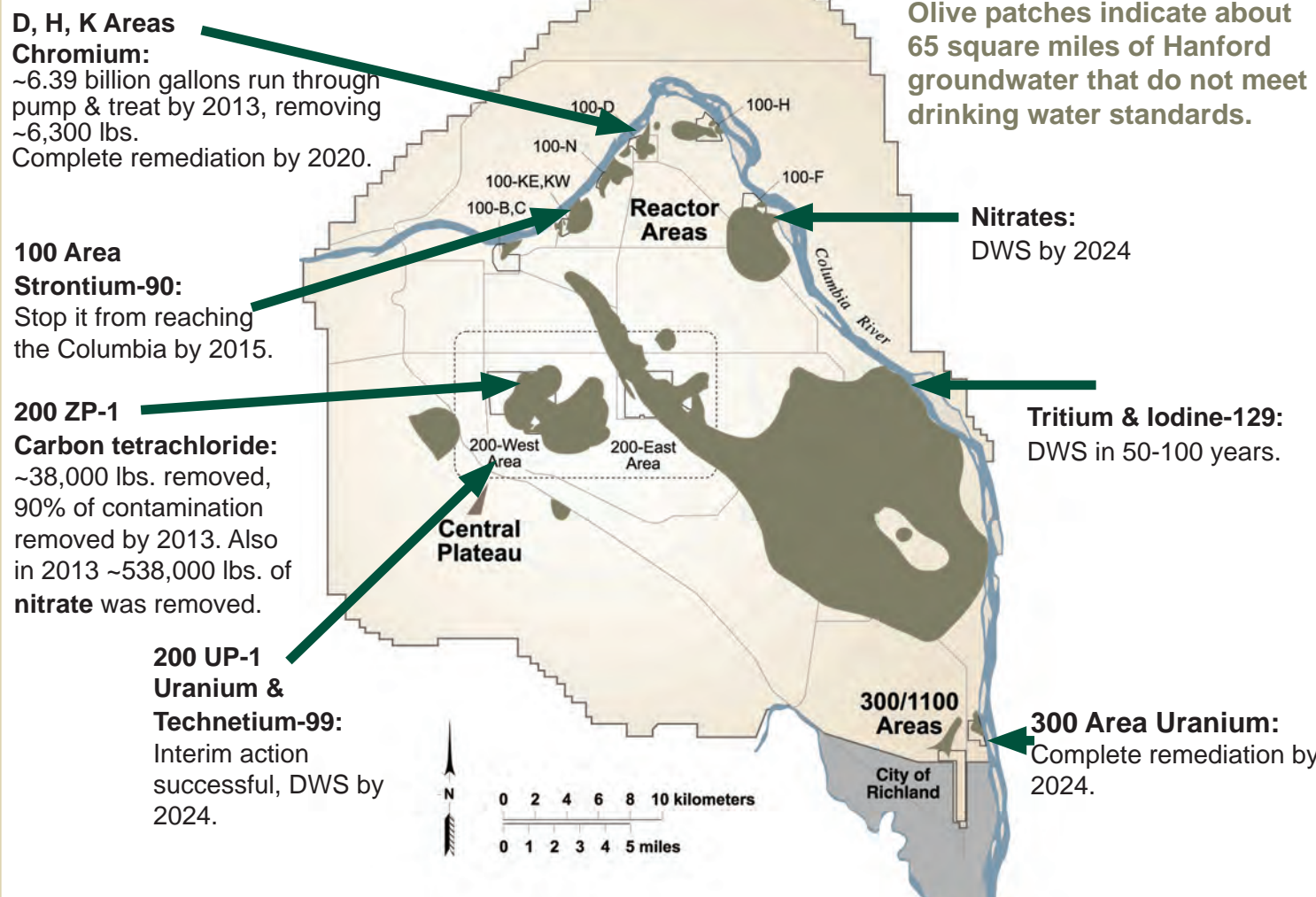


# Targeting Drinking Water Standards (DWS)



**Legal Standards for Cleanup**  
 Washington State's Model Toxics Control Act (MTCA), and the federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, also known as Superfund), require cleanup levels to be based on the highest beneficial use of groundwater.

**Revised Code of Washington 36.36.010**  
 The protection of subterranean water from pollution or degradation is of great concern. (RCW 36.36.010)

**Revised Code of Washington 90.54.010**  
 It is the intent of the legislature to work closely with the executive branch, Indian tribes, local government, and interested parties to ensure that water resources of the state are wisely managed.

**Washington Administrative Code 173-160-381**  
 Any well which is unusable, abandoned, or whose use has been permanently discontinued, or which is in such disrepair that its continued use is impractical or is an environmental, safety, or public health hazard shall be decommissioned.

**DEPARTMENT OF ECOLOGY**  
 State of Washington

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To request ADA accommodation including materials in a format for the visually impaired, call the Nuclear Waste Program at 509-372-7950. Persons with impaired hearing may call 711 Washington Relay Service at 711. Persons with speech disability may call TTY at 877-833-6341.

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# Cleaning Hanford's Groundwater & Protecting the Columbia River

## Hanford's Nuclear Legacy

The Hanford Site in southeastern Washington State was home to plutonium production for our nation's nuclear stockpile. The race to build the atomic bomb and win World War II (and the Cold War) unfortunately created what many consider to be the most polluted spot in the western hemisphere.

From 1944 to 1988, roughly 445 billion gallons of liquids, containing about 23 billion gallons of radioactive and hazardous chemicals, were released to the ground<sup>1</sup>. Some of these contaminants are held in the soil above the water table (the vadose zone), some have reached the groundwater, and others have reached the Columbia River via the groundwater.



## Hanford's Groundwater and Vadose Zone

At Hanford, the geology below the ground's surface is very complicated. Usually groundwater flows vertically, but in some places it moves horizontally through sand and gravel deposited by the Ice Age Floods. In other places, layers of mud or clay slow that movement. Where there are vertical clay formations called clastic dikes, water may meet them, drop deeper into the ground along their face, and move horizontally again farther underground.

These geologic properties make locating and addressing contamination in Hanford groundwater difficult.

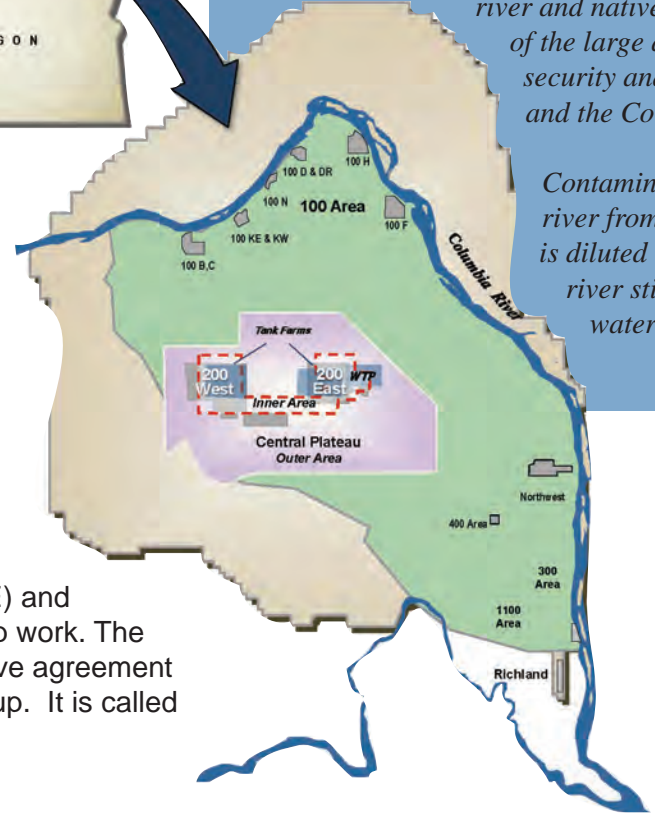
Fortunately, the river has such a large volume of flow that any current contamination reaching the river is diluted to non-detectable levels almost immediately. The river is considered a Class A water body by the state, meaning it is safe for recreation, drinking, etc. Regardless, work is underway to stop or reduce further contamination.

The Washington State Department of Ecology's Nuclear Waste Program (Ecology) oversees groundwater cleanup at Hanford, along with the U.S. Environmental Protection Agency (EPA). The U.S. Department of Energy (USDOE) and its contractors perform the actual cleanup work. The three agencies work through a cooperative agreement that sets deadlines and targets for cleanup. It is called the Tri-Party Agreement (TPA).

[Ecology.wa.gov/hanford](http://Ecology.wa.gov/hanford)

*Hanford is in the south central part of Washington state. The Hanford Reach National Monument forms much of the boundary of Hanford. The undammed river and native habitats are remnants of the large area needed for security and secrecy during WWII and the Cold War.*

*Contamination that enters the river from Hanford groundwater is diluted immediately, so the river still meets very high water quality standards.*



<sup>1</sup> Hanford Cleanup: The First 25 Years Oregon Office of Energy



# General Groundwater Concepts

Below are some common terms (**bold text**) used to describe groundwater and its properties and behaviors. The diagram at the bottom of the page depicts a visual representation of most of the terms.

**Groundwater** is the general term used for water saturating the interconnected cracks or pores between rocks or grains of sand below ground, while **aquifers** are usually named geologic units where groundwater is present.

**Water table** is the term used to reference the top of the saturated zone in an aquifer.

The **vadose zone** is the area between the ground surface and the top of the water table.

**Confined aquifers** are areas where the aquifer is contained between impervious (solid) layers, while **unconfined aquifers** are where groundwater moves through saturated layers in the ground, slowly working its way in or out of the earth.

An **aquitard** is a non-permeable area that groundwater travels around but not through. Features like clastic dikes (a vertical clay formation) can cause groundwater flow to change direction.

**Perched water** is water that was somehow trapped in an area separate from the main aquifers in a geologic unit (**p** in diagram.)

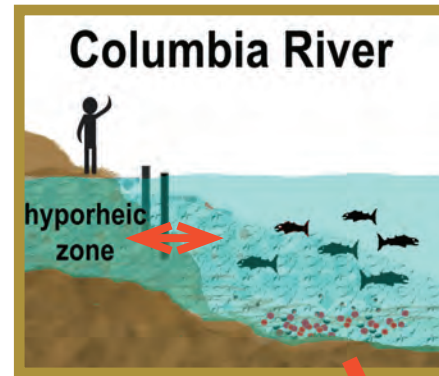
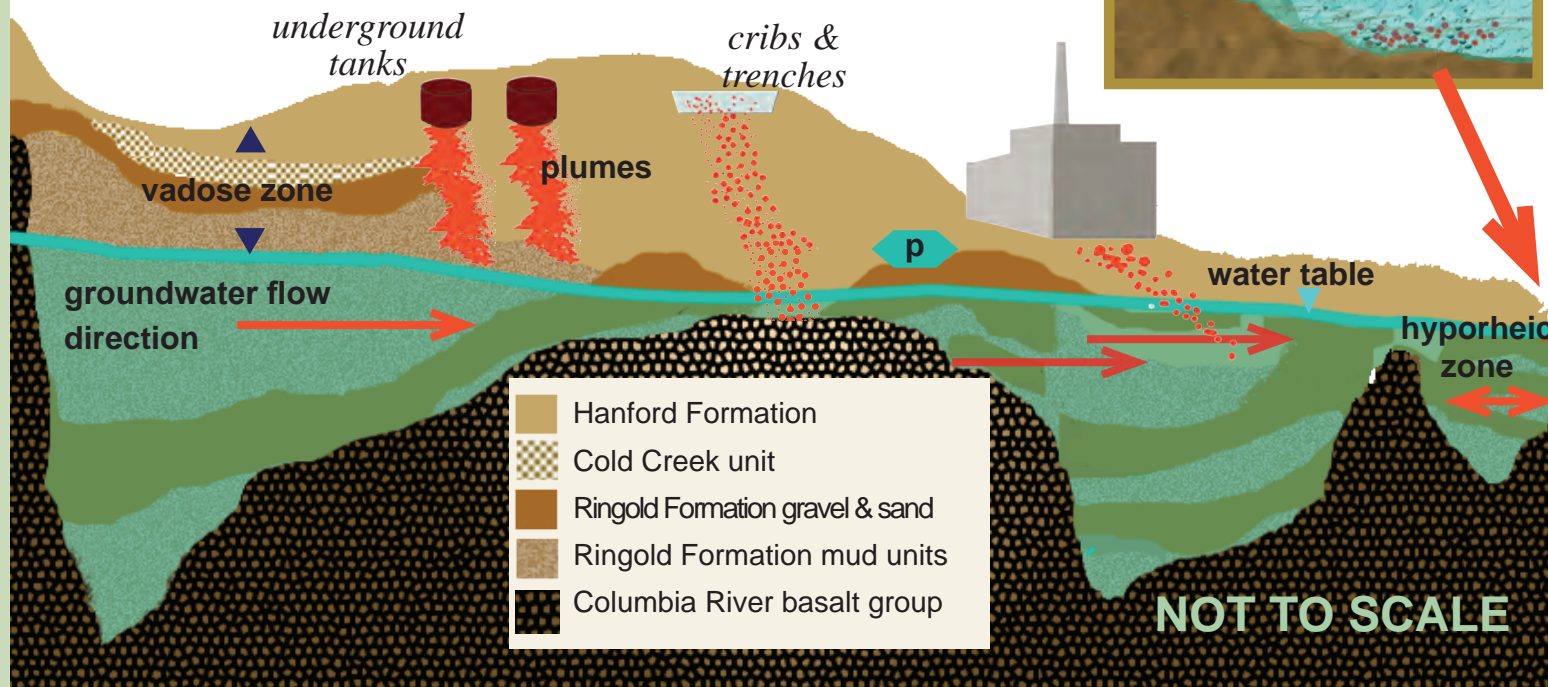
**Plume** (like a plume of smoke) is the term used to describe a trail of pollution spread underground. The shape of a plume is estimated by plotting out where contamination is detected in a set of wells.

Groundwater may **recharge** from the surface or underground from nearby rivers, lakes, or streams. Groundwater may recharge quickly or slowly.

A **hyporheic zone** is an area where the river influences groundwater and water moves freely between the stream channel and soils.

The geologic make-up of an area determines whether groundwater surfaces through springs, flows laterally into nearby water bodies, or sinks deeper into the earth. If too much water is pumped from wells, natural precipitation, or surface water may not be able to recharge an aquifer. The water table in central Hanford is about 200 feet below ground surface, while along the rivershore, water moves freely between the river and groundwater.

The below Hanford cross-section shows how contamination from various sources may move through the vadose zone and aquifer. Teal indicates saturated (groundwater) layers. Orange plumes move from facilities through soil to groundwater.



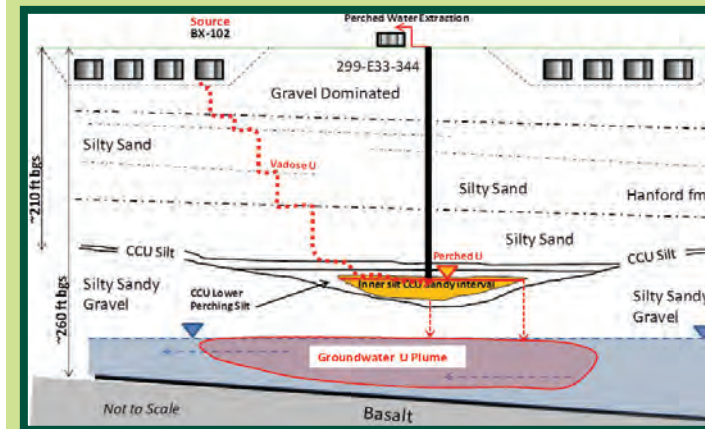
# Groundwater Success Stories

## Perched Water Extraction

Recently, perched water (see graphic below) was discovered in the vadose zone in the 200 East Area at Hanford. Perched water is like a puddle that is trapped between sand and silty sandy gravel, away from the primary aquifer. The water was contaminated with uranium (about 70,000 ppb), Tc-99 (45,000 pCi/L), and nitrate. Wells were installed to capture the heavily contaminated water before it could reach the groundwater.

The effort has captured 24 pCi/L of Tc-99, 42 kilograms (kg) of uranium, and 405 kg of nitrates in only 200,000 gallons of water.

By comparison, 42 kg of uranium were also captured by pump-and-treat at 200-UP-1, also in 200 East, but 45 million gallons of groundwater were pumped to capture it! (See map p.8)



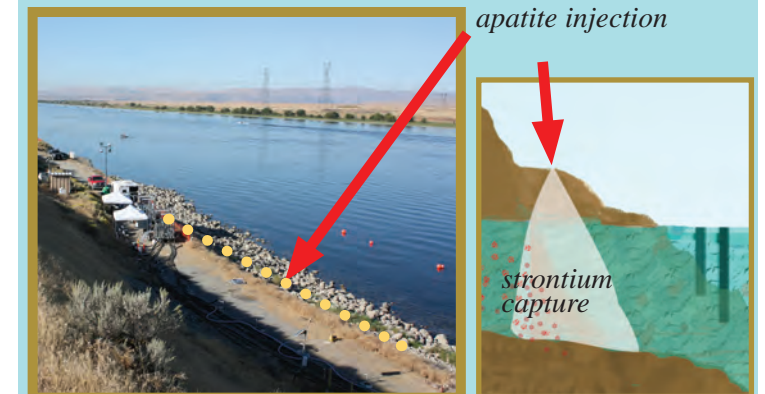
## Apatite Barrier

Apatite is a type of calcium phosphate that attracts strontium. In 2006 a test was conducted to see if apatite, in the form of fish bones, could prevent strontium from entering the Columbia River.

Apatite was pumped into the ground and the water table along 300 feet of shoreline. It created a sort of curtain through which groundwater passes. As the water passes through, strontium attaches to the calcium phosphate holding it in place.

The strontium concentrations are highest within several feet of the water table. When the river rises, it pushes into the hyporheic zone, elevating the water table and allowing the apatite to capture more strontium.

The 2006 test was extremely successful. Since then, more apatite has been injected along the shoreline. Eventually apatite will be injected into about 2,500 feet of shoreline.



## 100-D Area Big Dig Removes Chrome-6



In 100-D Area, bright yellow stains on the ground (close-up, left) showed a source for Cr-6 (hexavalent chromium) contamination. Ecology encouraged USDOE to dig up the contaminated soil in the hopes of limiting the opportunity for chromium to reach the river.

After years of requests, USDOE finally agreed and contractors started digging up the yellow stained soil, chasing the contamination deeper and deeper into the ground.

The "big dig" eventually reached groundwater and created a hole about an acre in size and 85 feet deep (aerial photo at right). It is about a half-mile from the Columbia River and the water level in the hole fluctuates with the river flow.

Removing the source of Cr-6 proved to work. Cr-6 captured by pump-and-treat in nearby wells dropped from 87,000 micrograms per liter ( $\mu\text{g/l}$ ) before the contaminated soil was removed to less than 800  $\mu\text{g/l}$ .





# Groundwater Treatment Methods

In 2009 Ecology and EPA agreed to make groundwater cleanup a priority. Groundwater cleanup methods vary across Hanford depending on available technology, the effectiveness of a method v. cost, and whether it will protect human health and the environment. In the end, we hope the USDOE is able to meet a 2024 target for all Hanford groundwater to meet drinking water standards.

## Reducing Recharge

One way to reduce the spread of contamination is to control water leaks by removing unneeded water lines. Another method involves testing active lines to make sure they don't leak. Preventing water from ponding over areas known to have contamination in the soil also reduces recharge. For example, in the T-Farms, a temporary cover is being tested over an area where a large tank leak occurred. The cover is intended to prevent rain or snowmelt from driving soil contamination deeper into the vadose zone and into groundwater.



Eventually, apatite will be injected into 2,500 feet of rivershore in 100-N.

## Natural Attenuation

Natural attenuation is a wait and watch approach. Some chemicals and radionuclides will degrade or stabilize on their own over time, but we will require USDOE to continue monitoring to determine when contamination is gone. If a technology is currently unavailable to treat contamination, we will encourage USDOE to seek new treatment technologies.

## Soil Vapor Extraction

Soil vapor extraction (SVE) removes harmful chemicals from the soil above the water table. Vapors are the gases that form when the chemicals evaporate. SVE extracts vapors from the soil above the water table by applying a vacuum to pull the vapors out.

## Calcium-phosphate Barrier

Also called apatite, calcium phosphate from crushed fish bones is pumped into the ground under pressure. There it forms a permeable barrier. Groundwater contaminated with radioactive Strontium-90 (Sr-90) passes through it. As it does, the Sr-90 binds to the apatite. This technique is dramatically decreasing the amount of Sr-90 reaching the Columbia River. (See Groundwater Success Stories, Apatite Barrier, p.7 for more details.)

## Source Removal

Removing contaminated soils from near the Columbia River prevents that contamination from reaching the river. When appropriate, contaminated soil is dug up and disposed of in the Environmental Restoration Disposal Facility (ERDF), Hanford's modern clean landfill. More than 15 million tons of debris and soil have been disposed there so far.



Soil removal is ongoing sitewide as a way to prevent contamination from spreading.



Above- Ecology joins USDOE and their contractors in celebrating the opening of a new pump and treat facility in 2012. The facility can treat seven major contaminants and more than double the volume of prior installations.

## Pump-And-Treat

A pump-and-treat system pumps contaminated groundwater out of the ground, removes the contaminants, and injects the clean water back into the ground. In most cases, pump-and-treat is time-consuming and costly and only addresses certain contaminants. However, there are cases where it is an appropriate solution. Pump-and-treat technology creates a secondary waste form which is safely disposed of at ERDF in the 200 Area.

## Phytoremediation

Phytoremediation uses plants to take up contaminants in their roots and leaves. This method is used quite extensively outside of Hanford. Ecology would like to see how phytoremediation can be used to 'polish' water along parts of the Columbia River. Plants like coyote willow are very effective. The plants could be cut down annually and the branches and leaves taken to ERDF, the Hanford landfill.

# Sources of Groundwater Contamination at Hanford

During production at Hanford, so much water was dumped to the ground that the water table rose about 75 feet. Surface ponds even developed in spots. When plutonium production stopped, the water table began to drop, leaving many monitoring wells dry. New monitoring wells may need to be installed to track contamination in the areas where wells are dry.

Sources of contamination range from deliberate waste discharges to waste that was spilled or leaked. The primary sources are described here along with general locations where they are located.

## Injection Wells

Normally wells are used to draw water (or oil) out of the ground. But sometimes contaminants were pumped directly into the ground as a way to dispose of them. This occurred at several facilities at Hanford.

## Plant Waste Discharge

There were nine reactors along the Columbia River, as well as several huge production facilities in central Hanford. Some of them disposed of waste directly to the soil outside the facility. Even when waste wasn't leaked or simply dumped, the management techniques were generally ineffective.



Left - Aerial view shows unlined trenches, the gray diagonal line in the lower left of the photo, and the zigzag gray line closer

## Underground Storage

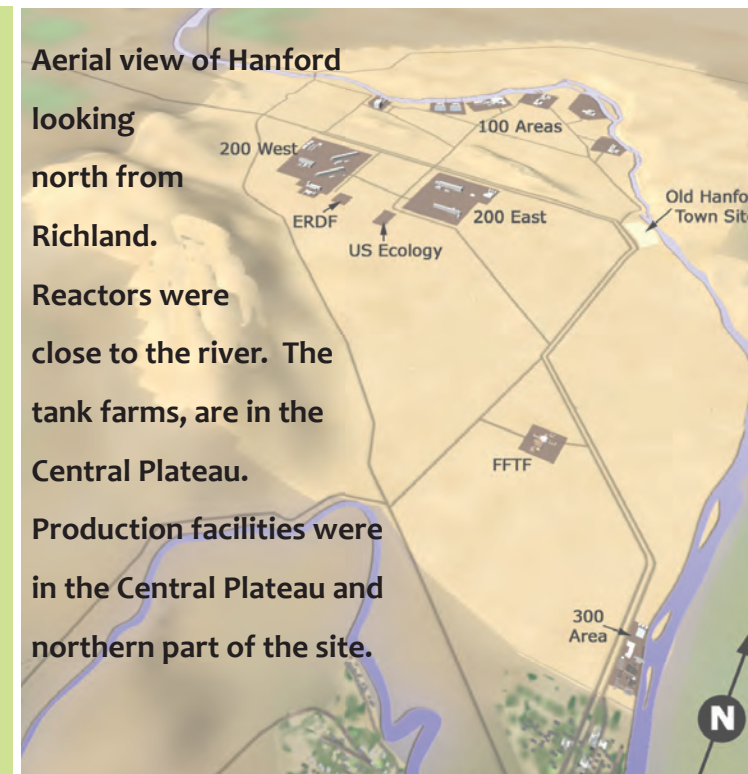
The most dangerous production waste was stored in underground tanks. There are 149 single-shell tanks (SSTs) and 28 double-shell tanks (DSTs) in Hanford's 200 Areas. They store more than 56 million gallons of radioactive and hazardous chemical waste. About 1 million gallons have leaked from 67 SSTs. There are 12 groups of tanks, known as farms. All have contaminated soil and groundwater. All SSTs have exceeded their design life by more than 40 years.

## Aerial view of Hanford

looking north from Richland.

Reactors were close to the river. The tank farms, are in the Central Plateau.

Production facilities were in the Central Plateau and northern part of the site.



## Cribs, Ponds, Trenches & French Drains

During production, cooling and waste water was directed to storage ponds, trenches, cribs, or French drains (perforated pipes that allowed liquid to release into rock-lined, soil-covered trenches). 121 million gallons of waste was sent to cribs and retention trenches near the single-shell tanks. There were trenches like this all over Hanford, and some were very close to the river. (See photo above.)



DSTs were built between 1968 and 1986.



Retrieving waste from aging tanks is an ongoing challenge.

## Pits, Burial Trenches & Landfills

Barrels and boxes containing solid and liquid waste were buried in trenches, pits, and unlined landfills across the Hanford site. As the containers break down, contaminants enter the soil and migrate to groundwater. The majority have been dug up, with the contaminated soil repackaged and waste moved to a lined landfill in central Hanford.



Above- Metal boxes and barrels break down and leak over time.



# Tracking Groundwater Contamination

## Groundwater Monitoring

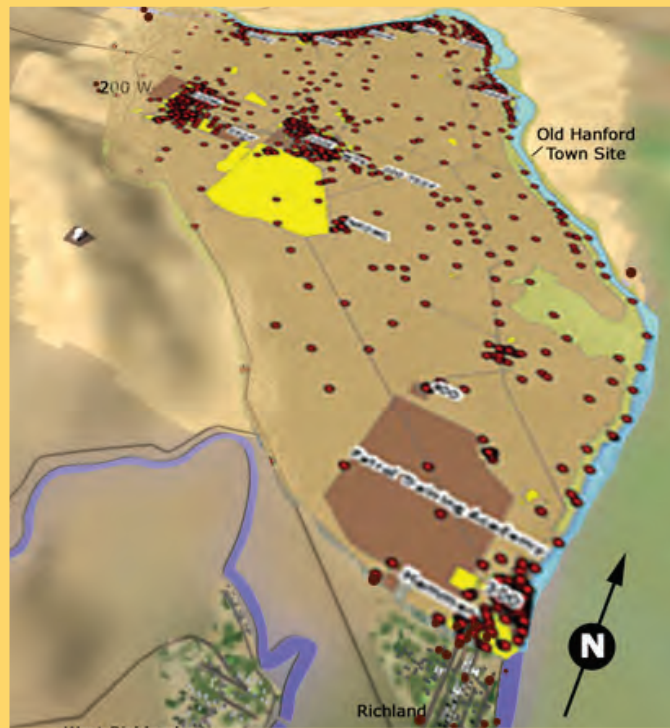
Groundwater at Hanford generally flows from northwest to southeast, or toward the Columbia River.

During production years, so much water was discharged to Hanford that groundwater rose and sometimes “mounded” or built up in places causing surface water ponds to develop.

At Hanford, about 3,000 samples from 1,000 monitoring wells are taken each year to detect the extent and type of groundwater contamination. Monitoring data shows about 170 square miles of groundwater contamination. About 65 square miles of groundwater at Hanford is contaminated beyond safe drinking water levels.

Since plutonium production stopped in 1989 water tables across the site have dropped, changing groundwater flow in some places and leaving monitoring wells dry. Some wells have been replaced with deeper wells. More wells need to be installed for contaminant detection and assessment, and to meet the required regulations.

Wells that no longer work must be properly filled and capped to prevent them from becoming conduits to groundwater. The agencies are working to meet this goal.



The red dots represent monitoring wells at Hanford as well as offsite in Richland and across the river in Franklin County.

## Vadose Zone Monitoring

The agencies monitor the vadose zone at many waste disposal and storage facilities. Soil samples reveal contamination in the vadose zone across the site, especially under the waste tanks and waste disposal facilities in the Central Plateau at Hanford.

## Columbia River Monitoring

In the early years at the Hanford Site, some contaminants were discharged directly to the river. While that practice has ended, some contaminants still enter the river from the groundwater. River shore soil, river water, river bottom sediment, plants, aquatic biota, and wildlife are all sampled on a regular basis to determine the impact of contamination. The samples are then analyzed for radionuclides and hazardous chemicals. Although reported results are well within surface water quality standards, Ecology remains vigilant and looks for ways to limit Hanford’s impact to the river.

## Did you know?

Richland, Kennewick, and Pasco, cities downstream of Hanford, use the Columbia River as a significant source of drinking water.

Every city must produce a drinking water report on a semi-annual basis. Contact your city’s water treatment managers to get yours.



Water from the Columbia River, groundwater surfacing at the river shore, and shoreline sediment, is tested to ensure contamination is not reaching the river in high enough quantities to impact humans and wildlife.

# Major Groundwater Contaminants at Hanford

## Measuring Chemicals and Radionuclides

Chemicals are measured in parts per million (ppm) in a liter of water. Often, ppm is used interchangeably in text with milligrams per liter or mg/l because it means the same thing. Sometimes detection of very small amounts is needed, thus parts per billion (ppb) or micrograms per liter (µg/l) is used instead.

Radioactive elements are measured in picocuries, A curie is a unit of radioactivity -- the amount of any nuclide that undergoes exactly 37 billion radioactive disintegrations per second.

Pico is one trillionth, or 10<sup>-12</sup>. So, a picocurie is equivalent to the radioactivity present in one trillionth of one gram of pure radium. Concentration of radionuclides in groundwater is measured in picocuries per liter (pCi/L).

## Carbon Tetrachloride

Carbon tetrachloride is found in the central part of Hanford. It contaminates about seven square miles of groundwater at levels beyond the drinking water standard of 5 mg/l. Carbon tetrachloride hasn’t been found in wells near the Columbia River, but studies indicate it may reach the river eventually. Soil vapor extraction to control plume expansion is underway. Chronic exposure can damage the kidneys and liver.

## Chromium

Chromium comes in several forms. Our primary concern is Chrome-6 (Cr-6). Some Cr-6 is in groundwater near the river shore and flows into the Columbia River. To protect aquatic animals, the agencies are pursuing a more stringent cleanup than required for drinking water. Remediation of chromium through soil removal and pump-and-treat systems has successfully reduced toxicity and is decreasing the amount entering the river. (See 100-D Area Big Dig, p. 7) Inhalation of Cr-6

Ecology’s top priority is protecting the Columbia River.

is known to cause cancer, ingestion may as well.

## Iodine-129

In the 200 East Area, iodine-129 contaminates about 42 square miles of groundwater. The drinking water standard is 1 pCi/L. Remediation technology is not currently available. Exposure to high levels of radioactive iodine may increase the risk of thyroid cancer.

## Nitrates

Nitrates contaminate about 25 square miles of Hanford groundwater. The drinking water standard for nitrates is 10 mg/l. Nitrate contamination has reached the Columbia River. Average contamination is slightly above drinking water standards. Large scale remediation of nitrate from groundwater is impractical. Nitrate ingestion in large volumes is thought to cause methemoglobinemia, which prevents blood from carrying enough oxygen.



## Strontium-90

Radioactive strontium-90 (Sr-90) pollutes about 1 1/2 square-miles of groundwater, mostly near the N and 200 East Areas. Sr-90 has entered the Columbia River. The drinking water standard is 8 pCi/L. Remediation is underway and has reduced the amount of Sr-90 entering the river. (See Apatite Barrier, p. 7) The main health concern is from ingestion, which can cause bone cancer.

## Technetium-99

Technetium-99 (Tc-99) is a long-lived radionuclide. In the 200 West Area, Tc-99 contaminates about 1 1/2 square miles. The drinking water standard is 900 pCi/L. Studies show that Tc-99 may reach the Columbia River. Remediation is underway to control its spread. Exposure to Tc-99 can increase cancer risk.

## Tritium

The largest tritium plume is in the 200 East Area, but it is found throughout Hanford groundwater. About 84 square miles are contaminated, and it has entered the Columbia River. The drinking water standard for tritium is 20,000 pCi/L. Remediation technology is not currently available. However, tritium has a short half-life, so natural decay will play a major role in reducing contamination over time. The main health concern from excess exposure is cancer in the soft organs.

## Uranium

Uranium contaminates about one square mile of groundwater in the 200 West Area and 300 Area. Contamination from the 300 Area enters the Columbia River. The drinking water standard is 30 µg/l. Interim remediation to remove uranium is being conducted in the 200 West Area. In the 300 Area, natural attenuation for uranium (waiting for it to decrease on its own) has been unsuccessful. The agencies are still looking for a potential treatment method. Long-term intake of uranium from food, water or air is both chemically and radioactively toxic.