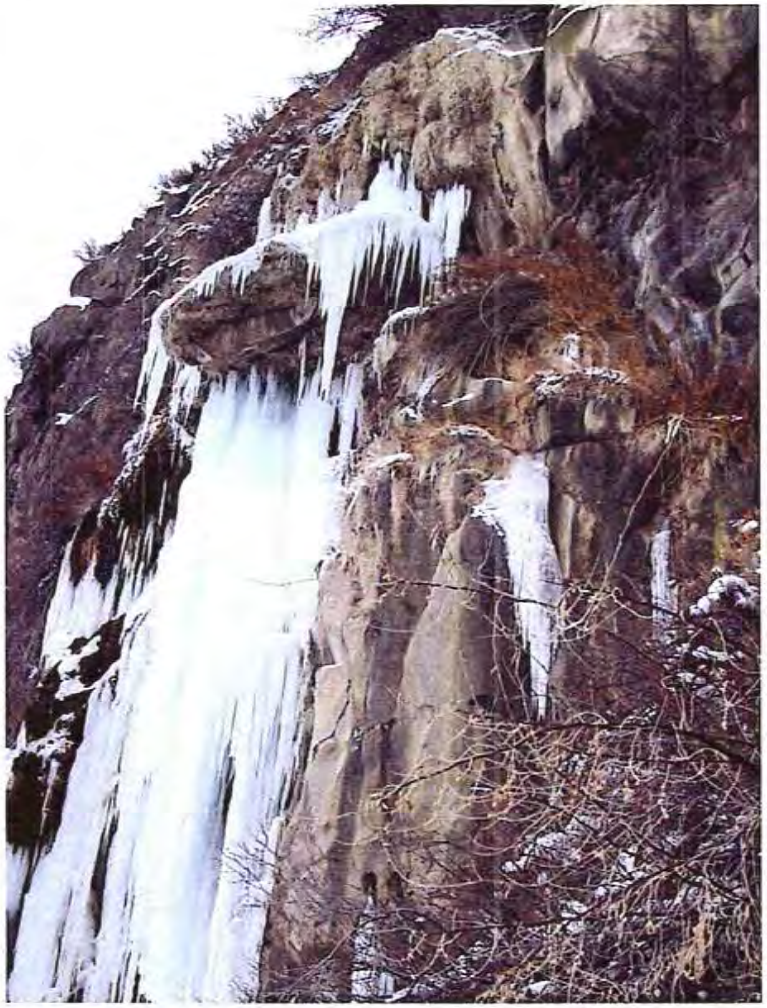

Photo 18 – View of rock overhang at STA 31+00

Photo 16 – View of rock outcrops at STA 28+00 to 29+10

Photo 17 – View of rock outcrop at STA 29+50

Photo 19 – View of rock outcrops STA 30+70 to 31+25

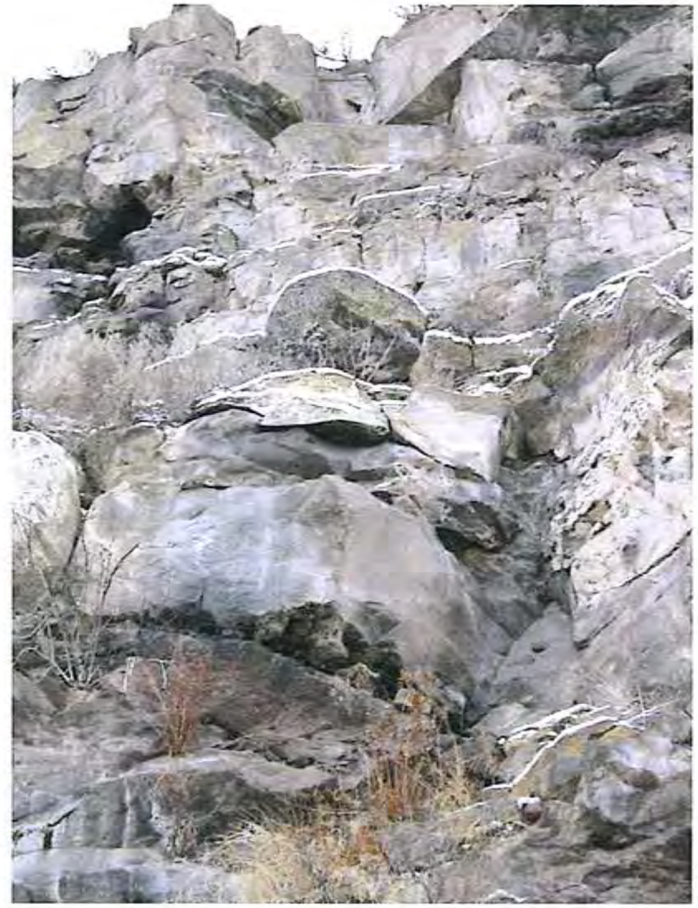

Photo 20 – View of boulders and past failures at STA 31+45

Photo 21 – View of rock face at STA 31+55 to 32+10

Photo 9 – View of large wedge failure in the past at STA 19+30 to 19+95

Photo 10 – View of detached boulder that is approximately 10 feet long, 3 feet wide and 5 feet tall at STA 19+80.

Photo 11 – View of upper rock face with past failures and numerous loose boulders at STA 20+45 to 20+55

APPENDIX B

Development and Implementation of the Idaho Highway Slope Instability and Management System (HiSIMS)

Prepared for

Idaho Transportation Department
Boise, Idaho

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By

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ABSTRACT

Following initiatives and recommendations from the Federal Highway Administration (FHWA), a number of state highway departments over the last 12 years have developed and implemented rockfall hazard management programs for highways. The primary goal is to improve highway safety, but reductions in maintenance and detour costs also result when slope hazards are mitigated. Additionally, a systematic method for agencies to identify and prioritize slope hazard sites allows for highway funds to be allocated efficiently for construction projects or counter-measures to deal with the recognized hazards. Some state highway departments have expanded the original focus on rockfall hazards to also include other types of unstable slope activity, such as landslides, debris flows, and accelerated erosion. A systematic highway slope hazard assessment protocol has been developed for the State of Idaho, which consists of a two-step procedure for hazard ratings: 1) a survey rating by maintenance personnel to classify pertinent slope segments as having a very high, high, or moderate potential of rockfall or erosional debris on the roadway; and 2) a detailed slope hazard rating based on extensive modifications of the FHWA Rockfall Hazard Rating System. The Idaho Transportation Department slope hazard management system has been developed for its centralized, intranet web server that will allow real-time operations from multiple users within the transportation agency. This intranet web-based system is known as Idaho HiSIMS (Highway Slope Instability Management System).

Key Words: slope stability, highway slopes, rockfall, slope hazards, slope erosion

INTRODUCTION

Slope instabilities along highways not only increase maintenance costs, but also may pose hazards that lead to detours, traffic delays, and safety issues for the traveling public. Limited funds and manpower resources are available for slope maintenance, repairs, and hazard mitigation projects. Thus, to improve fiscal efficiency and highway safety, some method of rational, systematic evaluation of highway slope instabilities and related hazards is needed to assess, compare, and prioritize (rank) problematic sites.

In the late 1990's, the Idaho Transportation Department (ITD) recognized the need for a rockfall hazard program for highways in the state and began a focused effort to develop such a program. Although some rockfall problem areas were well known in the state, the severity and extent of these problems could not be well established because a comprehensive inventory had not been completed for Idaho highways. This resulted in a pattern of reactive response to rockfall events and little focus on evaluating highway slopes for preventative treatments to enhance highway safety and to limit the State's liability for rockfall hazards.

The initial work to inventory Idaho's highways for rockfall hazards and develop a computer database for managing that information has gradually evolved into a more comprehensive system that includes other slope instabilities, such as landslides, debris flows, and accelerated erosion. An initial inventory survey was conducted statewide for sites known by ITD maintenance personnel to produce rockfall or erosional debris on highways. The follow-up ranking, or scoring, system for individual highway slope segments was based on the original Rockfall Hazard Rating System proposed by the Federal Highway Administration (FHWA) in the early 1990's (Pierson et al., 1990; Pierson and Van Vickle, 1993), but also included extensive modifications adapted for Idaho usage. The scoring system relies on two major categories of input: 1) the physical characteristics of the slope and its geologic materials, and 2) the hazard exposure (risk) to the traveling public. The highway inventory procedure and the development of the slope hazard evaluation method are described in the following sections, as is the ITD web-based computer database and management system now known as Idaho HiSIMS (Highway Slope Instability Management System).

HIGHWAY ROCKFALL INVENTORY AND SEVERITY RATINGS

Highway maintenance personnel in all six operating districts of the Idaho Transportation Department provided valuable assistance to University personnel in 1999-2000 by completing survey forms and providing first-hand knowledge of identified sites prone to at least minor rockfall problems across the State. The field forms included information on the highway route number, beginning and ending mile post stations for each site, and a rockfall severity rating of 1, 2, or 3 described as follows:

1 - Rock debris occasionally sloughs onto the roadway, with a low volume that usually requires only minor cleanup.
2 - Debris occurs on the roadway several times per year, with the larger rocks (> 15 cm) causing hazardous conditions during some such events.
3 - Debris occurs on the roadway frequently or in such a manner that produces a hazardous condition, such as rockfall on a curve; these sites often require immediate attention during or after storms.

Just over 950 sites along Idaho highways were included in this maintenance survey and inventory. Nearly 200 of those sites were identified as having a severity rating of "3" by the highway maintenance personnel (see Table 1). Survey results were input to a computer database for ease of future searching, sorting, and comparisons of rockfall locations and severity ratings.

This initial survey focused only on rock debris delivered to the roadway. Several other sites in some of the ITD operating districts also were noted as having a history or potential of erosional or mudslide debris to be delivered to the roadway. Though not included in the original survey, these sites should be included in the next round of slope hazard inventories. The survey indicated that modern roadway design standards have accomplished significant reductions in the amount of slope debris that reaches the road surface of highway segments recently constructed or realigned, but older segments and secondary routes, which have a low priority for maintenance or upgrade funds, still may be prone to persistent slope hazards.

Table 1. Summary of rockfall inventory and severity ratings.

ITD District	Total Number of Rockfall Sites	Number of Sites with Rockfall Severity Ratings: 1	2	3
1	167	116	17	34
2	310	104	136	70
3	125	54	46	25
4	216	120	61	35
5	83	52	25	6

6	86	18	53	15
ALL	987	464 (47%)	338 (34%)	185 (19%)

This statewide rockfall severity inventory also provided information on initial prioritization of the "worst" rockfall sites, based on comments from ITD maintenance personnel or on the high-hazard potential of certain areas that may not necessarily have a history of significant rockfall cleanup activities. Such sites represent those highway locations most worthy of receiving further attention with detailed hazard ratings and subsequent rockfall mitigation efforts (if warranted). These sites are listed below according to route and mile post (mp).

District 1

SH 3	mp 55.0; 73.7
SH 5	mp 10.0
SH 97	mp 70.3; 94.8; 95.7; 96.0
SH 200	mp 41.5; 56.1

District 2

US 12	mp 33.45; 56.45; 76.0; 78.8; 116.6; 120.1; 133.8; 159.6; 168.5; 172.4
US 95	mp 198.0; 231.2; 286.2
SH 7	mp 51.0
SH 11	mp 4.2
SH 13	mp 14.5; 19.4
SH 14	mp 7.6; 10.1; 12.9; 16.6; 33.0; 42.0

District 3

US 95	mp 144.6; 173.6; 175.1
SH 21	mp 11.1; 18.0; 73.8
SH 55	mp 67.7; 76.5; 80.7; 91.9; 93.5; 94.2; 150.2; 150.6; 151.9

District 4

SH 75	mp 155.7; 199.2; 202.1; 203.0; 205.1; 208.3; 213.1; 220.8

District 5

US 89	mp 35.8; 37.1
SH 34	mp 26.0
SH 36	mp 114.6

District 6

US 26	mp 374.5; 389.0
US 93	mp 264.0; 273.5; 281.6; 283.3; 319.5; 324.5
SH 47	mp 11.6
SH 75	mp 224.0

DEVELOPMENT OF IDAHO SLOPE HAZARD RATING SYSTEM

One initial goal of this project was to investigate available rockfall hazard rating systems and adapt their applicable components to build a customized hazard rating system for Idaho highways. We relied heavily on previous work done by Federal Highways and by the transportation departments in Oregon, Arizona, and Washington. As our field work progressed and we received input from ITD personnel, the Idaho rating system gradually evolved into a unique rating system that included other roadside hazards (e.g., landslides, debris flows, erosion) besides rockfall. This Idaho slope hazard rating system was intended to follow-up the statewide rockfall severity inventory and provide important detailed hazard information for specific sites, information that could be used to score, compare, and prioritize highway slopes for subsequent allocation of mitigation funds to improve highway safety.

Previous Work: Overview of FHWA Rockfall Hazard Rating System

A rockfall hazard rating system for highways was proposed by Wyllie (1987) at a geotechnical workshop sponsored by the FHWA (Federal Highway Administration). It relied on seven physical site characteristics and three "risk exposure" categories:

Slope geometry:
1. Slope height
2. Slope length
3. Effectiveness of catch-ditch at slope toe
4. Geologic structural condition
5. Shear strength (friction) of geologic structures
6. Size of rock blocks
7. Climate and water conditions

Risk exposure:
1. Decision site distance
2. Traffic quantity
3. Rockfall history

Scoring weights were assigned to "benchmark" values for each of the ten characteristics according to a cubic exponential increase in severity (see Table 2). A final hazard score for a given site then was obtained by summing the scores from each characteristic. A total score greater than 500 indicated a site with "high risk" of a rockfall-induced traffic accident, and a total score of 400 to 500 indicated "moderate risk" (Wyllie, 1987). English units (rather than metric) are presented below, because they were in the original systems and have been maintained by Idaho ITD for developing its own rockfall rating system.

This rockfall hazard evaluation tool became the foundation for a highway safety pooled-fund study sponsored by the FHWA and 10 states, led by the Oregon Department of Transportation. The FHWA rockfall hazard rating system (RHRS) that resulted from this study had much in common with the earlier Wyllie system, but used four benchmarks and related scores (3, 9, 27, 81) rather than the five used by Wyllie. It also included a separate option for evaluating differential erosion on a soil-like slope, in contrast to a rock slope case. The

Table 2. Highway rockfall hazard rating system according to Wyllie (1987).

	Benchmark Descriptions and Scores				
Site Characteristic	1	3	9	27	81
Slope height (ft)	< 15	15-25	25-35	35-45	> 45
Slope length (ft)	< 50	50-100	100-150	150-200	>200
Catch ditch effectiveness	Meets Ritchie* criteria	Adequate width, inadequate depth	Moderate Catchment	Limited Catchment	Nil
Structural geology	Massive, no fractures dipping out of slope	Discontinuous fractures with random orientations	Fractures form wedges	Discontinuous fractures dipping out of slope	Continuous fractures dipping out of slope
Rock fracture friction	Rough, irregular	Undulating	Planar	Smooth, slickensided	Clay, fault gouge
Rock block size (ft)	< 0.5	0.5 - 1	1 - 2	2 - 5	> 5
Climate and water	Dry; warm winter	Moderate rainfall; warm winter	Moderate rainfall; some freezing	Moderate rainfall; cold winter	High rainfall; cold winter
Rockfall history	Nil	Occasional minor events	Occasional events	Regular events	Major rockfalls, rockslides
Traffic quantity	Very light	Recreational only	Moderate	Heavy	Very heavy, continuous
Decision site distance	Adequate stopping distance; full shoulder	Good visibility and shoulder width	Moderate visibility and shoulder width	Limited visibility and shoulder width	Very limited visibility; no shoulder

Note: TOTAL HAZARD SCORE (sum) has a value from 10 to 810.

* Recommended ditch width and geometry based on slope height and steepness (Ritchie, 1963).

characteristic of "decision site distance" was further quantified using FHWA and AASHTO (American Association of State Highway Transportation Officials) guidelines for minimum decision site distance as a function of vehicular speed, and by calculating a percentage using the actual sight distance. The actual site distance (ASD) is the measured horizontal distance at which a 6-inch high object disappears from view when the eye height is at 3.5 ft above the roadway. The decision site distance (DSD) is defined as the minimum distance (ft) required for a driver in a moving vehicle to detect a hazard on the roadway, make an immediate decision, and take correction action. Therefore, the percent decision sight distance used in the RHRS is calculated as follows:

%DSD = (ASD / DSD) x 100% , where DSD is given by:

DSD = 450 ft when posted speed limit is 30 mph,
600 ft when posted speed limit is 40 mph,
750 ft when posted speed limit is 50 mph,
1000 ft when posted speed limit is 60 mph,
1100 ft when posted speed limit is 70 mph.

The RHRS provides a total hazard score by summing scores in all the categories, but only one option is used for the geologic condition; interpolation formulae also are provided for estimating scores in between the identified benchmarks (Pierson et al., 1990; Pierson and Van Vickle, 1993). The system is summarized in Table 3 below.

Table 3. Summary of FHWA rockfall hazard rating system (RHRS) adapted from Pierson and Van Vickle (1993).

	Benchmark Descriptions and Scores			
Site Characteristic	3	9	27	81
Slope height (ft)	25	50	75	100
Roadway width (ft)	44	36	28	20
Catch ditch effectiveness	Good catchment	Moderate catchment	Limited catchment	No catchment
Geology - Case 1 Rock structure	Discontinuous joints, favorable orientation	Discontinuous joints, random orientation	Discontinuous joints, adverse orientation	Continuous joints, adverse orientation
Rock-joint friction	Rough, irregular	Undulating	Planar	Clay, slickensided
Geology - Case 2 Erosion features	Few differential erosion features	Occasional differential erosion features	Many differential erosion features	Major differential erosion features
Erosion rates	Small difference in erosion rates	Moderate difference in erosion rates	Large difference in erosion rates	Extreme difference in erosion rates
Rock block size (ft) and volume (cu.yd.)	1 3	2 6	3 9	4 12
Climate and water	Low to mod. precip.; no freezing; no water on slope	Moderate precip. or short freezing periods or intermittent water on slope	High precip. or long freezing periods or continual water on slope	High precip. and long freezing periods; or continual water on slope and long freezing periods
Rockfall history	Few events	Occasional events	Many events	Constant events
Average vehicle risk*	25% of the time	50% of the time	75% of the time	100% of the time
Decision site distance	Adequate, 100% of low design	Moderate, 80% of low design	Limited, 60% of low design	Very limited, 40% of low design

Note: TOTAL HAZARD SCORE (sum of 10 scores) has a value from 30 to 810.

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* Average vehicle risk (AVR) = 100% x [Avg. Daily Traffic x Slope Length (mi.)] / [Posted Speed Limit (mph) x 24 hr/day]
Note: AVR greater than 100% indicates more than one vehicle is subjected to the site hazard simultaneously.

Adaptation of Hazard System to Idaho Highways

During the 1990's a number of states adopted the RHRS or a modified version specially designed to meet a given state's needs. In Idaho, work began in 1999 to systematically evaluate highway rockfall hazards and develop a statewide database and management system to deal with these hazards. The slope hazard rating system currently in use for Idaho highways is based partially on the FHWA RHRS but also includes elements from the Washington State DOT Unstable Slope Management System, which uses less geologic input than the RHRS and much more information tied to economic factors such as cleanup costs, detours/delays, and pavement damage (Lowell and Morin, 2000). The Idaho rating system requires the field investigator to input basic field observations and measurements, some of which are then used for internal computer calculations to provide intermediate scores for various hazard factors. Field data can be recorded on paper forms or typed into a database input screen on a laptop computer or PDA (personal digital assistant). Some of the information is obtained from ITD office files either prior to or after the field assessment. Required ***specific*** input for the database and for computing a hazard rating is given below:

S1. ITD District No.	Example: 3
S2. Highway Route No.	Example: US 95, SH 55
S3. Begin MP (milepost)	To the nearest 0.01 mile
S4. End MP (milepost)	To the nearest 0.01 mile
S5. Side (left or right)	As observed in the increasing milepost direction
S6. Geo-type (rock or soil or both)	If both, indicate which one is dominant
S7. Posted speed limit (mph)	
S8. Estimated sight distance (ft)	
S9. Impacted road length (ft)	
S10. Roadway width including paved shoulder (ft)	
S11. Catch-ditch width (ft)	
S12. Average daily traffic (ADT)	Available from ITD central database

Required ***categorical*** rating information includes the following:

C1. Slope height (ft)	< 30	30-50	50-70	> 70
C2. Slope angle (H:V) - rock	< 1:1	1:1 - .5:1	.5:1 - .25:1	> .25:1
- soil	< 3:1	3:1 - 2:1	2:1 - 1.25:1	> 1.25:1
C3. Slope/ditch condition	good runoff	some runoff	some slope	continuous slope;

	(soil slope only)	intercep. & veget.; ditch cleanout reqd. rarely	intercep. & veget.; ditch cleanout every 5-6 years	breaks/veget.; ditch cleanout every 2-3 years	nil breaks/veget.; ditch cleanout annually, or major events expected to overwhelm ditch
C4.	Failure frequency	1-3 per year	4-10 per year	Often and after signif. storms	Very often; nearly continuous
c5.	Maintenance/Cleanup	Minor; scrape off debris, clean ditch	Moderate; some loading & hauling	Major; signif. loading & hauling	Extensive work
C6.	Traffic Impact/Delays	Minor; some debris on shoulder; traffic slowed or minor delays (< 10 min.)	Moderate; debris in one lane; signif. delays (> 15 min.)	Major; debris in more than one lane; reroute traffic with signif. detour	Extensive; debris across the entire roadway; major detour

In general, the four benchmark divisions for these categorical characteristics receive scores of 3, 9, 27, and 81 (same as the RHRS). However, in the case of a rock slope, C1 and C2 are used in conjunction with S11 to obtain a single numerical score for catch-ditch effectiveness. The rationale is that slope height and steepness effects on rockfall hazard are controlled (tempered) by the catch-ditch effectiveness (primarily width) at a given site. That is, a high rock slope should not be assigned a high score (81) if an adequate catch ditch is in place at the toe of the slope. The criteria used for catch-ditch effectiveness is based on information provided in the Rockfall Catchment Area Design Guide from the Oregon DOT (Pierson et al., 2002). Application to the Idaho slope hazard system is summarized in Table 4. In the case of a soil slope that could be subject to erosion or landslide activity, the effectiveness of a catch ditch and/or barriers is assumed to depend on the same factors (C1, C2, S11) but is handled through a separate factor for soil slopes only (C3). Though not required at each site, photographs or digital images of the highway slope are highly recommended and should be incorporated into the computerized database (see Figures 1 and 2).

Optional field input for the Idaho slope hazard database includes information on geologic conditions (such as the orientation and planarity of rock discontinuities), size of rock blocks or landslide debris that may be deposited on the roadway, impact patterns/dents of rock debris on the pavement, climate (precipitation and freezing potential), and other comments that may include notes on number of traffic accidents due to rock/soil debris and on identifying potential repair/mitigation methods. The overall slope hazard rating score is the sum of ten individual factor scores as shown in Table 5. The total hazard score may range from 30 to 810. The last factor in the table was included at the suggestion of ITD geotechnical personnel in order to account for potential large-impact hazards that might be overlooked by focusing only on highway segments that had experienced some rockfall or erosion problems in the past. Although this scoring system is intended primarily for cut slopes above the roadway, it also can be applied to distress in fill slopes or embankments (differential settlements, slope instabilities) by replacing the ditch effectiveness factor with a shoulder/pavement damage severity factor.

Table 4. Estimating the slope hazard score for catch-ditch effectiveness based on experimental rockfall data from field tests in Oregon; ditch widths are in feet and represent the 0.60, 0.80, and 0.95 quantile values from published cumulative percent retained curves for slightly inclined ditch bottoms (Pierson et al., 2002).

Slope Angle (H:V)		1:1	0.5:1	0.25:1	Vertical
Height (ft)	Score				
<30	3	> 16	> 14	> 10	> 12
	9	12-16	12-14	8-10	10-12
	27	9-11	9-11	5-7	8-9
	81	< 9	< 9	< 5	< 8
30-50	3	> 26	> 20	> 12	> 14
	9	19-25	15-20	9-12	12-13
	27	14-18	11-14	6-8	10-11
	81	< 14	< 11	< 6	< 10
50-70	3	> 28	> 25	> 28	> 16
	9	20-27	18-25	19-27	13-15
	27	16-19	14-17	13-18	11-12
	81	< 16	< 14	< 13	< 11
> 70	3	> 38	> 27	> 36	> 18
	9	28-38	19-26	25-36	15-17
	27	19-27	14-18	18-24	12-14
	81	< 19	< 14	< 18	< 12

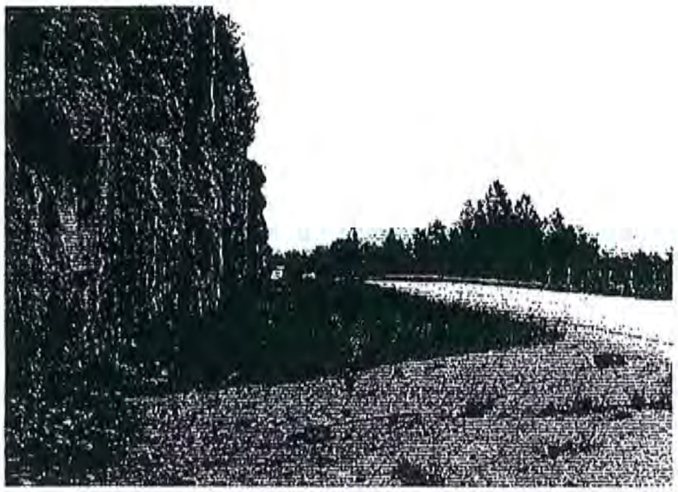

Figure 1. Vertical rock slope with a good rockfall catch area.

Figure 2. Near-vertical rock slope with inadequate catch ditch.

Approximately 100 highway slope segments have been rated using this system (or an earlier version of it). Evaluators used paper forms to gather input data in the field, then that information was transferred to a PC computer database. Rather than store any digital images directly in the computer database (due to storage space limitations), they were stored in a separate media (CD-ROM) to be available for retrieval as needed.

RECOMMENDATIONS FOR FIELD DATA COLLECTION

To maintain consistent and reliable standards for each of the input fields for the highway slope hazard rating, ITD should implement data collection protocols to be used statewide in all of the ITD districts. Our recommendations for the initial set of protocols are summarized below.

Site Location

The general location should be reported by designating the District and Route Number. More specific site location information includes the following:

1. Beginning and ending milepost for the slope hazard site, recorded to the nearest 0.01 mile if possible. The invesitigator should select these boundaries based on the longest extend of the highway slope that has fairly consistent characteristics (slope height, slope angle, catch-ditch width, site distance, etc.). Very rarely will a site extend much beyond a mile or so without an important site characteristic changing significantly. Rather, most sites likely will be less than 0.3 mile. As ITD personnel become familiar with HiSIMS, they will develop a uniform strategy for recognizing the road-span of a distinctive highway slope hazard site.

Table 5. Highway slope hazard rating system for Idaho.

SCORES:	3	9	27	81	Example Entry
Roadway Width (ft)	> 40	30-40	20-29	< 20	9
Slope and Catch Ditch Rock: Ditch Effectiveness OR		Obtain scores from Table 3.			27
Soil Slope/Ditch	good runoff intercep. & veget.; ditch cleanout reqd. rarely	some runoff intercep. & veget.; ditch cleanout every 5-6 years	some slope breaks/veget.; ditch cleanout every 2-3 years	continuous slope; nil breaks/veget.; ditch cleanout annually, or major events expected to overwhelm ditch	
Failure frequency	1-3 per year	4-10 per year	Often and after signif. storms	Very often; nearly continuous	3
Impacted road length (ft)	< 50	50 - 200	200 - 500	> 500	9
Maintenance/Cleanup	Minor; scrape off debris, clean ditch	Moderate; some loading & hauling	Major; signif. loading & hauling	Extensive work	27
Traffic Impact/Delays	Minor; some debris on shoulder; traffic slowed or minor delays (< 10 min.)	Moderate; debris in one lane; signif. delays (> 15 min.)	Major; debris in more than one lane; reroute traffic with signif. detour	Extensive; debris across the entire roadway; major detour	9
Average Daily Traffic	< 200	200 - 1000	1000 - 3000	> 3000	27
Average Vehicle Risk (AVR)*	< 25%	25 - 50%	50 - 75%	> 75%	81
Percent Decision Sight Distance (PDSD)*	> 100%	80 - 99%	60 - 79%	< 60%	9

Potential for Major/Extreme Rockfall, Landslide, Debris Flow, or Erosion Event not observed in recent years	Nil	Some potential	Moderate potential	High potential	9

EXAMPLE TOTAL: 210

* Calculated based on user-specified input information (such as posted speed limit).

2. Segment code for the slope hazard site. This is the ITD-designated code for highway segments, which is a unique identifier that can be used to differentiate between route sections that may have overlapping or duplicate mile post readings. In most cases, this information is not required and is left to the discretion of the investigator.
3. GPS data for the slope hazard site. If the latitude and longitude of the site have been obtained by a GPS unit (as recorded at the approximate "center" of the slope site), then this information can be added to the data base. We encourage ITD personnel to begin logging this GPS information into the data base for slope sites as soon as practical; this will allow for more advanced mapping, display, and analysis procedures in the future.
4. Side of the highway where the slope site is located. This designation is taken to be the right side or left side as a motorist travels in a direction of increasing mile post numbers.

Site Characteristics

5. Posted speed limit in the immediate vicinity of the slope hazard site. It the site is located on a curve, this speed limit may be less than the standard 55 or 60 mph for two-lane highways.
6. Estimated site distance for a driver to see an object on the roadway when approaching the slope hazard site from either direction. The recorded site distance should be the shorter (minimum) of the two measurements taken from the two directions. This distance is defined as the measured horizontal distance at which a 6-inch high object disappears from view when the eye height is at 3.5 feet above the roadway surface. We have had good field success using a laser, handheld range finder to take these measurements. Site distance may be affected by horizontal curves or by vertical grade changes along a highway.
7. Impacted road length is the typical length of roadway to be affected by a slope failure at the site. The actual estimated length should be recorded in the field (e.g., 85 feet), even though HiSIMS uses categories (e.g., <50 ft, 50-200 ft, and so on). The impacted road length could be as small as 15 feet

for an isolated rockfall (one rock) to as large as hundreds of feet for a rock slide or landslide.

8. Class of slope material at the site. The class of slope material will be designated as soil, rock, or a combination of both soil and rock. For "mixed-mode" sites, the type of material deemed most likely to cause problems should be designated.

Site Dimensions

9. Roadway width measured from edge to edge of the paved surface (including shoulders). The actual width should be measured and recorded in the field, even though HiSIMS uses categories (e.g., <20 ft, 20-29 ft, and so on).
10. Slope angle of the slope hazard site. The slope angle can be measured using a handheld inclinometer, Brunton compass, or it can be visually estimated (though this is not recommended). This angle should be recorded in degrees; it will be used to help evaluate catch-ditch effectiveness.
11. Slope height of the slope hazard site. This is the vertical height of the slope cut, slope fill, or natural slope that may contribute to rockfall or slope instabilities at the site. If a range finder is used to measure the slope distance (or slope height), then the vertical height is obtained by multiplying this slope distance by the sine of the slope angle.
12. Width of catch ditch is the typical width of the catchment area at the slope hazard site. This catchment may be a well-defined shallow depression or just a flat area where rockfall debris may collect alongside of the paved roadway. Its recorded width should be measured as the horizontal distance from the toe of slope to the edge of pavement.

Other Site Information

13. Average daily traffic counts (ADT) for this segment of highway. This information is readily available from ITD resources. The actual count should be recorded, even though HiSIMS uses categories (e.g., <200, 200-1000, and so on).
14. Failure frequency at the site. This is based on historical experience with cleanup of slope failure debris at the site by ITD maintenance crews. The investigator should select the appropriate category from the Idaho slope hazard rating system.
15. Maintenance and cleanup of slope failure debris at the site. This is based on historical experience and site characteristics that may be conducive or detrimental to the cleanup of slope failure debris. For example, some sites may allow ready disposal of debris off the shoulder of the road, while other sites (near streams) may require loading and trucking of debris for disposal. The investigator should select the appropriate category from the Idaho slope hazard rating system.
16. Traffic impacts and delays at the site due to a slope failure. This is based on historical experience with the extent of cleanup and on the availability of alternate routes in the vicinity for detours. The investigator should select the appropriate category from the Idaho slope hazard rating system.
17. Potential for a major event not observed in recent years at the slope site. This is based on the geological assessment of particular, potential problems at the site that may not have been maintenance issues in

the past, but could increase the hazard potential of the site. For example, steep terrain with numerous first-order drainages could be fairly stable in typical precipitation years, but could generate numerous mud slides or debris flows during storm events with return periods of 50 or 100 years.

18. Miscellaneous information on site geology, photographs, maintenance history, accident counts, and general comments can be added to the HiSIMS data base using the appropriate entry fields. We recommend that maintenance personnel use the "Historic Data" box on the Slope Data Page to track and update maintenance issues associated with slope hazard sites. For geologic information on key structures, the type of structure can be designated with a single letter code entered in either the dip direction or the dip field (such as: J124, 45 for a joint set with dip direction of 124° and dip of 45°; or F322, 68 for a foliation with dip direction of 322° and dip of 68°).

The HiSIMS website on the ITD intranet is ready for operation except for two aspects that will need to be completed by ITD Information Systems personnel in Boise. The first is to finalize and implement a security firewall protocol that will allow the uploading of digital images/photographs from District offices to the central website. The second task is to establish and implement password levels for ITD users across the state. Neither of these capabilities is now available in the HiSIMS test site on the ITD server.

RECOMMENDATIONS FOR FUTURE IMPROVEMENTS TO HiSIMS

Although a number of improvements were added to HiSIMS after receiving ITD feedback during the May 2003 workshops around the state, several "Stage 2" upgrades could not be incorporated into the current version of HiSIMS due to project time and budget constraints. These proposed second generation upgrades are summarized below, and an estimate of programmer days for each one is provided.

1. Flag a site to remove it from being searchable.

   This will require a re-structuring of some of the links in the data base, meaning that additional planning and development will be needed for HiSIMS. (4-6 programmer days)

2. Remove or edit historical comments.

   Such editorial capability of the data-base fields will require more sophisticated levels of data management within HiSIMS. (6-8 programmer days)

3. Add a new comment field for exclusive use for maintenance notes.

   This will require minor formatting and some substantial data link enhancements within HiSIMS; the capability to edit these comments will demand significant re-building efforts. (2-6 programmer days)

4. Capability to combine mitigation methods.

   To accomplish this within HiSIMS, a much more advanced level of handling the mitigation cost matrix and editor will be needed. (8-10 programmer days)

5. Develop an e-mail electronic submittal form (for remote Maintenance Shops without intranet access).

   This enhancement will require significant planning for formatting and electronic interfacing with HiSIMS, prior to development work. A front-end module likely will need to be produced for HiSIMS to make it ready for receiving such e-mail submittals. (10-12 programmer days)

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APPENDIX C

STRATA
GEOTECHNICAL ENGINEERING & MATERIALS TESTING
Integrity from the Ground Up

Construction Estimate

Canyon Springs Road
Rockfall Remediation
Twin Falls, Idaho

	units	unit type	@	Rate		Totals
		Remediation Area 1				
High Scaling	80	man-hours	@	$150	$	12,000.00
Rock Anchors	40	each	@	$4,300	$	172,000.00
Shotcrete Application	1	each	@	$10,000	$	10,000.00
			ESTIMATED COST		**$**	**194,000.00**
		Remediation Areas 2 and 3				
Rock Anchors	18	each	@	$4,300	$	77,400.00
Localized High Scaling	25	man hours	@	$150	$	3,750.00
			ESTIMATED COST		**$**	**81,150.00**
		Remediation Area 4				
High Scaling	40	man-hours	@	$150	$	6,000.00
Rock Anchors	25	each	@	$4,300	$	107,500.00
Supplemental Grouting	1	each	@	$10,000	$	10,000.00
Crane Rental	40	hours	@	$350	$	14,000.00
Assumes 40 Ton Crane from top of slope						
			ESTIMATED COST		**$**	**137,500.00**
			Preliminary Estimate:		**$**	**$ 412,650.00**