

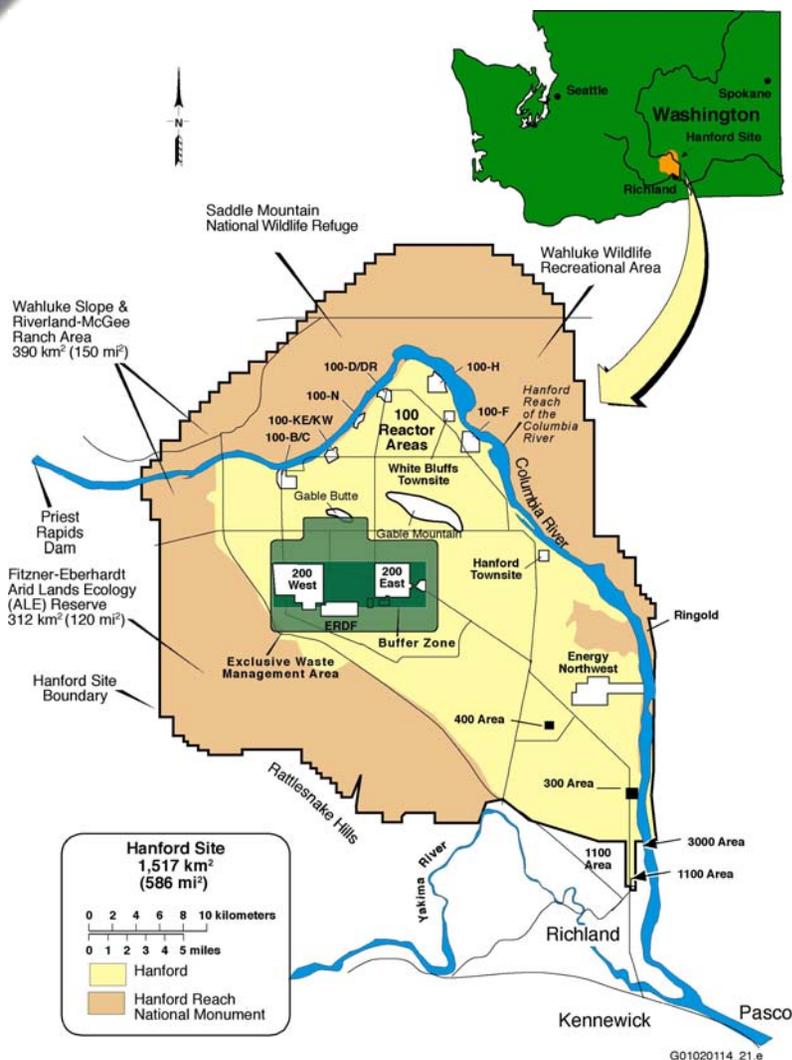
# **Hanford Site Groundwater and the Columbia River, South-Central Washington**

**R. E. Peterson, M. D. Williams,  
and G. W. Patton**

**Pacific Northwest National Laboratory**

***6<sup>th</sup> Washington Hydrogeology Symposium  
May 1-3, 2007, Tacoma, Washington***

***Abstract: PNNL-SA-56038***



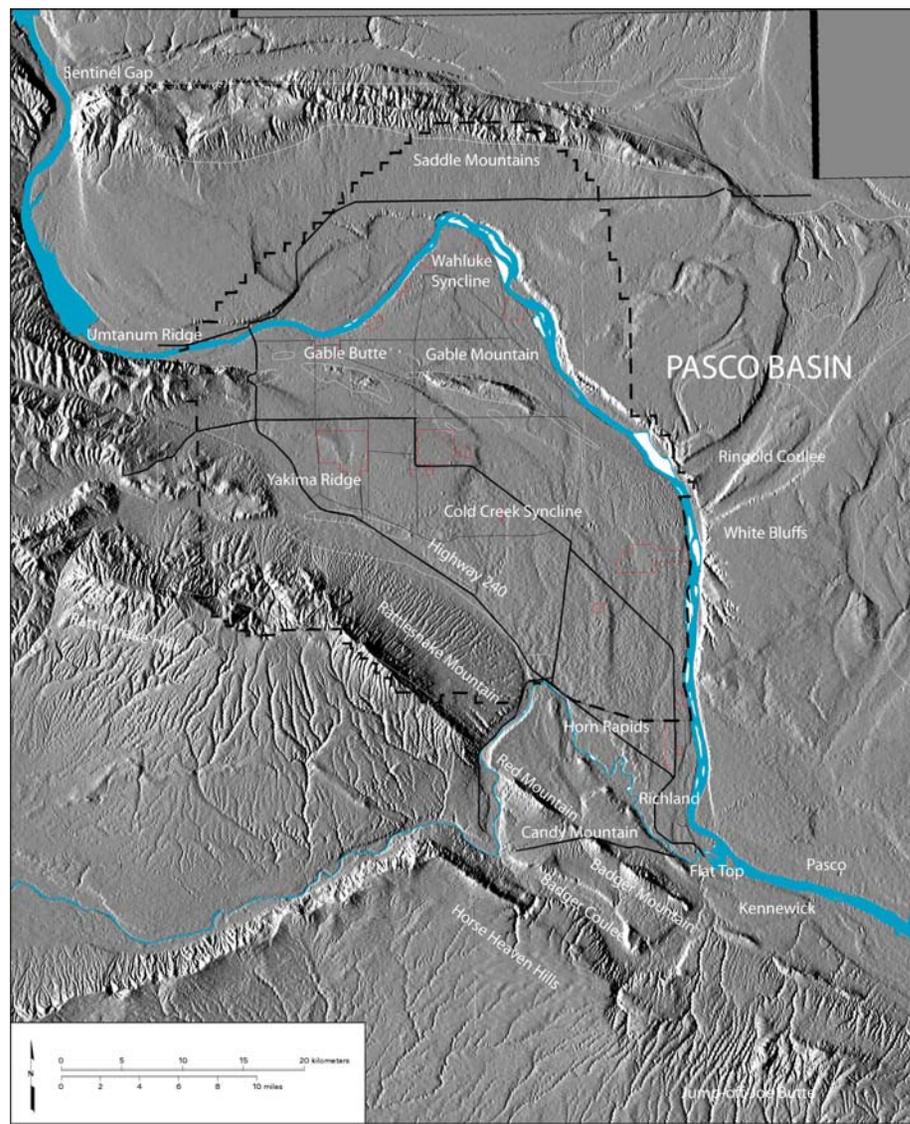
- ▶ **Hanford Site established in 1943 to produce plutonium for nuclear weapons.**
- ▶ **Major buildup during the Cold War years, i.e., late-1940's thru mid-1960's.**
- ▶ **The cycle: Fabricate fuel (300 Area), irradiate fuel (100 Areas), and separate strategic radionuclides (200 Areas).**
- ▶ **Current DOE mission is to manage legacy wastes, decommission facilities, and perform environmental cleanup.**

For more information:

**“Hanford: A Conversation about Nuclear Waste and Cleanup,” by Roy E. Gephart, Battelle Press, 2003**

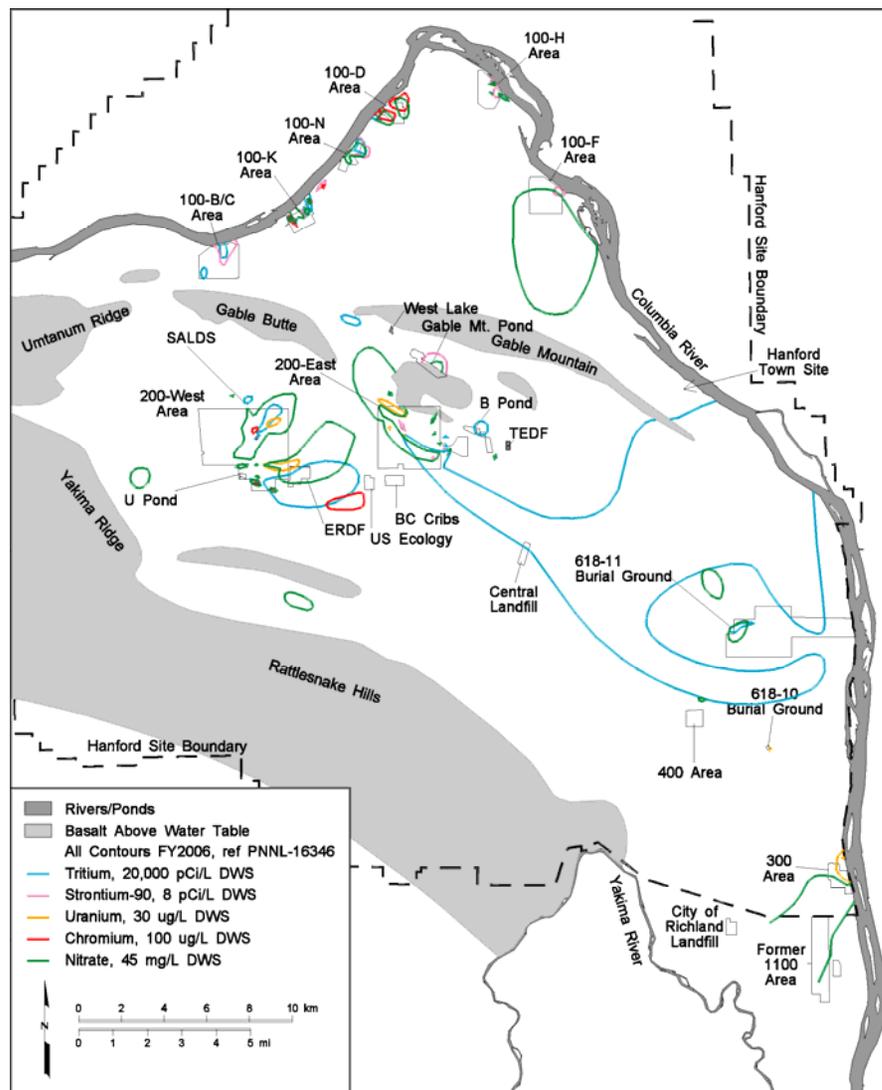
# GROUNDWATER and the COLUMBIA RIVER

- ▶ Contamination in groundwater
- ▶ Groundwater movement—rates and volumes
- ▶ Impact of groundwater discharge on river water quality



# GROUNDWATER PLUMES that CURRENTLY IMPACT the RIVER CORRIDOR

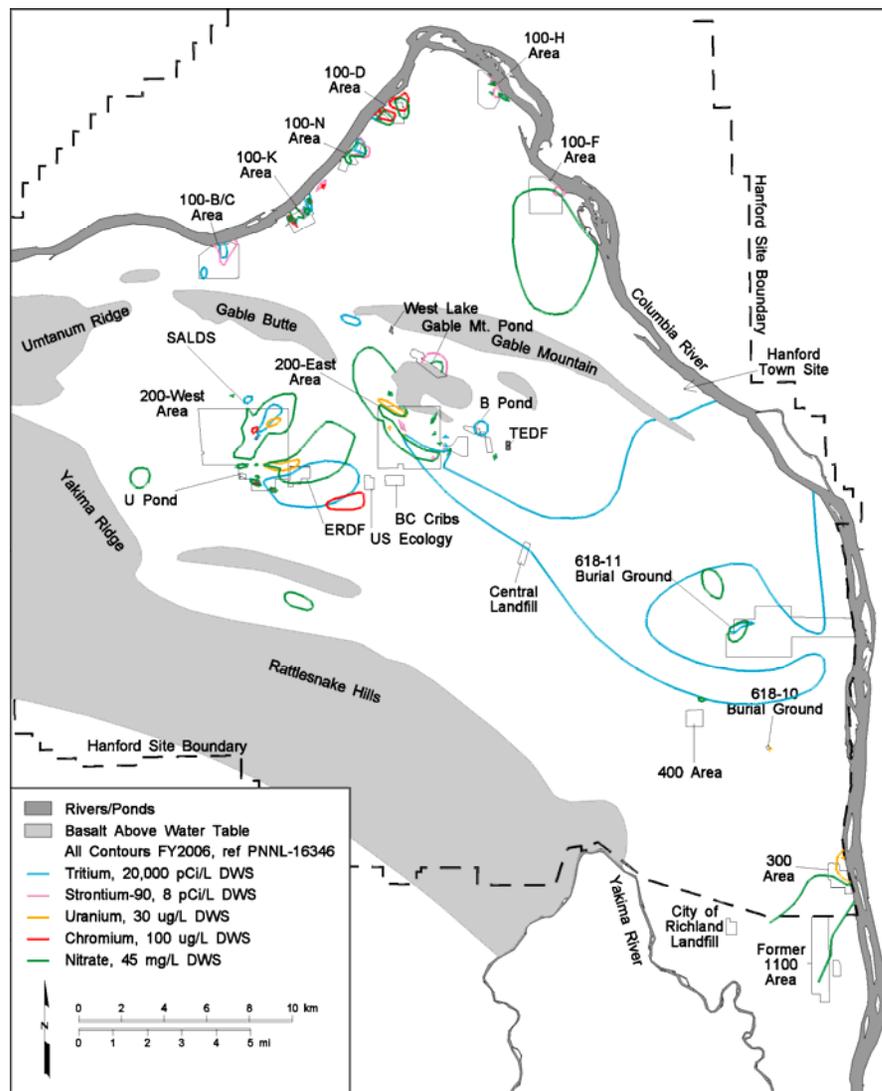
- ▶ **Tritium:**
  - Most widespread plume
  - Dissipating under natural processes (radioactive decay, dispersion)
  
- ▶ **Chromium & strontium-90:**
  - Remedial actions using pump-and-treat and *in situ* barrier systems
  
- ▶ **Uranium:**
  - Has persisted in the 300 Area longer than expected
  - Treatability tests



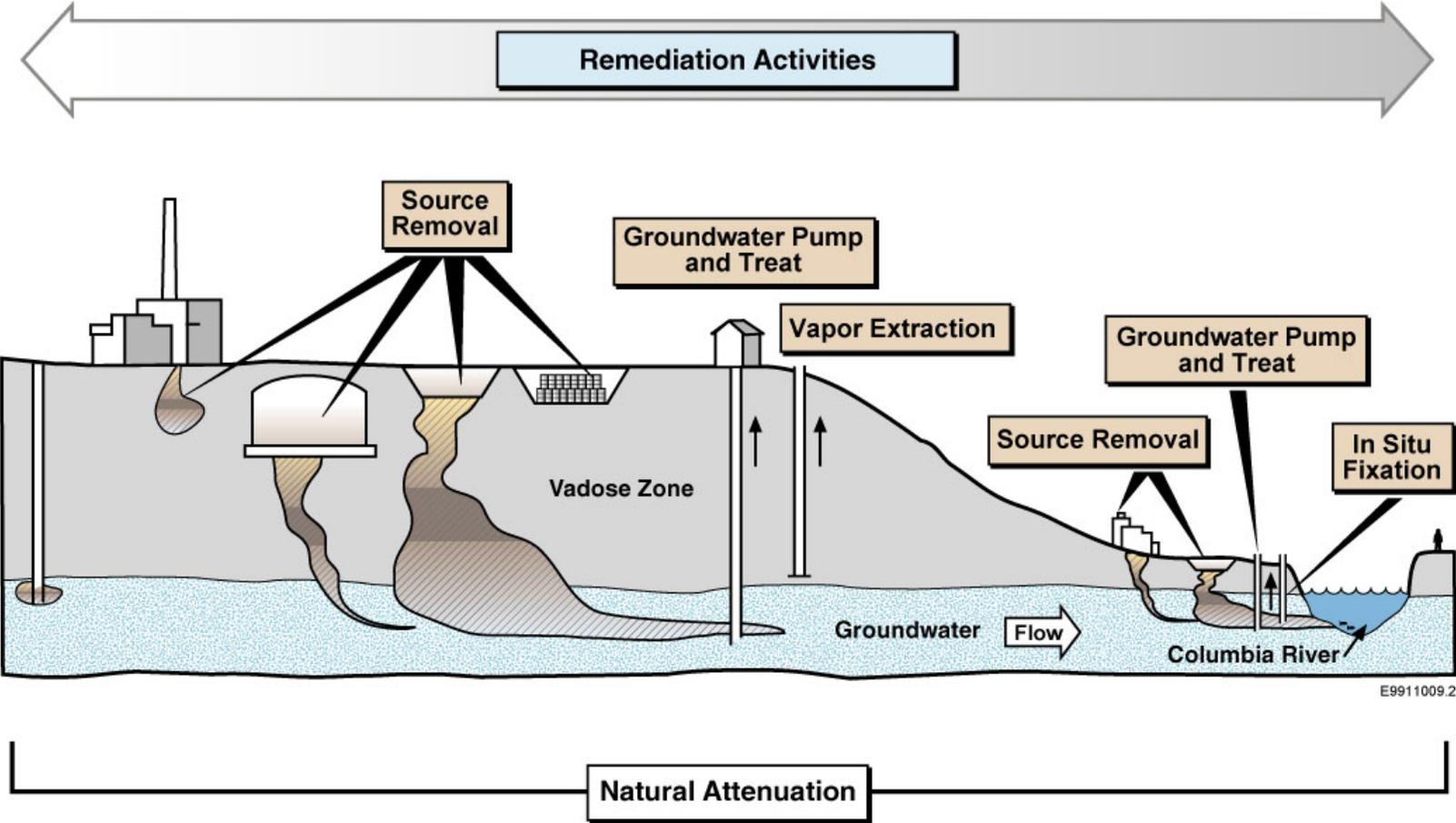
can\_pete07\_15 April 04, 2007 8:41 AM

Segment	Contaminant	Shoreline Impacted (meters)
100-B Area:	Cr+6 and Sr-90	973
	<sup>3</sup> H	85
100-K Area:	<sup>3</sup> H	366
	<sup>3</sup> H	250
	<sup>3</sup> H	324
100-N Area:	Sr-90	690
100-D Area:	Cr+6	133
	NO <sub>3</sub>	75
100-H Area:	Sr-90	480
600 Area:	<sup>3</sup> H	6,626
300 Area:	U <sub>total</sub>	1,518
	NO <sub>3</sub>	485
<b>Total:</b>		<b>12,326</b>

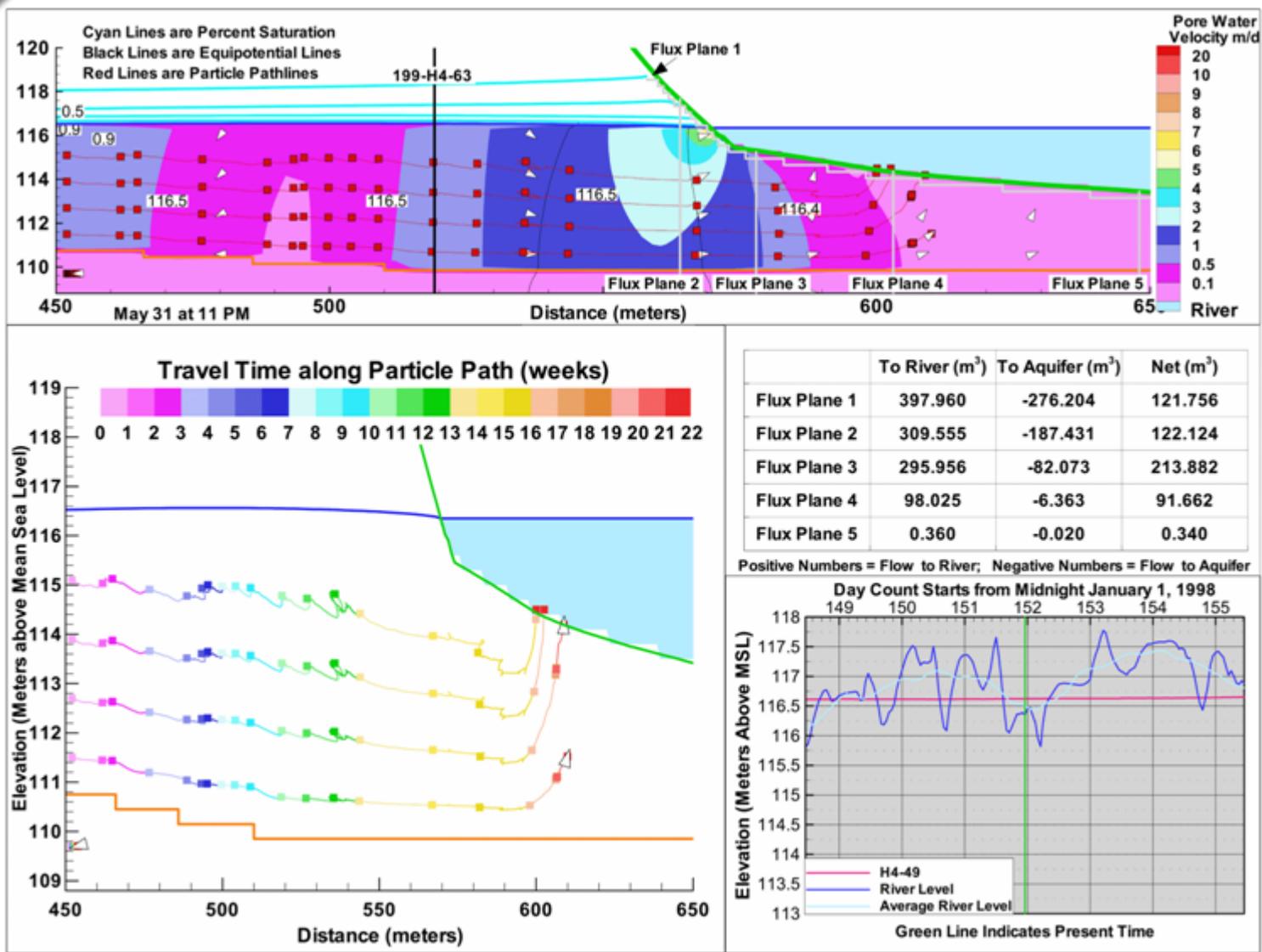
**\*\* Approximately 20% of the 64 km of shoreline that crosses the Hanford Site is impacted by contamination that exceeds regulatory standards.**



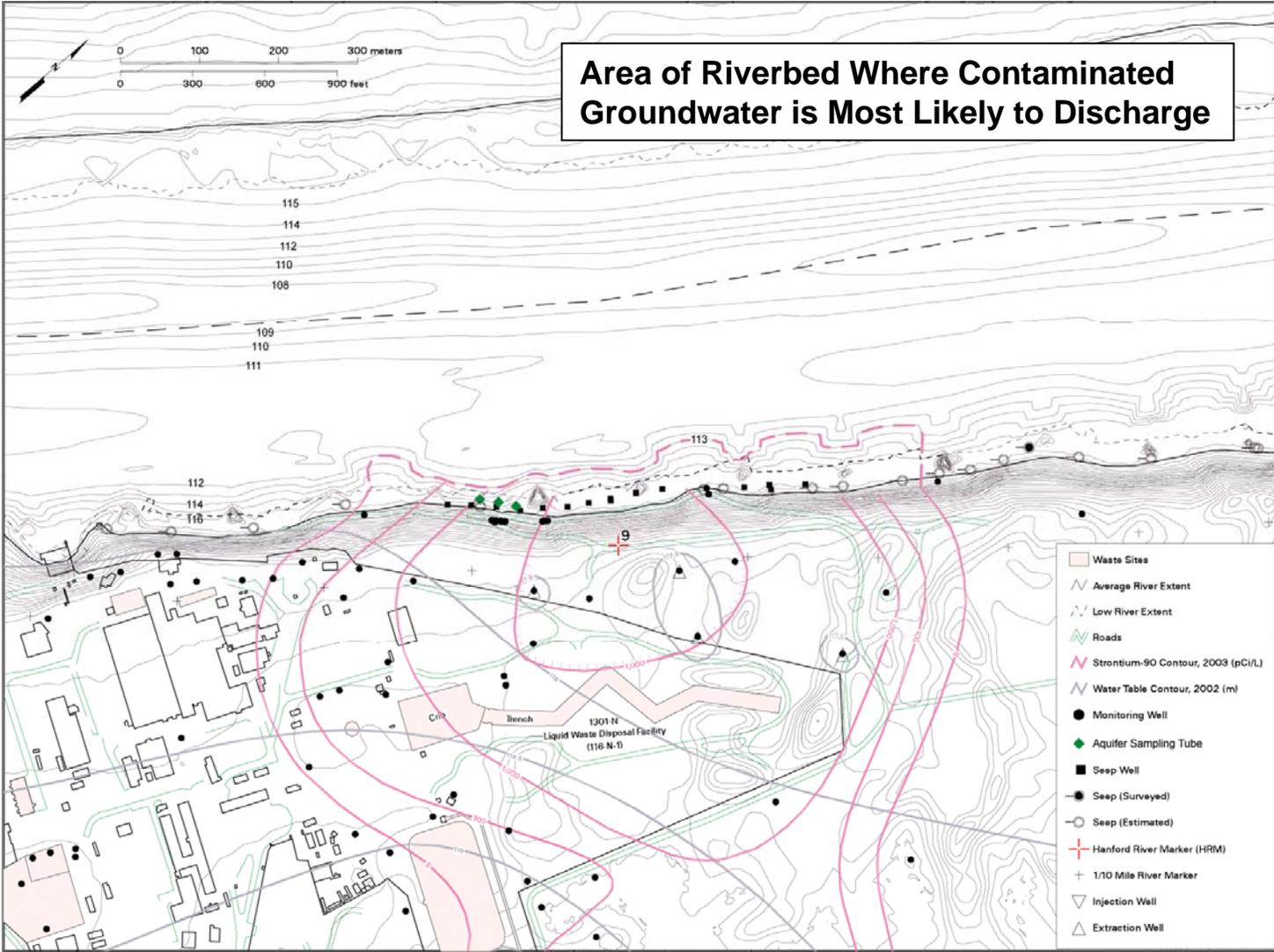
can\_pete07\_15 April 04, 2007 8:41 AM



E9911009.2



(Peterson and Connelly, 2001; 2004)

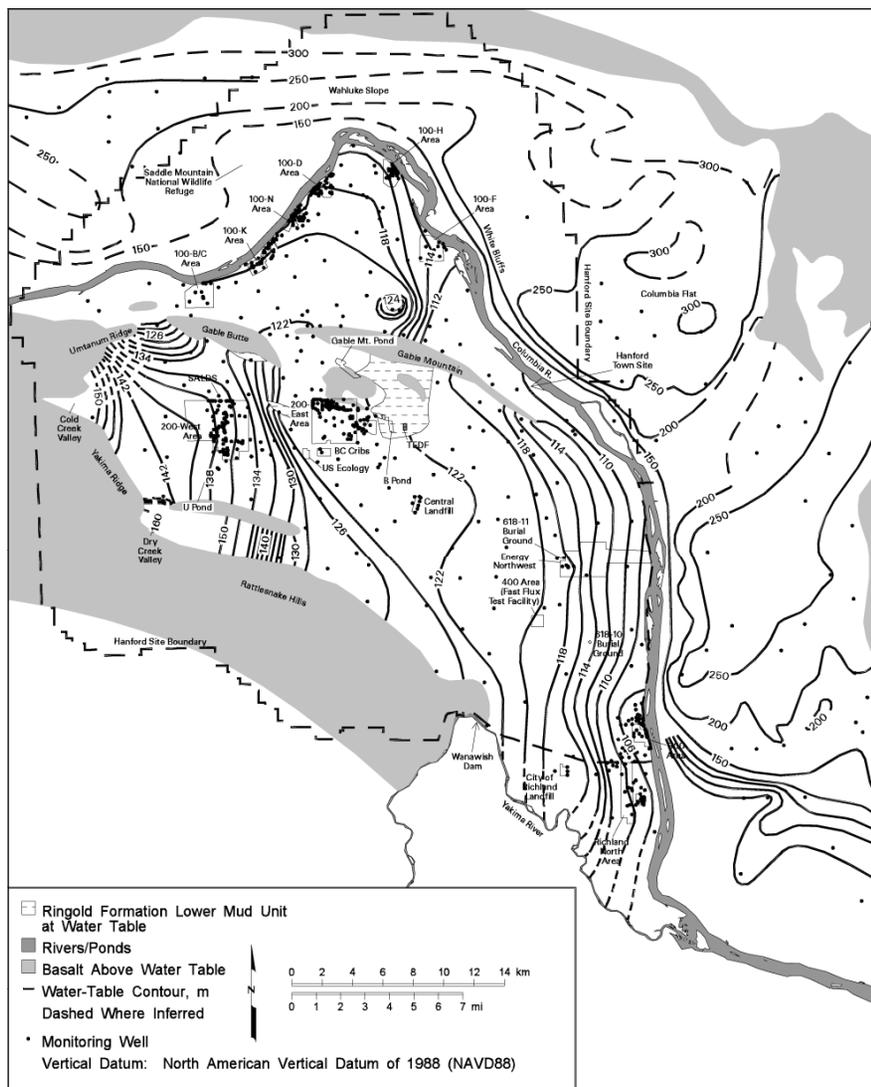


wdw04020.aml June 21, 2004 12:05 PM

## Topic 2--Perspective:

How much water is involved in the groundwater system?

Rates of recharge and discharge to the Columbia River?

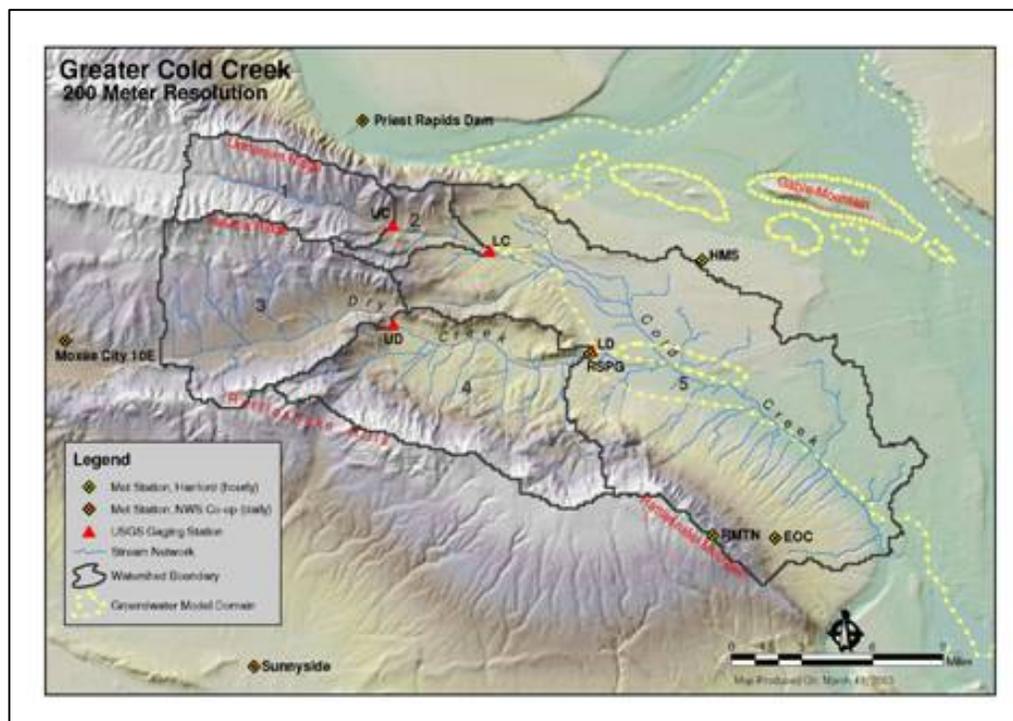


can\_gw02\_13 February 24, 2003 12:57 PM

## RECHARGE of the AQUIFER

- ▶ Recharge by natural precipitation:
  - 9.5M m<sup>3</sup>/yr (*Thorne et al. 2006—PNNL-14753*)
  - 8.5M m<sup>3</sup>/yr (*Fayer and Walters 1995—PNL-10285*)

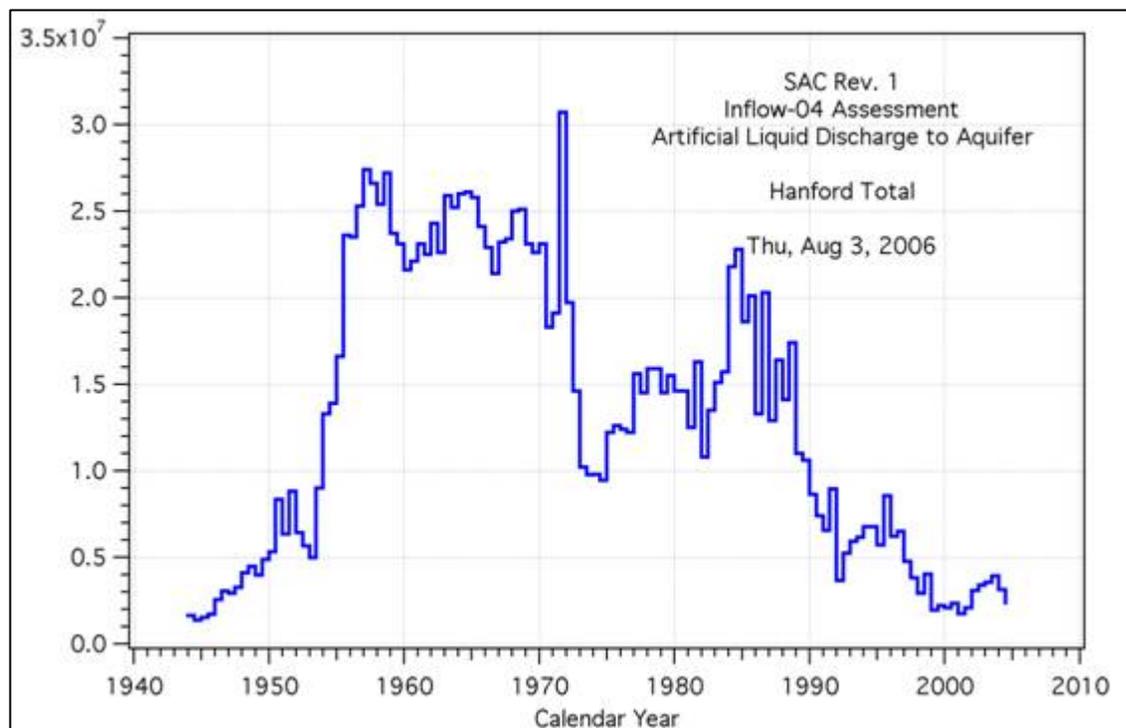
- ▶ Recharge from uplands to the west and south:
  - 13.3M m<sup>3</sup>/yr
  - Upper bounding value
  - (*Waichler et al. 2004—PNNL-14717*)



- ▶ Artificial recharge during production operations:
  - Nearly three times the recharge from natural precipitation (*Thorne et al. 2006*)

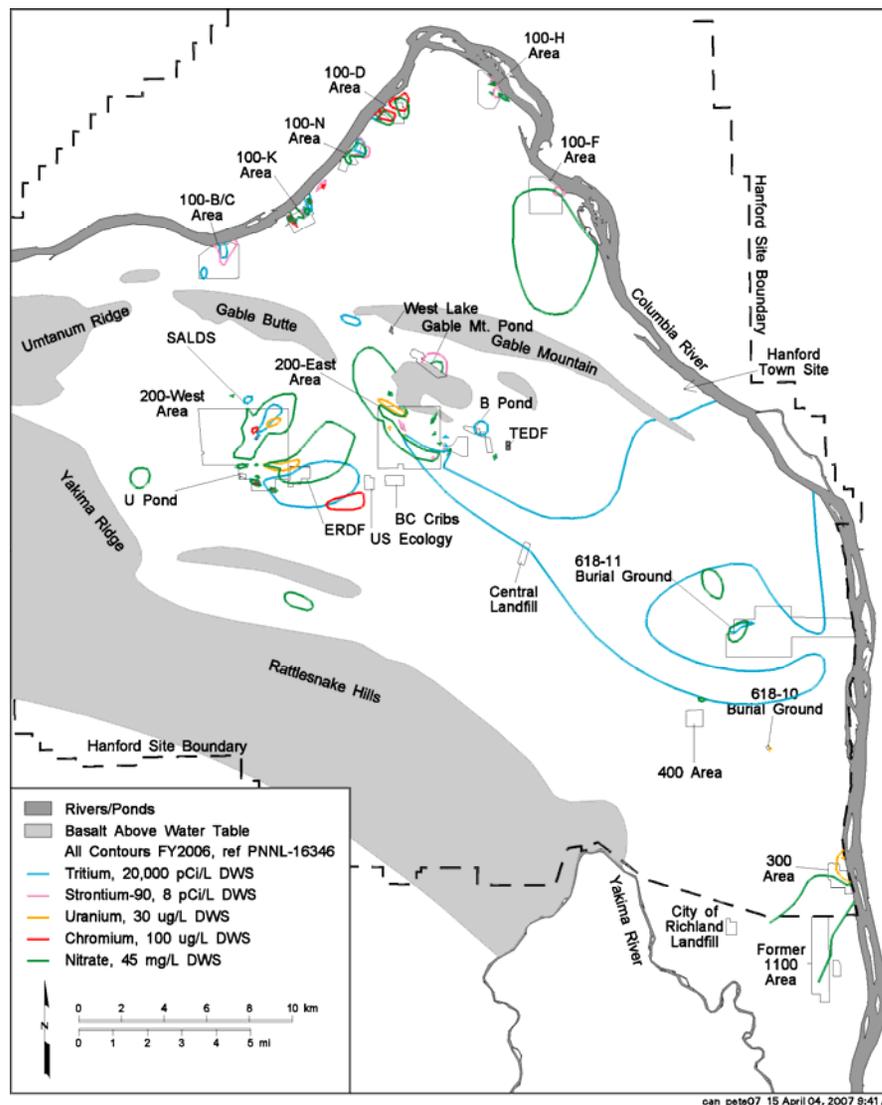
## ARTIFICIAL RECHARGE of the AQUIFER BECAUSE of OPERATIONS

- ▶ Average 1944 to 2006:  $\sim 24\text{M m}^3/\text{yr}$ , mostly to the Central Plateau region (*Nichols et al. 2007*)



## PLUME MOVEMENT

- ▶ **Plumes moved more quickly during the operating years because of steep gradients around mounds in the Central Plateau region (200 Areas)**
- ▶ **Under current conditions, predicting flow paths for plumes originating in the Central Plateau region is complicated by:**
  - **Low hydraulic gradients in the absence of mounds**
  - **Increased exposure of basalt as the water table continues lower**
  - **Predominant direction is easterly**
  - **Possibility of some flow to the north through Gable Gap**



can\_pete07\_15 April 04, 2007 8:41 AM

## GROUNDWATER TRAVEL TIME: CENTRAL PLATEAU to the COLUMBIA RIVER

- ▶ **During operations (peak—1948 thru 1970):**
  - **20~23 years** from 200 East to the Hanford Townsite
    - *Freshley and Graham, 1988 (PNL-6328)*
  - **10~20 years** from 200 East to the Hanford Townsite
    - *US Geological Survey (1987)*
  
- ▶ **Post-operation years, from 200 East:**
  - **~260 years** using VAM3D Model
    - *Law et al. 1996; Lu 1996*
  - **80~100 years** via northerly flow; **100~150 years** via easterly flow
    - CFEST: *Freedman et al. 2005 (PNNL-15377)*
  
- ▶ **Post-operation years, from 200 West:**
  - **~500 years** using VAM3D Model
    - *Law et al. 1996; Lu 1996*
  - **210~280 years** via northerly flow; **250~370 years** via easterly flow
    - CFEST: *Zhang et al. 2005 (PNNL-15399)*

## DISCHARGE from the AQUIFER to the COLUMBIA RIVER

- ▶ Historical assumption: **36M to 90M m<sup>3</sup>/yr** (40 to 100 ft<sup>3</sup>/s)
- ▶ 3-D flow model for the Hanford Site—average 1944-2000:
  - **31M m<sup>3</sup>/yr** (35 ft<sup>3</sup>/s)
    - *Vermeul et al. 2003 (PNNL-14398)*
- ▶ 3-D flow model for the Hanford Site—2005 conditions:
  - **45M m<sup>3</sup>/yr** (50 ft<sup>3</sup>/s)
    - *Thorne et al. 2006 (PNNL-14753)*
- ▶ Extrapolation based on net flux at 100-H Area:
  - **25M m<sup>3</sup>/yr** (28 ft<sup>3</sup>/s)
  - 2-D simulation under transient river stage conditions
    - *Peterson and Connelly 2001 (PNNL-13674)*



## COLUMBIA RIVER FLOW: HANFORD REACH

- ▶ **Recent seasonal range:**
  - **35,721M to 223,254M m<sup>3</sup>/yr** (40,000 to 250,000 ft<sup>3</sup>/s)
  
- ▶ **Perspective: Hanford Site aquifer discharge**
  - **45M m<sup>3</sup>/yr** (50 ft<sup>3</sup>/s)
  - Hanford Site aquifer discharge to the river may represent between 0.02% and 0.13% of the river flow
  
- ▶ **Perspective: Reactor coolant during operations**
  - Coolant flow per reactor was **411M m<sup>3</sup>/yr** (460 ft<sup>3</sup>/s--average)
  - At times, eight reactors would run simultaneously
  - Coolant discharge to the river via outfall pipes may have represented between 2% and 9% of the river flow

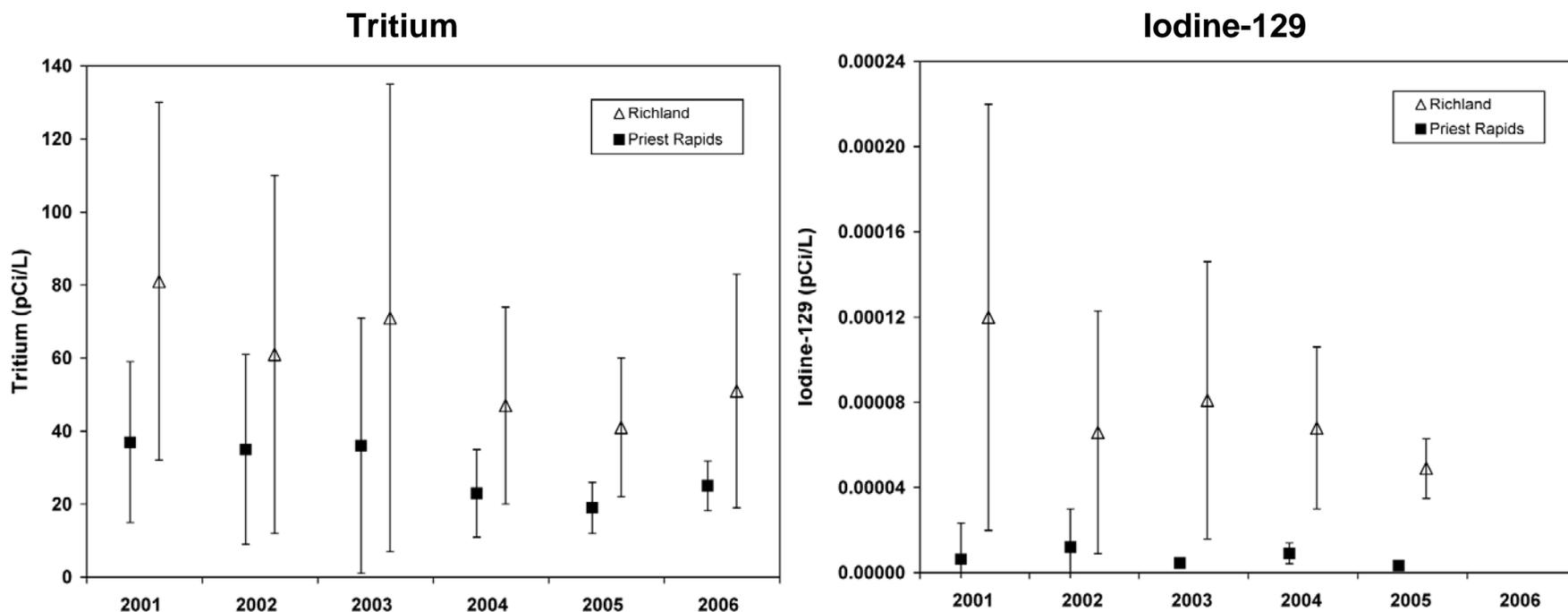


300 Area, view to south (March 2007)

## HANFORD SITE AQUIFER DISCHARGE and COLUMBIA RIVER WATER QUALITY

- ▶ **Columbia River water quality is monitored upstream, along, and downstream of Hanford plumes**
  - Surface Environmental Surveillance Project (PNNL)
  - U.S. Geological Survey
  - Annual Environmental Report
    - *Poston et al. 2006 (PNNL-15892)*
  
- ▶ **Contributors to Hanford Reach water quality**
  - Upstream: Mining industry, atmospheric fallout, agriculture
  - Along the Reach: Agriculture (irrigation returns), Hanford Site aquifer
  
- ▶ **State of Washington designates the Hanford Reach as Class A (Excellent) surface water body**
  - During 2005, there was no indication of deterioration of water quality resulting from Hanford Site operations

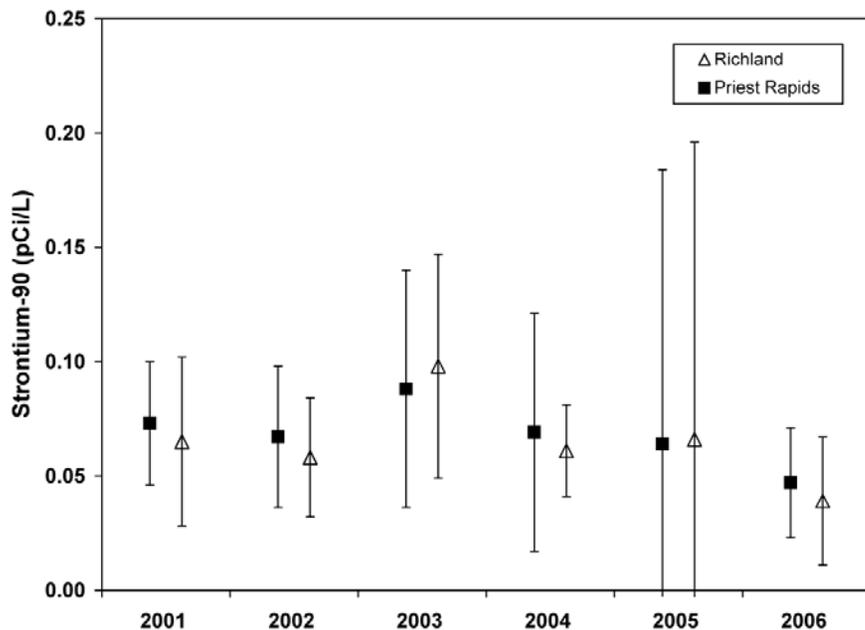
## UPSTREAM / DOWNSTREAM COMPARISONS: RADIONUCLIDES from SITEWIDE PLUME in the HANFORD REACH



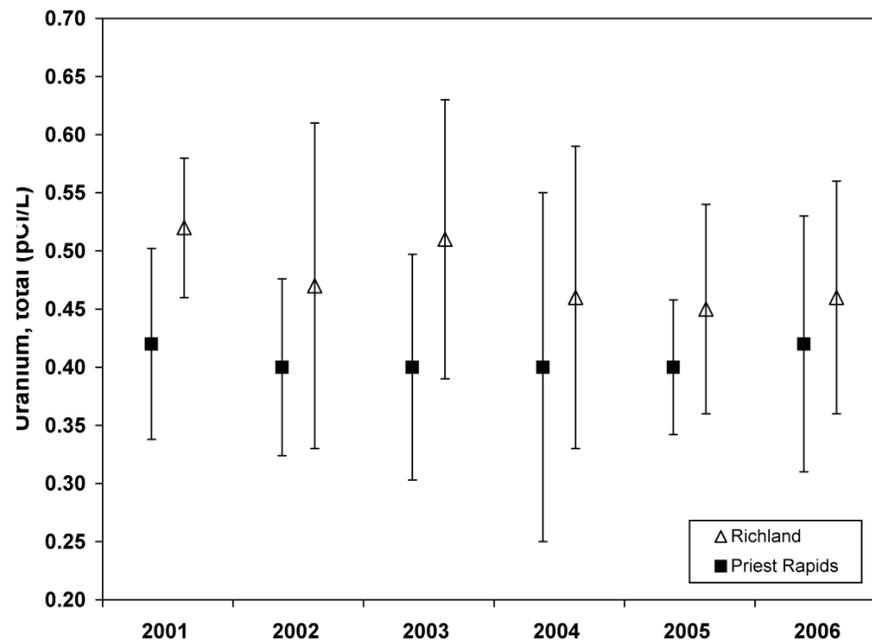
(Source: Hanford Site Environmental Report for 2006, in preparation)

## UPSTREAM / DOWNSTREAM COMPARISONS: RADIONUCLIDES in the HANFORD REACH from SPECIFIC PLUMES

### Strontium-90



### Uranium



(Source: Hanford Site Environmental Report for 2006, in preparation)

## URANIUM in the HANFORD REACH

- ▶ During 2005, the average difference between upstream and downstream uranium concentrations is **~0.02 ug/L**
  - This equates to an addition of **~2,000 kg** of uranium to the river in one year as it passes by the Hanford Site
  
- ▶ Estimates for various contributors
  - Irrigation returns (three): **~1,600 kg/yr**
  - Uranium from upstream sources: **~250 kg/yr**
  - 300 Area uranium plume: **~150 kg/yr** (from flux estimate for the area of riverbed where channel incises contaminated unit)
  
- ▶ Perspective: Contribution from other major streams that enter the Columbia River downstream from Hanford
  - Yakima River: **~4,000 kg/yr**

*(Source: Fritz 2006—PNNL-SA-51174)*

**(References Cited: Listed on Notes)**

**(References Cited continued: Listed on Notes)**

## FOR MORE INFORMATION:

- ▶ **Hanford Site Groundwater Monitoring for Fiscal Year 2006**
  - *PNNL-16346, March 2007*
  - <http://groundwater.pnl.gov>
  
- ▶ **Hanford Site Environmental Report for Calendar Year 2005**
  - *PNNL-15892, September 2006*
  - <http://hanford-site.pnl.gov>
  - Report for calendar year 2006 is in preparation (PNNL-16623, September 2007)
  
- ▶ **Contact the authors!**
  - Bob Peterson, (509) 373-9020 or [robert.peterson@pnl.gov](mailto:robert.peterson@pnl.gov)
  - Mark Williams, (509) 376-5787 or [mark.d.williams@pnl.gov](mailto:mark.d.williams@pnl.gov)
  - Greg Patton, (509) 376-2027 or [gw.patton@pnl.gov](mailto:gw.patton@pnl.gov)