Field Hydrologic Performance of Final Covers for High Elevation Mine Waste Containment

Craig H. Benson, PhD, PE, NAE

Wisconsin Distinguished Professor Emeritus
University of Wisconsin-Madison

Dean of Engineering Emeritus
University of Virginia

chbenson@chbenson.org

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Scientific Collaborators

William H. Albright and Brad Lyles
Desert Research Institute

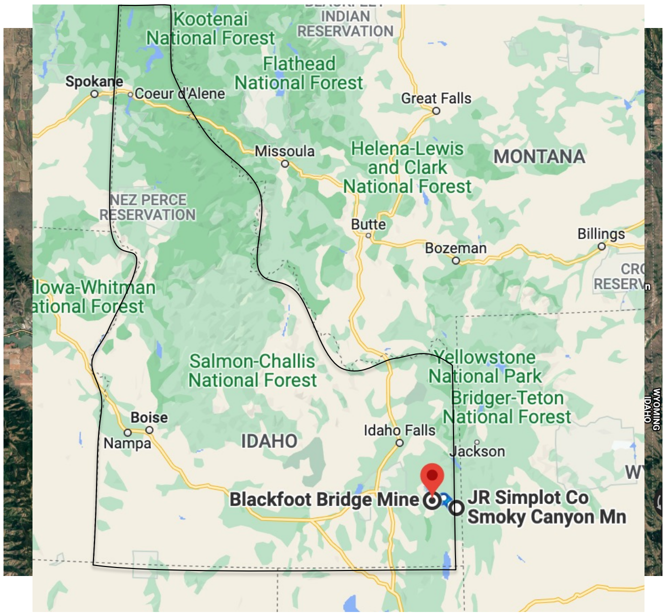
Preecha Apiwantragoon
Chulachomklao Royal Military Academy

Industrial and Government Collaborators

Bayer Corporation – Blackfoot Bridge Mine
Simplot Corporation – Smoky Canyon Mine
Idaho Department of Environmental Quality
US DOI Bureau of Land Management

Common interest in a vibrant and sustainable mining industry that is a good steward of the environment.

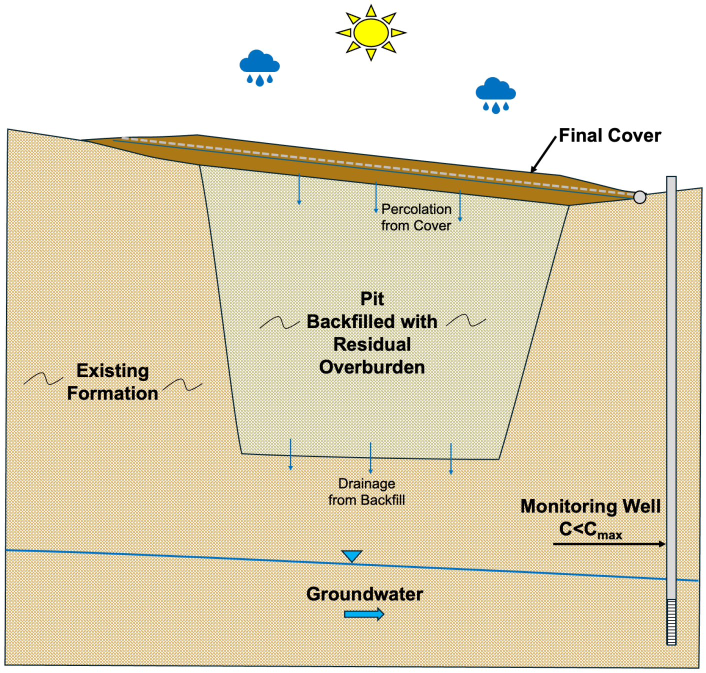
Mine Locations – Caribou Mountains in SE Idaho



Blackfoot Bridge (Soda Springs, ID)
Elevation = 1945 m
Precipitation: 354-725 mm/yr, 502 mm/yr (avg)

Smoky Canyon (Afton, WY)
Elevation = 2346 m
Precipitation: 370-914 mm/yr, 637 mm/yr (avg)

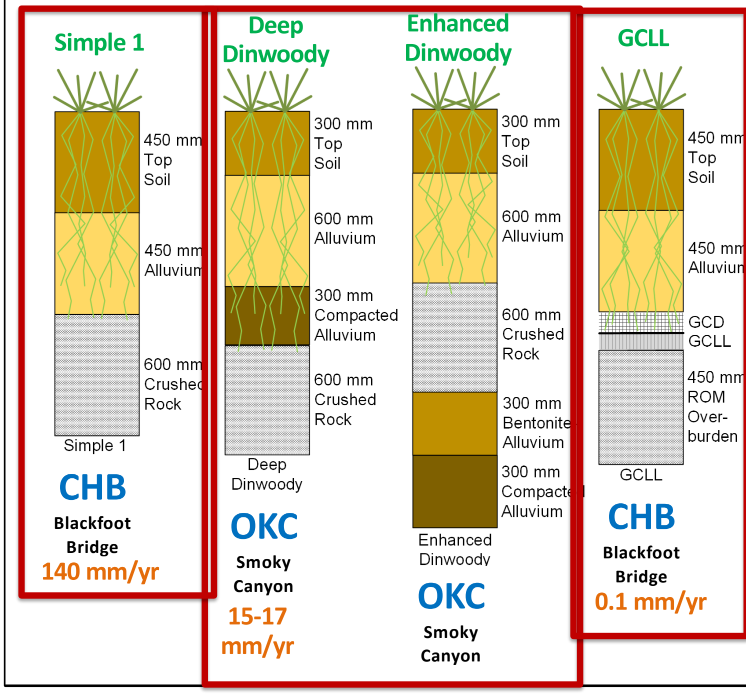
Smoky Canyon ≈ 135 mm wetter



Pit Backfill

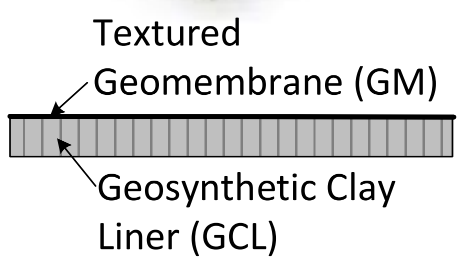
- Seleniferous residual overburden used as pit backfill.
- Control percolation rate into backfill to ensure release of Se to groundwater sufficiently low that Se concentration does not exceed maximum contaminant level (MCL, 50 μg/L) at point of compliance (POC).
- Geochemical controls (release of Se oxyanion) and hydraulic controls.
- Areas with higher Se loading require greater control, < 10-20 mm/yr percolation.

Cover Designs Being Evaluated



- **Three earthen covers** and **one geosynthetic cover**.
- Two earthen covers with **earthen hydraulic barrier layer**, one shallow and one deep.
- One **water balance cover** (*aka* **ET cover**) with a capillary break.
- One **geosynthetic cover** with a **laminated geosynthetic clay liner** (GCL with overlying geomembrane affixed), or GCLL, with geosynthetic drainage layer.
- Two evaluated by O'Kane Consultants (**OKC**) and two by presenter (**CHB**).

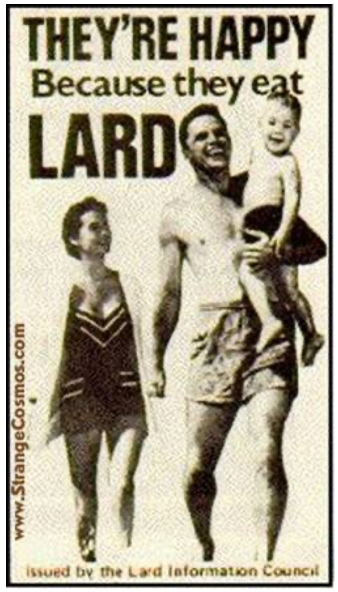
Laminated Geosynthetic Clay Liners (GCLLs)

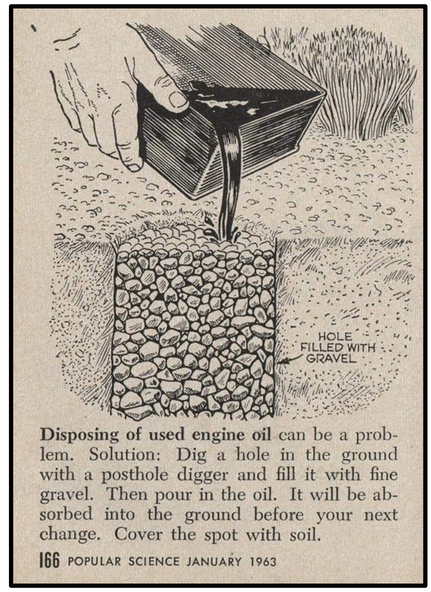


Objectives of Field Study

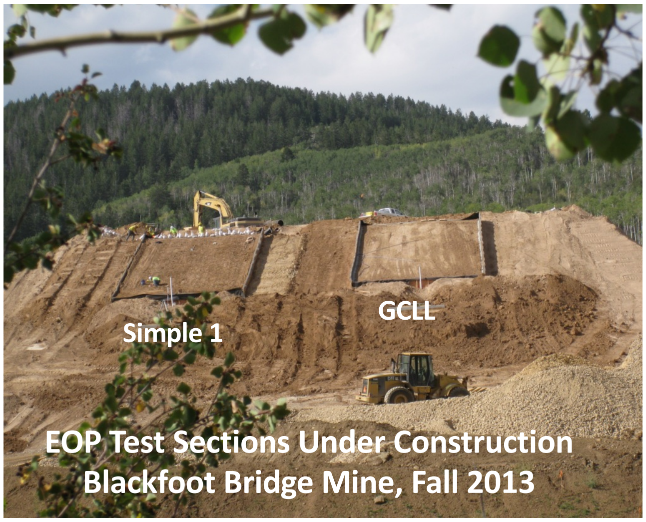
- Quantify **hydrologic control achieved with earthen and geosynthetic covers** over seleniferous pit backfill in SE Idaho.
- **Emphasis on percolation** - defined as flow from base of cover into pit backfill.
- What **percolation rates are achieved in the field? Consistent with predictions? Commitments in EIS?**
- Understand hydrology to improve design.

Why Conduct a Field Evaluation?
Perspectives and Beliefs Change Based on Data

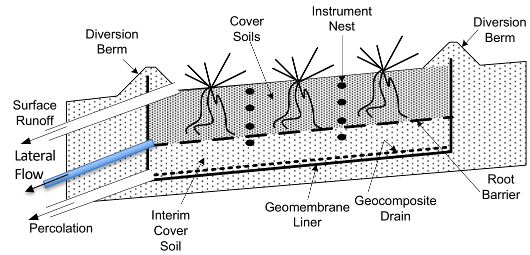




Lysimeters Used for Hydrologic Monitoring



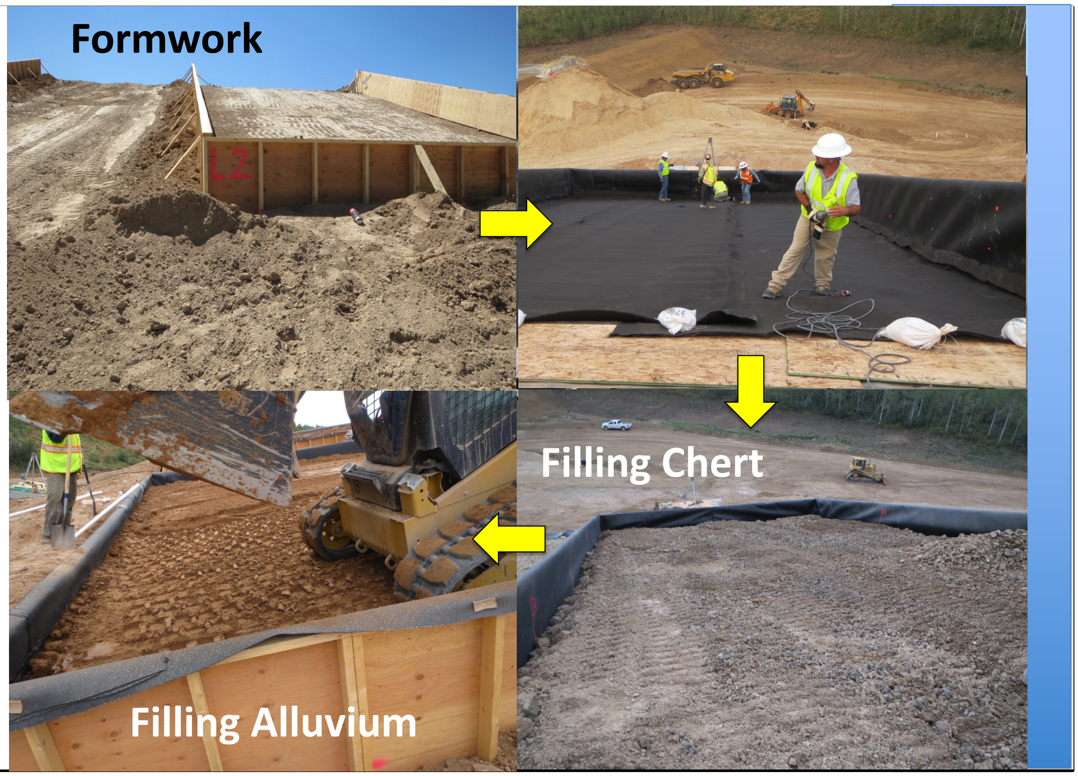
ACAP Drainage Lysimeters



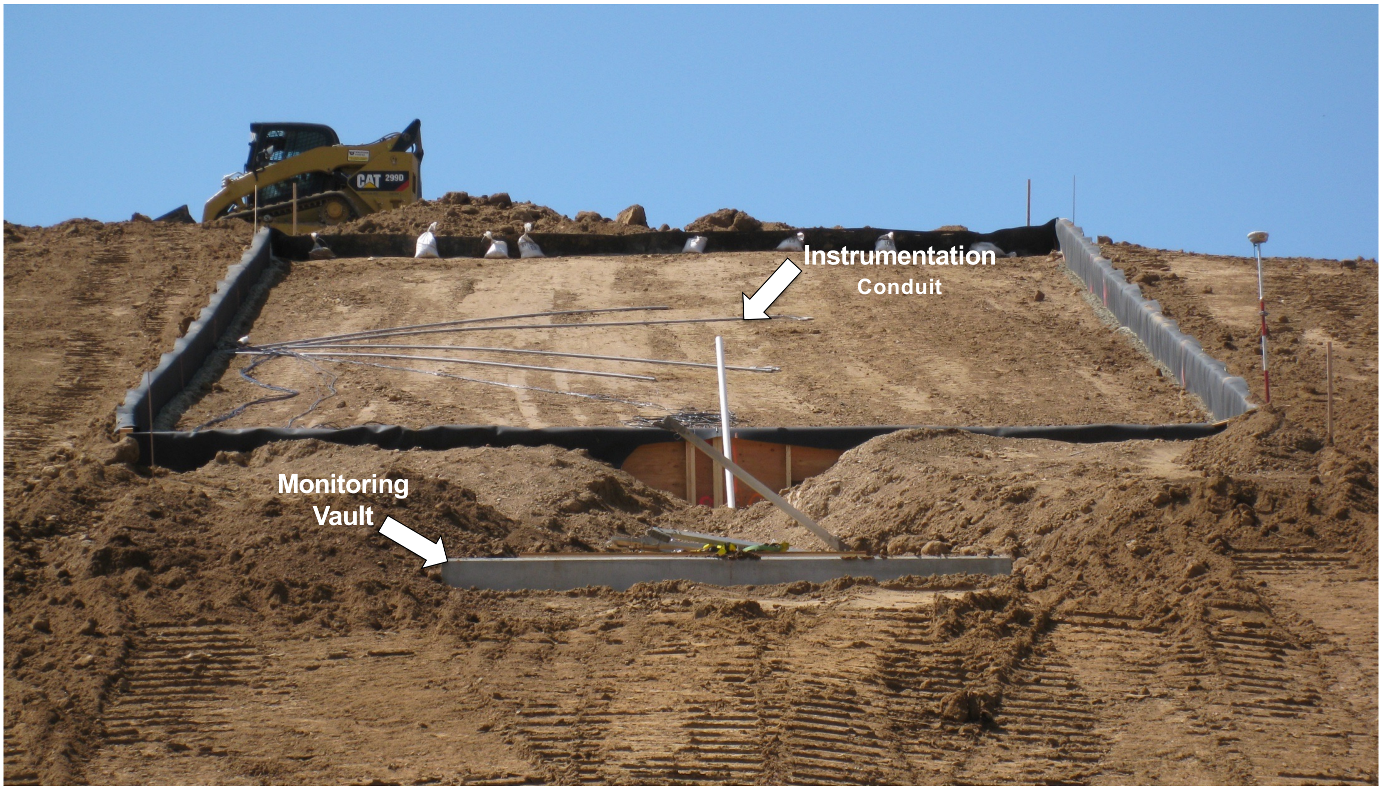
- **Directly measure all components of the water balance except for evapotranspiration (ET)**
- **ET computed by mass balance**

ET = Precip. – Runoff – Lateral Flow – Storage – Perc.

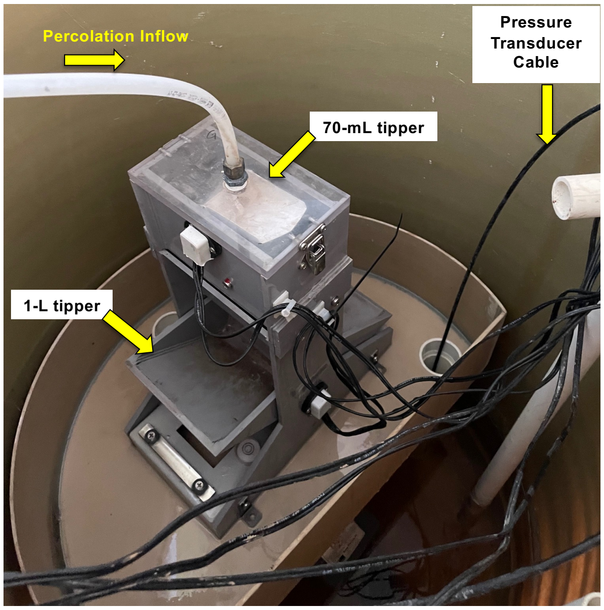
Simple 1
"Water Balance"
or
"ET" Cover
at
Blackfoot Bridge Mine

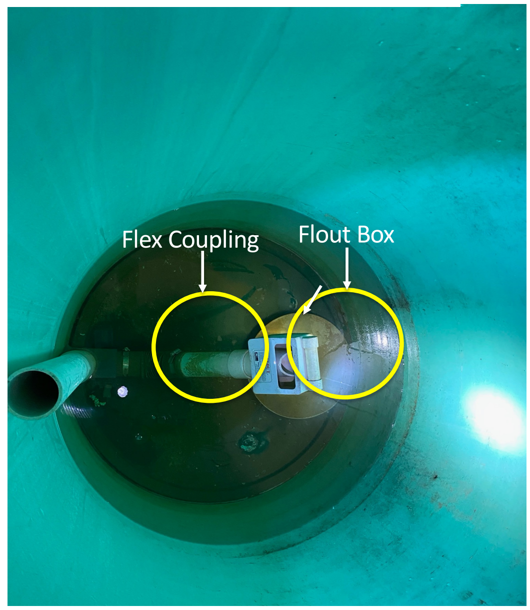


Built to Represent Full-Scale Condition


Instrumentation
Conduit
Monitoring
Vault

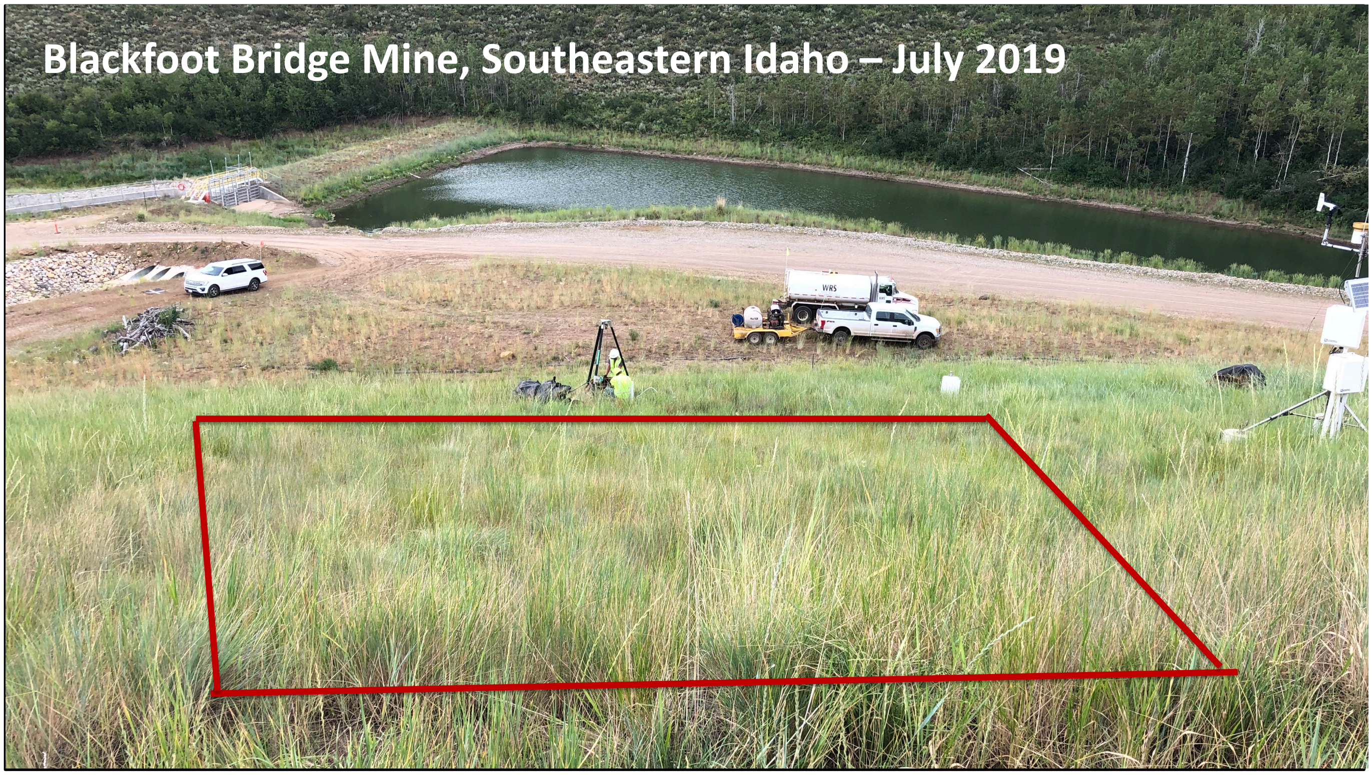
Flow Metering





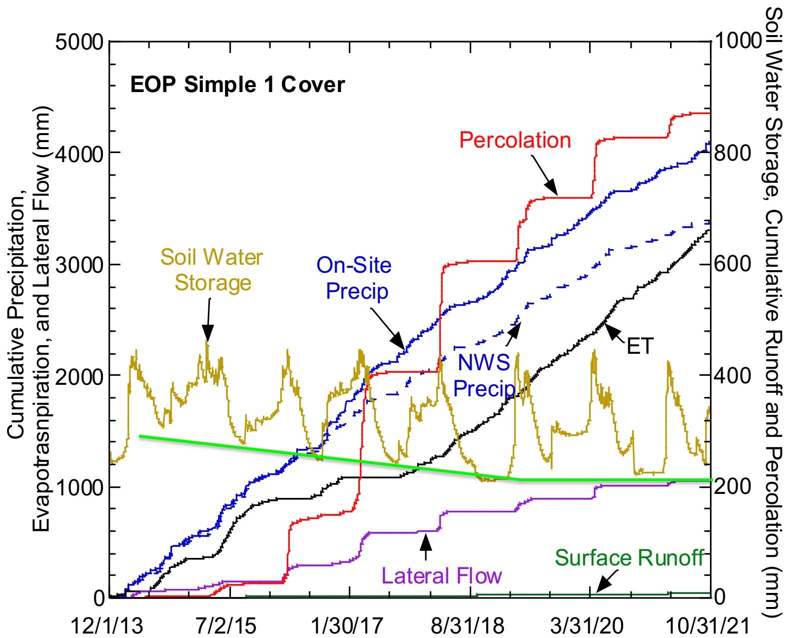
Percolation resolved to ≈0.1 mm/yr

“Flout” = floating outlet


Blackfoot Bridge Mine, Southeastern Idaho – July 2019
WRS

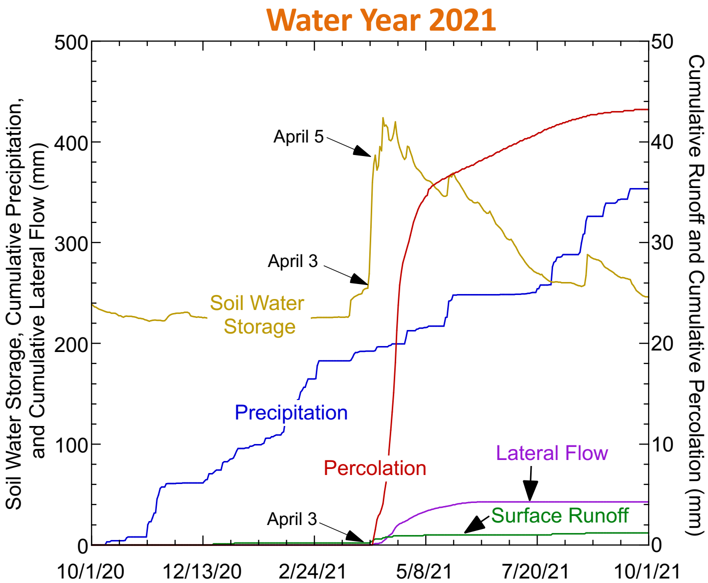

17 January 2023

Simple 1 Water Balance ("ET") Cover (< 140 mm/yr)



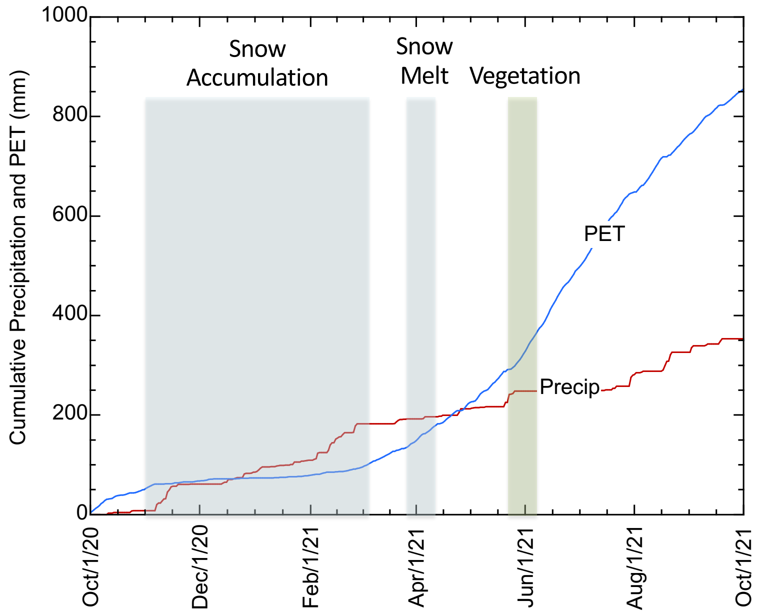
- Rapid snowmelt March and April, virtually no evapotranspiration.
- Runoff very small fraction of annual water balance (< 5%)
- Most water infiltrates, becomes **lateral flow on textural contrast, percolation, ET**
- Mature vegetation & rooting depth by 2018 (5 yr)
- Percolation ≈ **145 mm/yr**

Simple 1 Water Balance – Closer Look



- **Hydrology dominated by snowmelt.**
- Intense period of **snowmelt infiltration prior to plant transpiration**.
- Percolation and lateral flow in response to rapid increase in soil water storage during snowmelt.
- Runoff minor component of water balance - rough texture of surface and topsoil structure.

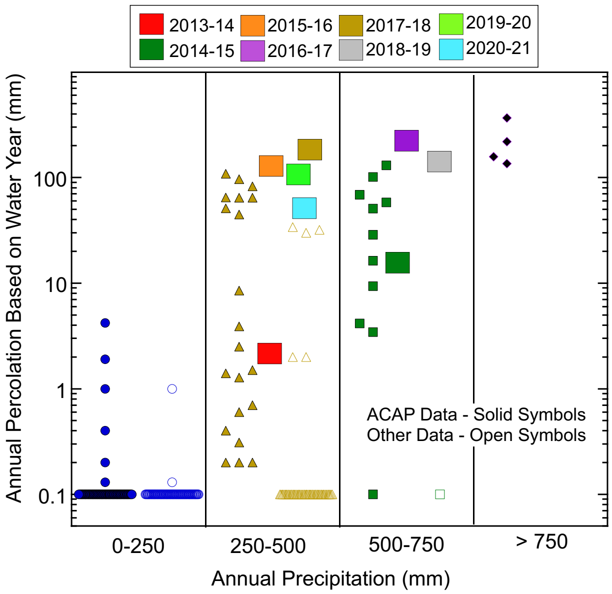
Precipitation and Potential Evapotranspiration (PET)

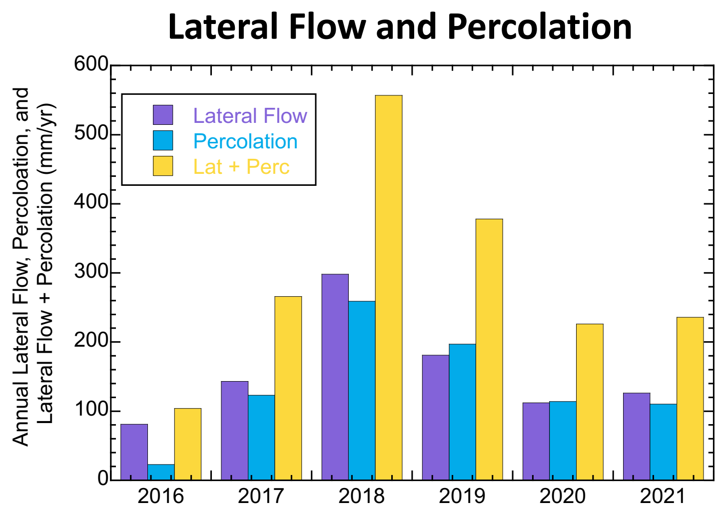


- Most of precipitation occurs before substantial energy available for ET.
- **PET in late March and early April induces snowmelt** (not ET).
- Large infiltration events in early April from snowmelt **before energy and plants available for ET**.
- Rapid increase in PET by June – July that supports vegetation to extract water.

Well-Developed Vegetation & Rough Surface

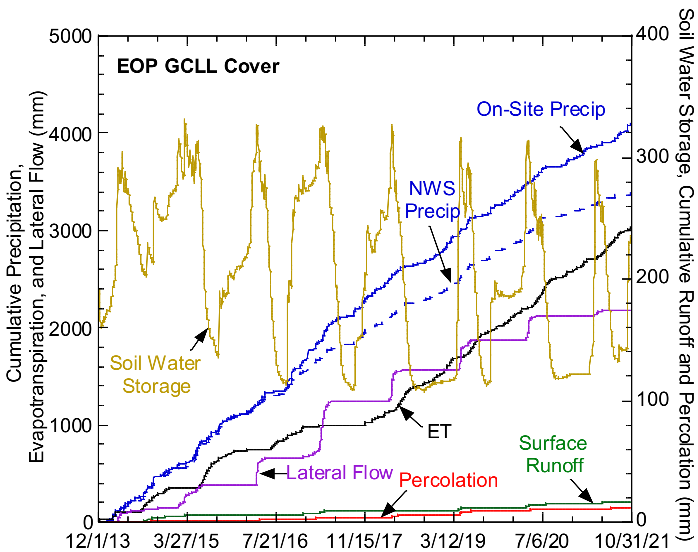
Simple 1 Percolation: Comparison with Other Data





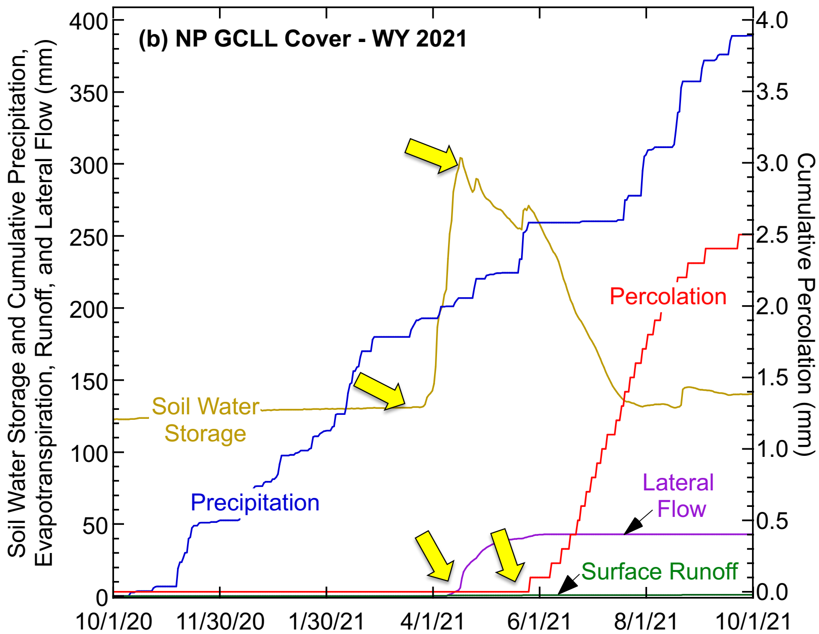
Lateral flow becomes percolation without take outs.

GCLL Water Balance: Blackfoot Bridge Mine



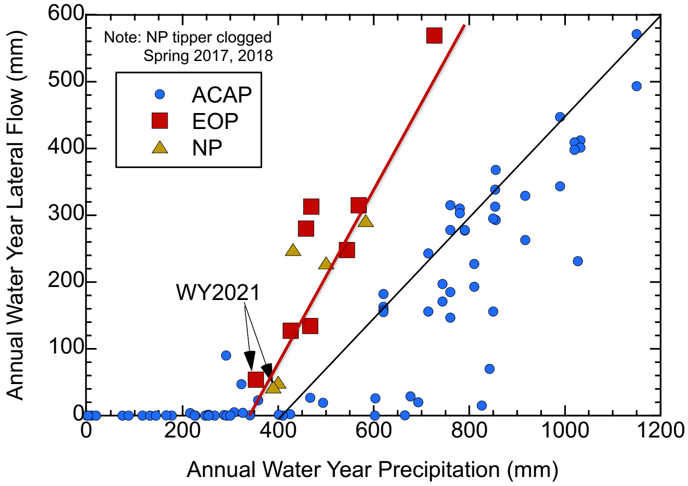
- Snowmelt in March and April, virtually no evapotranspiration.
- Runoff a very small fraction of annual water balance (< 5%)
- Most water infiltrates, becomes **lateral flow**.
- Percolation ≈ **2 mm/yr**

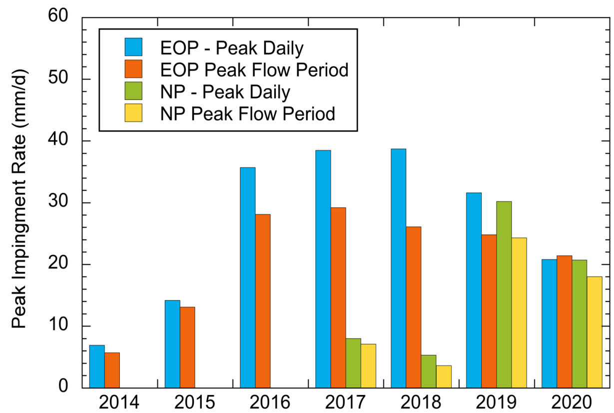
GCLL Water Balance: Closer Look



- Rapid infiltration of snowmelt and accumulation of soil water storage.
- Lateral flow begins as SWS approaches peak, followed by percolation.
- Percolation tailings to nil in September.
- WY21 perc: **2.5 mm**
- Avg: **3.0 mm/yr**

Comparing GCLL Water Balance Quantities: Lateral Flow

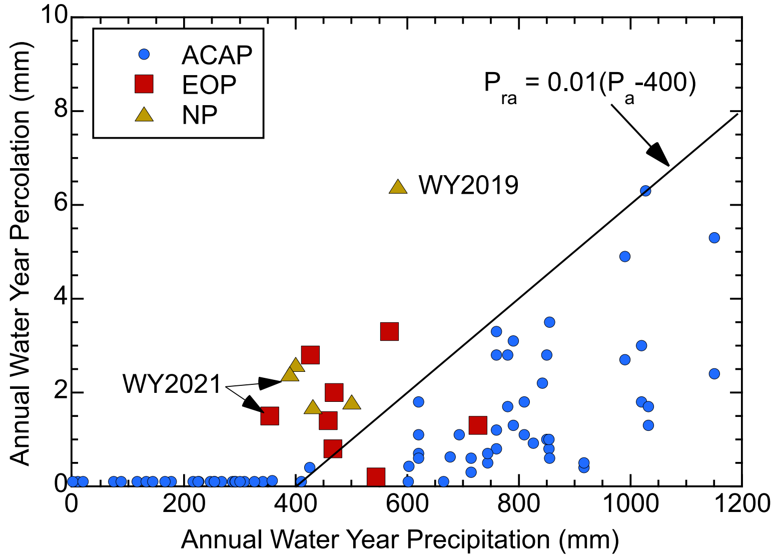




Impingement rates and lateral flow rates higher than anticipated!

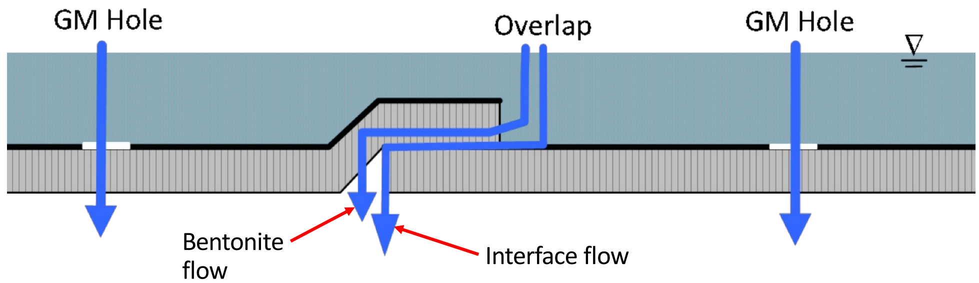
Need high capacity geocomposite drain!

Comparing GCLL Water Balance Quantities: Percolation



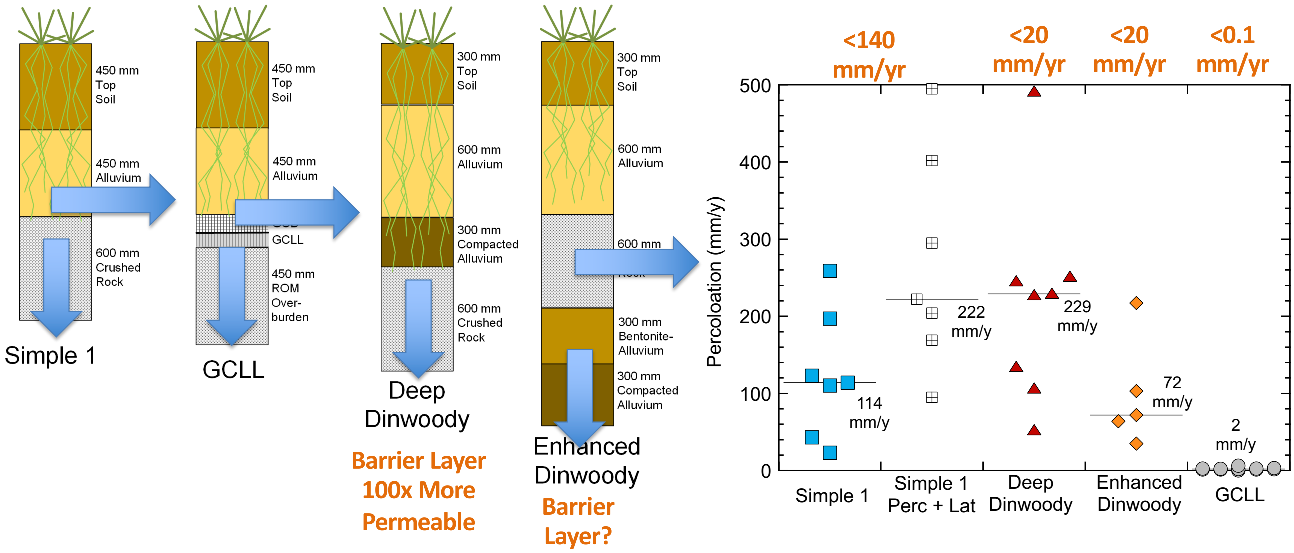
- Percolation modestly higher than ACAP and other data.
- WY2019 anomaly due to "double shot."
- E. Overburden Pit: **1.7 mm/yr**
- North Pit: **3.0 mm/yr**

GCLL Cover – Leakage Processes



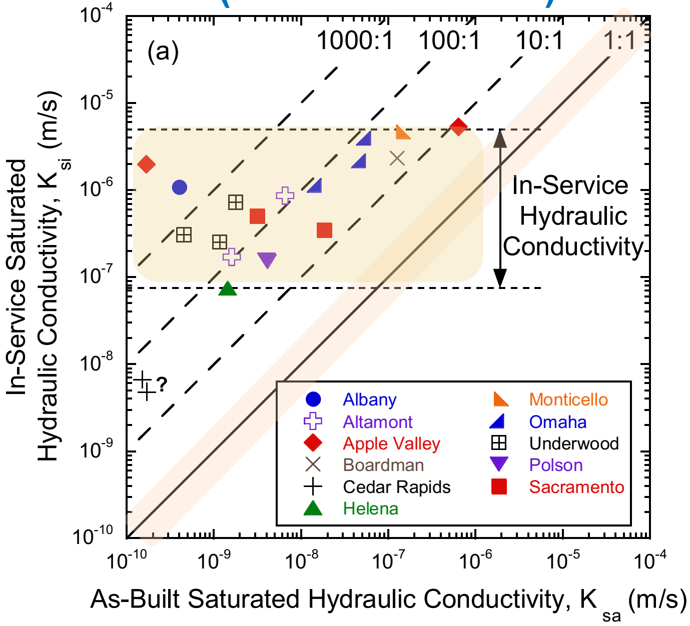
- Flow through defects/holes in geomembrane
- Flow through the overlap of panels
  - bentonite component
  - Interfacial component

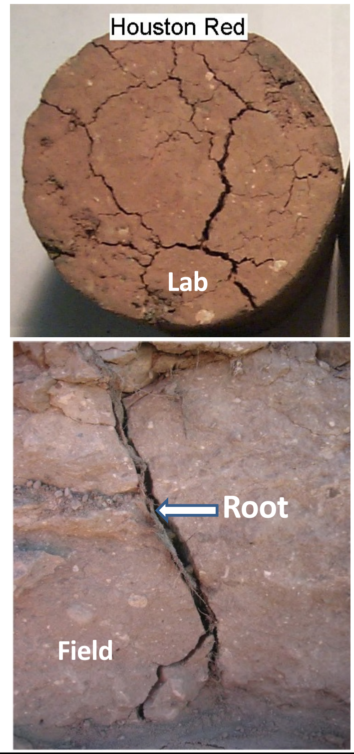
Cover Performance Comparison by Cover Type



Very low percolation rates difficult to achieve without a geosynthetic barrier

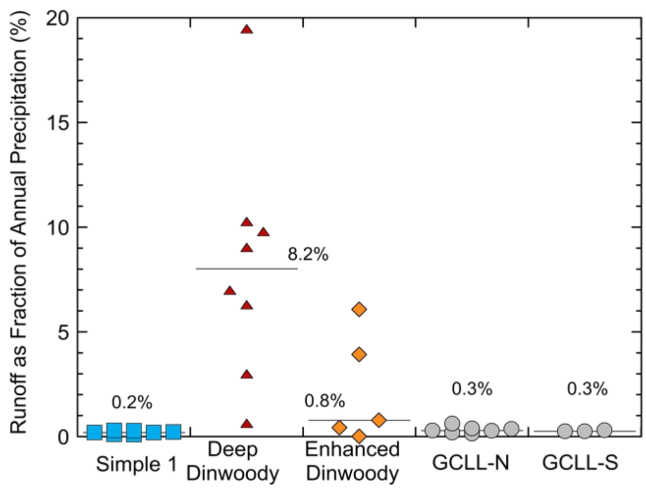
Pedogenesis in Barrier Layers (NUREG/CR-7028)





Benson, C., Albright, W., Fratta, D., Tinjum, J., Kucukkirca, E., Lee, S., Scalia, J., Schlicht, P., Wang, X. (2011), Engineered Covers for Waste Containment: Changes in Engineering Properties & Implications for Long-Term Performance Assessment, NUREG/CR-7028, Office of Research, US Nuclear Regulatory Commission, Washington, DC.

Surface Runoff: Small Fraction of Water Balance

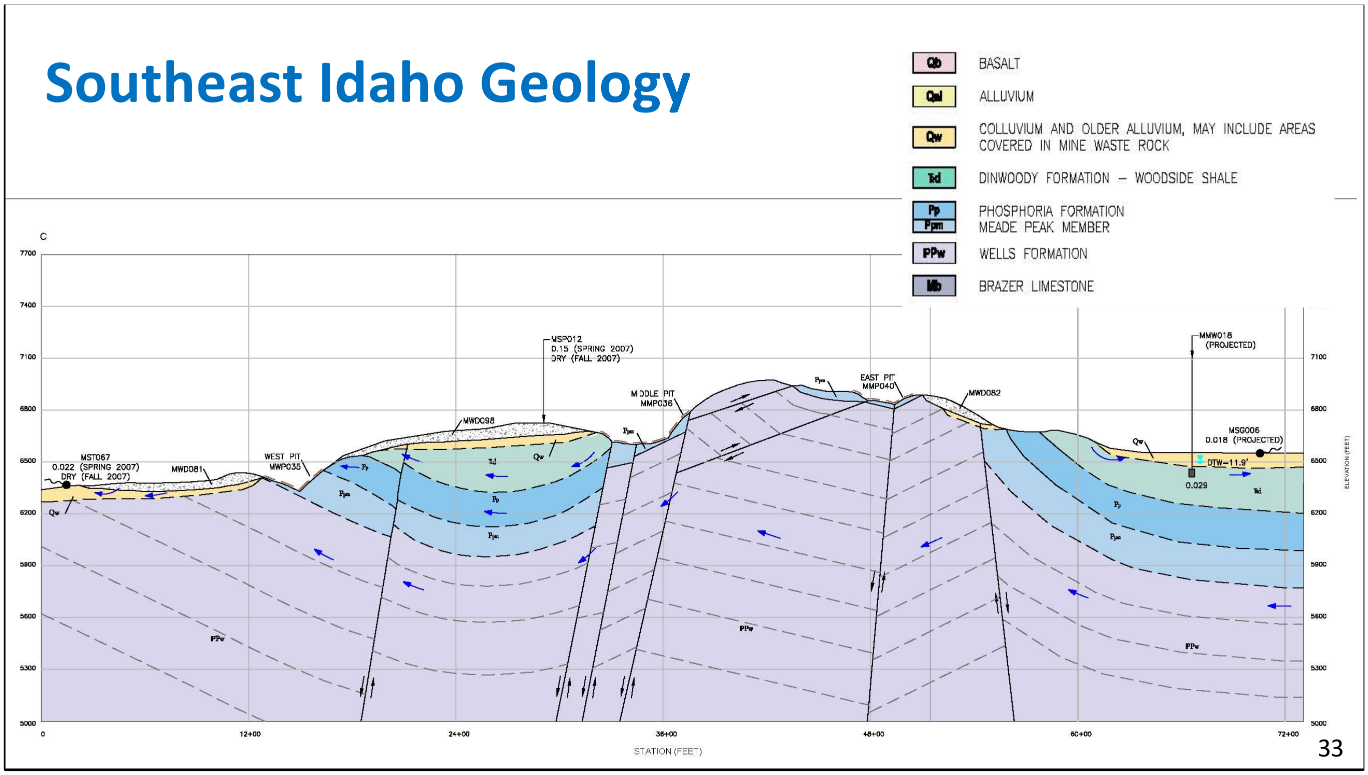


Designing to "**maximize runoff**" is **unrealistic ,** **inconsistent** with natural hydrology, **unsustainable.**

Lessons Learned

- Cover design driven by snowmelt hydrology – difficult to manage the water. Rapid infiltration and redistribution.
- Difficult to achieve very low percolation rates with earthen covers. Earthen barriers develop structure quickly. 100-1000x more permeable. Very low percolation rates require geosynthetics.
- Lateral drainage rates high with geosynthetic barriers. Difficult to design and source geosynthetic drainage layers to manage impingement (≈ 40 mm/d).
- Runoff is a very small fraction of water balance, < 5%.
- Manipulating water balance of earthen covers difficult, likely not sustainable – lateral takes outs on ET cover? Optimized runoff? Use caution and create sustainable design.

EXTRAS



Add geology key to each of x-section slides

This section across the mine shows several fault blocks offsetting the bedrock units with the topographic high of the Wells Fm.

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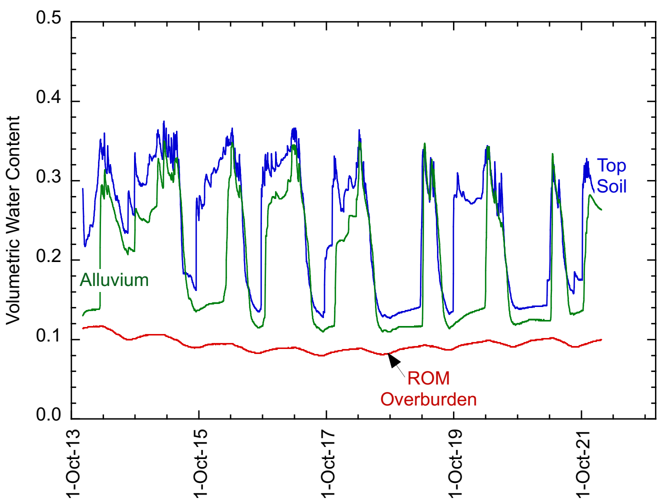
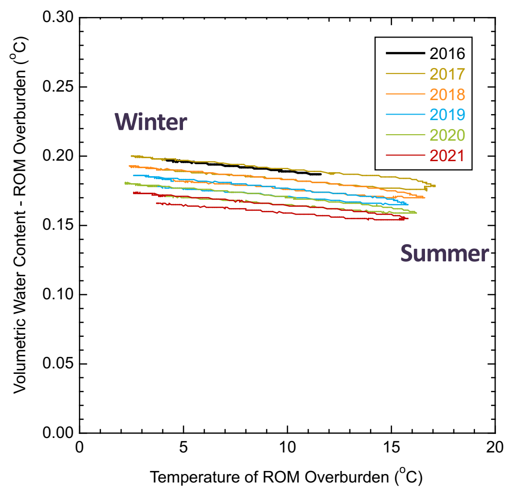
Recharge for the west side is in the area of middle pit MMP036. Seeps and springs discharge from the east highwall of West Ballard Pit and Wells Fm underlies this pit. We will discuss the Wells Fm beneath the West Ballard Pit in more detail in future meetings.

On the east side the strat sequence is believed to be more continuous until the Slug Valley fault to the east along Wooley Valley drainage.

Water Contents Above & Below GCLL: Thermally Driven Flows

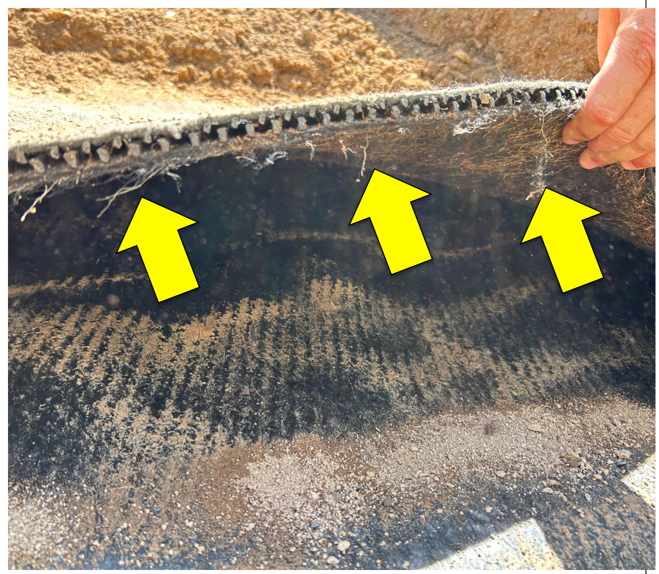




Sampling and Inspection of GCD

Few Roots in Interior of GCD

Roots on Lower Surface of GCD



Lower Surface GCD, Upper Surface GCLL

Root Covered Lower Surface GCD

Moist Upper Surface GCLL

Properties of In-Service GCD and GCLL

Test Pit	GCD Transmissivity (m^2/s)	GCL and Subgrade			
		Subgrade Water Content (%)	GCL Water Content (%)	Swell Index (mL/2 g)	Hydraulic Conductivity (cm/s)
TP-NP-U	$2.0x10^{-3}$	21.5	50.9	17	$4.2x10^{-9}$
TP-NP-M	$2.2x10^{-3}$	12.5	40.4	16	$2.5x10^{-9}$
TP-NP-L	$1.9x10^{-3}$	16.7	44.3	16	$2.3x10^{-9}$
New in Field	$1.7x10^{-3}$	-	-	~30	$1\text{-}4x10^{-9}$

New GCD required to have $T \geq 9x10^{-4}$ m^2/s for FS = 14.8. All GCD samples meet requirement.

GCD and GCLL have properties comparable to new product and were in "like new" condition when sampled.