PARAMETERIZATION OF FINITE-ELEMENT CRYO-HYDROLOGIC SAND DUNE MODEL TO CONSTRAIN DEBRIS-FLOW-INITIATING SUBSURFACE TEMPERATURES AND PORE-WATER PRESSURES, GREAT KOBUK SAND DUNES, ALASKA. C. L. Dinwiddie (cdinwiddie@swri.org) and D. M. Hooper (dhooper@swri.org), Southwest Research Institute®, San Antonio, Texas.

Introduction: We published field observations of debris flows (**Fig. 1**) that formed in March 2010 on two sunward, southwestward-facing lee slopes of the Great Kobuk Sand Dunes, Alaska [1], on late-winter days when ambient air temperatures measured onsite were continuously subfreezing [2].

To better understand how debris flows fed by liquid water form at subfreezing air temperatures, we are undertaking meteorology-driven, cryo-hydrologic numerical modeling using a commercial geotechnical engineering finite-element code—the VADOSE/W variably saturated porous media flow module of GeoStudio 2012 by GEO-SLOPE, v.8.14.1.10087 [3]. This is a fully coupled energy and mass balance model using adaptive time-stepping, which calculates evaporation, sublimation, net infiltration, change in storage, and runoff as part of the overall water balance.

Model Domain and Grid: A 1-m^2-area, 5-m-thick 1D column model domain was constructed to extend beneath the seasonally freezing and thawing active layer of the dune sands [4]. Where large vertical gradients are expected in the very near surface, element thickness is on the order of 1-mm; generally, the mesh consists of 2.5-cm-thick elements, 256 in total. VADOSE/W "surface layers" are directly influenced by meteorology and are extended here to 4.5 m below ground level.

Material Properties: The initial model domain is constructed of GKSD sand [5], which ultimately will be variably saturated with meteoric water in both solid and liquid phases. Air–water soil moisture characteristic and hydraulic conductivity functions of volumetric water content (**Fig. 2**) were derived from grain size analysis and knowledge of typical sandy soil field capacities and saturated hydraulic conductivities. With additional funding, these properties and their variability will be directly assessed through laboratory testing of available samples. The ice–water soil moisture characteristic is calculated internally by VADOSE/W and is not included as input. The thermal conductivity function of volumetric water content was developed by scaling the low-sand function of [6] using our heat-dissipation values of oven-dried GKSD sand thermal conductivity (**Fig. 3**). The volumetric heat capacity function of water content was estimated using the method of [7], based on our dual-probe heat-pulse values of oven-dried GKSD sand volumetric heat capacity (**Fig. 3**). With additional funding, available samples will undergo thermal testing in the laboratory at variable water contents to confirm the validity of the derived functions and their variability. VADOSE/W internally accounts for the thermal properties of liquid water, water ice, and accumulated snow.

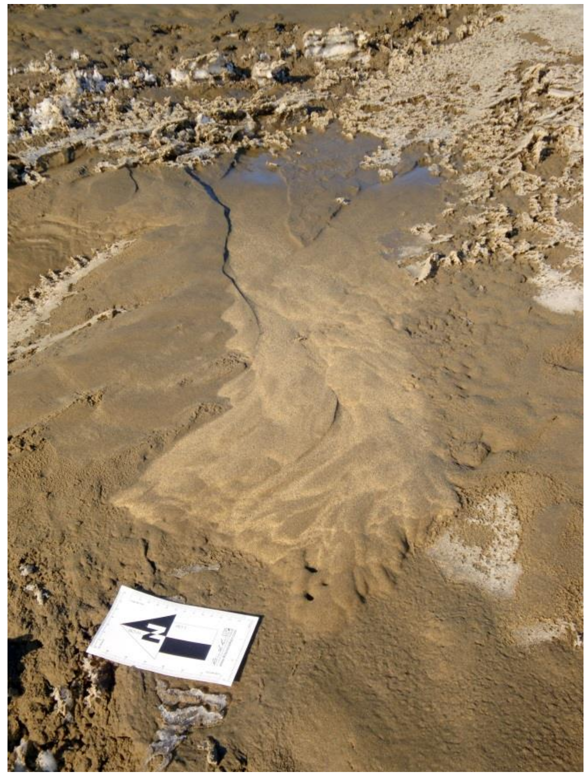

Fig. 1. GKSD debris flow, 25 March 2010. Scale is 10 cm.

Boundary Conditions: Atmospheric boundary conditions were developed based on 22+ years of Kavet Creek Remote Automated Weather Station (RAWS) data [8] and augmented with Bettles Field SNOTEL station solid precipitation data [9]. VADOSE/W ingests meteorological data records for: (i) daily maximum and minimum air temperatures; (ii) daily maximum and minimum relative humidities; (iii) daily mean wind speed, (iv) daily total precipitation; (v) optionally, it ingests daily net solar radiation; otherwise, it internally calculates daily net solar radiation based upon site latitude. The Kavet Creek RAWS data record includes only liquid precipitation, so a hybridized precipitation record (**Fig. 4**) was developed using Kavet Creek RAWS liquid precipitation [8] and appropriately scaled values of solid precipitation measured at the Bettles Field SNOTEL station [9].

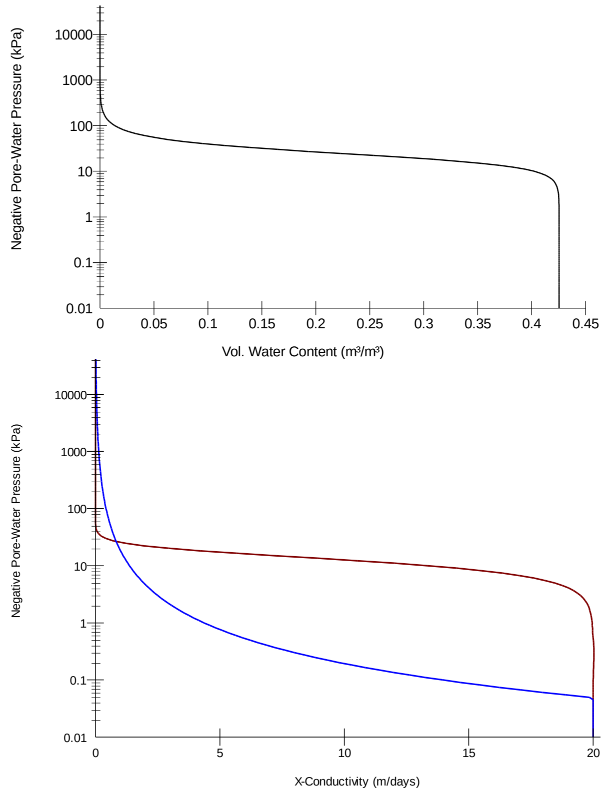

Fig. 2. GKSD sand hydraulic material properties (**black:** air–water soil moisture characteristic function; **red:** hydraulic conductivity function; **blue:** relaxed hydraulic conductivity function only used within upper 4 cm of sand to aid model convergence. Note that mean GKSD sand porosity is 42.5 percent.

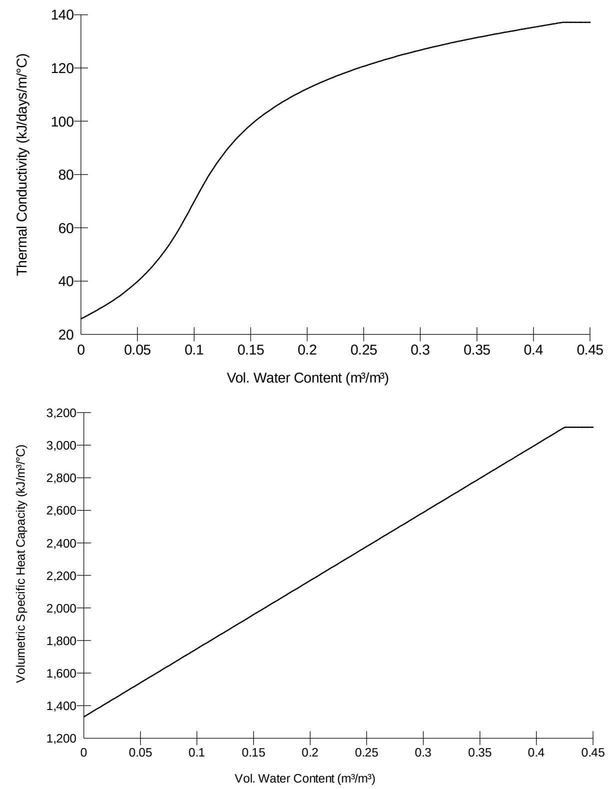

Fig. 3. GKSD sand thermal material properties.

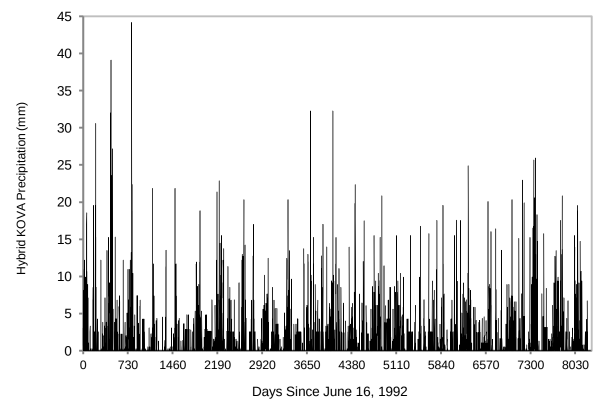

Fig. 4. Hybrid precipitation record for Kobuk Valley.

At the base of the model, unit hydraulic gradient and constant −0.2 °C thermal boundary conditions are applied, based on geophysical interpretations of [4].

Modeling Approach: A minimum sequence of four simulations will be run, with results from the former providing initial conditions for the next:

1. Develop steady-state pore-water pressure profile given constant 0.1 mm/yr input flux at dune surface.

2. Spinup subsurface equilibrium response to variable Kobuk Valley climate (22-yr simulation).

3. Simulate cryo-hydrologic response to climate from June 1992 until March 2010 (17-yr simulation).

4. Simulate March 2010 cryo-hydrologic precursor conditions incipient to debris flow events with high temporal resolution (~1-mo simulation).

Simulation results, analyses, and interpretations will be presented at the *4th International Planetary Dunes Workshop*.

References: [1] Hooper D. M. and Dinwiddie C. L. (2013) *Icarus*, *230*, 15–28. [2] Dinwiddie C. L. et al. (2012) *3rd Int'l Planet. Dunes Wkshp, LPI Contribution No. 1673*, Abstract #7034. [3] GEO-SLOPE International Ltd. (2012) *Vadose Zone Modeling with VADOSE/W: An Engineering Methodology*. Calgary, Alberta, Canada. [4] Dinwiddie C. L. (2014) *8th Int'l Conf on Mars*, Abstract #1256. [5] Dinwiddie C. L. et al. (2011) *LPS XLII*, Abstract #2501 [6] Becker B. R. et al. (1992) *Int'l Com in Heat and Mass Transfer, 19,* 59–68 [7] de Vries D. A. (1963) *Physics of Plant Environment.* Amsterdam, Netherlands: North Holland Publishing Co., 210–235. [8] Western Regional Climate Center (2015) www.raws.dri.edu/cgi-bin/rawMAIN.pl?akAKAV. [9] Natural Resources Conservation Service (2015) www.wcc.nrcs.usda.gov/nwcc/site?sitenum=1182.