Micropile Application in Salmon River Road Slope Stabilization

Gary A. Quinn, P.E.[1] and Rich Barrows, P.E.[2]

Abstract
Salmon River Road is a designated Wild and Scenic By-Way route following the Salmon River into the mountainous region of central Idaho. The road was originally constructed in the 1930's by the Civilian Conservation Corps as part of the relief program for the Great Depression. Interestingly, the next major upgrade for the road is now underway as America works through another significant economic recession.

The roadway was originally constructed in mountainside cut-fill sections that follow along the steep, narrow canyon of the Salmon River. The canyon has been cut deeply into gneiss and schist bedrocks, and the valley walls are thinly mantled with wind-blown and colluvial sands that overlie dense bouldery colluvium and bedrock. Over the roadway life, shallow surface slides have developed randomly in areas along the toe of roadway cut slopes. In addition, outside fill slopes are very steep and marginally stable as a result of filling and differential erosion above river level. In order to fit the desired roadway width (6m) into this difficult corridor, both inside cutting and outside shoulder widening have been required at relatively high cost. This paper presents the combined solutions developed for stabilization of such a difficult cut and fill area (designated as Wall 8-9) along a 0.1 mile segment of the Salmon River Road where chronic shallow sliding above the road and oversteepened and eroding fill slopes have presented significant design and construction challenges.

The outside shoulder areas along the very steep and irregular river bank require stabilization for safety of traffic and roadway integrity. To provide this stabilization, micropile-supported MSE sections have been designed. Micropiles are being used to provide toe support for the MSE sections via a reinforced concrete grade beam located along the edge of the outboard slope. The grade beam is expected to provide uniform support across some abruptly differing edge-of-roadway terrain. The micropiles will be founded in schist bedrock or cemented gravel beneath the marginally stable fill and colluvium. The micropile section was designed to provide independent support for the retention system and allow a margin of error for future outboard shoulder subsidence. The inside cuts range up to 10m in height at inclinations of 60°, and slope stabilization has been designed using a soil nail and high-strength steel mesh (Tecco-Geobrugg) system to provide progressive support and long-term restraint for top-down cut construction.

1. Principal/Geotechnical Manager, NTL Engineering & Geoscience, Inc./a Terracon Company, Great Falls, Montana
2. Senior Geotechnical Engineer, Federal Highway Administration, Western Federal Lands Highway Division, Vancouver, Washington

The generalized location of the stabilization areas is shown in Figure 1 below:

SALMON RIVER ROAD
Walls 8 and 9
Location of Stabilization Measures

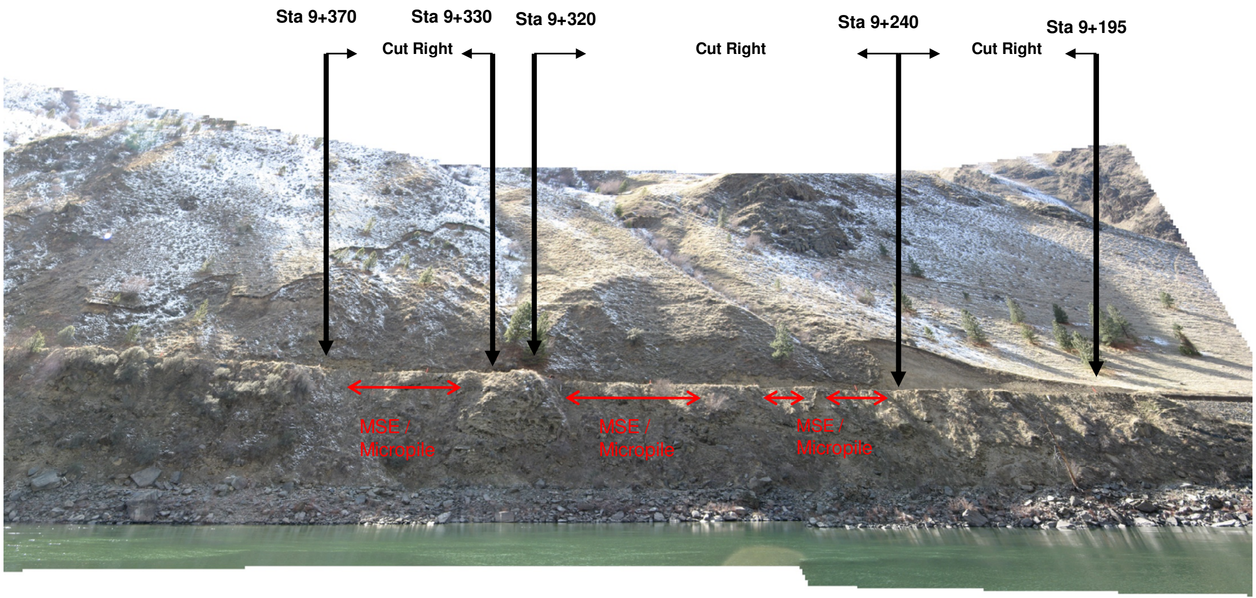

Figure 1 –Left shift of alignment (toward outside shoulder) with micropile MSE wall stabilization areas.
Right shift of alignment option (into hillside) with approximate limits of cut restraint anticipated.

1. Project Geology

The 17 km stretch of Salmon River Road under reconstruction is located in the Nez Perce National Forest and parallels the Salmon River as it flows in a westerly direction toward the town of Riggins, Idaho. The river canyon has been cut through a series of metamorphic rocks of the Riggins Group. These rocks consist predominantly of schist and gneiss produced in the metamorphism of prior oceanic sediments in early Cretaceous time (100 mya) as crustal deformation and subduction occurred along the western continental margin of North America at that time.

The river has downcut through the metamorphic rocks leaving steep canyon walls with inclinations often in the range of 40°to 50° controlled by foliation or joint structure. The colluvial cover consisting of surficial windblown sand over a dense mixture of gravel, cobbles, and boulders in a silty sand matrix has developed at generally similar inclination.

2. Subsurface Investigation/Slope Characterization

Most recently for the Wall 8-9 area, some additional drilling in conjunction with a seismic refraction study was conducted to provide better definition of subsurface conditions for the stabilization design. Borings were made left of existing centerline at Stations 9+310 and 9+365 toward the outboard shoulder, and a seismic refraction survey consisting of five lines totaling approximately 325m in length was also conducted along the roadway and on the existing cut slope.

The overburden soils encountered in the borings consisted of approximately 3m of roadway fill comprised of medium dense silty sand with gravel and cobbles overlying a medium dense to dense mixture of sand, gravel, cobble, and boulder colluvium with a silt to fine sand matrix. This zone of the slope extended to depths ranging from about 6 to 7.5m below which schist bedrock was encountered. The colluvial zone included a layer of cemented gravel-cobble material as had been noted in the exposed slope below the roadway over the course of the various investigations and as can be seen in the accompanying photographs below. The schist bedrock was moderately hard and variably fractured with RQD values spanning a range of 10 to nearly 90% indicating a poor to high quality rock fabric. The schist had some shear zones associated with regional tectonics and had some intervening, well-cemented and brecciated zones.

The seismic refraction survey indicated a generally similar slope composition consisting of three zones of velocity that increased markedly with depth. The upper or surficial colluvial zone had a velocity averaging about 300m per second (mps), while the underlying denser, or sometimes cemented, colluvium had an average velocity exceeding 600 mps. The bedrock was encountered at moderate depths typically on the order of 8 to 10m along the seismic lines and had velocity characterized in excess of 2100 mps.

3. Stabilization Design Concept

Project geotechnical study has been on-going since 1999 with various reconnaissance, drilling, and analysis efforts taking place as the project design has evolved. This particular segment of the project alignment from approximate Stations 9+195 to 9+370 was originally designed with MSE wall sections (Walls 8-9) extending over the outside shoulder of the existing alignment to provide increased width for the proposed roadway section. This improvement was intended to widen the roadway from the existing section of little more than a one lane to the proposed 5.4m traveled way. The original design philosophy had been to gain necessary width without disturbance to the inside cut slopes where shallow instability was evident as seen in Figure 2.

Figure 2 – Wall 8-9 area looking upstation with shallow slides right and irregular outboard

However, with required MSE wall heights reaching in excess of 9m in very difficult terrain, alternate solutions were ultimately sought. To add to the difficulty with the proposed wall construction, it was a project requirement that the road remain open to residential and recreational traffic during selected daily time windows. The combination of these factors became prohibitive with respect to construction of 9m high reinforced backfill zones within the existing narrow roadway corridor. Therefore, the road alignment was shifted into the slope to reduce requirements for outboard retention. With this approach, MSE section height requirements could be reduced to 2.5m in conjunction with a Tecco (Geobrugg) soil nail and high-strength steel mesh stabilization of inside cuts. The MSE sections, though decreased in height, still required foundation construction in steep, irregular terrain as shown in Figure 3 below. To provide a reasonable level of foundation security, micropile support was designed for the toe areas along the slope crest.

Adoption of this combined approach to fitting the roadway alignment was believed to provide economy over the original wall-only design plus reduce the potential for associated construction delays and claims. The inward shift of the alignment also afforded the advantage of incorporating some toe area stabilization for the cut slope which in the original design would not have realized any improvement to the existing, marginal stability.

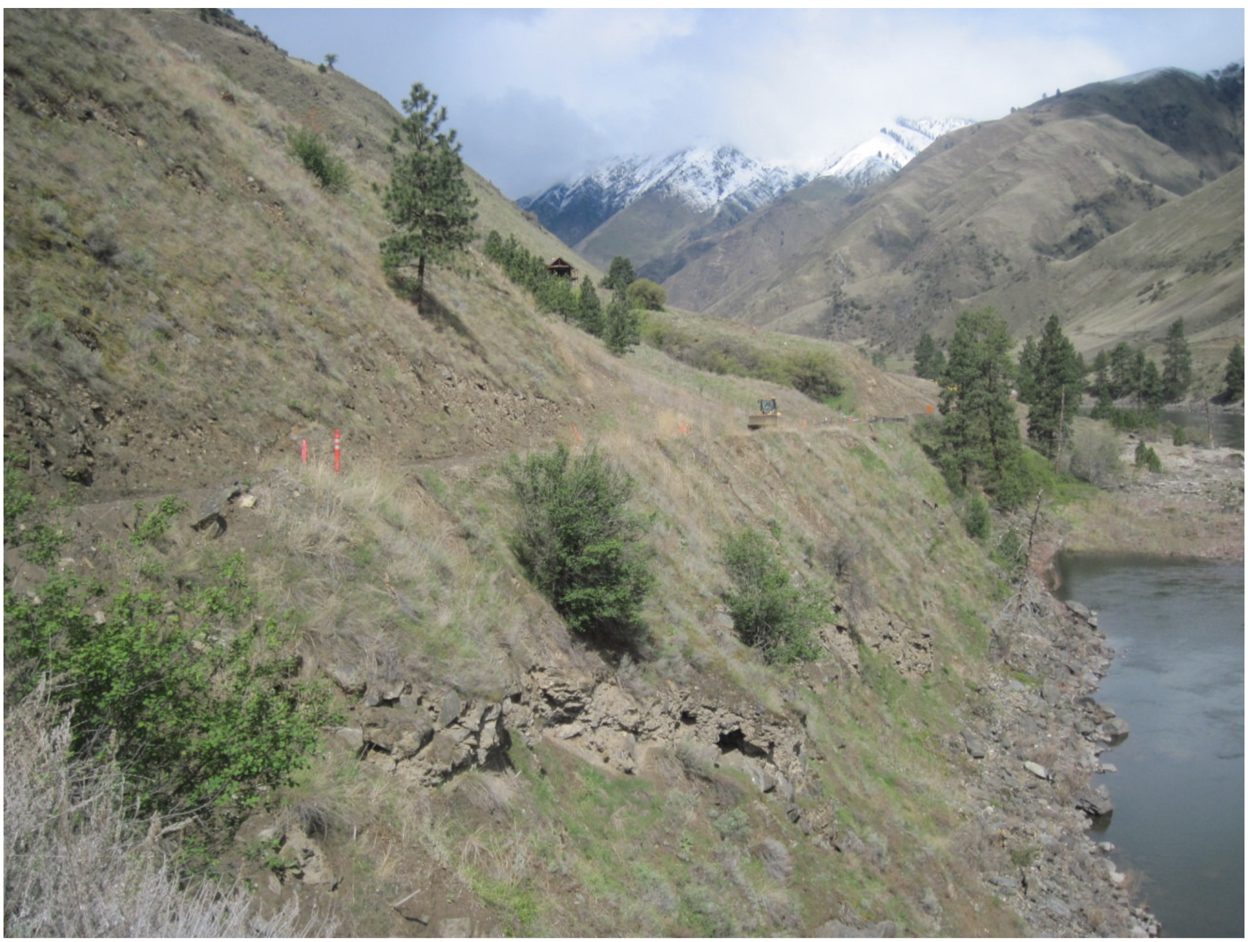

Figure 3 – Close-up view of irregular downslope terrain in Shoulder Stabilization

4. MSE Shoulder Stabilization/Micropile Design

The initial stabilization concept for this location was to build across the unstable outboard shoulder areas with welded wire faced and reinforced embankment sections. The facing was proposed to battered to an angle that matched the existing native slope. The concept utilized closely-spaced reinforcement layers that extended across the roadway. This approach provided excellent roadway support while being robust enough to provide some buttressing against future toe-of-cut movements and stiff enough to bridge over possible shoulder undermining. However, as stated previously, the alignment shift was designed with the intention of limiting both inboard cut and outboard fill requirements along the narrow sidehill corridor. In addition, involving the entire roadway width in the MSE section construction would impose some significant difficulty for the "open-to-traffic" project requirements. Therefore, to accomplish the project objectives and avoid abrupt shoulder conditions, a broken-back stabilization alternate was developed; this section had a 1.25m vertical MSE section that transitioned to a 1.25m reinforced 1V:1H slope at the roadway edge as shown in Figure 4 below:

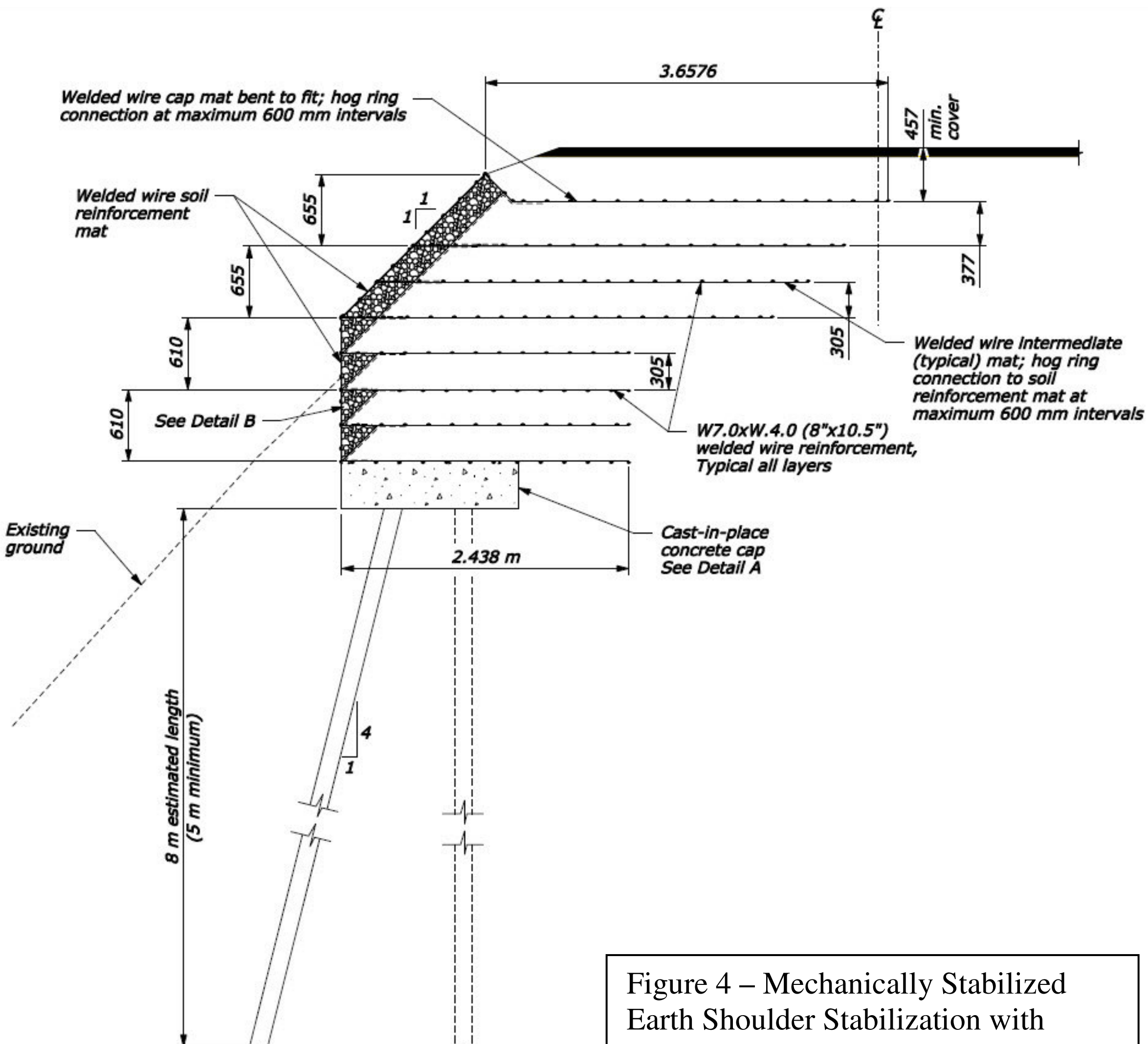

Figure 4 – Mechanically Stabilized Earth Shoulder Stabilization with Micropile Support

The foundation for the MSE section was expected to be positioned within 1m of the outboard slope crest with limited setback distance or embedment available. It was also considered that any embedment or setback for the toe area could be lost due to erosion or local instability. In order to provide positive foundation support in such circumstances, a pile cap/platform and micropile system was selected to provide additional toe support for the MSE section. Based on conventional geotechnical methods and in accordance with Federal Highway Administration (FHWA) guidelines, a staggered micropile array with front piles battered at 4V:1H was designed to support the structure in the event that undermining along any given 3m length of slope should occur. The design philosophy was to reasonably maximize micropile coverage along the slope crest to account for subsurface variables; therefore a 900mm staggered spacing pattern was decided upon as shown by the typical details in Figures 5 and 6 below:

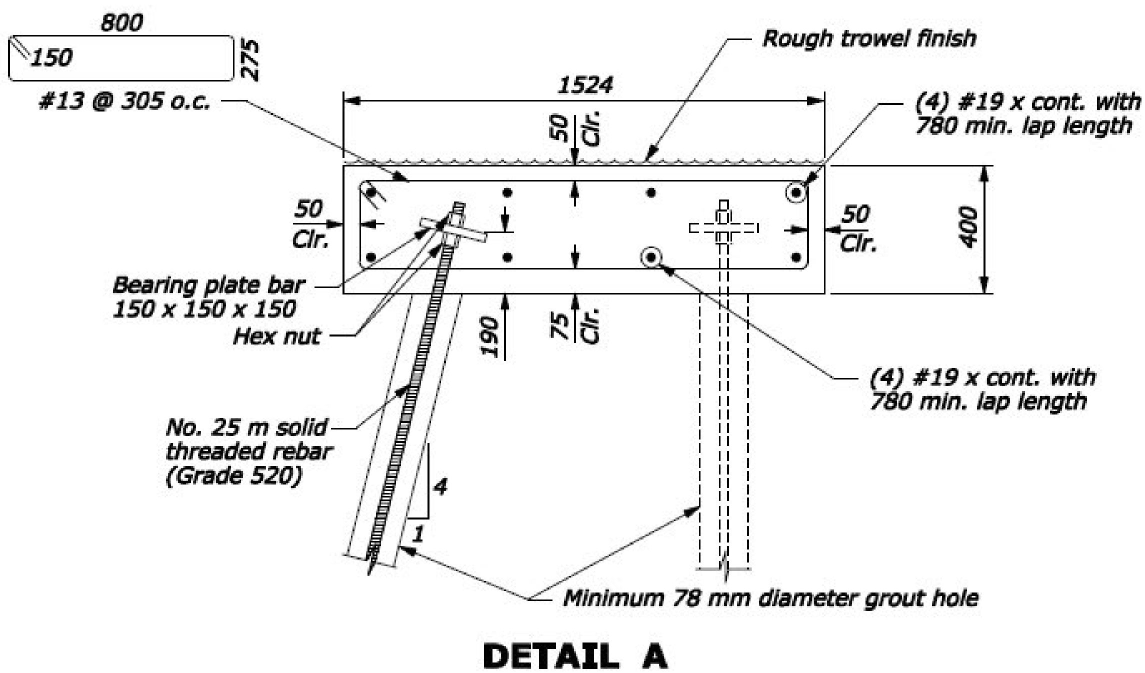

Figure 5 – Micropile Cap Typical Detail

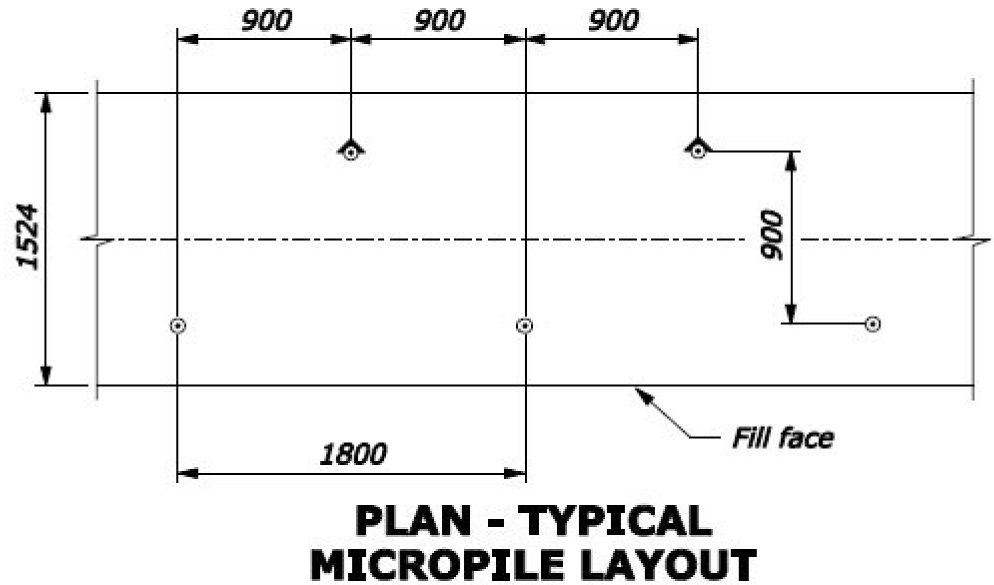

Figure 6 – Staggered Spacing of Micropiles with Battered Front Pile

Maximum demand on the micropiles to resist overturning in this case was about 120 kN in compression with the micropile configuration set to maintain all piles in compression under the design conditions. Based on this modest loading, the micropile element selected for the design was a No. 25m (Grade 520) solid, continuously threaded bar. The bar was to be installed in temporarily cased drill holes of minimum 78mm diameter. Based on ultimate bond stresses of 200 kPa in the gravel/cobble alluvium and 1000 kPa in the schist bedrock, the micropile length was estimated at 8m in order to develop the design load at a Factor of Safety, FS=2.

Considering the potential for difficult drilling through cobble-boulder colluvium with some cemented zones and schist bedrock, temporary casing methods for installation of the micropiles were required. Type A and Type B micropile grouting methods per FHWA nomenclature were specified to maintain integrity of the pile section with pressures limited to prevent fracturing and slope disturbance during grout placement and casing removal. Verification load tests of sacrificial micropiles were specified at four locations to ascertain ultimate load capacity for the potentially varying installation and subsurface conditions at each MSE site. Proof testing of 15 micropiles was specified to verify 150% capacity for production elements and assess possible need for pile length adjustment over the course of the foundation installation process.

5. Cutslope Stabilization Design

Based on observations over the course of project design and construction, it was concluded that the upslope slides were of a shallow, "skin-slide" nature as often seen in steep mountainous terrain in which road construction must be accomplished by cutting and oversteepening the toe-of-slope area. Observations indicated that the native slopes above the road, although having slipped in recent history, were stable at relatively steep inclinations over a long period prior to road building as indicated by the substantial amount of topsoil (typically on the order of 0.6 m) seen rimming the various slide scarps on the hillside. Furthermore, these slides had not developed beneath the roadbed. It was then concluded that the slides were primarily associated with over-steepening of the toe cut areas and their subsequent response to various weathering agents and creep forces.

The shifting of the alignment into the hillside required that the new toe cuts to be constructed at inclinations of 60° (steeper than those now existing) be stabilized by providing restraining forces to account for lost ground. It was determined that this could be accomplished by top-down construction methods as cuts were made using high strength steel mesh nailed into the denser colluvium or bedrock which are present at relatively shallow depths beneath the active surface zone of generally finer-grained colluvium. The selected Tecco (Geobrugg) system was designed to apply sufficient compression to the slope face to retain the toe cuts plus provide some additional restraint versus future creep-type movements of the mobile "skin-slide" masses. Although design expectations for this system were not to eliminate future concern about creep or incremental sliding above the cut restraint, some stability improvement relative to the original non-encroachment approach to the slope was expected. Construction of the Tecco system in similar manner in difficult terrain has already been demonstrated as feasible elsewhere on the project. The nails were designed as No. 25m, solid, continuously threaded bars 5 to 9m tightened to an 80 kN tension load. Spacing of the nails was designed as 3m horizontal and 2m vertical in a staggered pattern.

6. Interim Project Status

Project plans and specifications have been completed for the Wall 8-9 stabilization, and contract negotiations are in progress. However, due to the summer construction restrictions in this recreation corridor wherein the contractor is not permitted to close the road to traffic during daylight hours, the start-up of the Wall 8-9 stabilization work has been delayed and will begin in the fall of 2010. The construction will resume with verification load testing for micropiles and nails. However, the contractor has elected to begin the work with the inboard slope nail-mesh stabilization, and some of the initial soil nail verification is now in progress. Results of the micropile load testing and slope stabilization program will be forthcoming over the final quarter of 2010 and early 2011 with final conclusions to this paper to be presented in a future ISM newsletter and/or workshop.

Some slope stabilization at other wall locations has been completed using lightly-loaded, hollow injection bars. This stabilization has been conducted by installing vertical bars along slope edges with the intent to provide some reinforcing of looser fill materials and pinning into the more competent colluvium or bedrock deeper in the profile. The elements installed thus far have not been structurally connected to the wall sections. Proof load testing of these bars has indicated ultimate bond stress magnitudes in silty gravel fill and colluviums soils in excess of 200 kPa (30 psi).