In-situ Monitoring of a Closed Waste Rock Facility

Michael Milczarek, Dale Hammermeister, Margaret Buchanan, Bryce Vorwaller, and Teresa Conner

With Special Thanks to Gary Goodrich

GSA GeoSystems Analysis, Inc.
Arizona • Nevada • Oregon

DASH Waste Rock Disposal Area

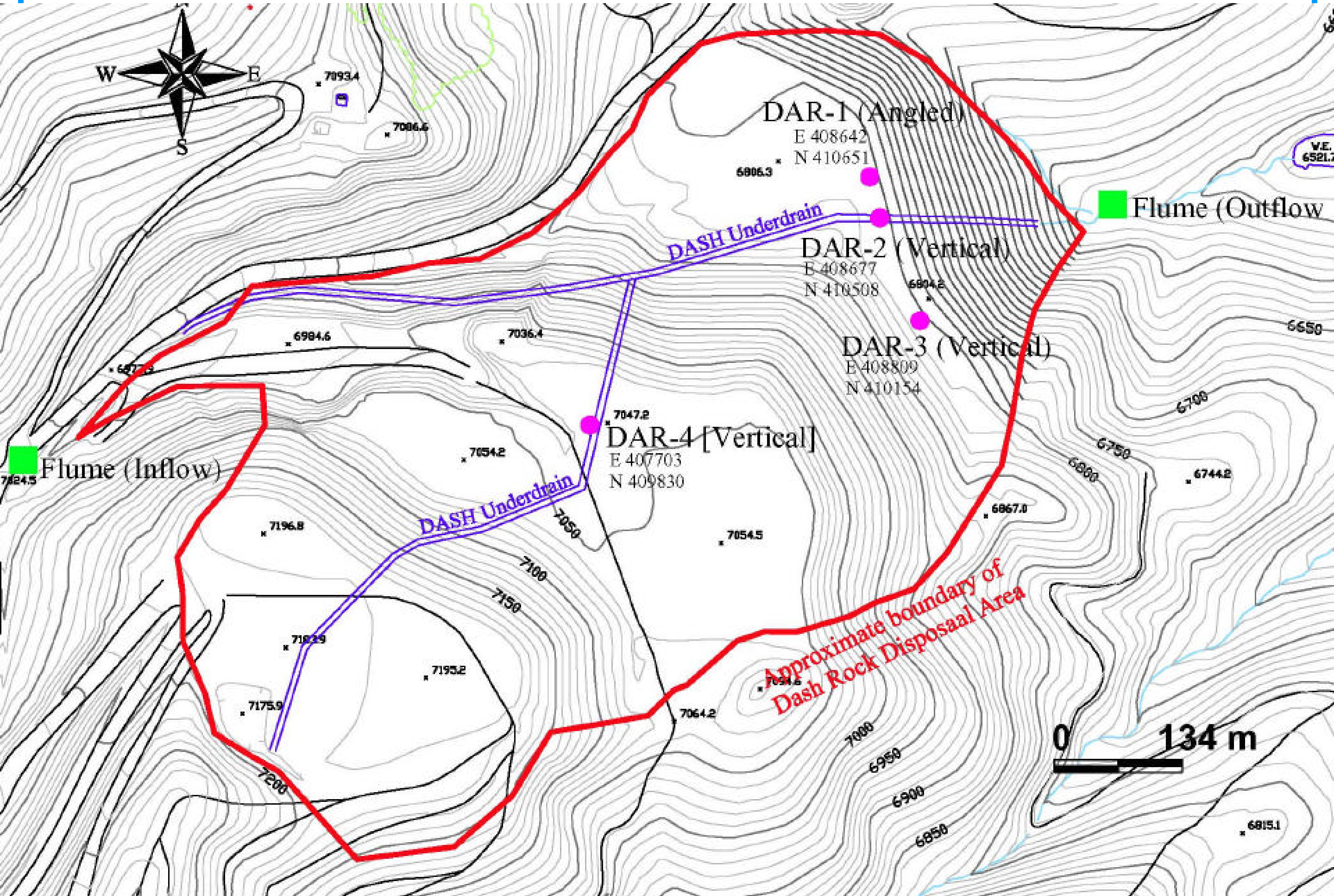
- Approximately 45 hectares, High ANP/Low AGP waste rock disposal area (RDA)
- Reclaimed with approximately 60 cm of cover soil
- Un-reclaimed lower angle of repose (DAR) slope
- Emits neutral pH, high sulfate & TDS water from underdrain system:
  – State of Nevada: Caused by infiltration of precipitation and air-flow into DAR slope??
- Conduct drilling and in-situ monitoring program to assess solution and air movement in waste RDA

GSA GeoSystems Analysis, Inc.
Arizona • Nevada • Oregon

Investigation and Monitoring Approach

- Drill through waste rock and instrument four vadose wells
  - Three wells at crest of DAR slope (40 to 60 m bgs)
  - One well 450 meters upslope (87 m bgs)
  - Monitor for temperature, oxygen, water content at various depth intervals
  - Collect solution chemistry samples (quarterly)
- Install flumes upstream and downstream of the under-drain system, monitor flow rates and electrical conductivity

GSA GeoSystems Analysis, Inc.
Arizona • Nevada • Oregon

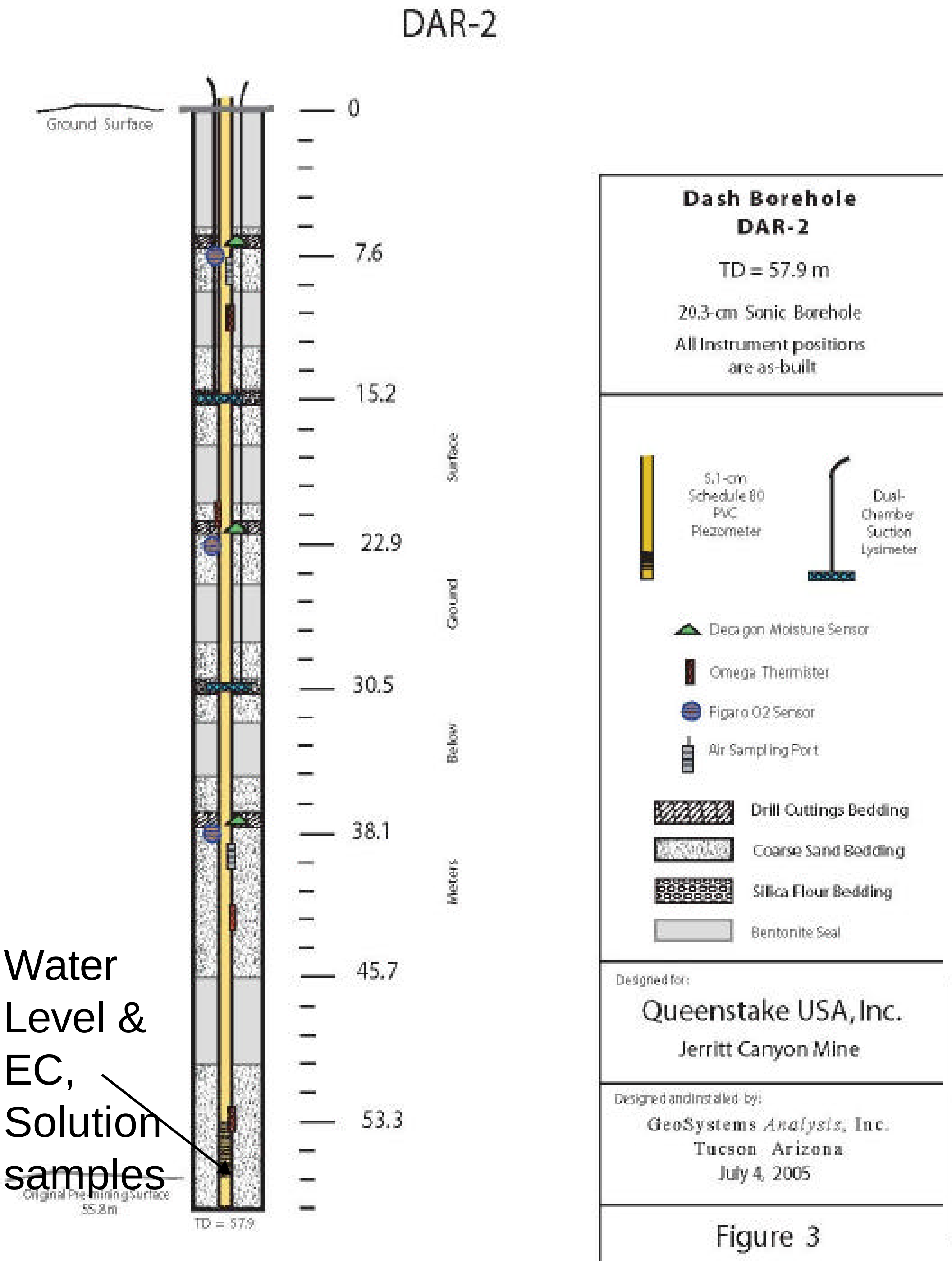


Analysis, Inc.
Arizona • Nevada • Oregon

DAR-1 Drilling & Completion

- 60 meter 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

GSA GeoSystems Analysis, Inc.
Arizona • Nevada • Oregon

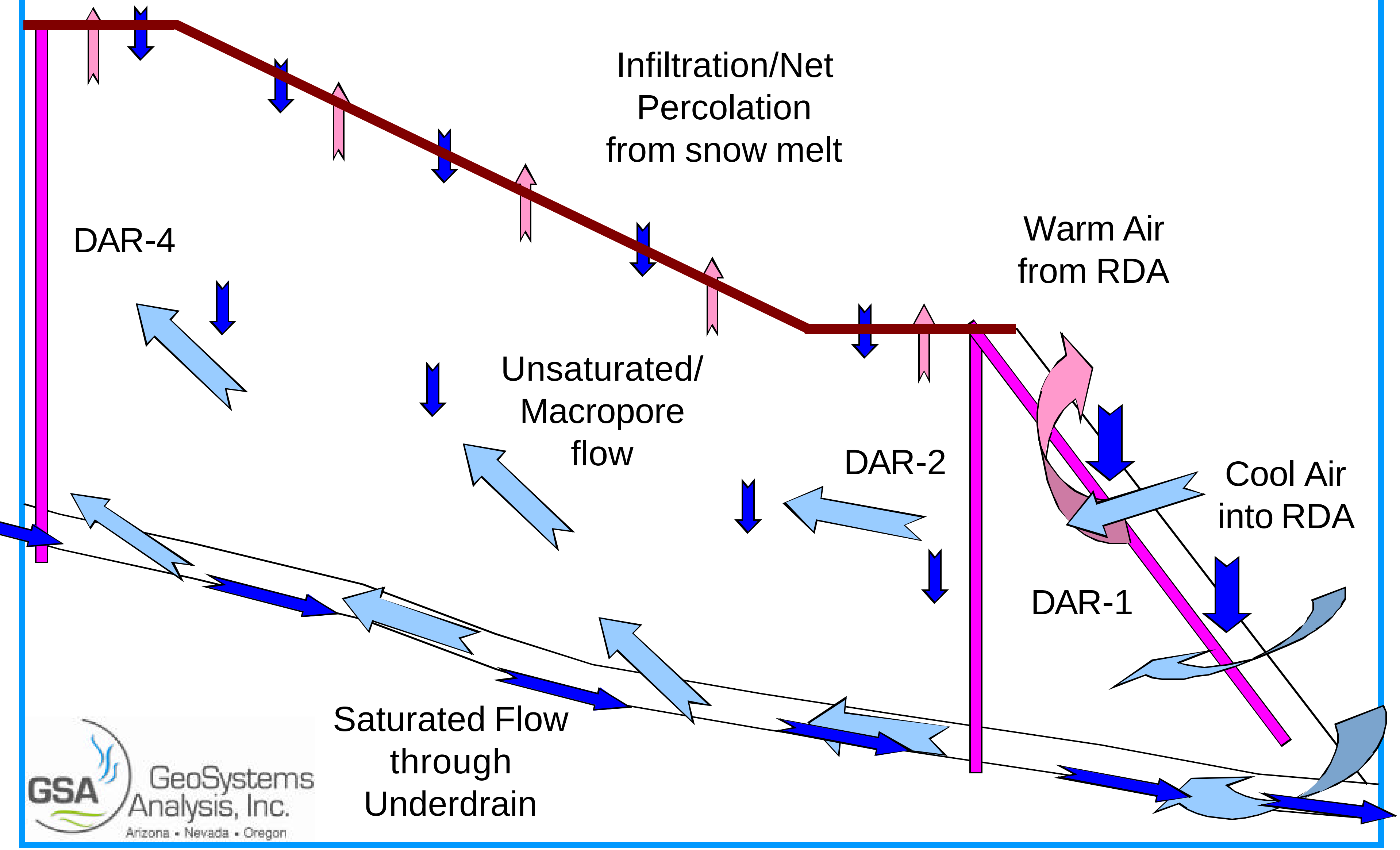


Water Level & EC, Solution samples

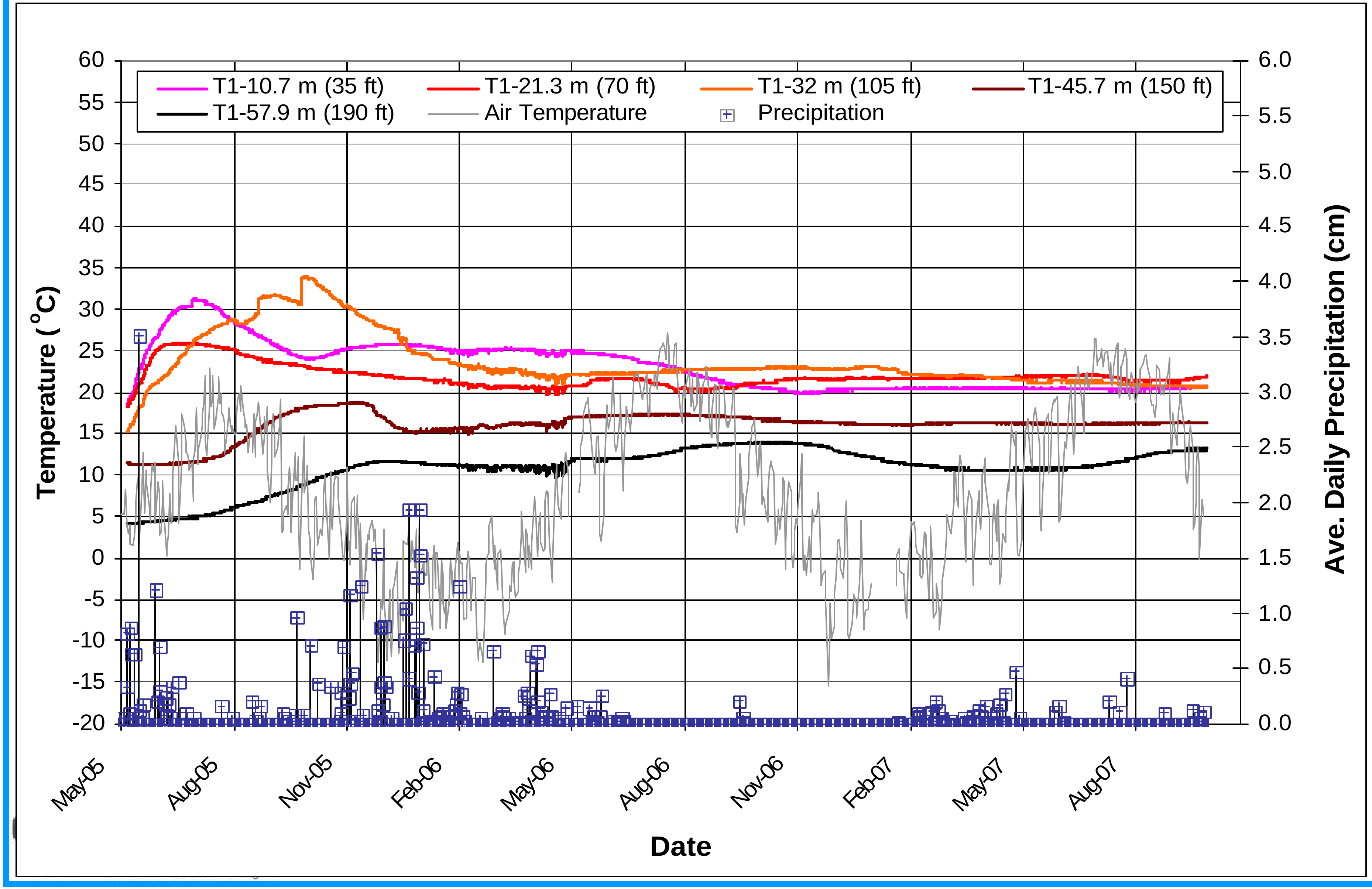

Lower Lift Looking
North, DAR-1 Angle
Hole Drilling


Vadose Well Data

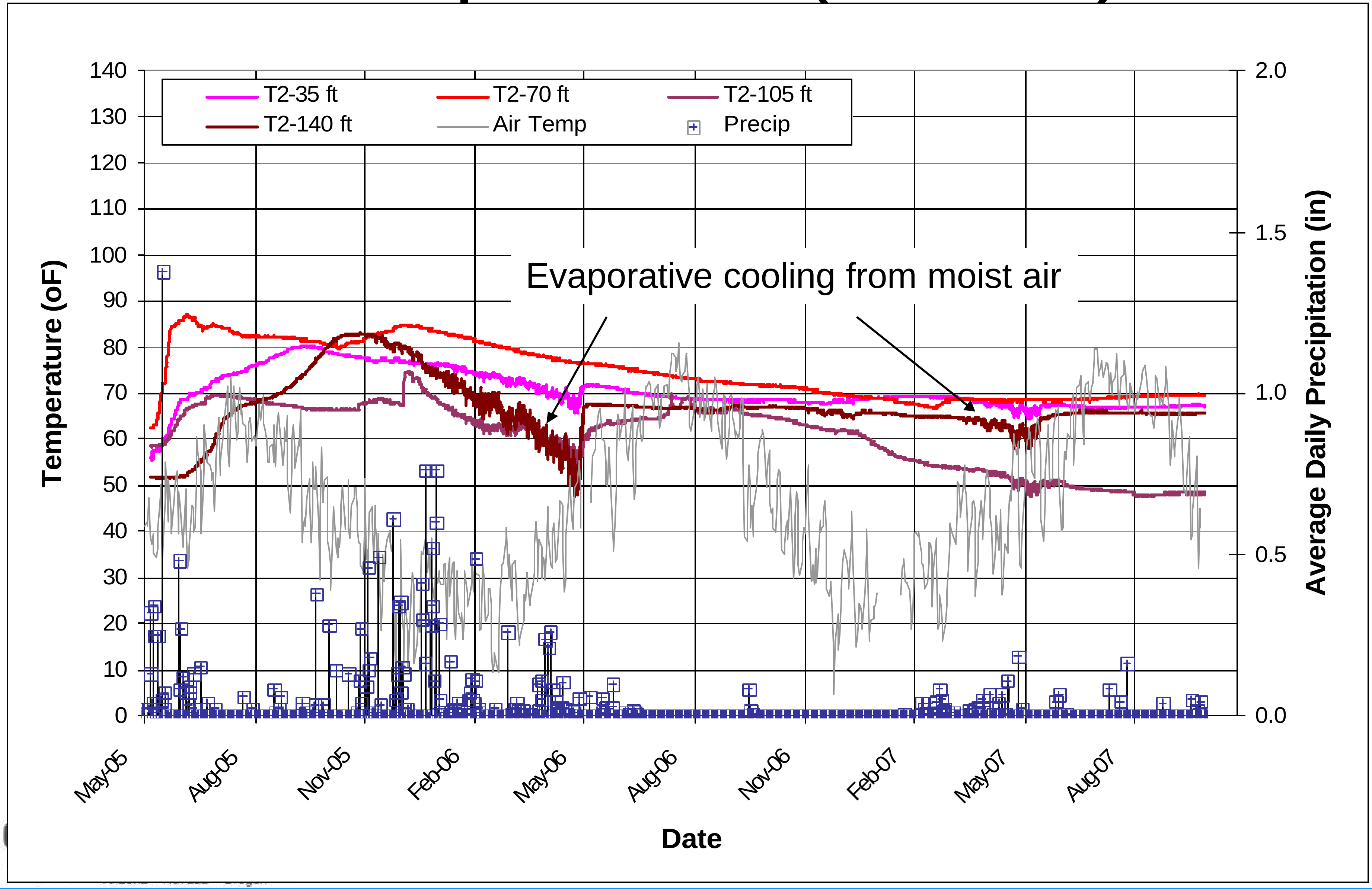
Conceptual Diagram of Flow System



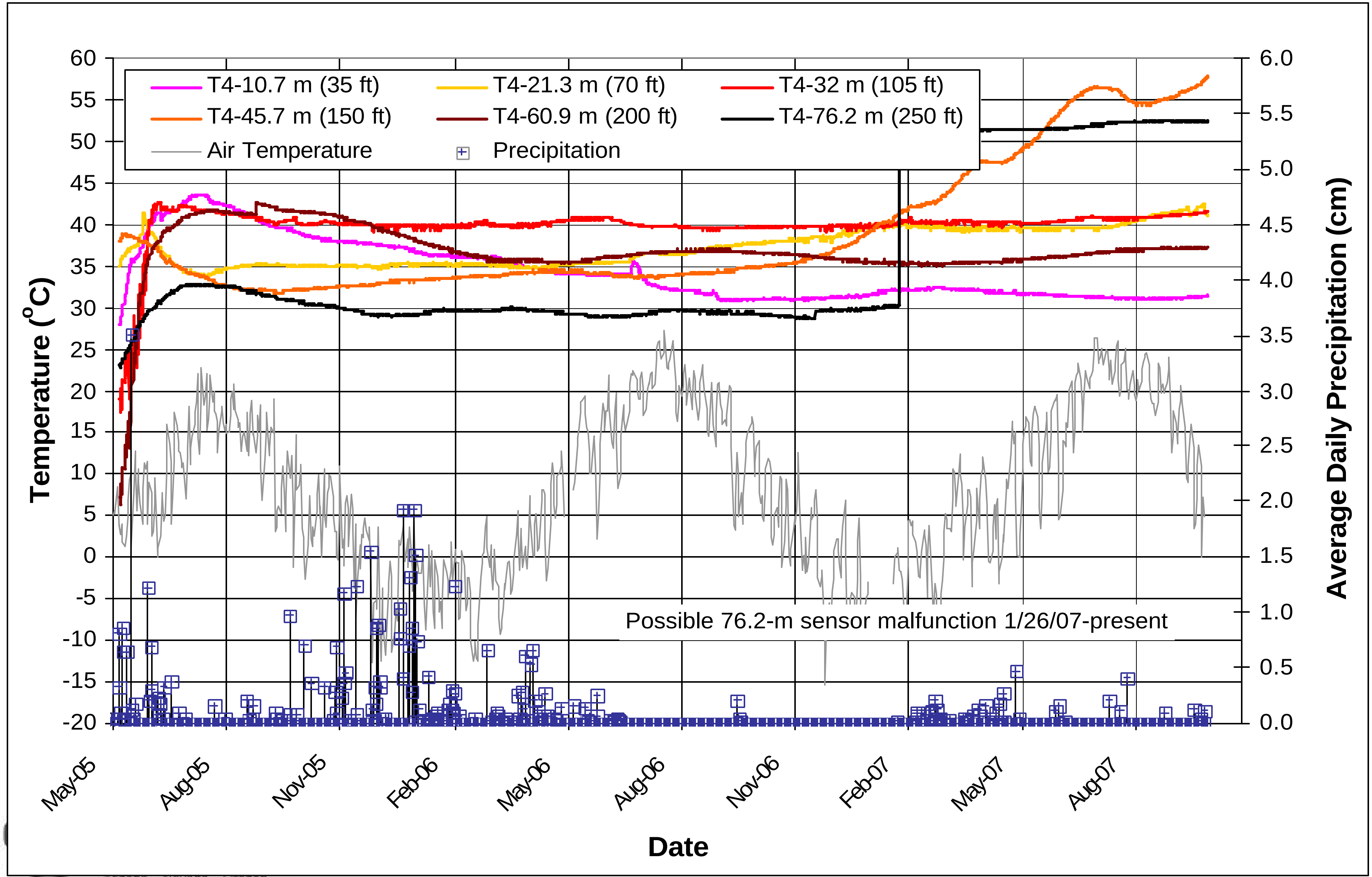
Temperature (DAR-1)



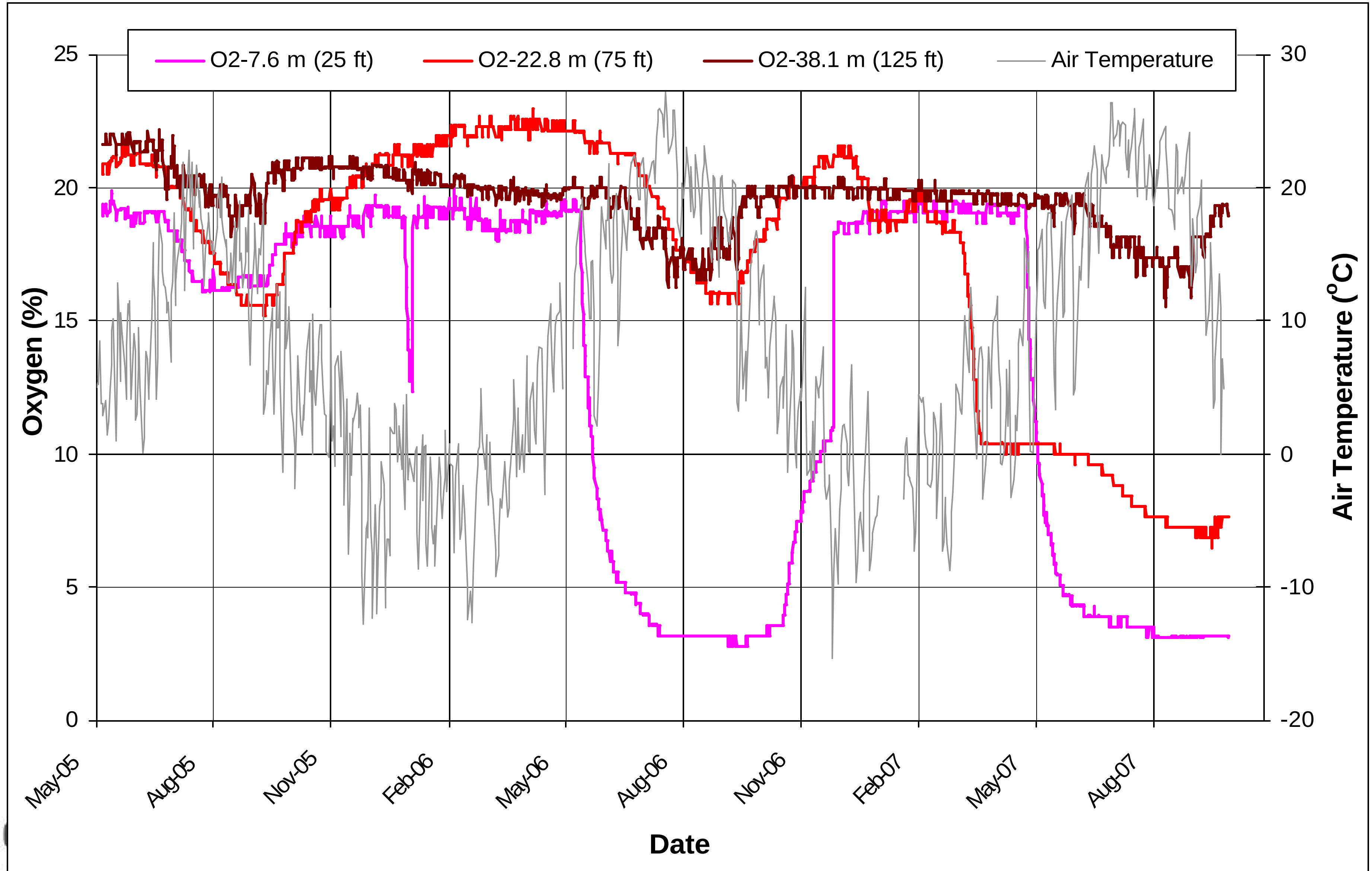
Temperature (DAR-2)



Temperature (DAR-4)

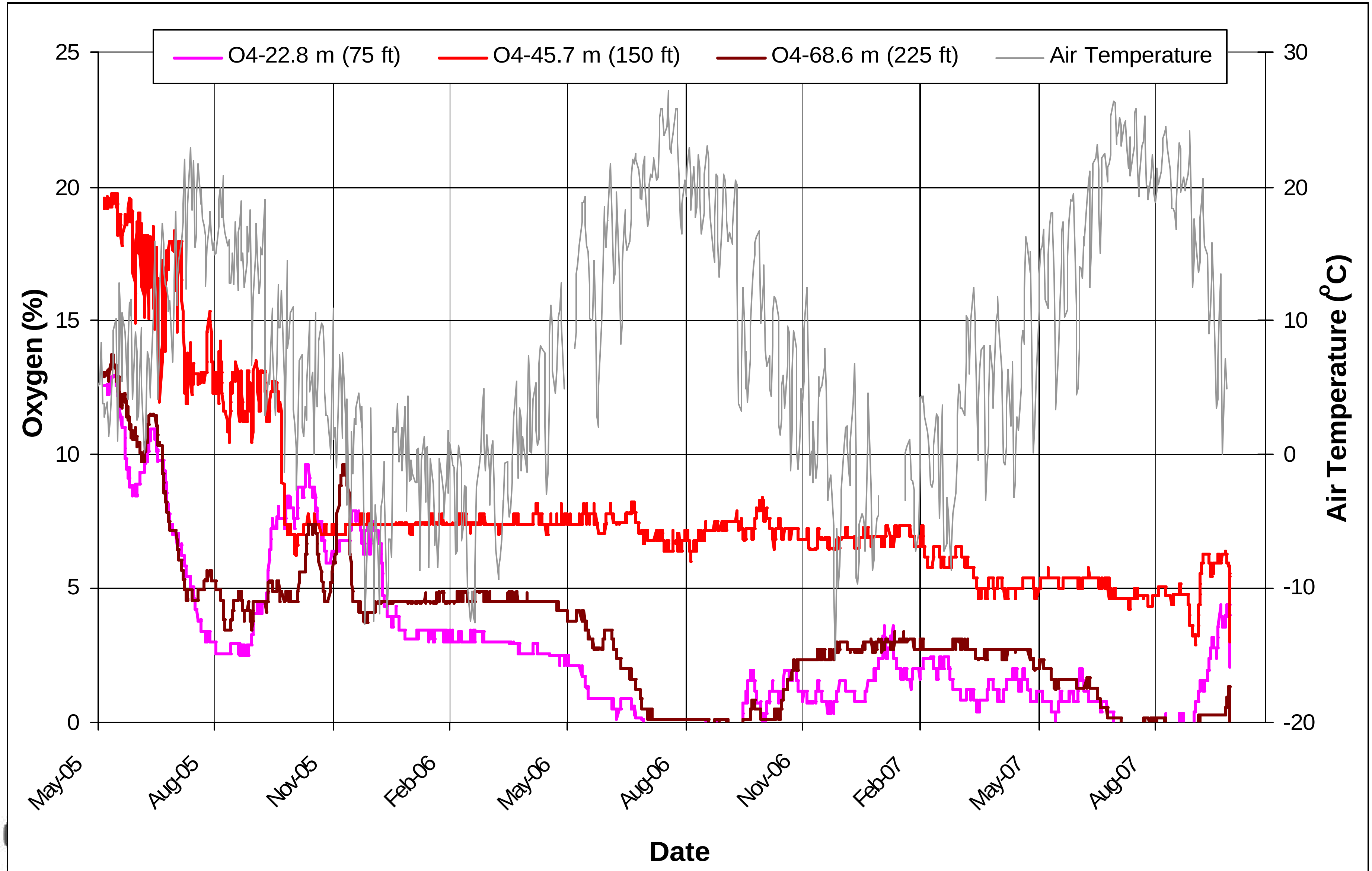


Oxygen Data (DAR-2)



Arizona • Nevada • Oregon

Oxygen Data (DAR-4)



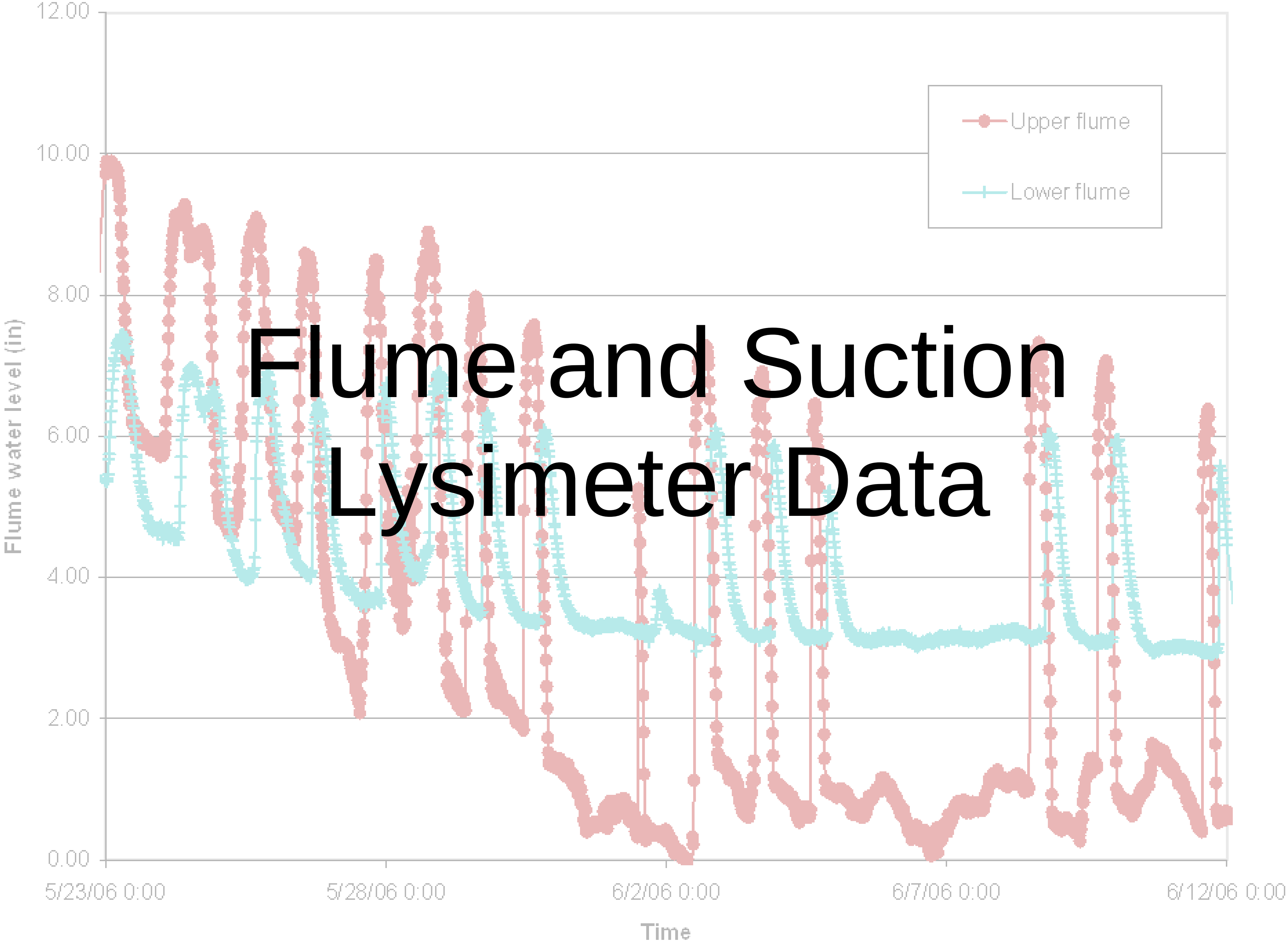
Arizona • Nevada • Oregon

Vadose Well Data

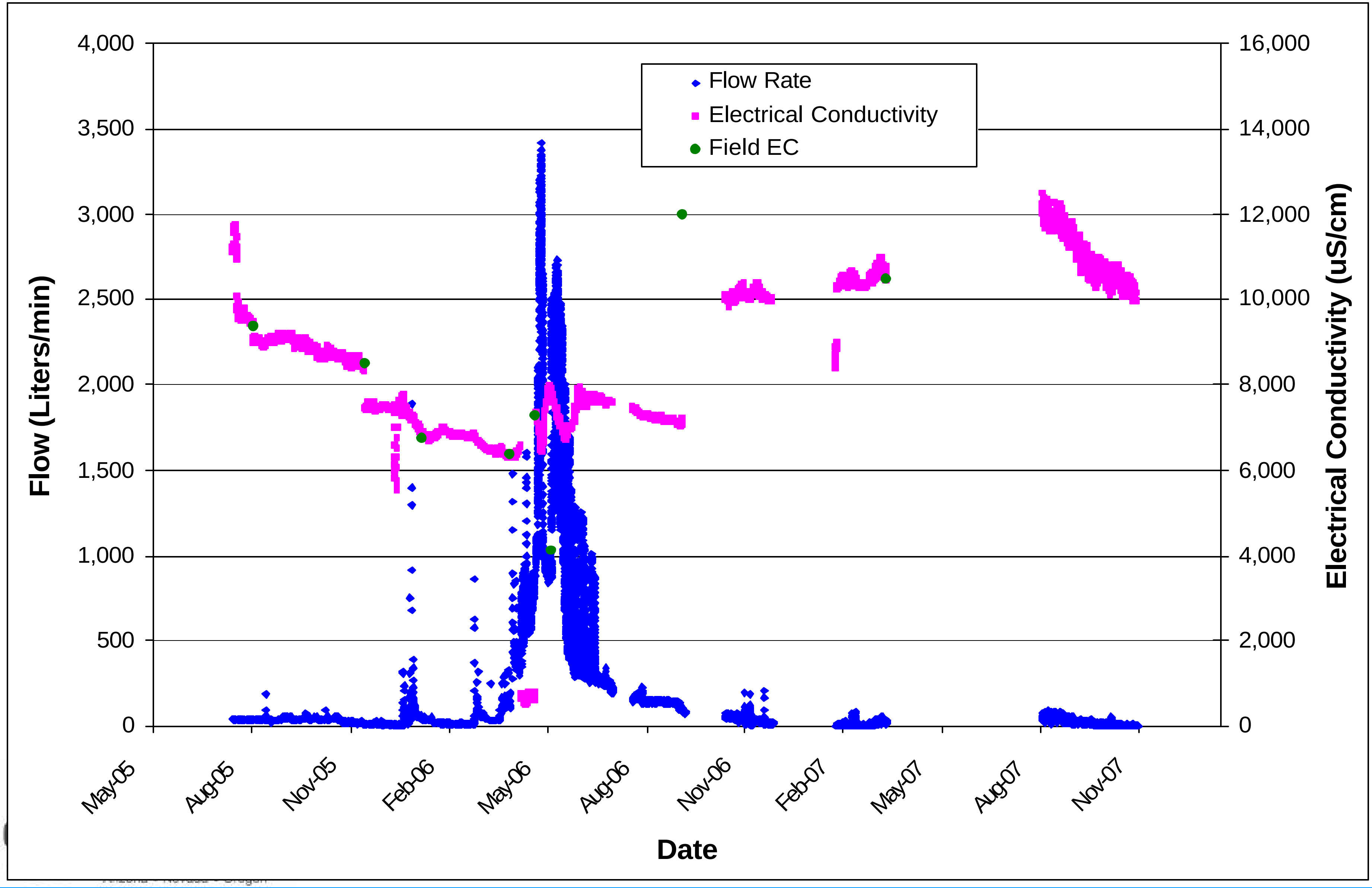
- Core results showed higher levels of pyrite in DAR-4 (2% vs 1%)
- Temperature data:
  - Elevated temperatures (< 27^{o}C) in DAR-1, -2 and -3, indicate low to moderate oxidation rates
  - Higher temperature (30 to 55^{o}C) in DAR-4, higher oxidation rates
  - Cool air flows into the base and underdrain at the DAR face
  - Diurnal temperature changes indicate evaporative cooling
- Oxygen data:
  - Driven by temperature gradients between DASH and atmosphere
    - higher oxygen during the cooler fall and winter months (more air flow)
    - lower oxygen when temperatures rise in the summer (less air flow)
  - Greatest oxygen in DAR-2 is observed in the deepest sensors
  - Low oxygen levels in DAR-4 suggest high oxidation rates
- Estimated water content data:
  - Water contents generally increase with depth in DAR-1 and DAR-2 (influx of moist air)
  - Water contents in DAR3 and DAR-4 relatively stable

GSA GeoSystems Analysis, Inc.
Arizona • Nevada • Oregon

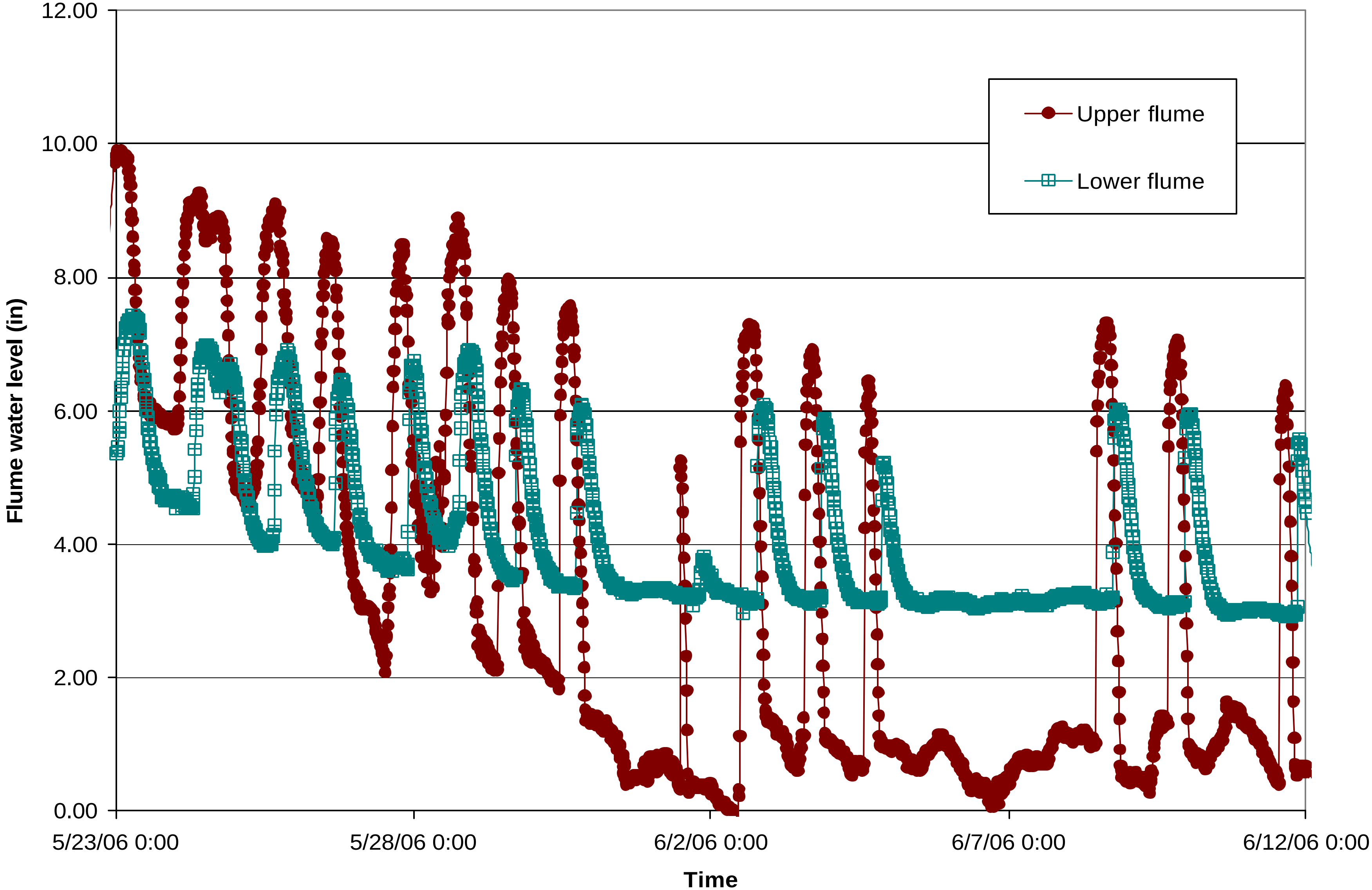
Flume and Suction Lysimeter Data



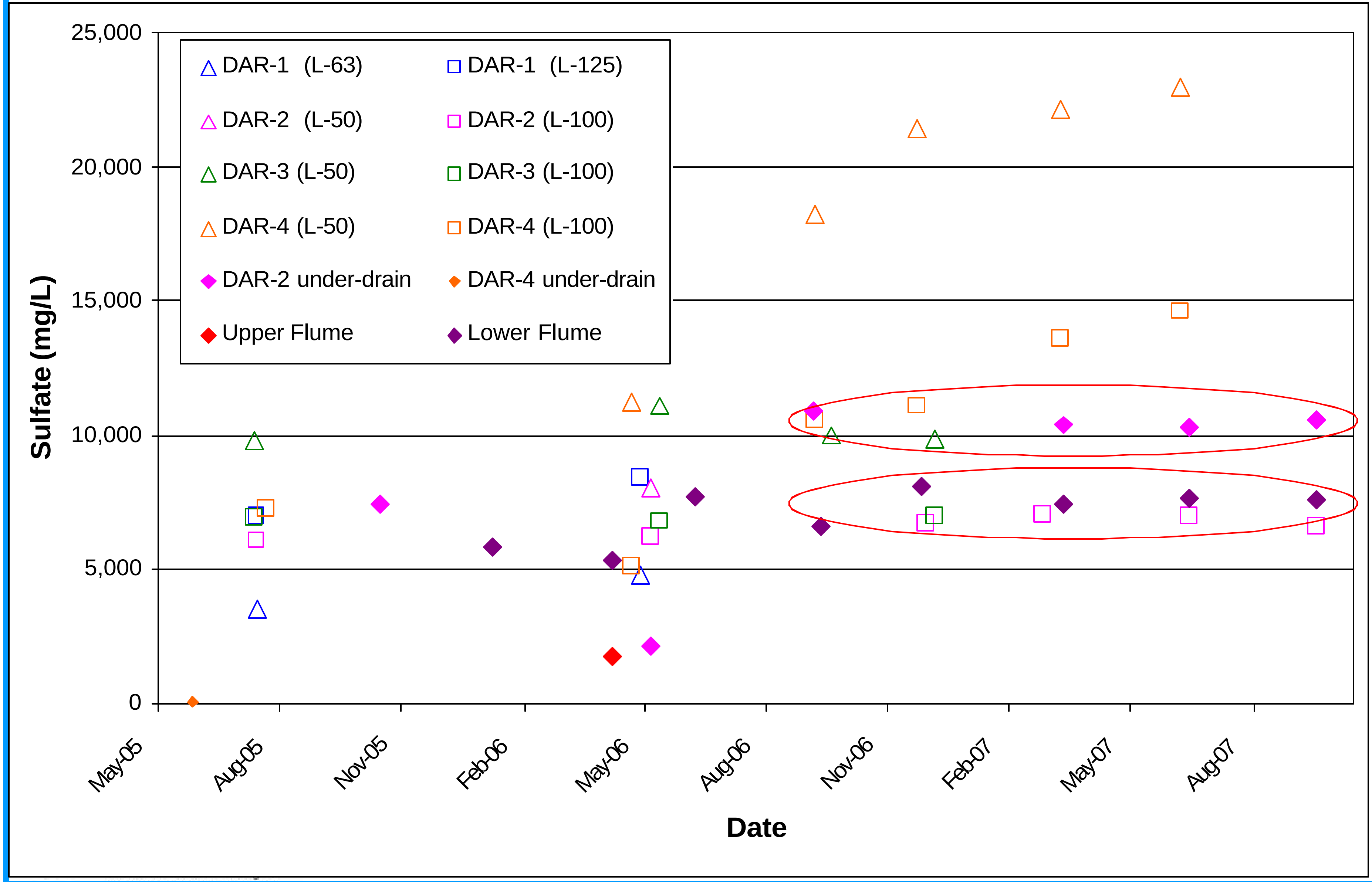
Lower Flume Data



Upper and Lower Flume Data



Sulfate Concentrations



Flume and Lysimeter Data

- Heterogenous flow and chemistry
- Salinity of outflow corresponds to:
  1. Initial contribution of upgradient flow into RDA (low salinity)
  2. Initial flush of waste rock pore solution (high salinity)
  3. Decreasing salinity with declining flow (pore solution drainage)
- Water chemistry
  - Sulfate levels in the DAR-1, -2, and –3 lysimeters similar to the lower flume samples
  - DAR-4 lysimeters showed the highest sulfate levels
  - Under-drain water quality improves from DAR-2 to lower flume.
  - DAR-2 lysimeter shows lower sulfate than DAR-2 underdrain
  - Sample volumes: DAR-1, DAR-3 lysimeters yield smaller sample volumes than DAR-2 and DAR-4 (less net percolation through cover/DAR in these areas)

GSA GeoSystems Analysis, Inc.
Arizona • Nevada • Oregon

Conclusions

- Monitoring system identified general influence of DAR slope
  - All vadose monitor wells show evidence of pyrite oxidation, sulfate generation, and moisture flux
  - Air flow to vadose wells are primarily from the base of the DAR: temperature and pressure gradients
  - DASH under-drain system may promote air flow
- Net percolation through cover system appears to be primary source of drainage and TDS/sulfate
- Re-grading and reduction of the DAR slope may not be effective in reducing sulfate generation
- Need to:
  - improve cover system performance (thicker and/or better vegetation)
  - evaluate controlling air flow into under-drain system
  - evaluate areas away from underdrain, air flow through DAR face

GSA GeoSystems Analysis, Inc.
Arizona • Nevada • Oregon