APPENDIX E

PRELIMINARY GEOTECHNICAL REVIEW REPORT
GALLUP AND GLACIER CREEKS

FEASIBILITY STUDY FOR SR 542 CROSSINGS AT GALLUP AND GLACIER CREEKS

SR 542 CHRONIC ENVIRONMENTAL DEFICIENCY (CED) PROJECT

WSDOT AGREEMENT NO. Y-9739 - TASK AG

May 5, 2008

Washington State Department of Transportation
Northwest Region, Mt. Baker Area Headquarters
1043 Goldenrod Road, Suite 101
Burlington, WA 98233-3415

Attn: Mr. Robert McGaughey, P.E.
Project Engineer, H.W. Lochner, Inc.

Draft

RE: GEOTECHNICAL REVIEW, SR-542 GLACIER CREEK/GALLUP CREEK FEASIBILITY STUDY, GLACIER, WASHINGTON

This letter presents the results of our scoping-level geotechnical review for the Glacier Creek/Gallup Creek feasibility study. We understand that the purpose of this study is to assess options to address aggradation and scour problems at the Gallup and Glacier Creek bridge crossings of SR-542 near Glacier, Washington. Our role in this project is to conduct a geotechnical review and to evaluate foundation options. This letter provides a brief summary of our field reconnaissance, aerial photographic review, and a literature search of existing geological and geotechnical data, and presents conceptual foundation recommendations. Subsurface explorations were not conducted as part of this review.

The task was authorized by Mr. Robert J. Munchinski of H.W. Lochner, Inc., on November 20, 2007, as part of Washington State Department of Transportation (WSDOT) Agreement: Y-9739-Task Order: AG, Amendment 6, SR542 Glacier Creek/Gallup Creek Feasibility Study.

SITE DESCRIPTION

The proposed bridge improvements are located in the town of Glacier, Washington where SR-542 crosses the Gallup and Glacier Creeks. Two bridge crossings are considered in this letter: the Gallup Creek bridge and the Glacier Creek bridge. The Gallup Creek Bridge is located approximately 400 feet east of the intersection of Vaughn Avenue and SR-542. The Glacier Creek bridge is situated approximately 400 feet east of the Gallup Creek bridge. Gallup and Glacier Creeks have independent drainages with headwaters situated in the mountains that lie to the south.

The existing Glacier and Gallup Creek bridges have similar constructions; bridge abutments for both bridges are founded on conventional spread footings. The Glacier Creek bridge consists of a single span approximately 80 feet long. The length of the Gallup Creek bridge is approximately 100 feet and includes two intermediate piers. Steel girders forming the bottom of the existing Glacier Creek bridge are positioned approximately 12 feet above the current stream bed. At their highest, girders forming the bottom of the Gallup Creek bridge is approximately 3 to 4 feet above the water level in the stream. During our site visit, we noted damage to the upstream side of the Gallup Creek bridge in the form of dents in the steel girders and concrete foundations.

GEOLOGY AND SUBSURFACE CONDITIONS

The geology and subsurface conditions at the Gallup and Glacier Creek bridge crossings were evaluated based on field reconnaissance, aerial photographic review, and a review of existing literature. A geologist and licensed engineer from our firm visited the site on February 11, 2008.

The following existing information was used in our review:

- The Geologic Map of the Mount Baker 30- by 60-Minute Quadrangle, Washington (Tabor and others, 2003).
- The *Glacier* and *Groat Mountain* U.S. Geological Survey 1:24,000 topographic quadrangles.
- Aerial photographs provided to University of Washington library by the Washington State Department of Transportation; photographs 4-226 and 4-227 of EMM series, dated July 12, 1964.
- As-built plans for the Glacier and Gallup Creek bridges supplied by the Washington State Department of Transportation, dated September 12, 1955.

Site Geology

Based on our field reconnaissance and review of information in existing literature, surficial deposits in the vicinity of the Glacier and Gallup Creek bridges consist primarily of debris-flow

Draft

deposits, Holocene alluvium, and older landslide deposits,. The geologic map shows that the area in the vicinity of the bridges is underlain by older landslide deposits (Tabor and others, 2003); however, the scale of the geologic map (1:100,000) may be too small to show younger alluvium and debris-flow deposits that appear to line Glacier and Gallup Creeks. During our site visit, we observed rocks and wood debris piled against the upstream side of the Gallup Creek Bridge that probably represents the remnants of a debris flow that occurred since bridge construction. This observation, along with apparent damage to the upstream side of the bridge and recent reports of aggradation and scour from WSDOT, suggests that surficial deposits under the bridges are likely young. Deposits that underlie the SR-542 on either side of the bridges probably consist of debris-flow, older landslide, or alluvial deposits. Due to heavy snow cover and rip-rap embankments, we were unable to observe the deposits that flank the bridge abutments during our site visit.

Soil Conditions

Our assessment of soil conditions is based on existing WSDOT records related to the construction of the bridges, and to limited observations of exposures near the bridge sites. Three test holes performed by WSDOT for the September 12, 1955 report were located on the outside of the bridge abutments for the Glacier Creek bridge and extended to depths of 6.5 to 7.5 feet. Soil in the test holes is described as clean or slightly silty, sandy gravel with boulders. Density information was not provided; however, because the material is likely not overridden, densities in the range of loose to medium dense are anticipated. During our field visit, we observed cobble and boulder deposits (debris flow) in the stream beds with boulders up to 1.5 feet in size. Cut banks located upstream and downstream of the bridges expose deposits of cobbles and boulders with matrices of fine to medium sand.

CONCLUSIONS AND RECOMMENDATIONS

Based on our current understanding of the proposed project and the results of our site reconnaissance and evaluation, we developed preliminary recommendations for foundation design alternatives. In our opinion, the proposed bridge replacements could be supported on deep foundations. Conventional spread footings would be effective only if constructed below

Draft

likely scour depths. We understand Glacier and Gallup Creeks have historically migrated, and periodically deeply scoured their banks. Therefore, we anticipate deep excavations would be required to protect foundations from scour. Such deep excavations would extend below groundwater, which would require temporary construction dewatering. Thus, deep foundations may be a more feasible option for supporting the proposed new bridges.

Deep foundations should extend below the estimated depth of scour and bear in the underlying medium dense, debris-flow deposits. Additional subsurface soil information is required to provide a better assessment of the subsurface conditions. Because of the potential presence of boulders and other large obstructions associated with the course alluvium observed at the ground surface, deep foundations installation will likely encounter these obstructions. If driven steel piles are used, they would likely result in damaged piles, horizontal location tolerance exceeded, longer installation time, and redesign of pile caps. Drilled foundations would also likely encounter boulders, cobbles, and potentially logs; however, they can be drilled out with a hardened steel core barrel and would therefore be a more suitable and economical foundation system. Traditional methods of drilling, such as auger drilling, may be used at this site; however, removal of obstructions may be required and would likely result in longer installation times. An oscillator/rotary drilling system may be more advantageous at this site.

The following sections provide preliminary geotechnical recommendations for foundations, the use of on-site soils, and additional explorations.

Draft

Earthquake Engineering

Ground Motions

We understand that the seismic design of the bridge will be in accordance with the 2008 Interim Revisions of the 2007 4th edition AASHTO LRFD Bridge Design Specifications. Computation of seismic forces in this code is based on seismological input and site soil response factors.

The seismological inputs are the peak ground acceleration coefficient (PGA), short period spectral acceleration (S_S) and spectral acceleration at the 1 second period (S_1) shown on Figure 3.10.2.1-1 to 3 in the specification. PGA, S_S and S_1 are for ground motions with a 7 percent probability of exceedance in 75 years or about a 1,000 year return period. The US Geological Survey prepared the PGA, S_S and S_1 figures in the specification using the data from

Draft

the 2002 National Seismic Hazard Mapping Project. The PGA, S_S and S_1 values in the vicinity of the project site are 0.26g, 0.59g and 0.19g, respectively.

The site soil response factors are based on determination of the Site Class. In our opinion, the site is best classified as D based on our understanding of the site subsurface conditions. Site Class D corresponds to soils that within 100 feet of the ground surface have an average shear wave velocity between 600 and 1,200 feet per second or an average SPT blow count (N-value) between 15 and 50 (see Table 3.10.3.1-1 in the specification). The F_{pga} value corresponding to Site Class D and a PGA of 0.26g is 1.3; the F_a value corresponding to Site Class D and S_S of 0.59g is 1.3; and the F_v value corresponding to Site Class D and S_1 of 0.19g is 2.0 (see Tables 3.10.3.2-1 to 3 in the specification). These values can be used to construct a design response spectrum following the procedures presented in section 3.10.4.1 of the specification.

Earthquake-Induced Geologic Hazards

Earthquake induced geologic hazards that may affect a given site include liquefaction and associated effects (loss of shear strength, bearing capacity failures, loss of lateral support, ground oscillation, lateral spreading, etc.), settlement, landsliding, and ground surface fault rupture. In our opinion, these hazards pose a low risk at this site.

In our opinion, the gravelly, cobble and boulder deposits at the bridge site are highly permeable, which would preclude development of high pore water pressure required for a soil to liquefy. These soils are not susceptible to liquefaction nor to associated effects (e.g., lateral spreading, ground oscillation, bearing capacity failure). We do not have data to quantitatively assess potential differential settlement. However, given the coarse grained nature of the deposit and the high-energy depositional nature, significant differential settlement is unlikely, in our opinion. Similarly, it is our opinion that seismically-induced slope instability in the immediate vicinity of the bridge abutments would most likely be shallow raveling of the surface materials along the banks, and the risk of deep-seated landsliding is low. The potential for ground surface fault rupture is also low as there are no known active faults within 5 miles of the site.

Spread Footings

As-built documents show that existing Glacier and Gallup Creek bridge abutments are supported on spread footings bearing at the elevations where loose to medium dense, debris flow deposits were encountered in previous test pits. The following sections provide geotechnical recommendations and discussions for spread footings that might be used away from the creeks where scour is unlikely.

Bearing Capacity and Settlement

Based on the results of our preliminary review, the footings would likely bear on loose to medium dense, clean to slightly silty, sandy gravel. Based on Table C10.6.2.6.1-1 of the AASHTO LRFD manual, we estimate a nominal bearing pressure from 7 to 9 kips per square foot (ksf) for footings bearing in loose to medium dense gravel. A resistance factor of 0.45 is recommended to be applied to these bearing pressure values for evaluation of the service limit state. For the extreme event, the recommended resistance factor is 1.0.

The recommended bearing capacity values for the service limit state assume settlement of 1 inch. The foundation soils at this site are mainly cohesionless (non-plastic). Cohesionless soils typically undergo elastic rather than time dependent consolidation settlement, whereas settlement of cohesive soils is usually time-dependent. Thus, it is our opinion that the total estimated settlements would be primarily elastic and that about 90 percent of the estimated settlement would likely occur almost simultaneously with load application.

Lateral Resistance

Resistance to lateral forces caused by wind, seismic, unbalanced earth pressures, and/or other forces can be provided by both passive earth pressures acting against the embedded portion of foundations and frictional resistance against base of the foundations. We recommend using an ultimate coefficient of friction between cast-in-place concrete and the loose to medium dense subgrade of 0.45 to calculate the resistance to sliding at the base of the footings. A resistance factor of 0.8 is recommended when evaluating the sliding resistance to lateral movement for evaluation of the service limit state.

Passive resistance should be ignored in the upper 24 inches and/or above the scour depth, which is unknown at time of writing (scour study performed by others). Based on the subsurface conditions encountered in the previous test pits, passive earth pressures in loose to medium dense debris-flow deposits can be estimated using an equivalent fluid weight of 600 pounds per cubic foot (pcf) above groundwater levels and 300 pcf below the groundwater level.

Draft

A resistance factor of 0.5 is recommended to be applied to these values to limit lateral movements for evaluation of the service limit state.

Drilled Shafts

Based on discussions with you, we understand that abutments at both bridge locations would be located outside of the high water mark at the creek's edge and have single spans of about 150 feet. The total abutment widths at the proposed Glacier and Gallup bridges are approximately 36 feet.

Because of likely presence of cobbles and boulders, small diameter drilled shafts would be more difficult to construct than larger diameter shafts. We anticipate that drilled shafts would range from 4 to 6 feet in diameter. Based on an assumed medium dense, granular soils at the base of the shafts, a 30- to 40-foot-long drilled shaft likely would have a capacity of about 500 to 900 kips.

Abutment Walls

Lateral earth pressures will act on the back of the abutment substructure and wing walls. We estimate that the walls will be approximately 12 feet high and, at-rest earth pressures are recommended for design. These earth pressures will consist primarily of static earth pressures, although compactive earth pressures and some seismic loading would also impact the substructure. Based on our experience with bridge structures, we recommend that at-rest earth pressures represented by an equivalent fluid weight of 55 pcf be used in the design of the bridge substructure and walls. The recommended lateral earth pressure is for a level (horizontal) backfill and assumes that groundwater will not collect behind the wall.

Drainage

We recommend that abutments be backfilled with free-draining granular soils to prevent buildup of hydrostatic pressures behind abutment structures.

Temporary Construction Dewatering

We recommend that the groundwater inflow into the excavations be controlled to provide dry conditions for construction activities. The contractor should be responsible for the control of ground and surface water within the contract limits. In this regard, sloping, slope protection,

Draft

ditching, sumps, dewatering, cofferdams, and other measures should be used to direct water away from the excavation to prevent ponding of water next to and in the excavations. Wet weather conditions may require the use of sumps or wells to control the surface and/or groundwater and allow for an accessible excavation.

Draft

Additional Studies for Project Final Design

Soil borings will be required to better determine the subsurface soil and groundwater conditions along Glacier and Gallup Creek bridge alignments. We recommend that four (4) borings be drilled; two borings located adjacent to both Gallup Creek bridge abutments, and two adjacent to both Glacier Creek bridge abutments. Foundation-specific axial capacities and lateral resistances should be evaluated for final design based on the chosen foundation alternative and the subsurface conditions encountered in the borings. Hydrogeological studies should be performed to develop suitable groundwater control for temporary excavation during construction.

Site Preparation and Excavation

Site preparation should commence by temporarily collecting and diverting away from proposed excavations all sources of surface water flow, including Glacier and Gallup Creeks. The proposed bridge and roadway embankment alignments should be cleared of brush, trees, and other vegetation and then stripped of surfical soil containing significant amounts of roots or other objectionable debris and organic material. While no contaminated soils were reported in the previous test pits, contaminated fill should be disposed of off site according to procedures provided by a qualified environmental consultant. After stripping is completed, all loose or soft soil and all soil containing organic material should be removed from beneath bridge abutments and areas to receive structural fill. Abutment and roadway embankment subgrades should be evaluated by an experienced geotechnical engineer during construction to verify the presence of competent bearing soil and to determine that all loosened, disturbed soils and all unsuitable fill have been removed. Roadway embankment subgrades should be compacted by proof-rolling with a backhoe or similarly sized equipment.

Based on the surface conditions observed during the site reconnaissance and subsurface conditions encountered in previous test pits, we anticipate that excavations can be accomplished using conventional excavating equipment. We observed many boulders at the ground surface ranging from about 1.5 to 2 feet in size. Based on our experience with similar deposits in the Puget Sound region, we anticipate that larger boulders may be present. Boulders that are too large to be moved using conventional earthmoving equipment may require drilling and splitting and/or blasting to be removed. Boulders should not be used in structural fill, but could be used as slope armoring.

Backfill Material, Placement, and Compaction

All fill placed beneath areas to be paved such as the required approach fill or against below grade walls or other foundation elements should consist of structural fill. Structural fill should be placed on subgrade material that has been proof-rolled to a dense, unyielding condition.

Imported structural fill should conform to the quality and gradation characteristics of Gravel Borrow as defined in Section 9-03.14 (1) (Gravel Borrow) of the current WSDOT Standard Specifications, but should have a maximum particle size of about 3 inches. During wet weather or wet conditions it should not contain more than about 5 percent fines (material passing the No. 200 mesh sieve) by weight, based on the minus ¾-inch soil fraction. Structural fill should not contain organics or deleterious material. It should be placed in horizontal lifts and compacted to at least 95 percent of its Modified Proctor maximum dry density (ASTM International [ASTM] D 1557, Method C), and should be deemed to be in a dense and unyielding condition. The thickness of loose lifts should not exceed 8 inches for heavy equipment compactors, and 4 inches for hand-operated compactors.

In our opinion, some of the on-site soil excavated at the site may be suitable for re-use as structural fill providing the moisture content is sufficiently close to optimum, the work is conducted under dry conditions, and the material is not contaminated.

Wet Weather Earthwork

In the Glacier area, wet weather generally begins about October and continues through about May, although rainy periods may occur at any time of the year. Therefore, we recommend scheduling earthwork during the normal dry weather months of June through September. In our opinion, earthwork performed during the dry weather months would be less costly than wet weather earthwork.

Draft

The following recommendations are applicable if earthwork is to be accomplished in wet weather or in wet conditions:

- Fill material should consist of clean, well-graded sand, or sand and gravel, with not more than 5 percent passing the No. 200 sieve, based on wet-sieving the minus ¾-inch fraction. Any fines should be non-plastic.
- The ground surface in and surrounding the construction area should be sloped as much as possible to promote runoff of precipitation away from work areas and to prevent ponding of water.
- Covering work areas or slopes with plastic, sloping, ditching, use of sumps, dewatering, and other measures should be employed as necessary to permit proper completion of the work. Bales of straw and/or geotextile silt fences should be used to control surface soil movement and erosion.
- Earthwork should be accomplished in small sections to reduce exposure to wet conditions. Excavation or the removal of unsuitable soil should be followed immediately by the placement of concrete or a layer of compacted clean structural fill or lean-mix concrete.
- No soil should be left uncompacted and exposed to moisture. A smooth drum vibratory roller, or equivalent, should be used to seal the surface if wet weather is anticipated. Wet surface soils should be removed prior to filling each day. Stockpiles of structural fill should be protected from wet weather with waterproof sheeting.
- In-place soils or fill soils that become wet and unstable, and/or too wet to suitably compact, should be removed and replaced with clean granular soil (see above).
- Excavation and fill placement activities should be observed on a full-time basis by an experienced geotechnical engineer if these activities are to be completed during wet weather or under wet conditions.

The above recommendations for wet weather earthwork should be incorporated into the contract specifications.

Additional Services

During the final design phase, we recommend that our firm be retained to review those portions of the plans and specifications that pertain to the geotechnical aspects of the project to determine if they are consistent with our recommendations. In addition, we should be retained to observe the geotechnical aspects of construction, particularly foundation installation and backfill. This observation would allow us to evaluate the subsurface conditions as they are exposed during construction and to determine that the work is accomplished in accordance with our recommendations and the project specifications.

CLOSURE

This letter was prepared for the exclusive use of WSDOT, H.W. Lochner, Inc. and other members of their design team to assist in the conceptual design and construction of the Glacier and Gallup Creek feasibility study. The analyses, conclusions, and recommendations contained in this report are based on site conditions as they existed during previous explorations and our 2008 site visit and on the site and project descriptions as presented herein. We should be notified if differences are identified. We assume that the previous explorations summarized in the project data report (by others) are representative of the subsurface conditions throughout the site; i.e., the subsurface conditions everywhere are not significantly different from those disclosed by the explorations. If conditions have changed due to natural causes or construction operations at or adjacent to the site, we recommend that we review this letter to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

Within the limitations of the scope, schedule, and budget, the analyses, conclusions, and recommendations presented in this letter were prepared in accordance with generally accepted professional geotechnical engineering principles and practice in this area at the time this letter was prepared. We make no other warranty, either express or implied. These conclusions and recommendations are based on our understanding of the project as described in this letter and on site conditions as documented at the time of the previous explorations.

Unanticipated soil conditions are commonly encountered and cannot be fully determined by a field reconnaissance or merely by taking soil samples or completing test pits or borings. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs.

The scope of our services for this project did not include any environmental assessment or evaluation regarding the presence or absence of wetlands or hazardous or toxic materials in the

Draft

soil, surface water, groundwater, or air, on or below or around the site, or evaluation for disposal of contaminated soils or groundwater, should any be encountered.

Shannon & Wilson has prepared and included an Appendix, "Important Information About Your Geotechnical Engineering Report," to assist you and others in understanding the use and limitations of our reports.

Please call if you have any questions regarding this letter. We appreciate the opportunity to be of service and look forward to working with you during the next phase of the project.

REFERENCES

Tabor, R.W., Haugerud, R.A., Hildreth, W., and Brown, E.H., 2003, Geologic Map of the Mount Baker 30- by 60-Minute Quadrangle, Washington. U.S. Geological Survey Geologic Investigation Series I-2660, Scale 1:100,000.

Draft

Sincerely,

SHANNON & WILSON, INC.

Christopher A. Robertson, P.E., L.E.G.
Vice President

PHZ:JXM:CAR:JW/phz

Enclosure: Important Information About Your Geotechnical Report

Draft