Long-term Results of Cover System Monitoring in Semi-arid Western USA

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Themes

- Cover characteristics that contribute to cover system performance
  - Cover and waste material
  - Cover material depths/ layering
  - Slope aspect/ position
- Factors affected by cover system characteristics
  - Vegetation type and density
  - Salinity/ pH migration
  - Net percolation through cover system
- Importance of long-term monitoring, particularly in the semi-arid Western, US

Barrick Goldstrike AA Leach Pad

- Cover material
- Slope position
- Slope aspect

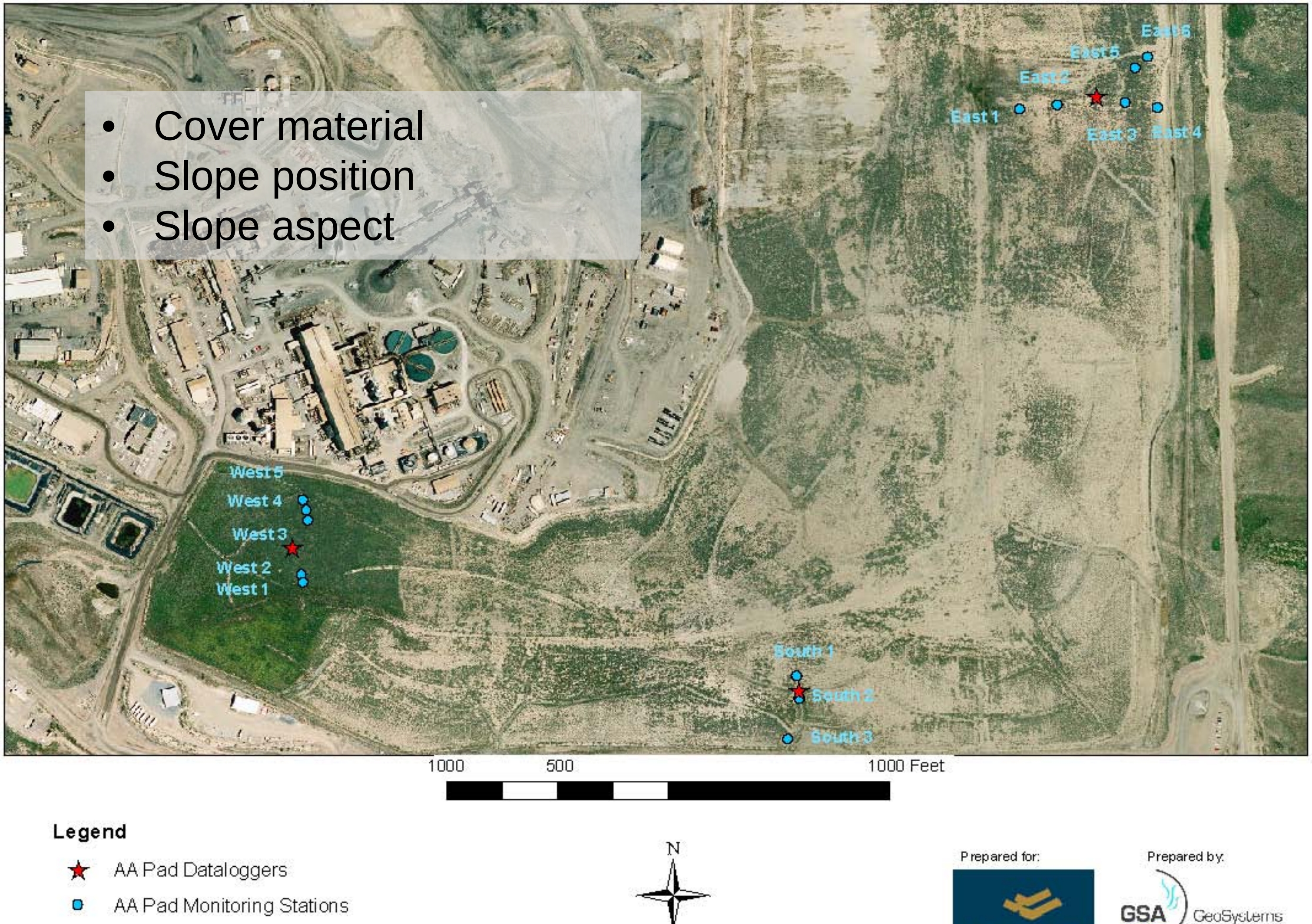
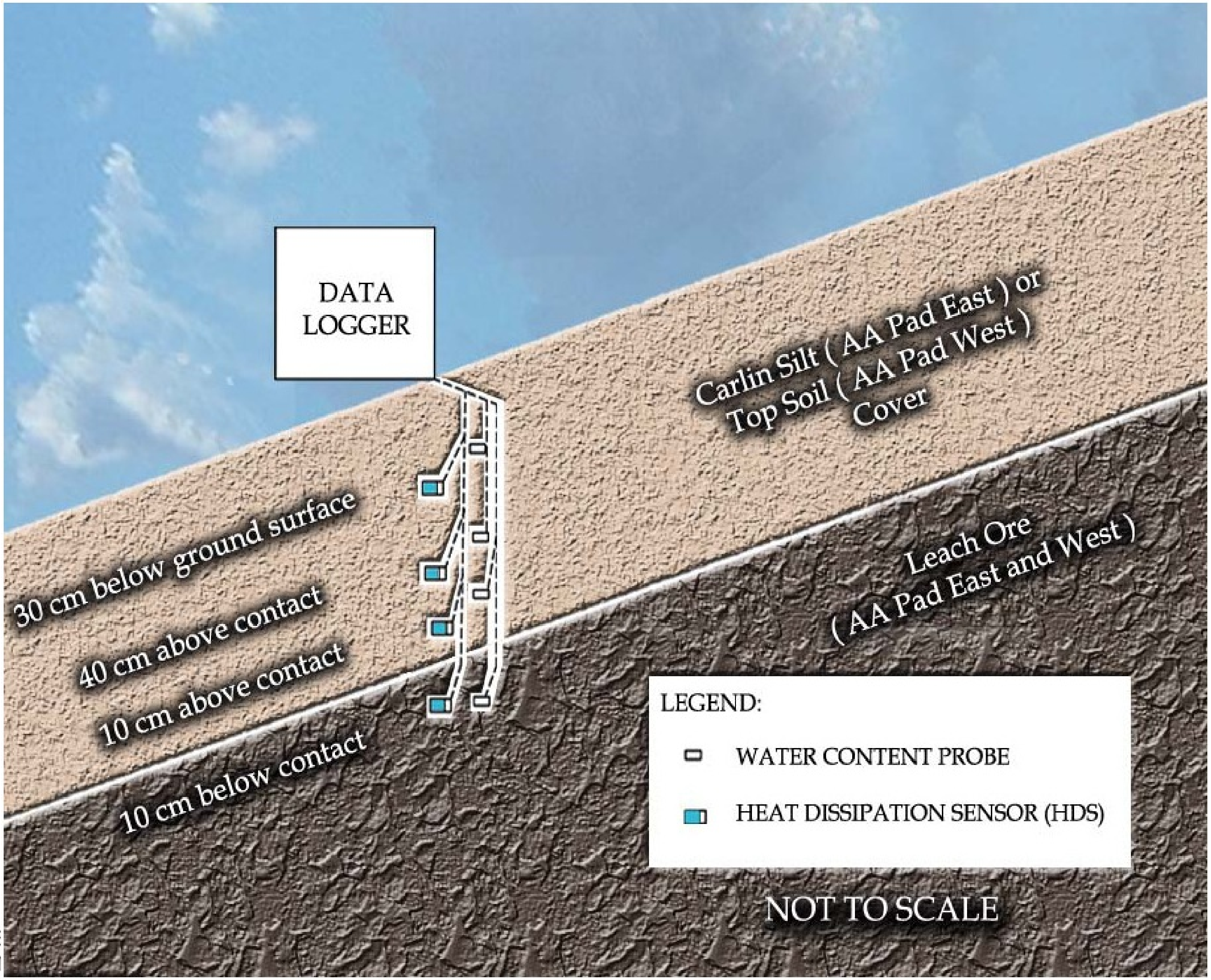


Figure 2. Monitoring sites at AA Pad

Monitoring Stations



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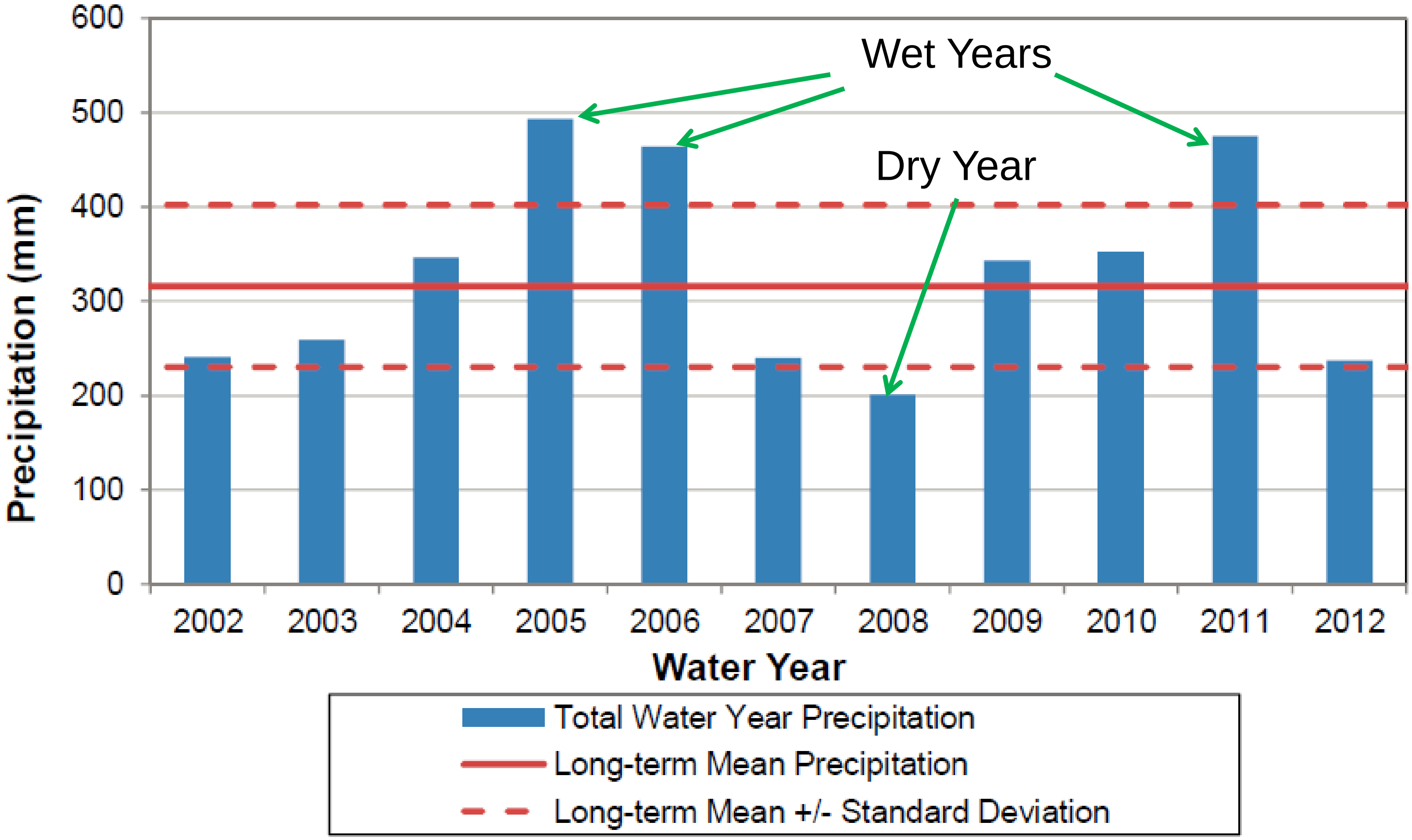
Precipitation



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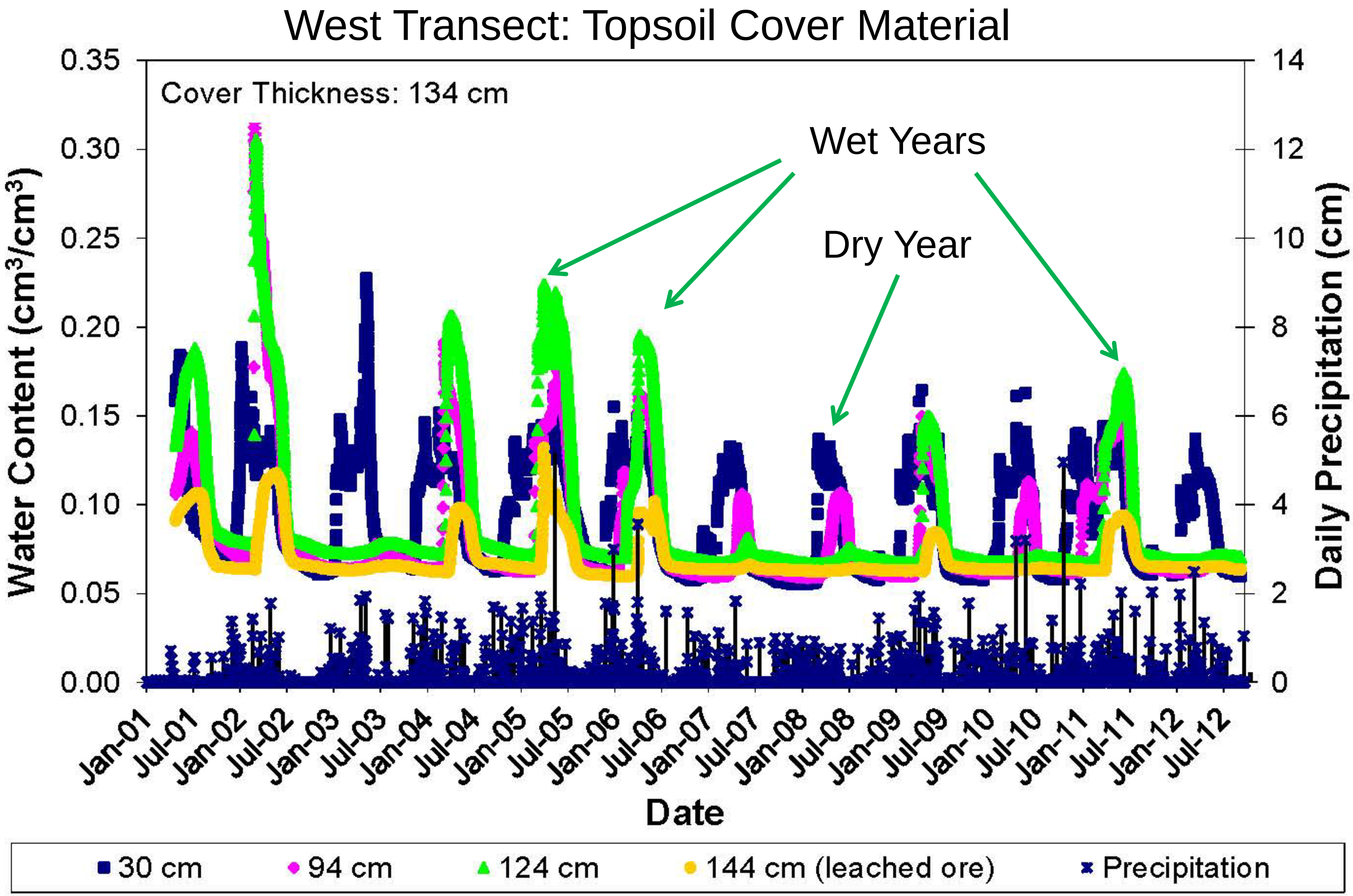
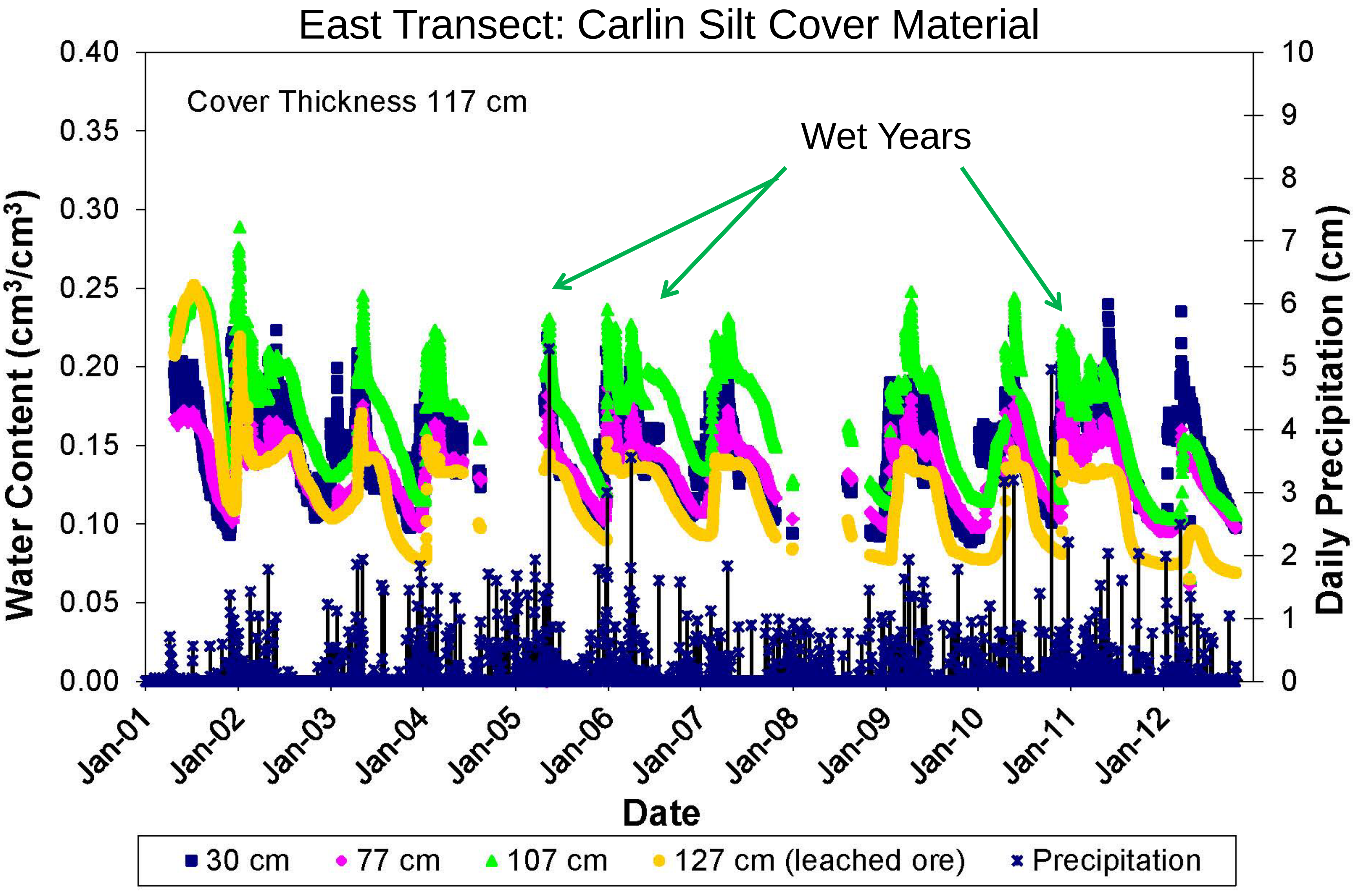
Water Content Data



Water Content Data



Effective Water Holding Capacity

Location	Cover Thickness (cm)	Estimated Plant-Available Water (cm)
Carlin Silt Cover		
East 1 (Crest)	94	7.8
East 2 (Mid-slope)	117	8.7
East 3 (Mid-slope)	119	11.0
East 4 (Foot-slope)	110	7.7
East 5 (2nd Order Channel)	91	8.2
East 6 (1st Order Channel)	92	7.7
East Transect Average	**104**	**8.5**
Topsoil Cover		
West 1 (Crest)	130	16.3
West 2 (Mid-slope)	134	10.5
West 3 (Mid-slope)	150	13.3
West 4 (Mid-slope)	160	14.1
West 5 (Foot-slope)	150	24.9
Topsoil Average	**145**	**15.8**

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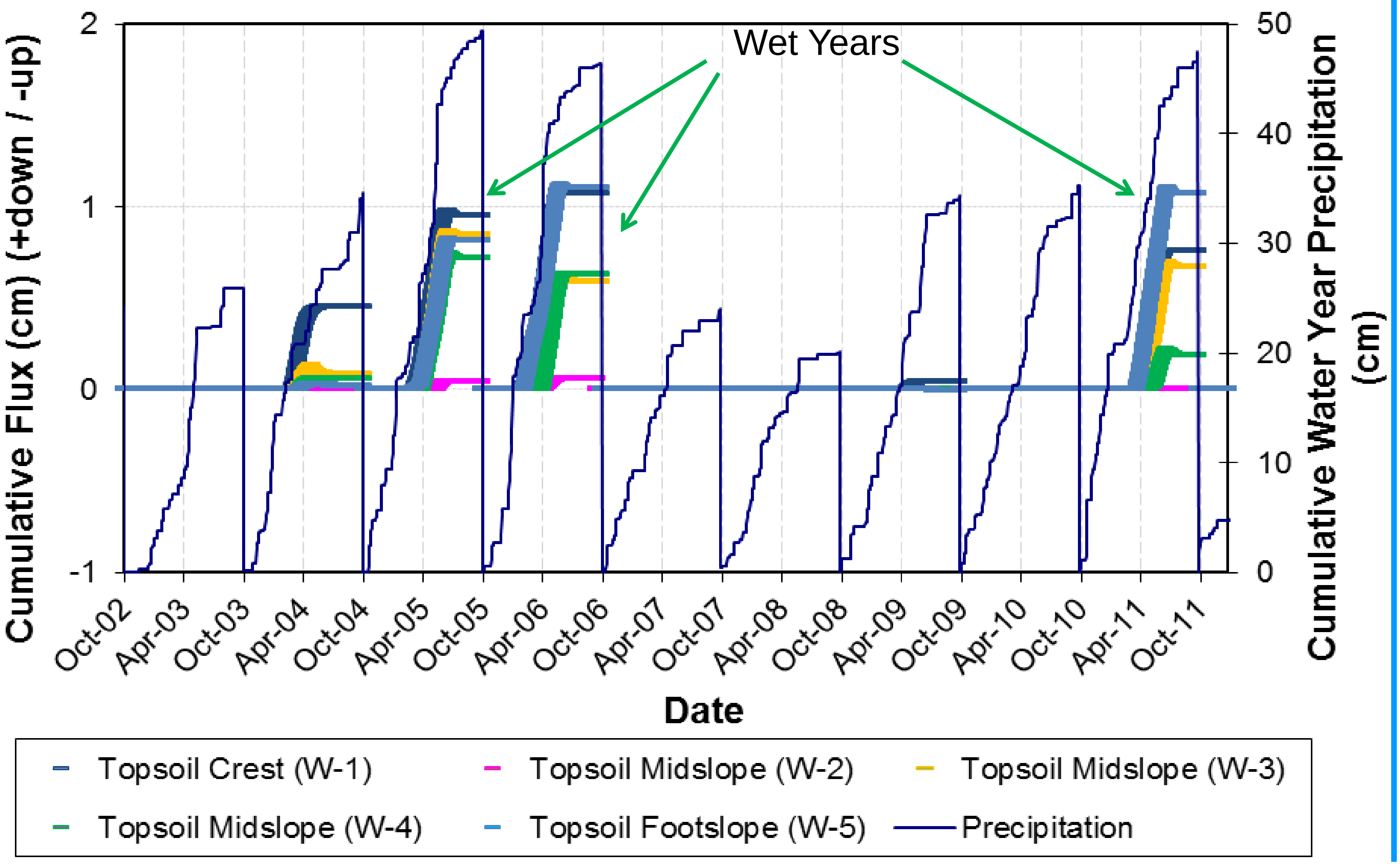
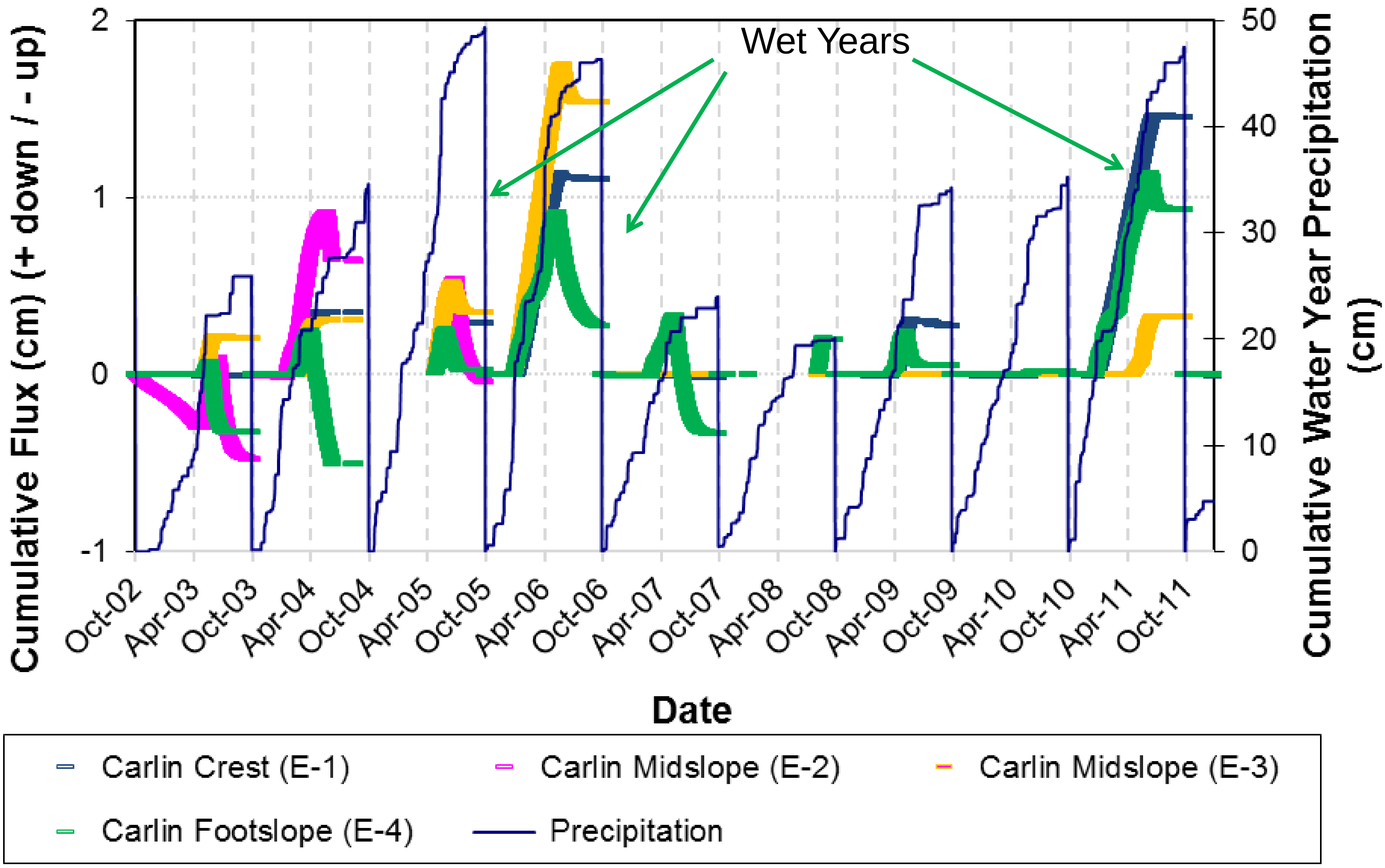
Matric-potential-based (MPB) Flux



Matric-potential-based (MPB) Flux



Decommission - Root Density

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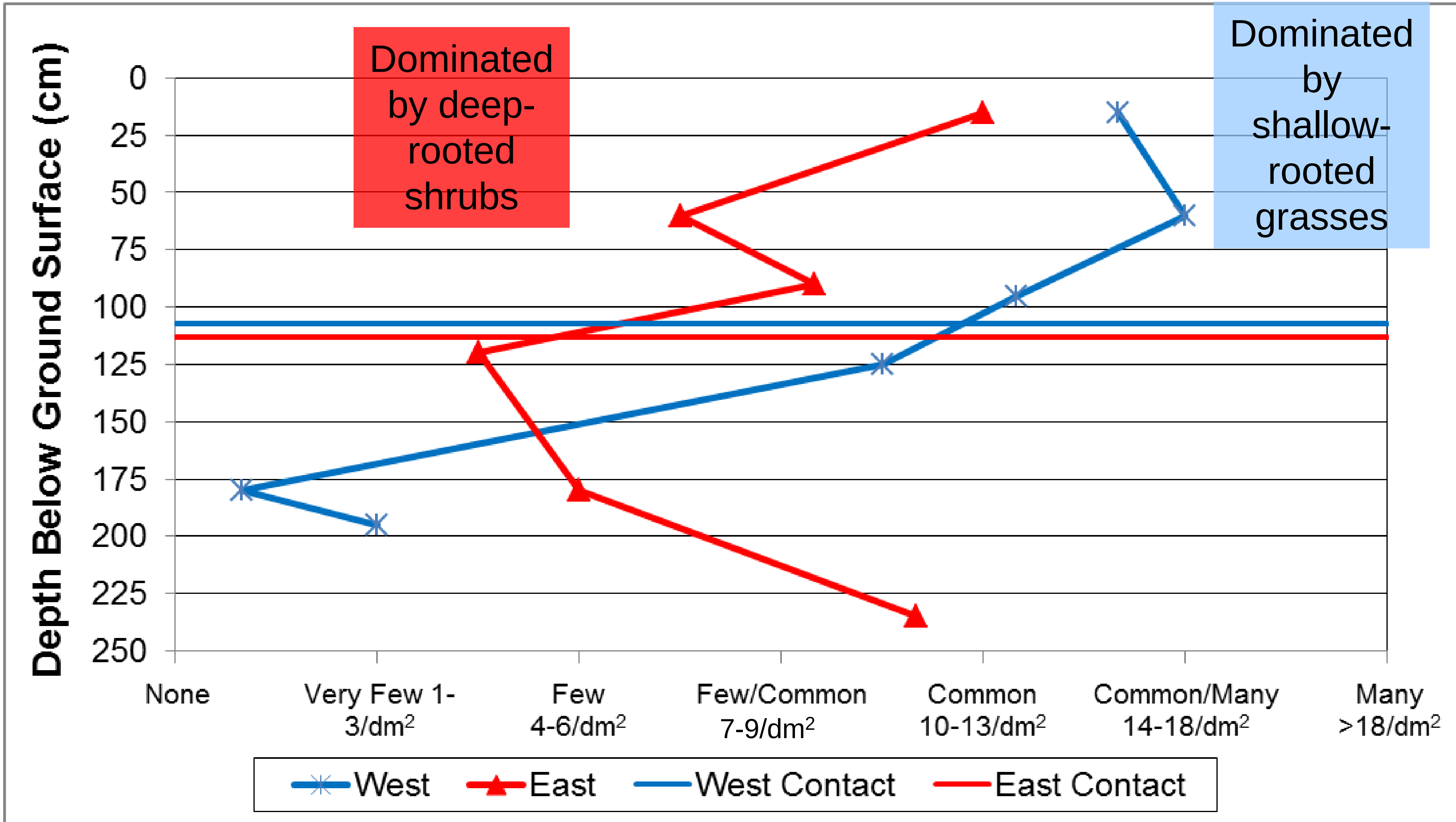
Decommission - Root Density



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Average Annual Flux by Solar Aspect

Station	Water Years 2003-2012	
	Average Annual Flux (cm)	Average Flux as % of Precipitation (%)
South Carlin Silt Average	0.02	0.08
West Topsoil Average	0.21	0.62
East Non-Channel Carlin Silt Average	0.23	0.67
Channel Carlin Silt East Average	1.09	3.21

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Estimated Flux by Slope Position

Slope Position	Area (hectares)	Percent of Total Area	Average Estimated Annual Flux (cm)	In-Situ K_{sat} Area-Weighted Average Flux (cm/yr)
Crest	16.4	17%	0.21	0.04
Mid-slope	66.3	69%	0.12	0.08
Foot-slope	8.1	8%	-0.13	-0.01
Channels	4.8	5%	0.81	0.04
Total	95.6	100%		**0.15**

Less than 1% of precipitation

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AA Pad Conclusions

- Percolation rates are lower on south-facing slopes
- Percolation rates near the channel are higher.
- Percolation mainly occurs in wet years. Multiple years of monitoring are necessary.
- Rooting is not limited to cover material.
- Percolation is less than 1% of precipitation during the 11 years of monitoring period.

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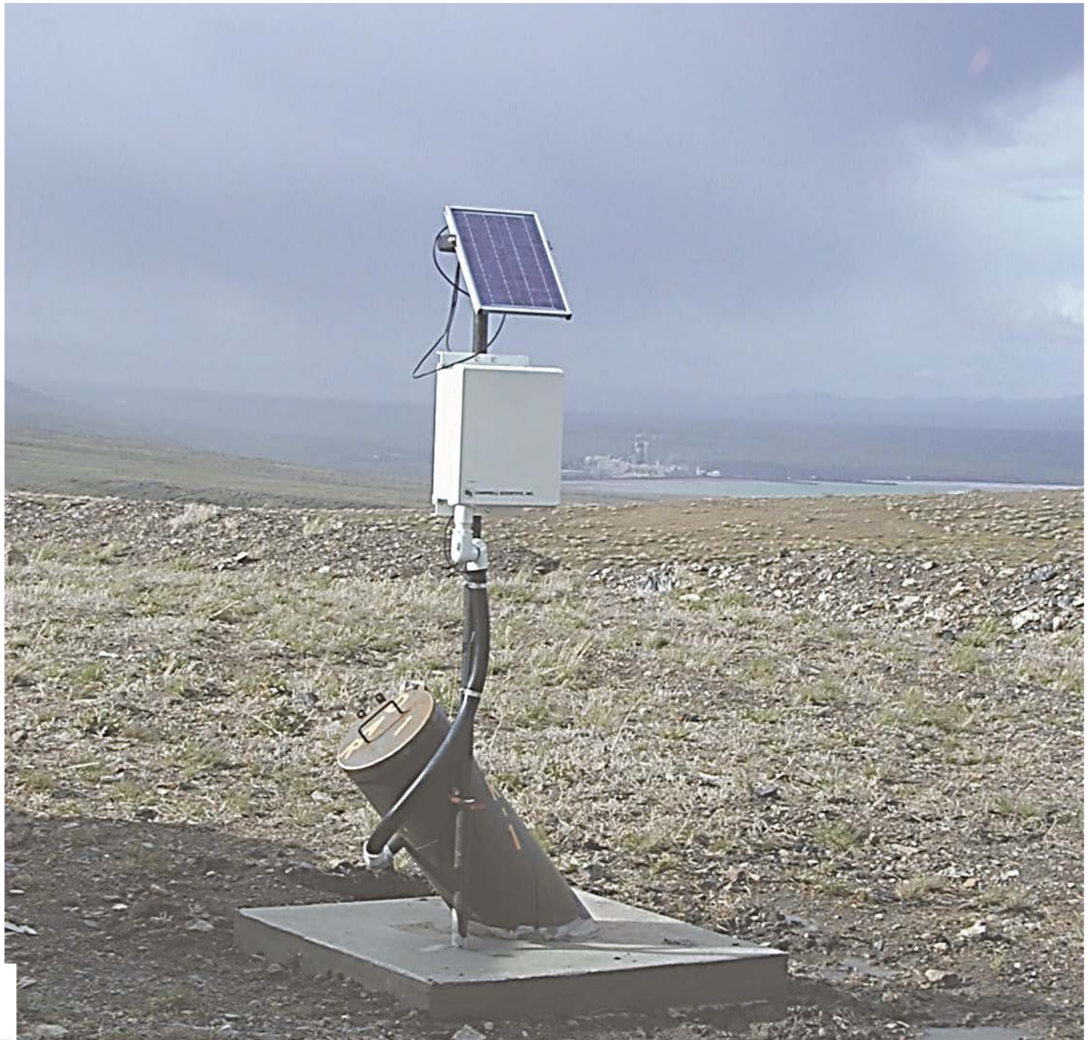
Jerritt Canyon
Evolution Monitoring Wells



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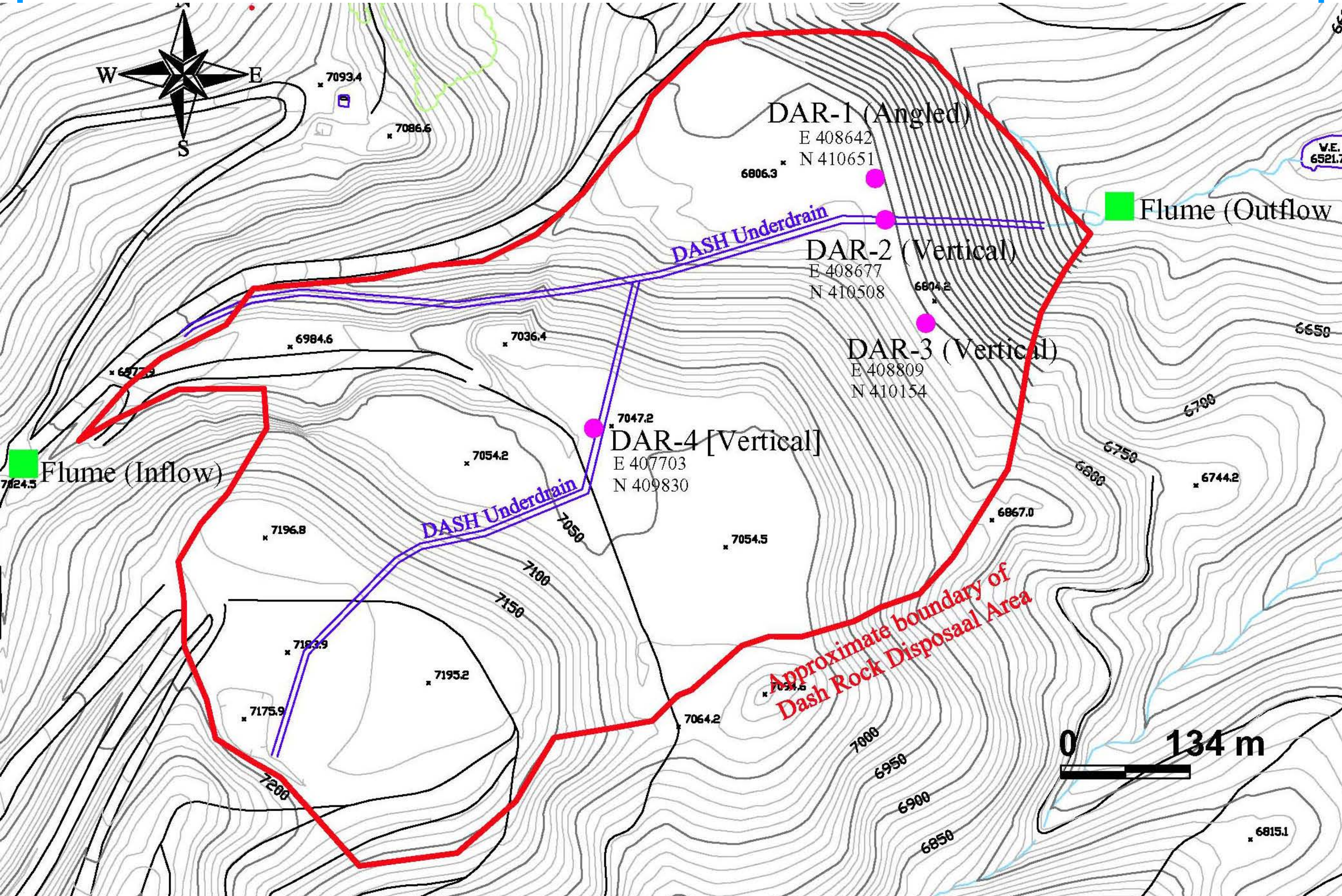
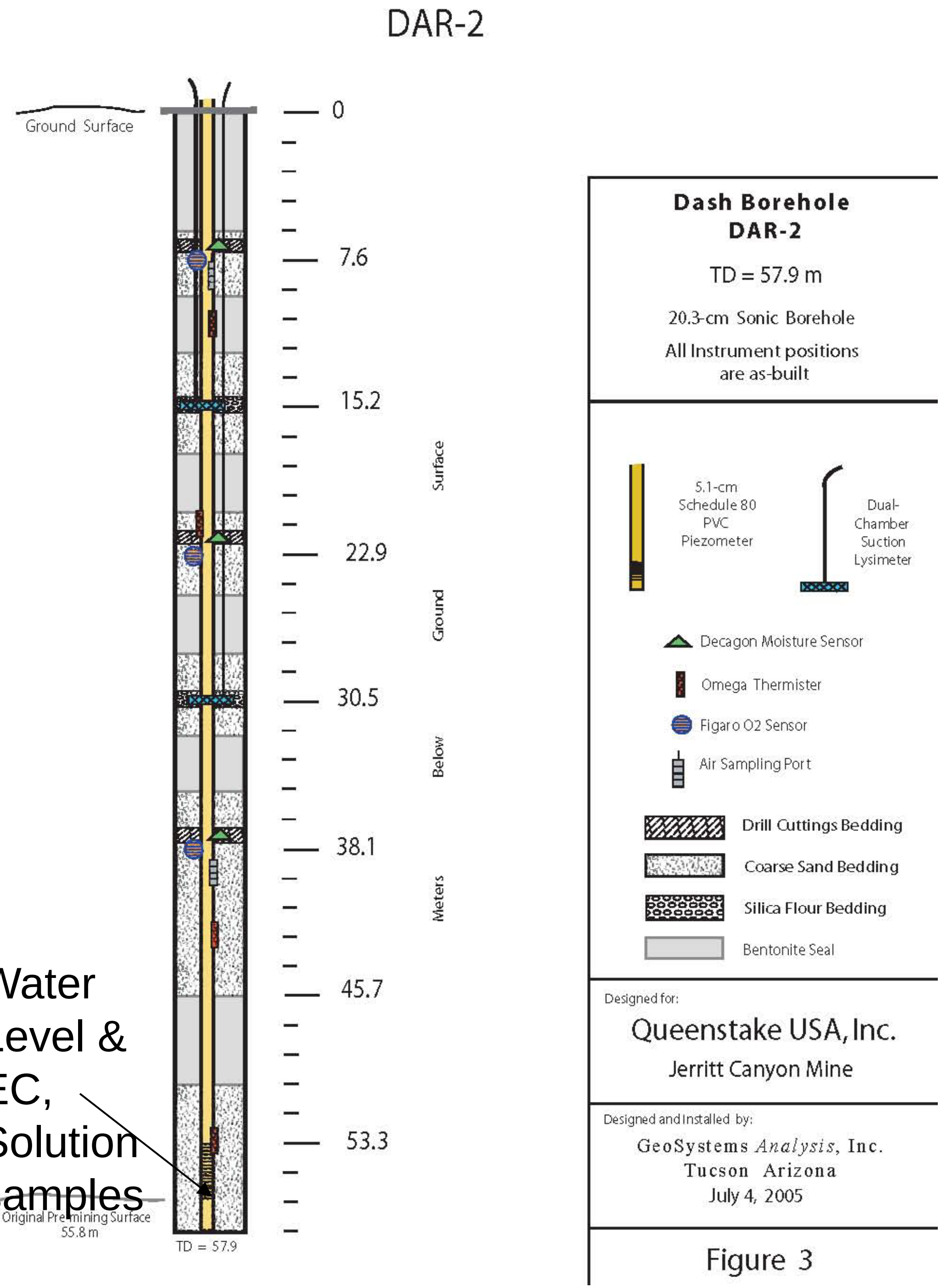
DASH Waste Rock Disposal Area

- Approximately 112 acres, High ANP/Low AGP waste rock
- Reclaimed with approximately 2 feet of cover soil
- Un-reclaimed lower angle of repose (DAR) slope
- Emits neutral pH, high sulfate & TDS water from underdrain system:
  - State of Nevada: Caused by infiltration of precipitation and air-flow into DAR slope??


W
E
S
7093.4
7086.6
DAR-1 (Angled)
E 408642
N 410651
6806.3
V.E.
6521.7
Flume (Outflow
DASH Underdrain
DAR-2 (Vertical)
E 408677
N 410508
6804.2
DAR-3 (Vertical)
E 408809
N 410154
6650
6984.6
7036.4
6700
7047.2
DAR-4 [Vertical]
E 407703
N 409830
Flume (Inflow)
7054.2
6750
6800
6744.2
DASH Underdrain
6867.0
7196.8
7050
7054.5
7100
7150
Approximate boundary of
Dash Rock Disposaal Area
7183.9
7195.2
7175.9
7064.2
0
134 m
7000
6950
7200
6900
6850
6815.1

DAR-1 Drilling & Completion

- Borehole below angle of repose
  - Sonic core drilling
  - Geochemical and hydrologic characterization
- Instrument with
  - Temperature sensors (5)
  - Pressure potential (moisture) content sensors (3)
  - Oxygen sensors (3)
  - Air piezometers (3)
  - Suction lysimeters (2)
- Central data acquisition (4 times/day)
- Manual sampling of suction lysimeters and air piezos



Water Level & EC, Solution samples

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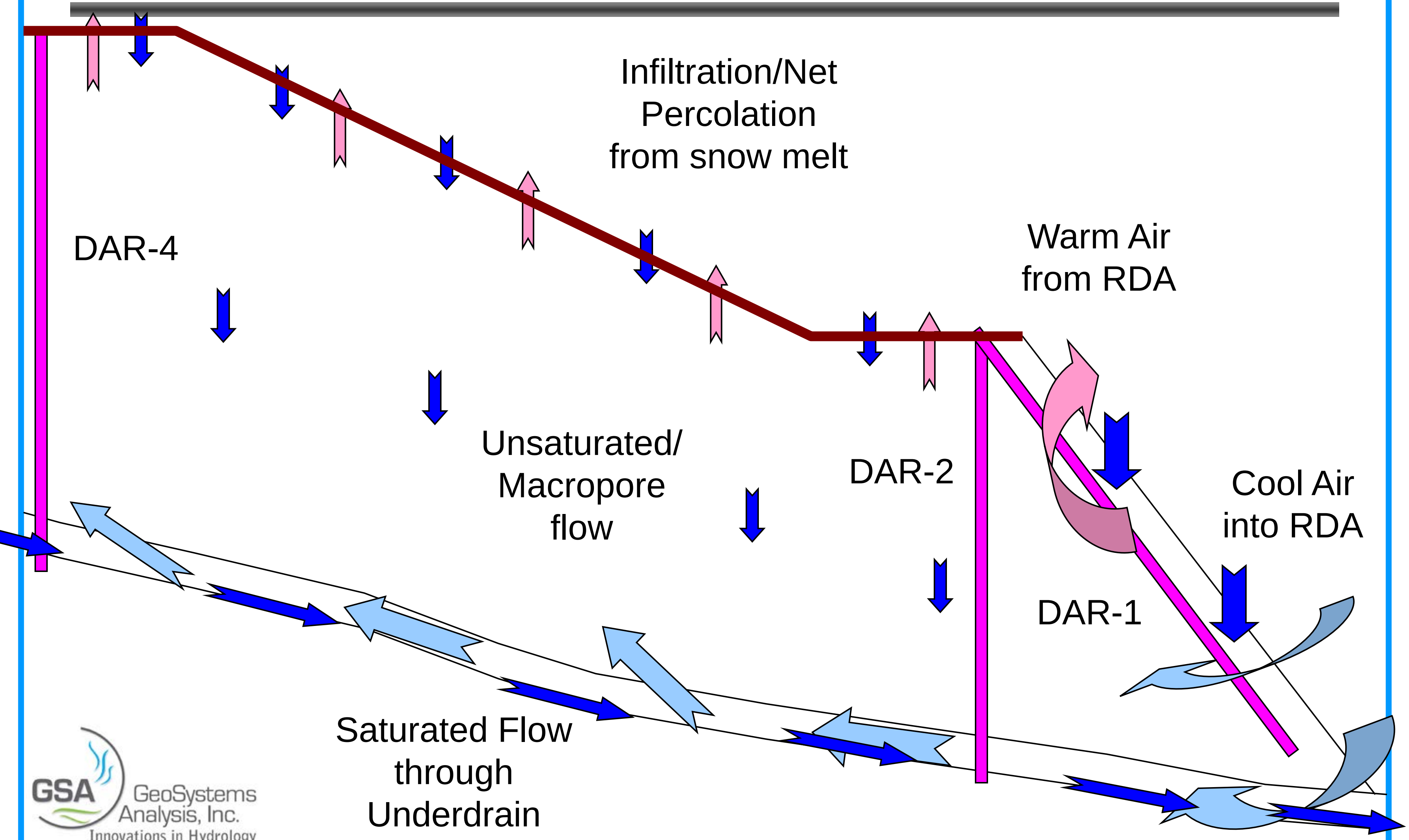
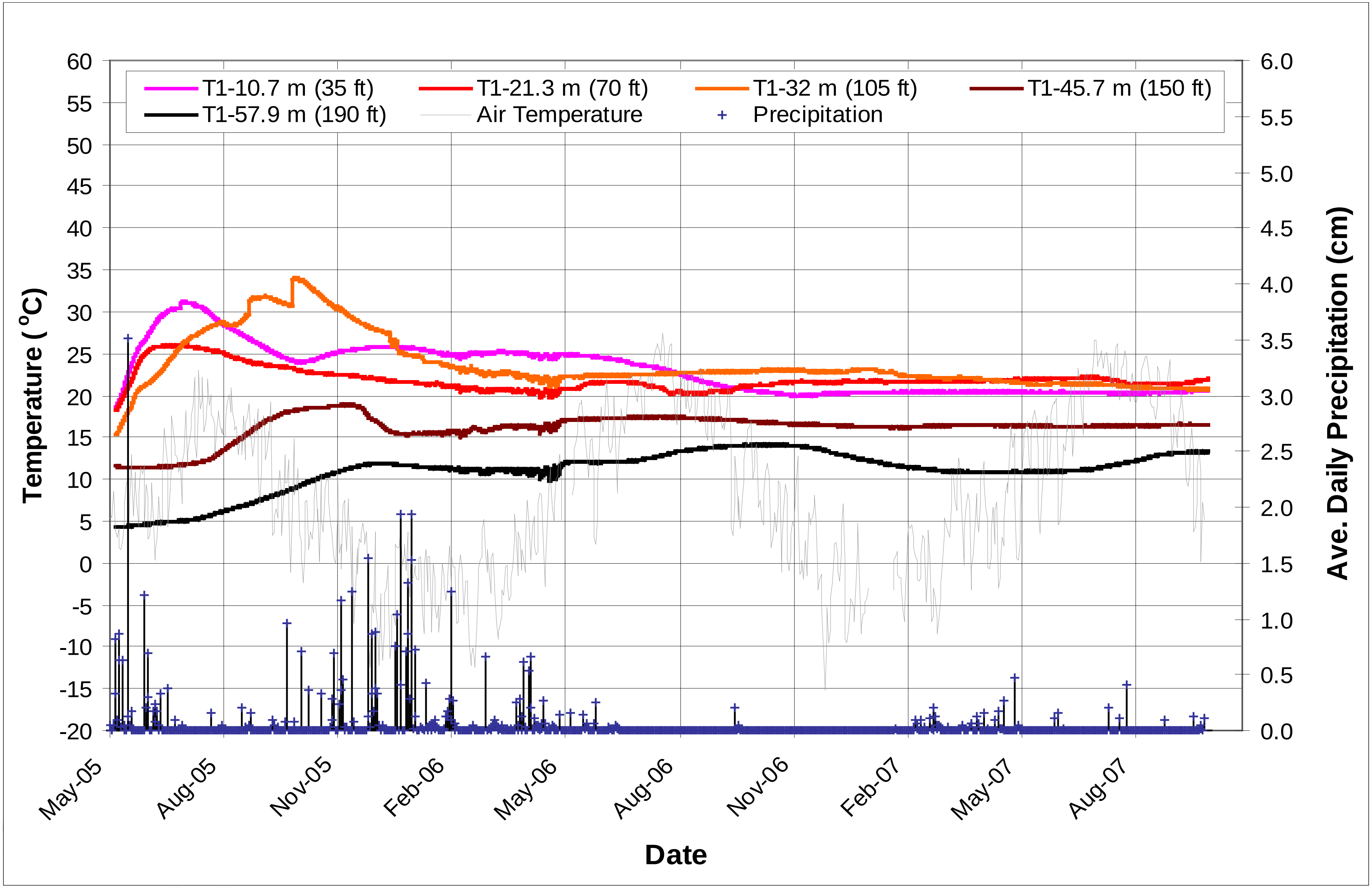
Lower Lift Looking
North, DAR-1 Angle
Hole Drilling

Conceptual Diagram of Flow System

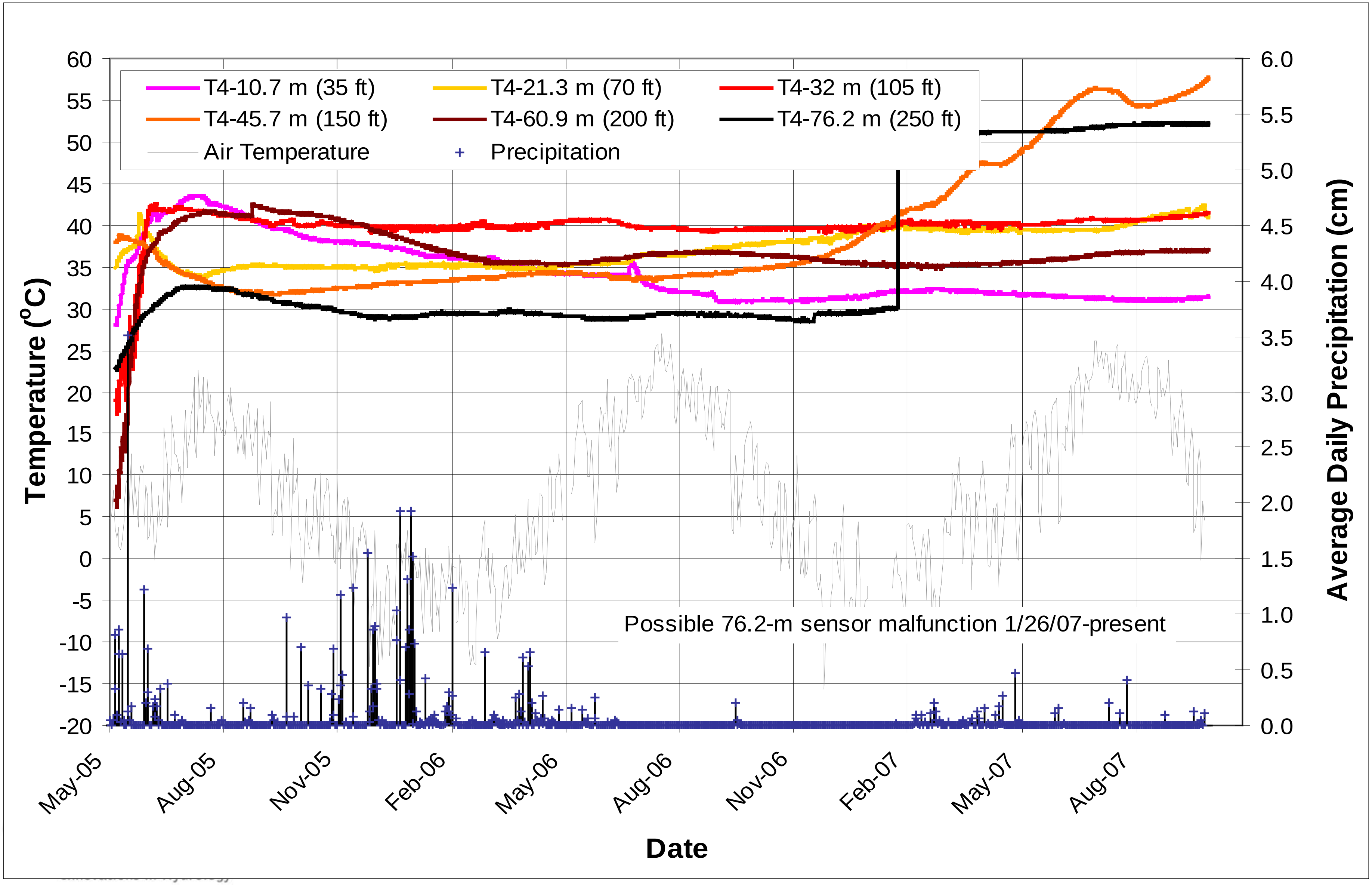


Vadose Well Data

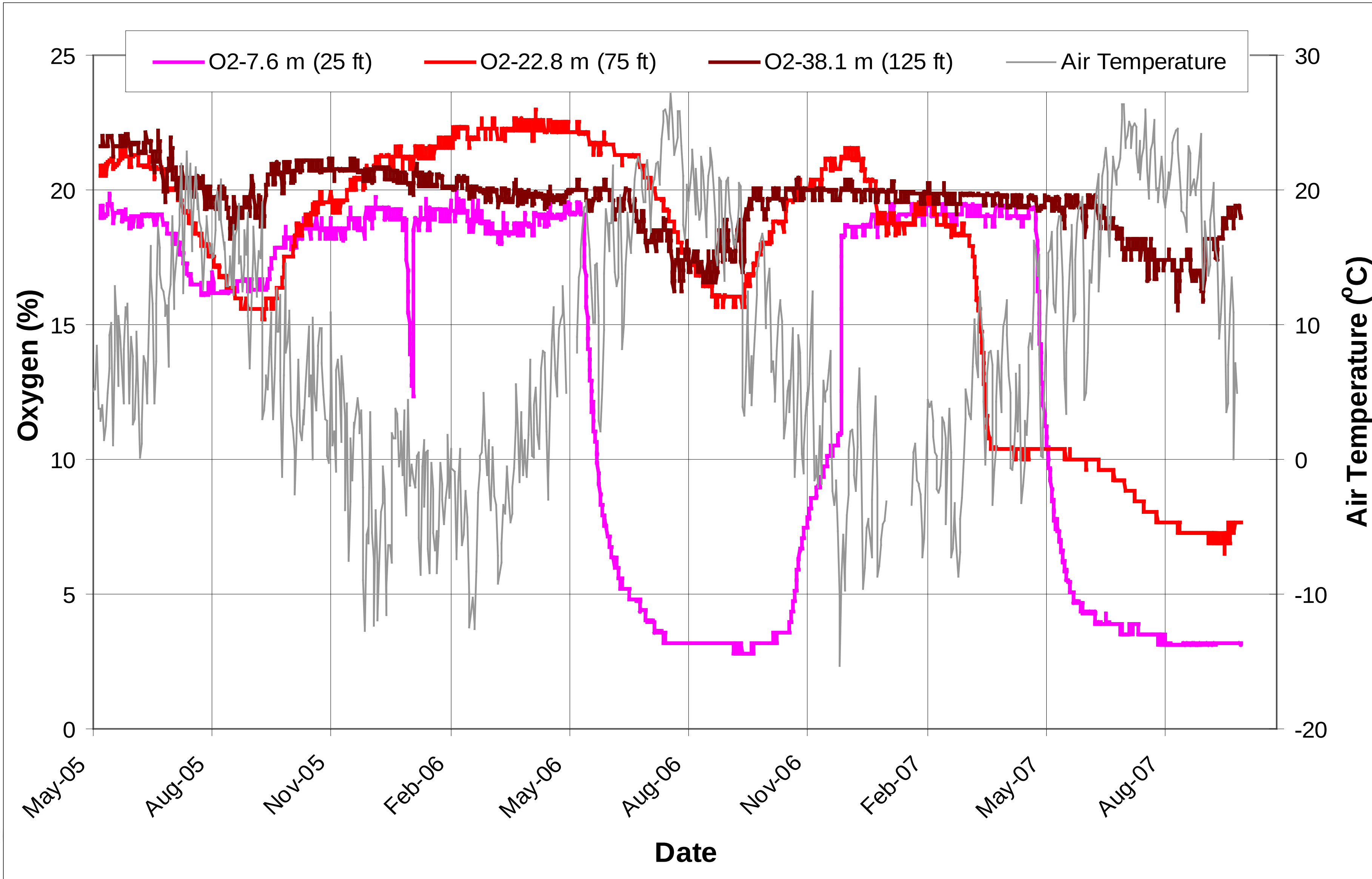
Temperature (DAR-1)



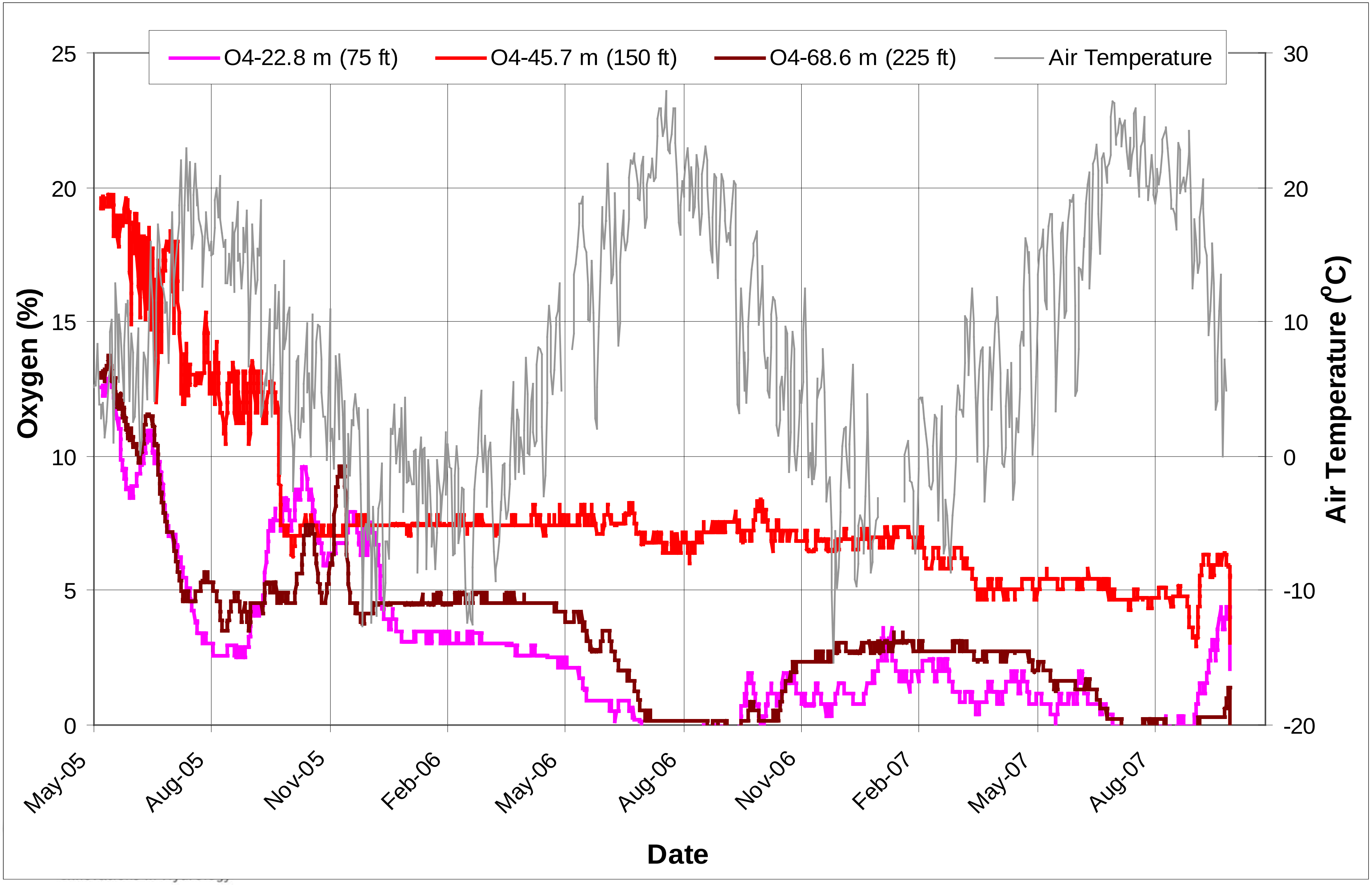
Temperature (DAR-4)



Oxygen Data (DAR-2)



Oxygen Data (DAR-4)



DASH Conclusions

- Net percolation through cover system appears to be primary source of drainage and sulfate rather than
- All vadose monitor wells show evidence of pyrite oxidation, sulfate generation, and moisture flux
- Air flow to vadose wells are from the base of the DAR and under-drain; driven by temperature gradients
- Water quality and flume data confirm these results

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Low-pH and Saline Solution Migration into Monolayer Covers

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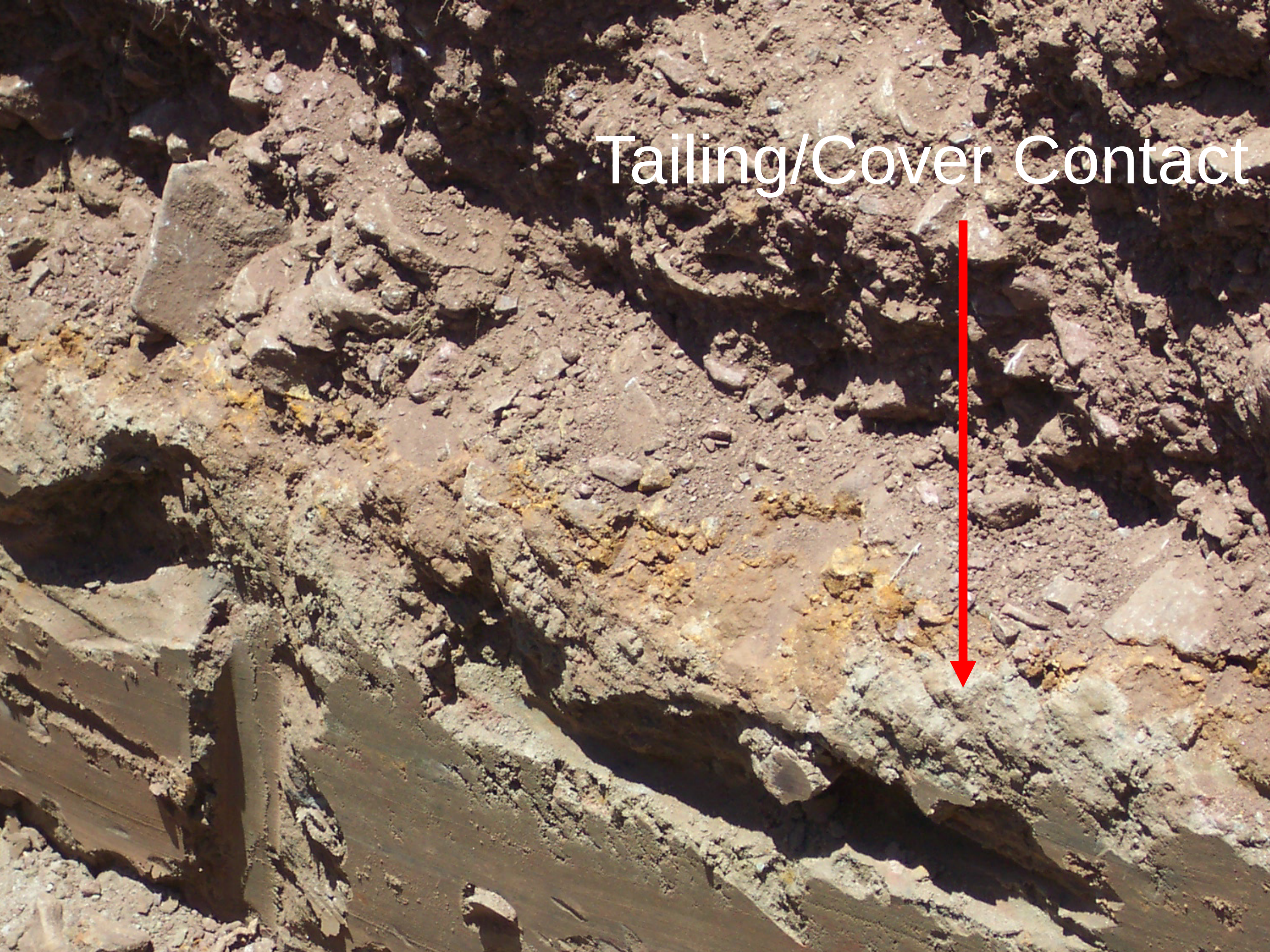
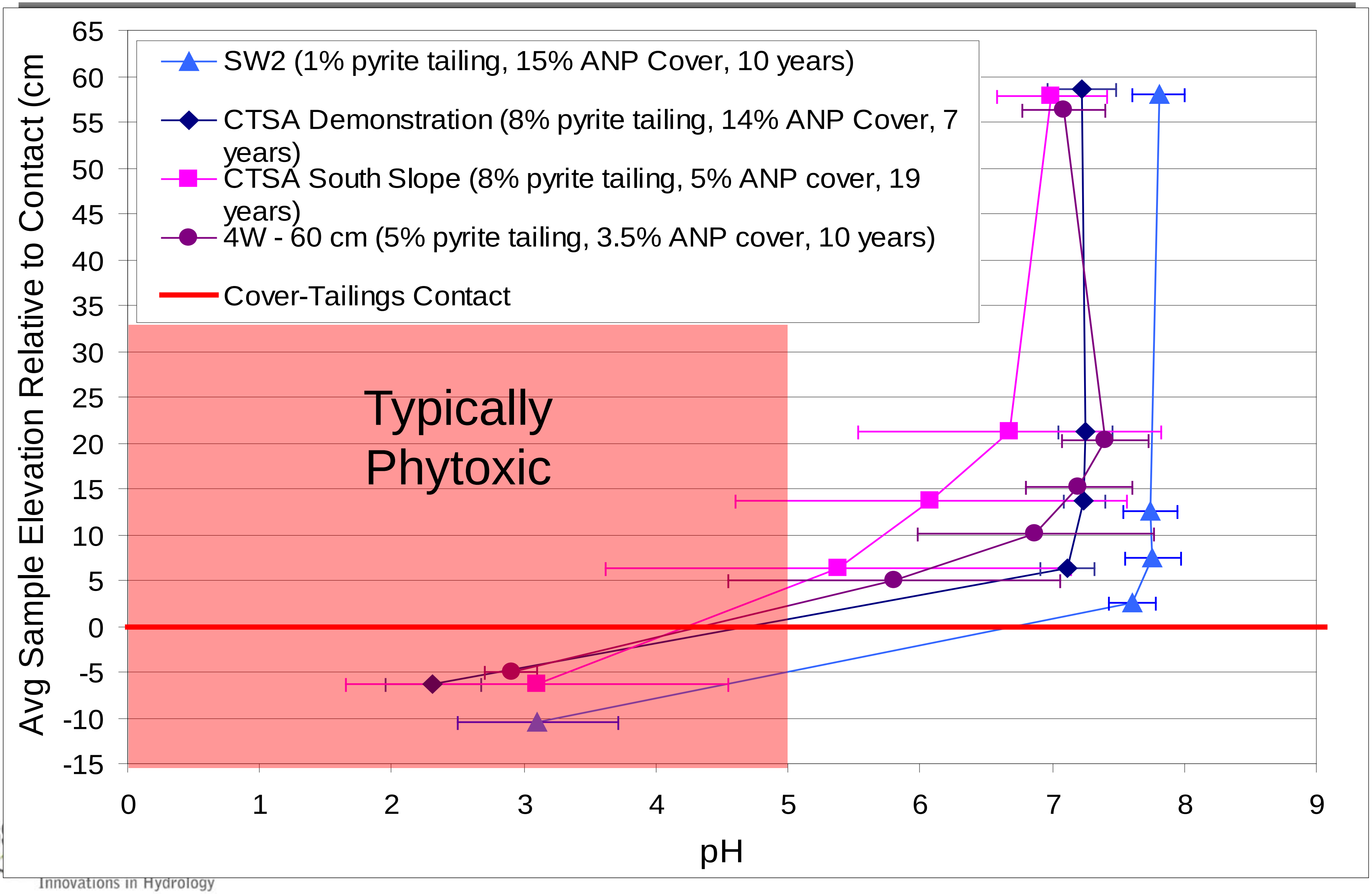
Trench Sample Design


Tailing/Cover Contact

pH Profiles



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Acid and Salinity Migration Considerations

- In a semi-arid environment salinity and acid migration observed to be limited to ≈ 15 cm above contact
- Phytotoxic levels of pH and salinity in cover material generally absent ≈ 5 cm above contact
- Increased migration above contact with decreased cover thickness (30 vs 60 cm)
- Acidity and salinity migration may be limited due to:
  - Unsaturated hydraulic conductivities and upward flux rates greatly diminish with distance above the contact
  - High calcium carbonate contents in the cover material neutralize low-pH solution

Conclusions

- Long-term monitoring is key to accurately estimate flux
- Monitoring can guide cover management decisions
- MANY factors influence cover system performance:
  - Slope location
  - Slope aspect
  - Cover material
  - Waste material
  - Vegetation (shrub vs. grass, density)
- Upward salinity/pH migration may be limited
- No "one size fits all" solution

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