Uranium Contamination in the Subsurface Beneath the 300 Area

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- This presentation provides a brief overview of information presented in the recent report “Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington” (PNNL-17034, February 2008).

- Uranium contamination in 300 Area groundwater lies beneath former liquid waste disposal sites, such as the South Process Pond, the 307 Process Trenches, the North Process Pond, and the 300 Area Process Trenches. Leakage from the Process Sewer and radiological sewer systems may also have contributed to the uranium plume.

- Work in addition to the Phase III Feasibility Study that is associated with uranium in the 300-FF-5 Operable Unit includes a field treatability test using polyphosphate to immobilize uranium, research associated with uranium geochemistry and mobility as part of DOE's Integrated Field-Scale Challenge program, and an investigation of volatile organic compounds in deeper portions of the unconfined aquifer than previously monitored.

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Previous Work:

- **Understanding of uranium contamination in 300 Area groundwater has evolved as a consequence of numerous investigations:**
  - **1979: Geohydrology and groundwater quality beneath the 300 Area**
  - **1988: Investigation of 300 Area Process Trenches (RCRA)**
  - **1990-1994: Initial remedial investigation/feasibility study (CERCLA)**
  - **2004: Expanded groundwater report for 300-FF-5**
  - **2006: Limited Field Investigation involving uranium in 300 Area**
  - **~2004 to present: Geochemistry investigations on uranium; hyporheic zone investigations (DOE Office of Science)**
- **Central question: Why has the uranium plume in 300 Area groundwater persisted longer than predicted?**
  - ***Where is the inventory of uranium that feeds the plume?***
  - ***How is the inventory of uranium mobilized to re-supply the plume?***
  - ***How long can the inventory continue to supply uranium to the plume?***

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Lindberg, J.W. and F.W. Bond. 1979. *Geohydrology and Groundwater Quality Beneath the 300 Area, Hanford Site, Washington.* PNL-2949. Pacific Northwest National Laboratory, Richland, Washington.

Schalla, R. and others. 1988. *Interim Characterization Report for the 300 Areas Process Trenches*. PNL-6716, September 1988. Pacific Northwest Laboratory, Richland, Washington. (R.W. Wallace, R.L. Aaberg, S.P. Airhart, D.J. Bates, J.V.M. Carlile, C.S. Cline, D.I. Dennison, M.D. Freshley, P.R. Heller, E.J. Jensen, K.B. Olsen, R.G. Parkhurst, J.T. Rieger, and E.J. Westergard)

DOE-RL. 1994. *Phase I Remedial Investigation Report for the 300-FF-5 Operable Unit.* DOE/RL-93-21, Rev. 0, Vol. 1, January 1994. U.S. Department of Energy, Richland, Washington. (information volume)

DOE-RL. 1995. *Remedial Investigation/Feasibility Study Report for the 300-FF-5 Operable Unit.* DOE/RL-94-85, Rev. 0, May 1995. U.S. Department of Energy, Richland, Washington.

Peterson, R.E. (editor). 2005. *Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for FY 2004.* PNNL-15127, March 2005. Pacific Northwest National Laboratory, Richland, Washington. (Contributors: E.J. Freeman, C.J. Murray, R.E. Peterson, P.D. Thorne, M.J. Truex, V.R. Vermeul, M.D. Williams, S.B. Yabusaki, J.M. Zachara, J.L. Lindberg, and J.P. McDonald)

Williams, B.A., C.F. Brown, W. Um, M.J. Nimmons, R.E. Peterson, B.N. Bjornstad, D.C. Lanigan, R.J. Serne, F.A. Spane, and M.L. Rockhold. 2007. *Limited Field Investigation Report for Uranium Contamination in the 300 Area, 300-FF-5 Operable Unit, Hanford Site, Washington.* PNNL-16435, November 2007. Pacific Northwest National Laboratory, Richland, Washington.

Zachara, J.M. (editor). 2005. *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume*. PNNL-15121, March 2005. Pacific Northwest National Laboratory, Richland, Washington. (Collaborators: J.A. Davis, C. Liu, J.P. McKinley, N. Qafoku, D.M. Wellman, and S.B. Yabusaki)

Zachara, J.M., C. Liu, C. Brown, S. Kelly, J. Christensen, J. McKinley, J.A. Davis, J. Serne, E. Dresel, and W. Um. 2007. *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site.* PNNL-17031, October 2007. Pacific Northwest National Laboratory, Richland, Washington.

Fritz, B.G., R.D. Mackley, N.P. Kohn, G.W. Patton, T.J. Gilmore, D.P. Mendoza, D. McFarland, A.L. Bunn, and E.V. Arntzen. 2007. *Investigation of the Hyporheic Zone at the 300 Area, Hanford Site*. PNNL-16805, October 2007. Pacific Northwest National Laboratory, Richland, Washington.

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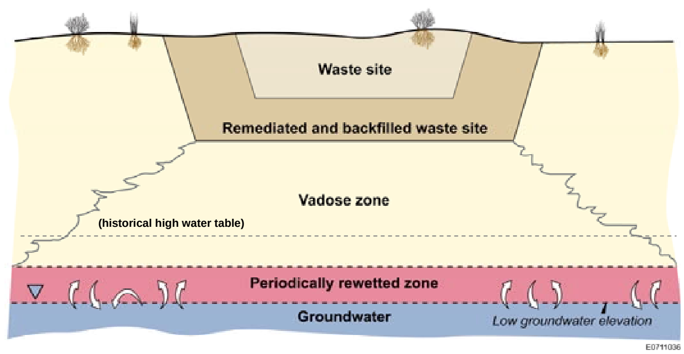

Source: Washington Closure Hanford

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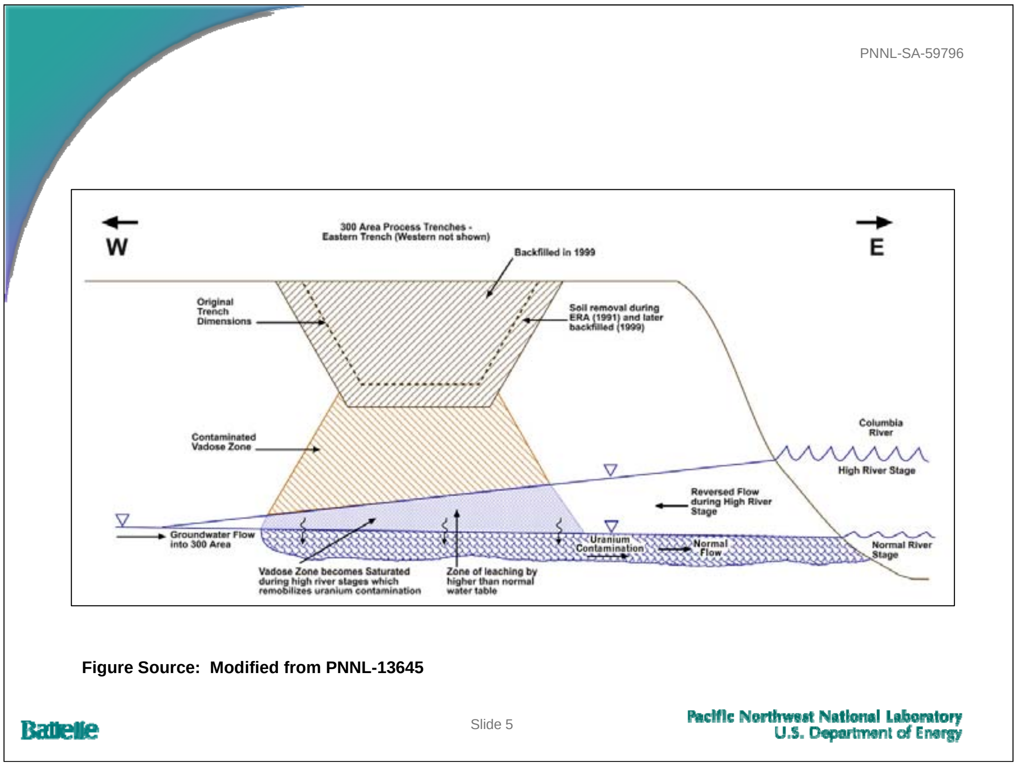
- Diagram identifies the principal features of the subsurface that are relevant to discussions of contaminant pathways from waste sites to groundwater. Conceptual model is representative of conditions beneath the former North and South Process Ponds, and 300 Area Process Trenches.

- Contaminated soil has been removed from the major liquid waste disposal facilities in the 300 Area. Some contamination remains at the bottom of excavations, as documented in the Cleanup Verification Packages, but the level of that contamination has been deemed to be protective of groundwater.

- For contamination remaining in the vadose zone to impact groundwater, two conditions must be present: (1) the uranium must be in a form that can be mobilized, i.e., “labile,” and (2) some transporting medium must be available, such as moisture.

- Detailed characterization of contaminants in the vadose zone beneath or close to remediated waste sites has been done only for very limited areas within the 300 Area. Only one characterization borehole has been drilled through the footprint of a waste site; borehole 399-2-5 was drilled through the south-central portion of the former South Process Pond.

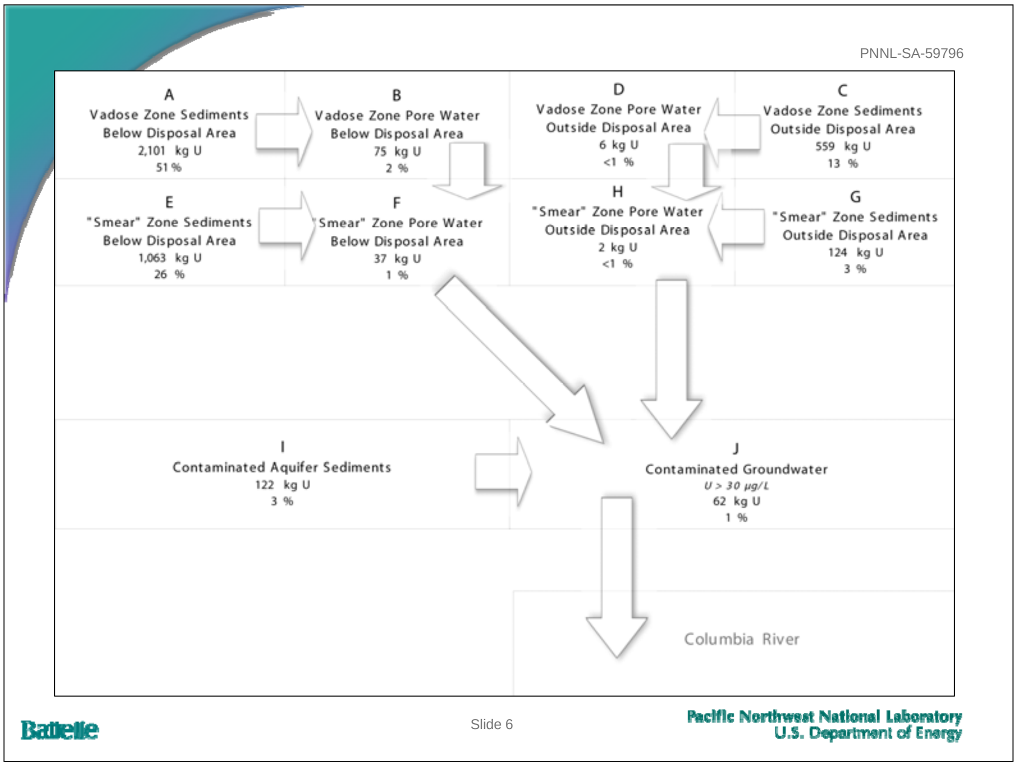


- Subsurface hydrologic conditions beneath the 300 Area are made complex because of the influence of the Columbia River on (a) water table elevation, and (b) infiltration of river water in the region along the shoreline.

- The highly permeable sediment of the Hanford gravels hydrologic unit contributes to this complexity, resulting in rapid changes in groundwater movement patterns and flow velocities. (The uppermost hydrologic unit within the unconfined aquifer are saturated sediments of the Hanford gravels formation; this unit contains the bulk of contaminant uranium in groundwater).

- Variations in Columbia River stage are caused by reservoir level control at McNary Dam, and by releases from Priest Rapids Dam upstream. River elevations may vary through a range of up to 3 meters at the 300 Area. During high river stage conditions, river water may infiltrate the aquifer inland as far as 400 meters (i.e., halfway to Stevens Drive).

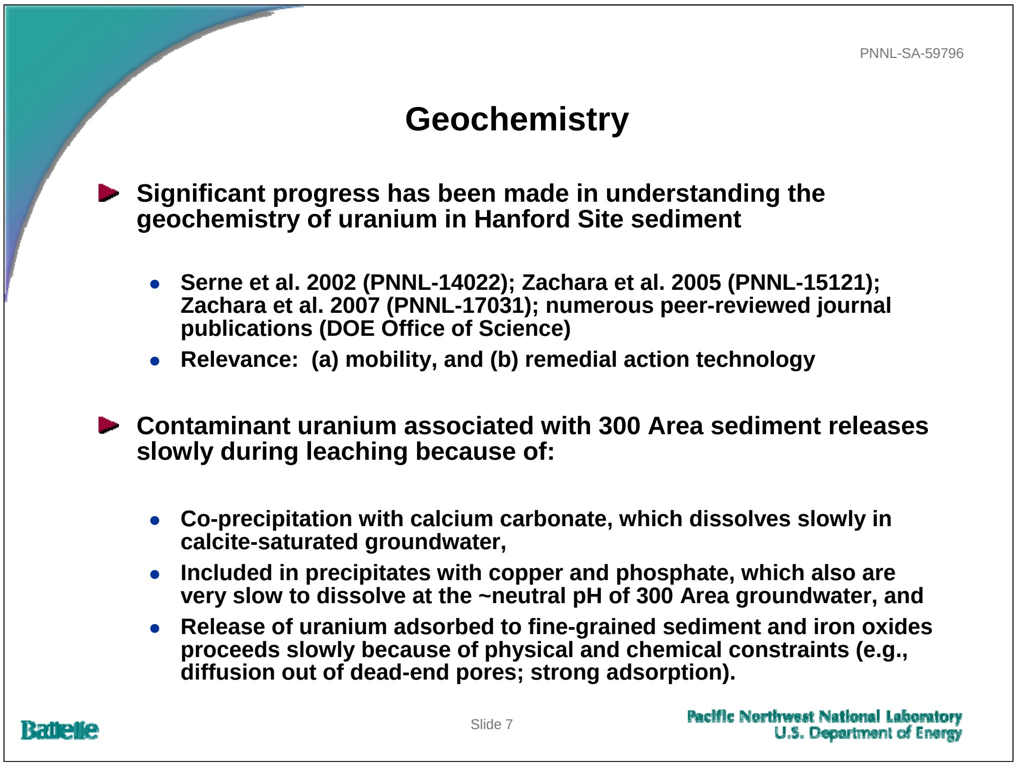
- The very high permeability of the contaminated sediments, along with the dynamic, complex hydrologic processes at the water table, pose significant challenges for the design and implementation of a remediation action technology.



- The subsurface has been subdivided into various compartments ("box" model) for the purpose of estimating the inventory of contaminant uranium remaining in the subsurface.

- Estimates for the mass of uranium in each compartment are based on available samples.

- The arrows illustrate the principal exchange routes among the compartments. Defensible estimates for mass flux associated with each arrow are not yet available, with the exception of preliminary estimates for the rate of loss to the Columbia River, and withdrawal from a water supply well.



Serne, R.J., C.F. Brown, H.T. Schaef, E.M. Pierce, J.W. Lindberg, Z. Wang, P.L. Gassman, and J.G. Catalano. 2002. *The 300 Area Uranium Leach and Adsorption Project.* PNNL-14022. Pacific Northwest National Laboratory, Richland, Washington.

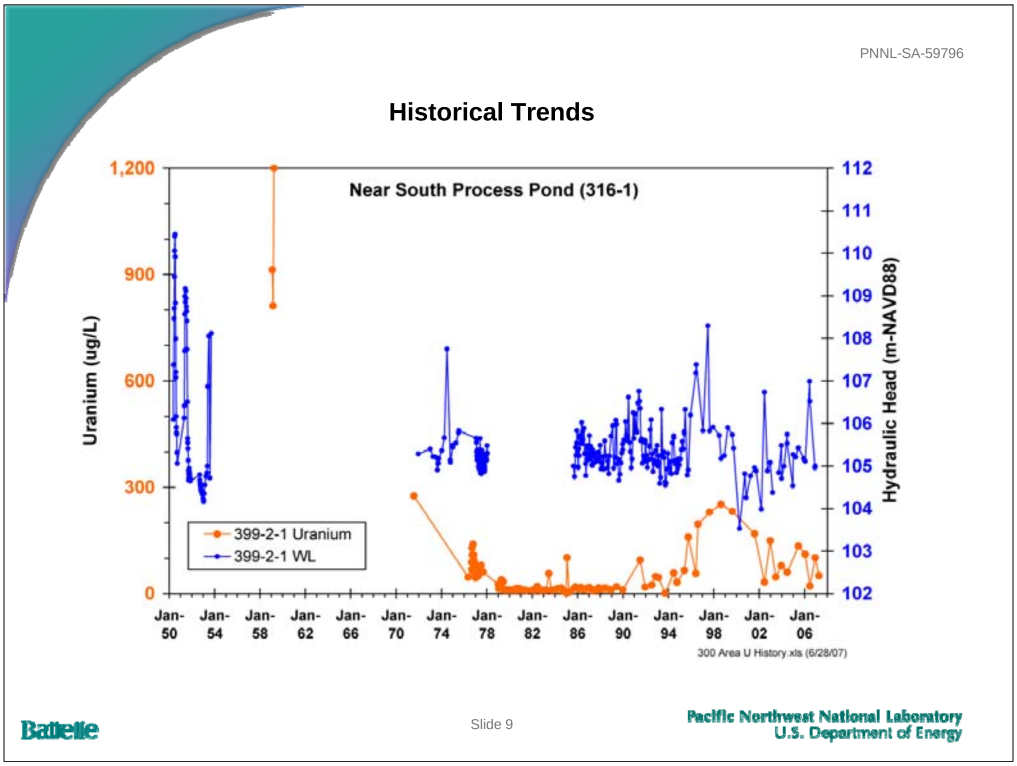
Zachara, J.M. (editor). 2005. *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume*. PNNL-15121, March 2005. Pacific Northwest National Laboratory, Richland, Washington. (Collaborators: J.A. Davis, C. Liu, J.P. McKinley, N. Qafoku, D.M. Wellman, and S.B. Yabusaki)

Zachara, J.M., C. Liu, C. Brown, S. Kelly, J. Christensen, J. McKinley, J.A. Davis, J. Serne, E. Dresel, and W. Um. 2007. *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site.* PNNL-17031, October 2007. Pacific Northwest National Laboratory, Richland, Washington.

- Aerial imagery from ~2000, when excavations at major liquid waste disposal sites were still open.

- The most recent intentional disposal of liquid effluent containing uranium occurred in the mid-1980s at the former 300 Area Process Trenches.

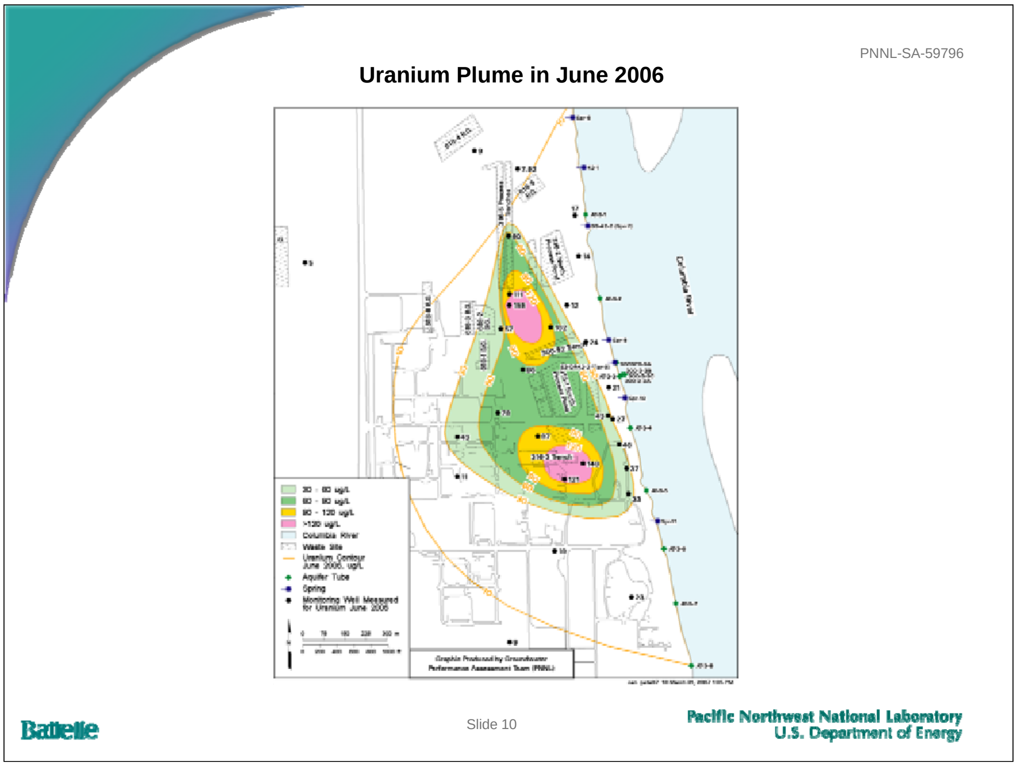
- The only major liquid waste disposal facility not yet remediated is the 307 Process Trenches (316-3), which operated between 1953 and 1963, when they were taken out of service and backfilled with contaminated sediment from the South Process Pond.



(point out scales and axes)

- Uranium concentrations in groundwater during the South Ponds' operating years were considerably higher than during subsequent years.

- Range in water table during 1950s reflects pre-Priest Rapids Dam conditions. Water table may have been elevated to some unknown degree by mounding beneath the ponds.

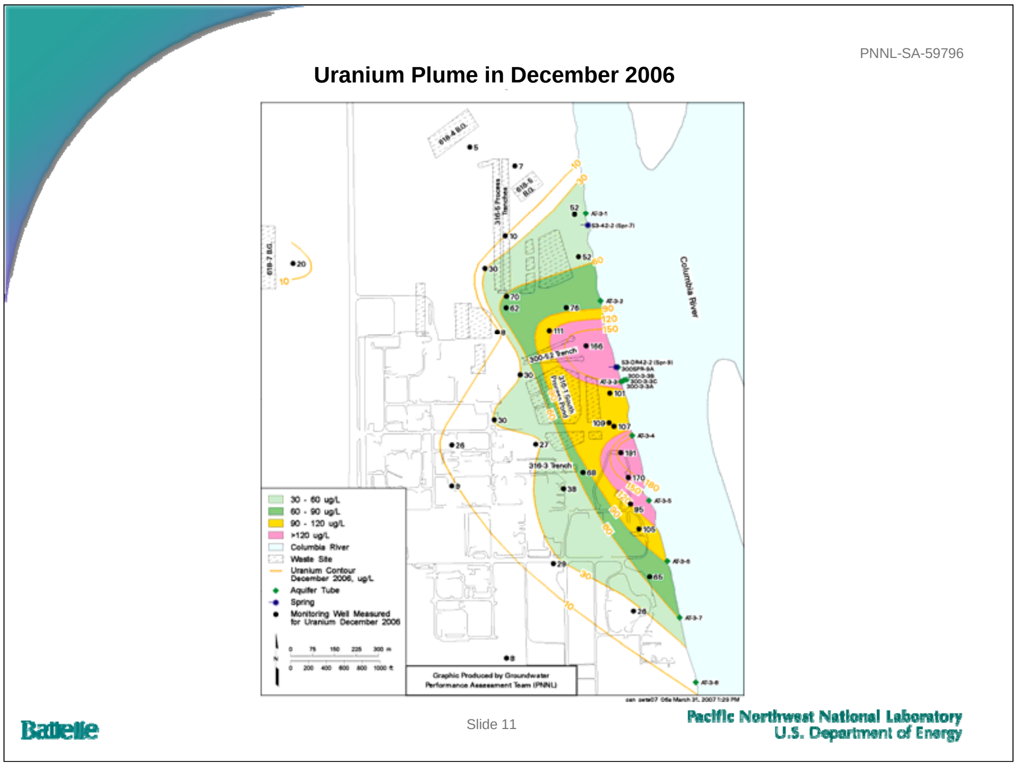


- Conditions during June 2006 reflect seasonal changes in uranium concentrations and distribution patterns. The general area occupied by contaminant uranium remains very similar to the area as mapped in the 1980s; this is also true for the area where the drinking water standard is exceeded.

- When the water table is high, increases in concentrations are observed near suspected areas of mobile contamination held in the lower portion of the vadose zone.

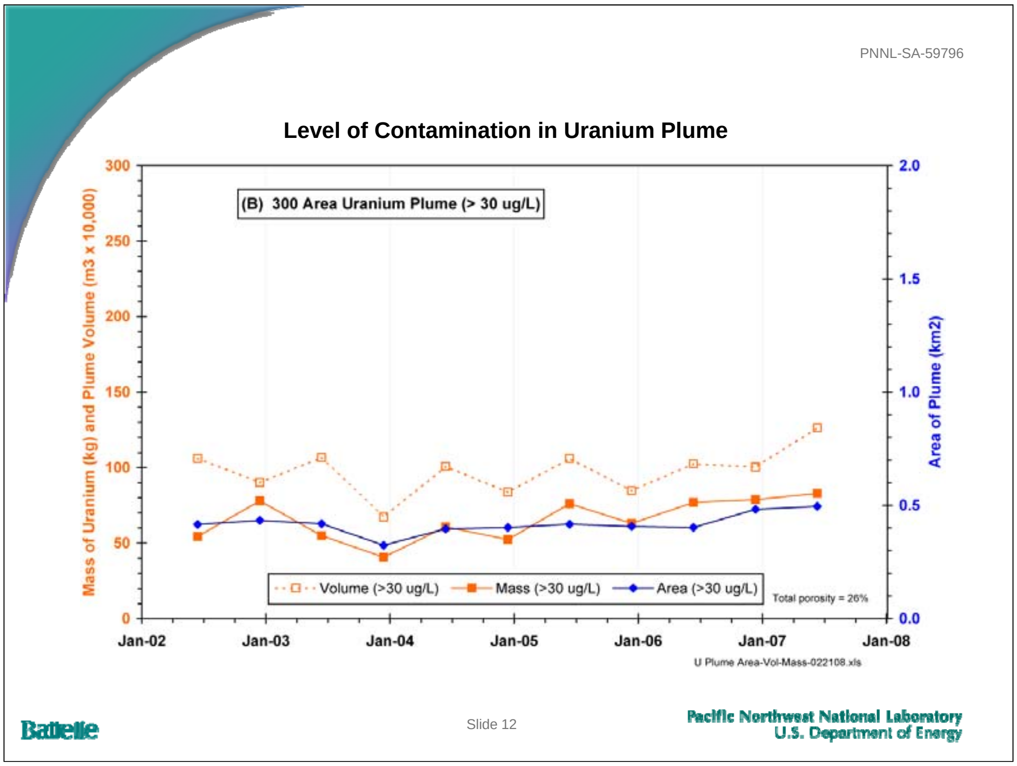
- Also, during high river stage conditions, river water infiltrates the near-river region and mixes with contaminated groundwater, thus lowering the concentration of contaminants. Infiltrating river also changes the geochemical environment such that tendency for adsorption of uranium onto sediment is enhanced.

- Monitoring data reveal that the patches of increased concentrations migrate rapidly toward the Columbia River. Tracer tests associated with the recent Polyphosphate Treatability Test confirm the rapid rates. Velocities as high as 15 meters per day have been observed.



- Conditions during December 2006 reflect (a) migration of patches of increased concentrations toward the river, (b) the absence of dilution created by infiltrating river water, and (c) possibly the release of uranium temporarily sequestered on near-river sediment, as the geochemical environment shifts from that created by infiltrating river water to pure groundwater, which enhances the desorption of uranium from sediment.

- Because of highly permeable sediment and rapidly changing hydraulic gradients, the concentration of uranium seen at any particular time or well can change rapidly. Thus, the timing associated with collecting monitoring data is an important consideration, not only for wells, but also at river monitoring locations.



- Plume parameters that are relevant to discussing trends in the "level" of contamination and for designing a remedial action are estimated from plume maps and knowledge of the 3-dimensional space occupied by the contaminant plume.

- This graphic is limited to plume maps drawn for the past five years, because maps for those years are reasonably consistent in (a) the way plume contours are drawn, (b) in the assumptions regarding uranium source areas and groundwater flow patterns, and (c) the number of monitoring wells that are in service.

- The white double arrows indicate where cross sections have been drawn to illustrate the hydrogeologic framework within which the uranium contamination resides.

- EarthVision™ software is being used to manage spatial framework data, and also to generate graphics.

- These cross sections reveal the new interpretations developed as part of the limited field investigation for uranium (next slide shows the west-east cross section as an example).

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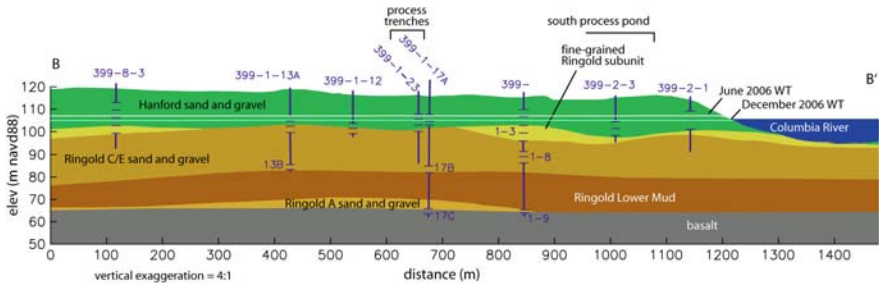
**Northwest-to-Southeast Cross Section:
Northern Portion of 300 Area**



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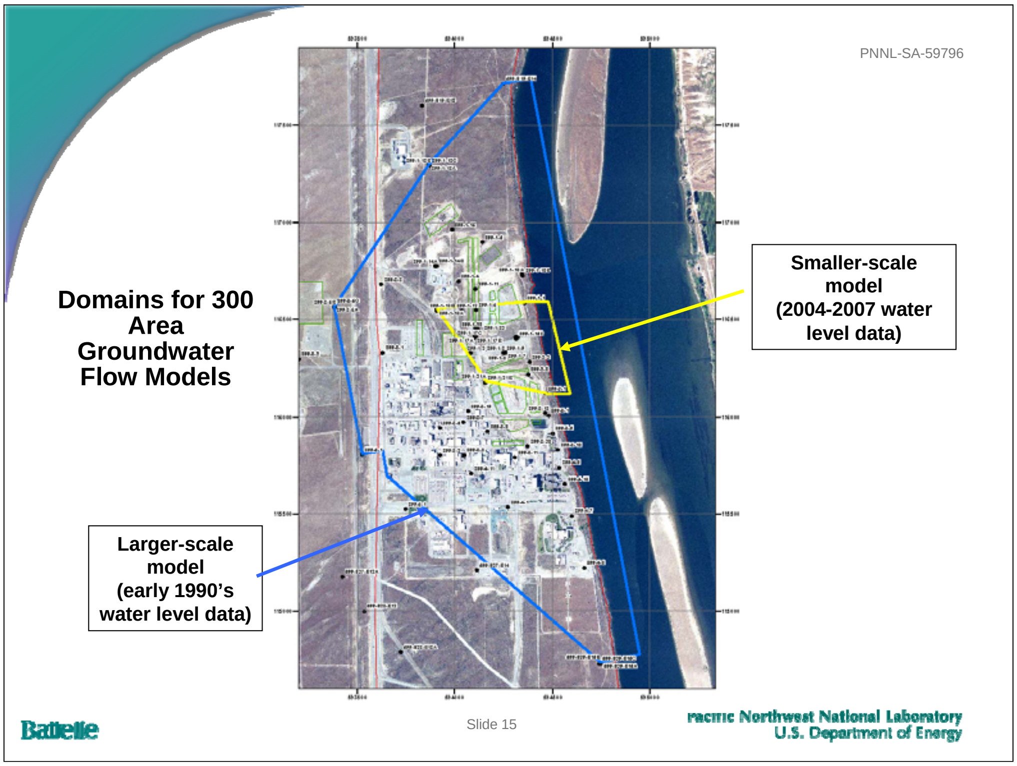
- This cross section is drawn along a path line that might be followed by a plume migrating from the vicinity of the former 300 Area Process Trenches toward the Columbia River.

- Uranium contamination is primarily contained within the saturated Hanford sand and gravel hydrologic unit (green layer below the water table).

- The zone between the high and low water zones cycles from partial to complete saturation, creating a dynamic hydro-geochemical environment. Where contaminated groundwater is present, this zone may be referred to as the “smear zone.”



- Computer simulation of groundwater flow in the unconfined aquifer beneath the 300 Area has been developed at two scales.

- The new information from the limited field investigation has allowed significant updates to the 3-D groundwater flow model.

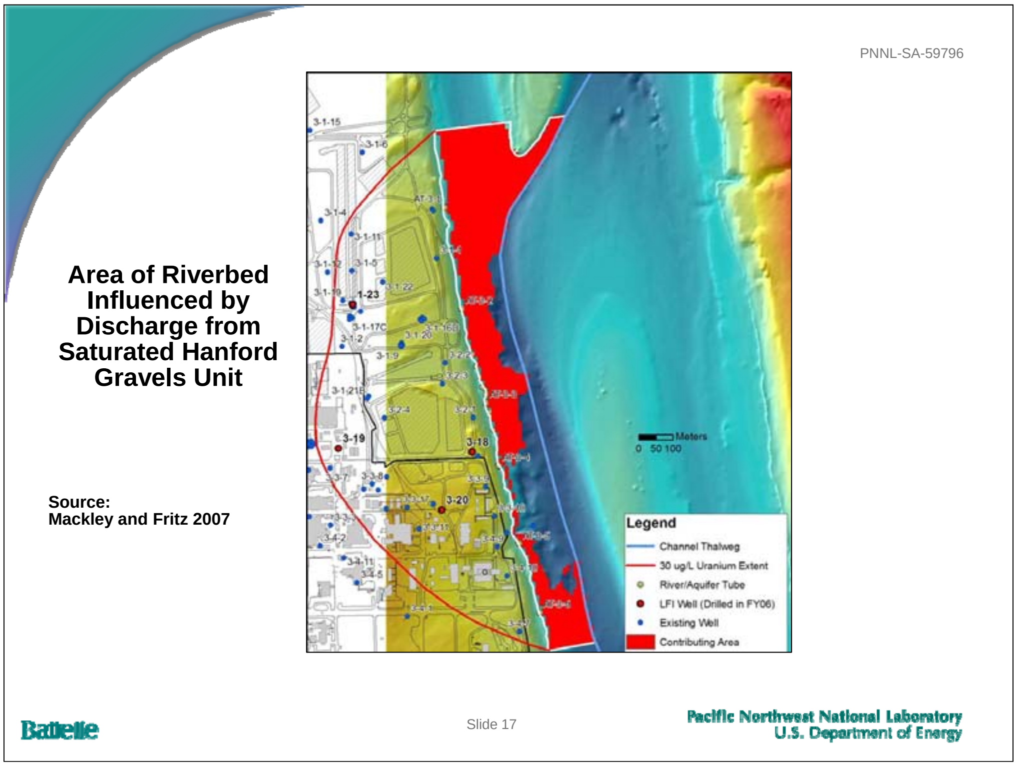
- The updates involve the hydrogeologic framework and aquifer hydraulic property parameters.

- The flow model is currently in use to estimate a water balance for the aquifer, i.e., how much groundwater flows into the 300 Area, and how much flows out. Input comes primarily from the northwest and west, while loss is through the eastern boundary to the river and also to the south. Groundwater has also been withdrawn since 1982 from a water supply well that serves the 331 Life Sciences Building.

- Additional detailed modeling that focuses on reactive transport modeling, using the 300 Area plume as a test case, is in progress under a DOE Office of Science project.

- The uranium-contaminated unconfined aquifer beneath the 300 Area is incised by the Columbia River channel, thus exposing some portions of the riverbed to contamination carried by groundwater. Because of aquifer discharge from both sides of the river, discharge from the Hanford Site aquifer does not extent beyond the centerline of the channel (thalweg).

- Computer simulation of flow beneath the zone of groundwater/river interaction suggests that discharge from the aquifer is not evenly spread across the interface at the riverbed, but rather is biased towards the nearshore region.

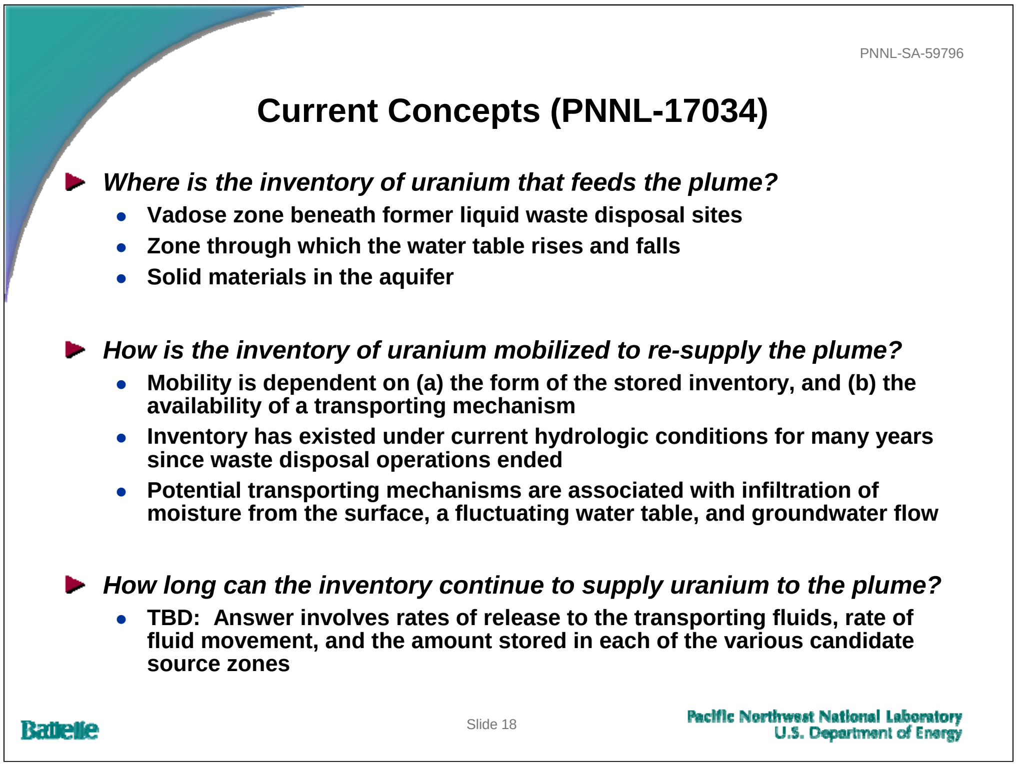


- The area of riverbed where uranium-contaminated groundwater discharges from the saturated Hanford gravels into the riverbed substrate is shown in red. Either saturated Hanford gravels or more recent river alluvium may form the substrate within the mapped area.

- This representation is created using data on (a) the elevation of the contact between Hanford gravels and the underlying Ringold Unit E, as observed in wells and projected into the river channel, (b) river channel bathymetry, and (c) field observations to refine the boundaries, which is needed because of lateral variations in hydrologic unit thickness, presence, etc.

- This information helps to limit the area and water depths where characterization of ecological receptors and sensitive habitat is needed for risk assessments.

Mackley, R.D. and B.G. Fritz. 2007. *Characterizing the Hydrogeology of the Hyporheic Zone Along the 300 Area of the Hanford Site, Washington.* PNNL-SA-56035. Oral presentation at the 6th Washington Hydrogeology Symposium, May 1-3, 2007, Tacoma, Washington.



- (transition to Mike Nimmon's presentation on remedial action alternatives)