

<i>Project Title</i> <b>Subsurface Drainage for Landslide and Slope Stabilization</b>		<i>Agmt./Task No.</i> <b>GCA6381</b>	<i>Item No.</i>	<i>Agency Bgt. No.</i>
<i>Research Agency</i> <b>WSU/Desert Research Institute (DRI)</b>		<i>Start Date</i> <b>3/2007</b>	<i>Estimated Completion</i> <b>12/2010</b>	<i>Revised Completion</i> <b>12/2011</b>
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<i>Funding Source</i> <b>CA, MD, MS, MT, NH, OH, PA, TX, WA, WY</b>		<i>Schedule Status</i> <input type="checkbox"/> On schedule <input type="checkbox"/> Ahead of schedule <input checked="" type="checkbox"/> On revised schedule <input type="checkbox"/> Behind schedule		
<i>Research Area</i> <input type="checkbox"/> Bridges & Structures <input type="checkbox"/> Environment <input checked="" type="checkbox"/> Highway Design & Safety <input type="checkbox"/> Mobility & Intermodal Planning <input checked="" type="checkbox"/> Operations & Materials <input type="checkbox"/> Traffic & Intelligent Transportation Systems Evaluation				
<i>Original Estimated Cost</i> <b>\$ 300,000</b>	<i>Revised Cost</i>	<i>% Funds Expended</i> <b>45%</b>	<i>% Work Completed</i> <b>85%</b>	
<i>Objective</i> <b>(1) Provide best practices and guidance for subsurface drainage applications for slope stabilization, including subsurface investigation and testing, groundwater-flow characterization, analysis, drain configurations and design, installation methods, monitoring, and maintenance. (2) Evaluate new applications of existing materials and technologies, such as trenchless technologies (horizontal directional drilling, micro tunneling, guided boring, etc.) and other innovative technologies and materials, for stabilizing slopes using subsurface drainage.</b>				

**Project Progress:**

A meeting was held at WSDOT on June 20<sup>th</sup> to discuss progress to date and what is remaining. Below is a synopsis of what has occurred recently and what came out of the meeting.

Tasks to date include the following:

- Site US 101 MP 69.8 was redone with no GHB boundary condition at the up-gradient location.
- Scale of the site was corrected when error was found in the water balance.
- A methodology was established to calibrate models with sufficient pre and post-drain data.
- A methodology was outlined for developing recharge based on the SCS curve number approach.
- A methodology was outlined for developing a 24 hour 100-year return period event and to test current drain configurations and sensitivity of pore pressures to elevation of drains, length of drains and drain efficiency.
- A simplistic approach to computing the factor of safety was done on a cell-by-cell basis using a graphical method assuming infinite slope. The method proved most sensitive to slope and much less sensitive to pore pressure. This approach was then dropped during the June 20, 2011 WSDOT meeting based on inappropriate assumptions in the calculation. In the future the factor of safety calculation will rely on limit-equilibrium analysis for stability calculations.
- Site US 101 MP 321 was modeled as a one-layer model since issues of numeric stability occur using a more complex three-layer approach. The GHB boundary condition was dropped and the conceptual model relies on recharge for pore-water changes.
- MP 321 was calibrated to steady state and transient conditions.

- During the June 20, 2011 meeting, the conceptual model of the site was found incorrect and highlights the need for DOT field site and modeling teams to coordinate for successful model development. Changes to the model are currently underway to correct the conceptual flaw such that the failure surface should occur just below the upper gravels in the fine lacustrine material. Calibration of this new conceptual model is currently underway.
- Preparation of the modeling approach and the model results to date were completed and presented at the WSDOT offices on June 20, 2011.

### New Period Proposed Activity:

- Future tasks as outlined in the meeting include:
  - Revise MP 321 conceptual model.
  - Use 2000-2005 piezometer data for wells P-100, P-200, P-300 and P-400 as these are screened in the upper gravels. Do not use the H-wells as these are screened in the lower tills, which occur below the failure surface.
  - Use the 2009-2010 drain flow data as an estimate of drain flow during winter rains.
  - Recalibrate and redo the sensitivity analysis of drain parameters.
  - Compose appendices describing the model procedures for MP 69.8 and MP 321. This will be included with the DOT manual.
  - Develop simpler, step-by-step examples for DOT personnel in model development. This will include screen captures of GMS to aid in the pre/post processor use.
  - Establish thresholds (potentially based on  $r/K$  ratios) where drains are not a practical solution to lower pore pressures.
  - Coordinate with B. Muhunthan with regards to transfer of pore pressures for the calculation of the factor of safety.
  - Develop a series of design problems for appendices in the manual. These will go from start to finish and include determination of site suitability, stability analysis to determine requisite GW/PP reduction to achieve stability, evaluation of steady state and transient GW conditions in MODFLOW, and final design. Tom B. will work with Muhunthan and Rosemary to develop example problems.
  - Write a draft of the manual for DOT review. Draft should be ready for review by the end of August or September.
  - No-cost extension pushed to the end of December 2011.