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Uranium Geochemistry in Groundwater and How to Communicate These Concepts to Laypeople

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Session Track 1.1: Advancing current practices at mission and non-mission sites within the Department of Energy: General LTS Practices

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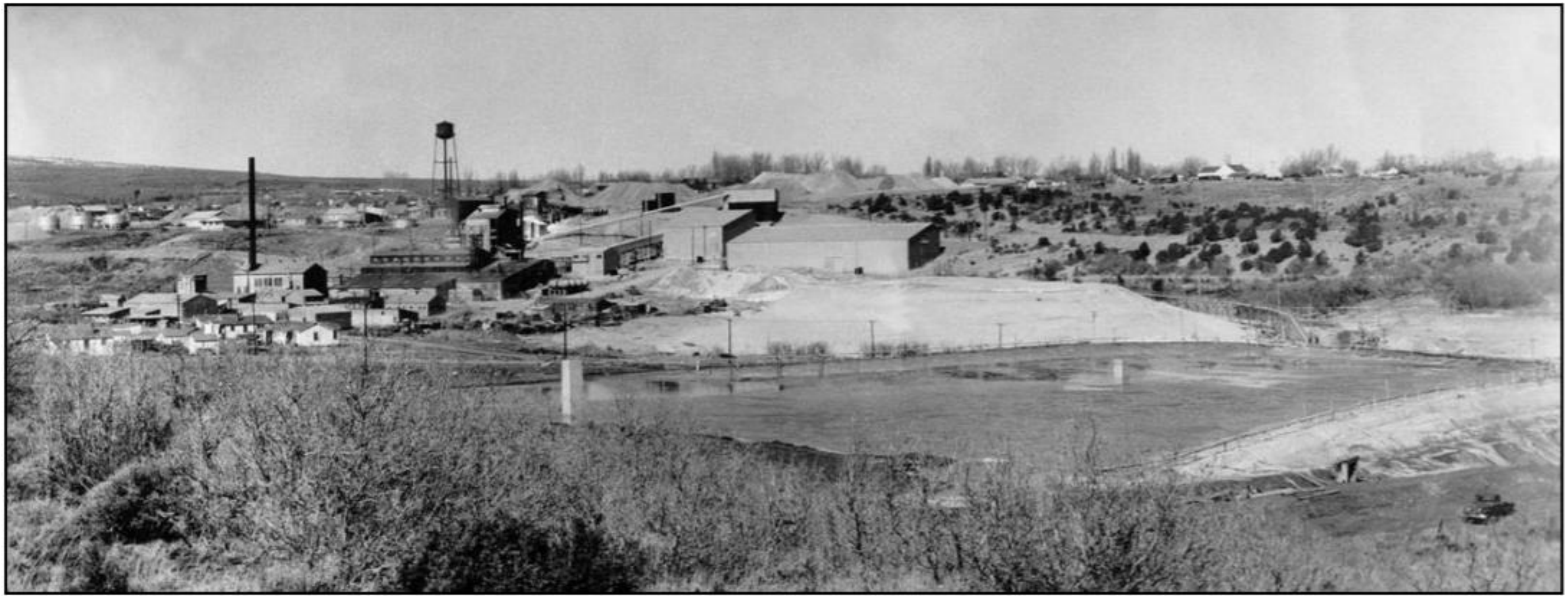
Mill Tailings = Original Uranium Source



Monticello, Utah

Tailings Removed or Capped in Place

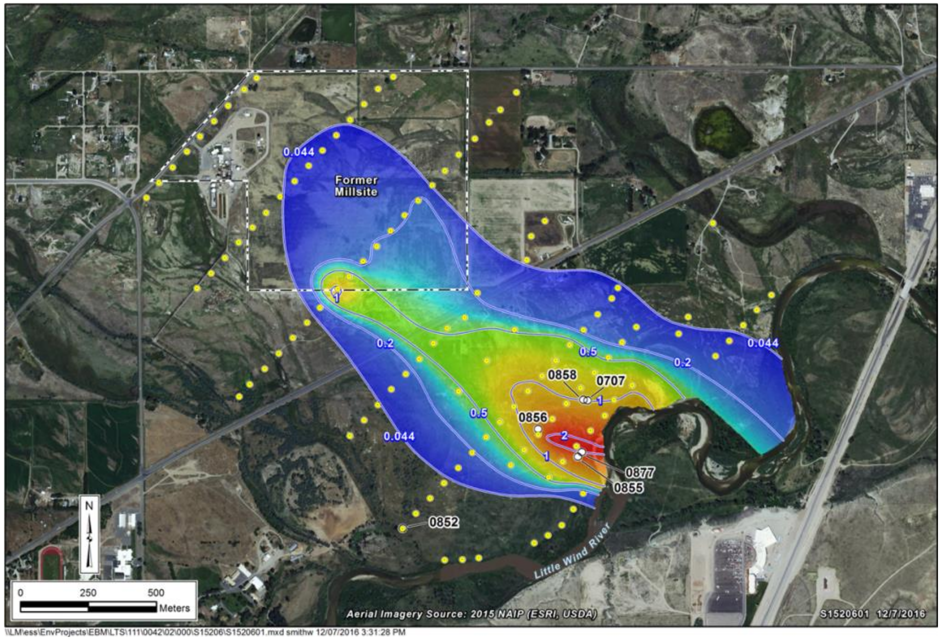
- Surface remediation
- Still have uranium plume

Tuba City, Arizona

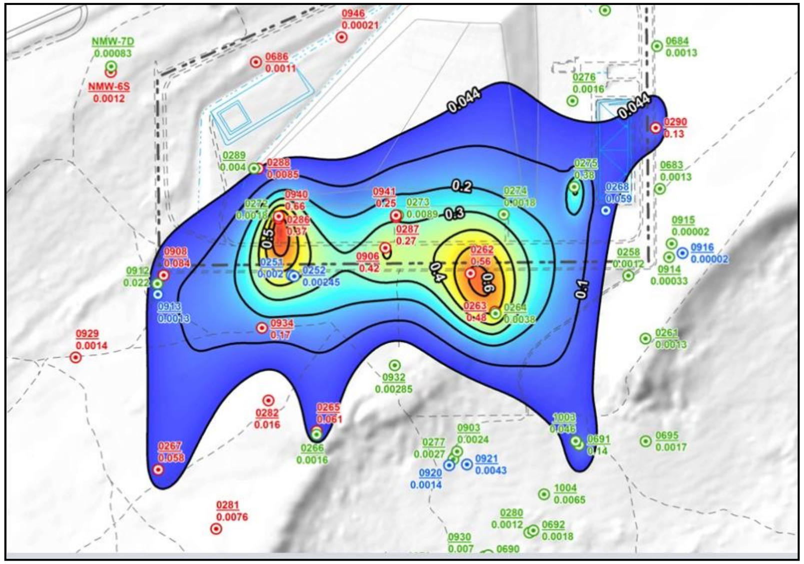
Riverton, Wyoming

Current Uranium Plume

- Ongoing long-term surveillance (LTS) concern to laypeople
- Other contaminants too
- Uranium plume development depends on: 1) source, 2) underlying and downgradient material, and 3) geochemical reactions



Riverton, Wyoming: Uranium



Tuba City, Arizona: Uranium

Uranium Transport Fundamentals

- Generally mobile under oxidizing conditions
- But can precipitate with the right geochemistry
  - Carnotite (oxidizing with high vanadium)
  - Autinite (oxidizing with high phosphate)
- Can also precipitate (uraninite) under strongly reducing conditions
- Generally, complexes in groundwater that make uranium more mobile include:
  - Alkalinity (carbonate)
  - Calcium
  - Magnesium
  - Dissolved organic carbon
- Uranium likes to sorb to iron, clays, and organics under oxidizing or reducing conditions
- Key: geochemistry of the water AND the solid phase is important

Tailings

- If sulfide rich, produces low pH waters with sulfide oxidation, but may be buffered if ore had carbonates
- When open, lots of oxygen coming in
  - Oxidizing environment, mobile uranium, high sulfide-oxidation rates with release of iron and low pH waters, high flow rates to underlying aquifer
- Once covered, may not be much oxygen
  - Reducing environment, low sulfide oxidation, less uranium mobility if precipitation occurs, lower flow rates to underlying aquifer

Aquifer

- May have dissolved oxygen
- May have a good buffering capacity
- Geochemical reactions occur as groundwater mixes with tailings fluid
- Amount of mixing depends on aquifer and tailings fluid quantities

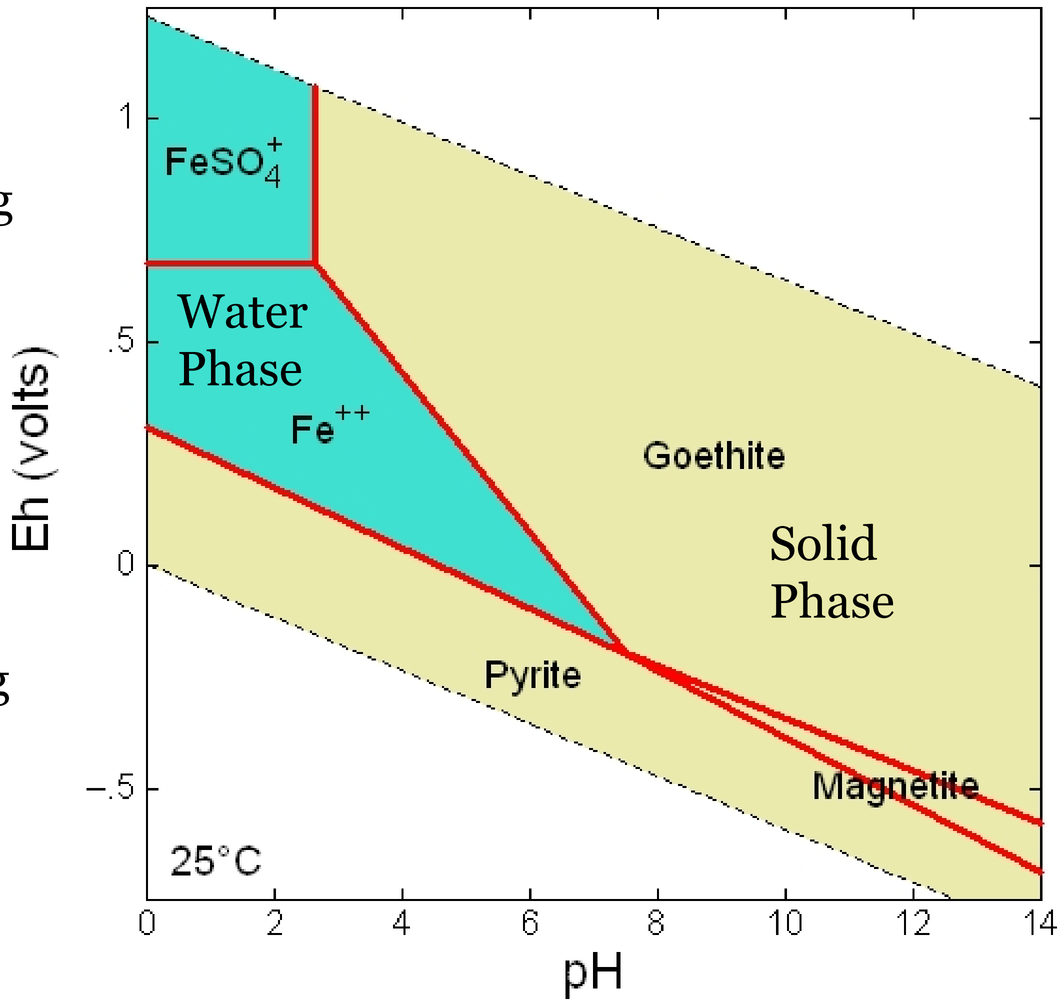
Uranium Plume Development

- Low pH keeps uranium and iron mobile
- Low pH is neutralized by calcite dissolution in tailings or aquifer material
- Calcite dissolution: adds CO_2, Ca, and alkalinity that keeps uranium mobile, but is balanced by iron precipitation, which depends on pH and oxidizing/reducing conditions (Eh/pH diagram, next slide)
- CO_2 degassing: if this occurs, then precipitate calcite, and uranium may be less mobile (different pH and less alkalinity)
- Precipitation of iron on the solid phase reduces uranium mobility (sorption) and becomes a subsequent uranium source zone below or away from the original tailings source
- **Removing tailings does not equal full source removal**
  - **Can still have mill-related subpile solid phase contamination**
  - **Can still have mill-related groundwater contaminant plume**

Eh/pH Diagram

Oxidizing

Reducing

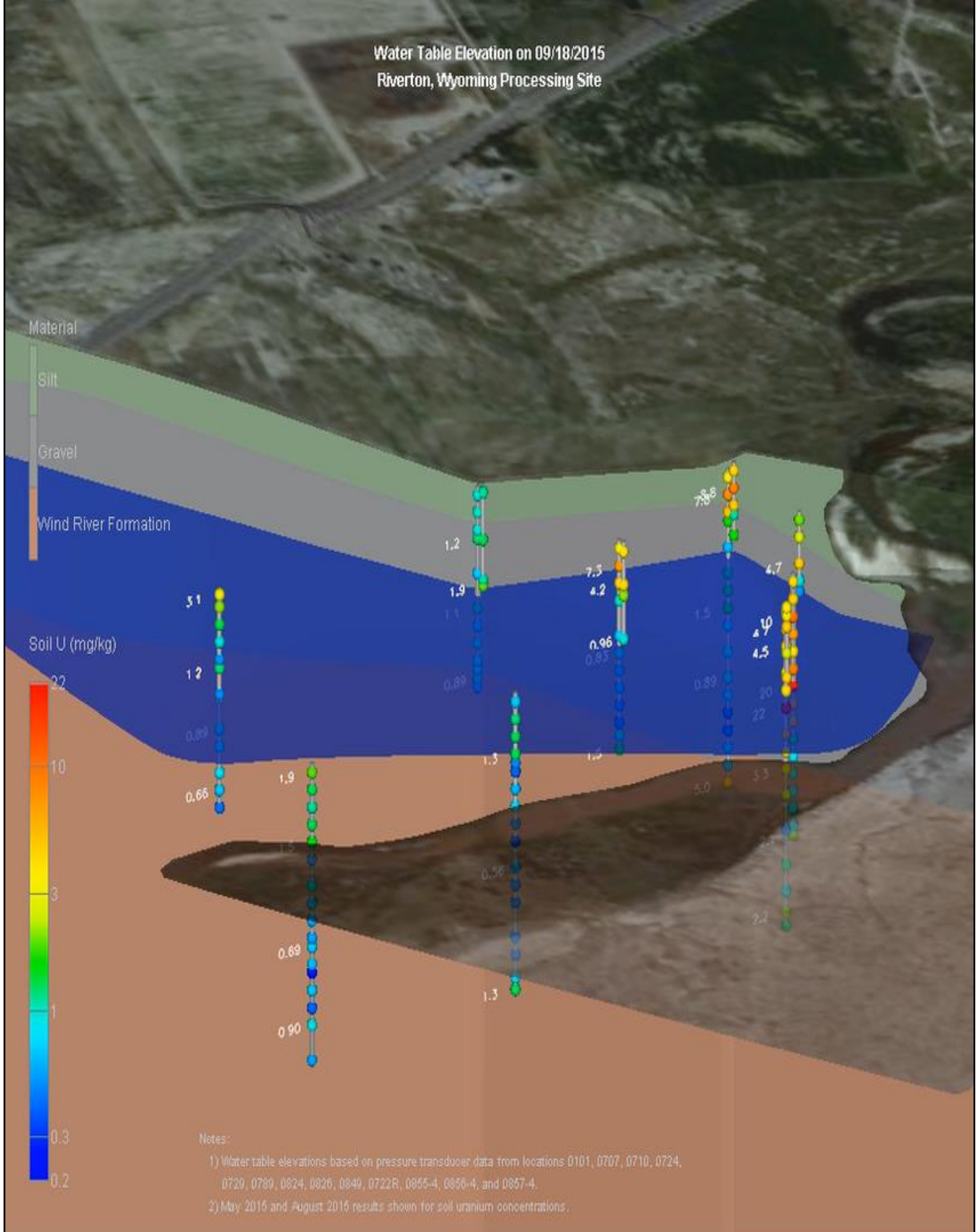


Key Communication Items for the Layperson

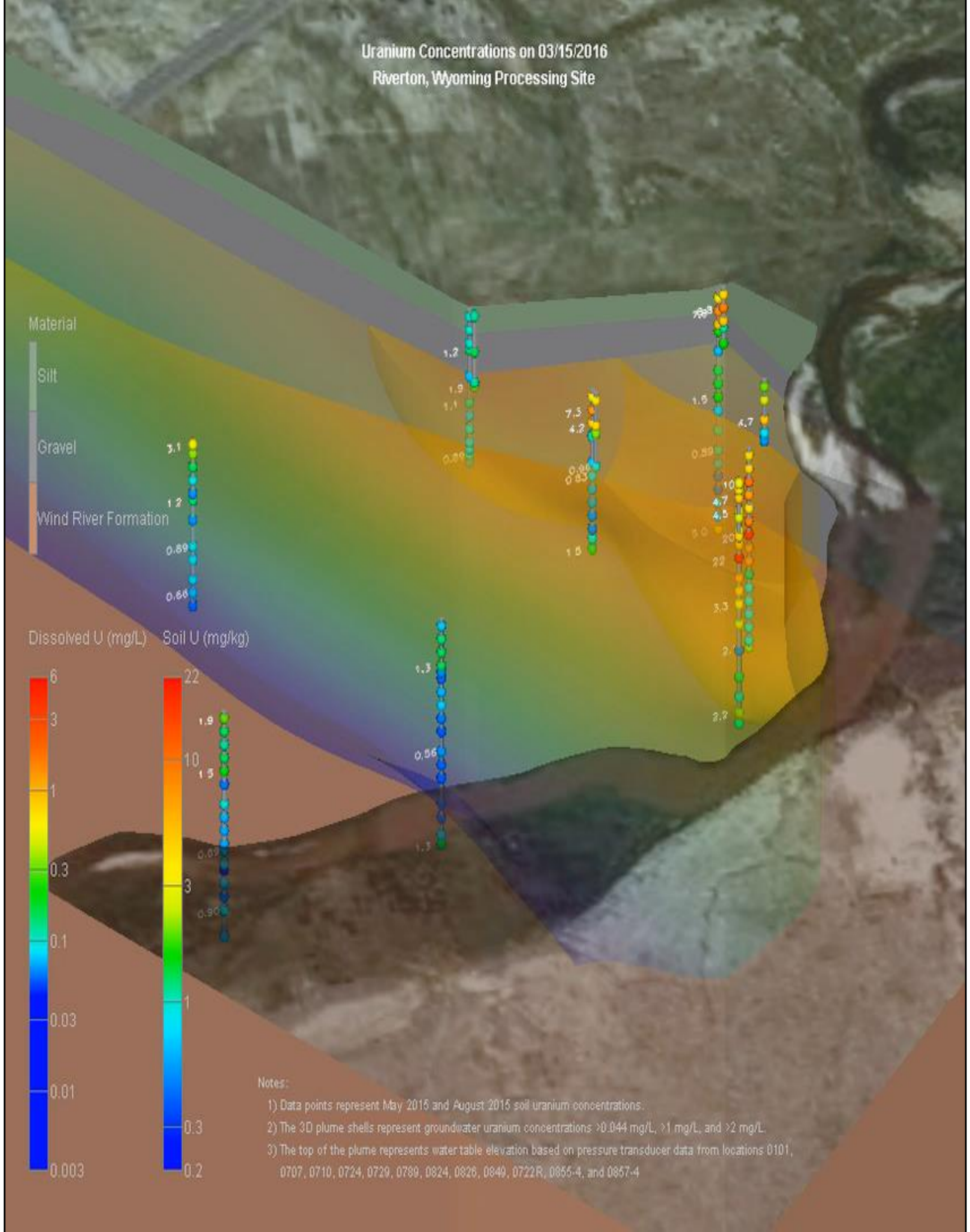
- Discuss how we got to current conditions
  - Source zone location
  - Groundwater flow direction
  - Plume development
- Going forward
  - Future plume movement and concentrations
  - Downgradient discharge or exposure points
  - Plans for LTS and/or active remediation
  - Ongoing source zone or not (key information, not always well known)
- Predictions rely on many factors, including: adequate site conceptual models, numerical simulations /trend analyses, and understanding of uranium geochemistry in the water and solid phases
- Predictions have uncertainty (like weather forecasts)

Communication Tools

- 3D graphics with
  - Real LTS data
  - Groundwater and solid phase concentrations
  - Presenter discussing geochemical complexities verbally
  - Future predictions
- Examples using 3D rendering software
  - Riverton geology, water table, and solid phase
  - Riverton with addition of plume
  - Naturita future plume movement based on trend analyses



Water Table Elevation on 09/18/2015
Riverton, Wyoming Processing Site
Material
Silt
Gravel
Wind River Formation
Soil U (mg/kg)
22
10
3
1
0.3
0.2
Notes:
1) Water table elevations based on pressure transducer data from locations 0101, 0707, 0710, 0724, 0729, 0789, 0824, 0826, 0849, 0722R, 0855-4, 0856-4, and 0857-4.
2) May 2015 and August 2015 results shown for soil uranium concentrations.



Uranium Concentrations on 03/15/2016
Riverton, Wyoming Processing Site
Material
Silt
Gravel
Wind River Formation
Dissolved U (mg/L)
Soil U (mg/kg)
6
3
1
0.3
0.1
0.03
0.01
0.003
22
10
3
1
0.3
0.2
Notes:
1) Data points represent May 2015 and August 2015 soil uranium concentrations.
2) The 3D plume shells represent groundwater uranium concentrations >0.044 mg/L, >1 mg/L, and >2 mg/L.
3) The top of the plume represents water table elevation based on pressure transducer data from locations 0101, 0707, 0710, 0724, 0729, 0789, 0824, 0826, 0849, 0722R, 0855-4, and 0857-4

Visit Stations

- Sand tank (David Dander)
- 3D graphics (Ron Kent)
- Posters (Nicole Gordon and Ray Johnson)

Open Discussion

- Other communication ideas?
- Level of complexity on uranium geochemistry?
- Balance of transparency versus communicating all the details?
- How to communicate uncertainty?