U.S. Department of the Interior
U.S. Geological Survey

# Nitrate Concentrations in Ground Water of the Central Columbia Plateau

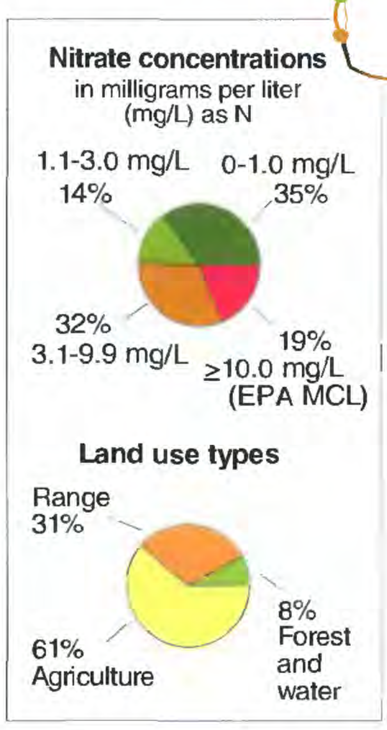
*Open-File Report 95-445*
*Sarah J. Ryker and Joseph L. Jones*

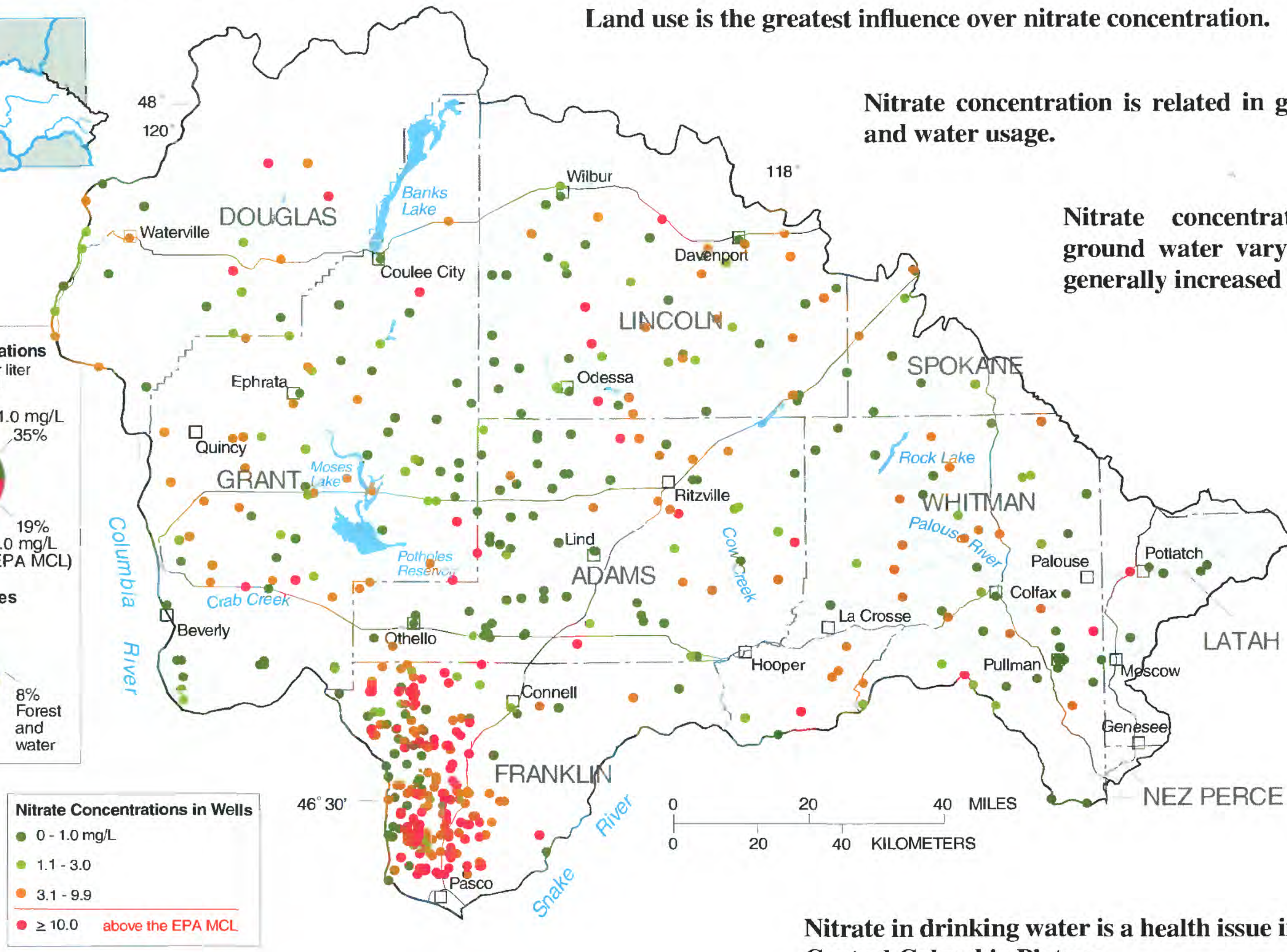
The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program is designed to assess the status of and trends in the quality of the Nation's water resources, and to gain a better understanding of the natural and human factors that affect water quality. The Central Columbia Plateau is one of 60 NAWQA study units (major river basins and parts of aquifer systems) located throughout the Nation. In the Central Columbia Plateau, nitrate concentrations for 19% of the 573 wells shown below exceed the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for drinking water. These concentrations include USGS samples from 1942-94, although 93% of the data are from 1980-94. Where more than one analysis was available for a well, this document refers to the mean concentration as the nitrate concentration for the well.

**Land use is the greatest influence over nitrate concentration.**

**Nitrate concentration is related in general to fertilizer and water usage.**

**Nitrate concentrations in shallow ground water vary greatly, but have generally increased since the 1950's.**


Data from Jones and Wagner, 1995.

**Nitrate in drinking water is a health issue in parts of the Central Columbia Plateau.**

## LAND USE practices are the dominant influence over the distribution and concentration of nitrate in ground water.

Nitrogen fertilizers applied to fields are the primary source of nitrate in shallow ground water. Nitrogen fertilizers not used by crops can be carried to the underlying aquifer by water percolating through the soil. In the arid Central Columbia Plateau, irrigation water carries nitrate into shallow ground water. Irrigated agriculture is consequently associated with high nitrate concentrations and high frequency of contamination of ground water in the study area.

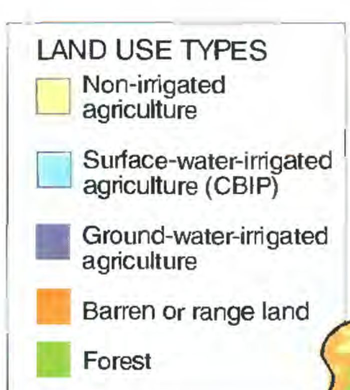
**Percentage of wells with nitrate concentrations exceeding the EPA MCL**

| | | Domestic and public supply* | All wells |
|---|---|---|---|
| County** | Adams | [illegible]8% | 8% |
| | Douglas | [illegible]0% | 14% |
| | Franklin | [illegible]3% | 33% |
| | Grant | [illegible]% | 7% |
| | Whitman | 4% | 5% |
| Subunit | Palouse | 4% | 6% |
| | Quincy-Pasco | [illegible]9% | 28% |
| | North-Central | [illegible]5% | 9% |
| | Study area | [illegible]1% | 19% |

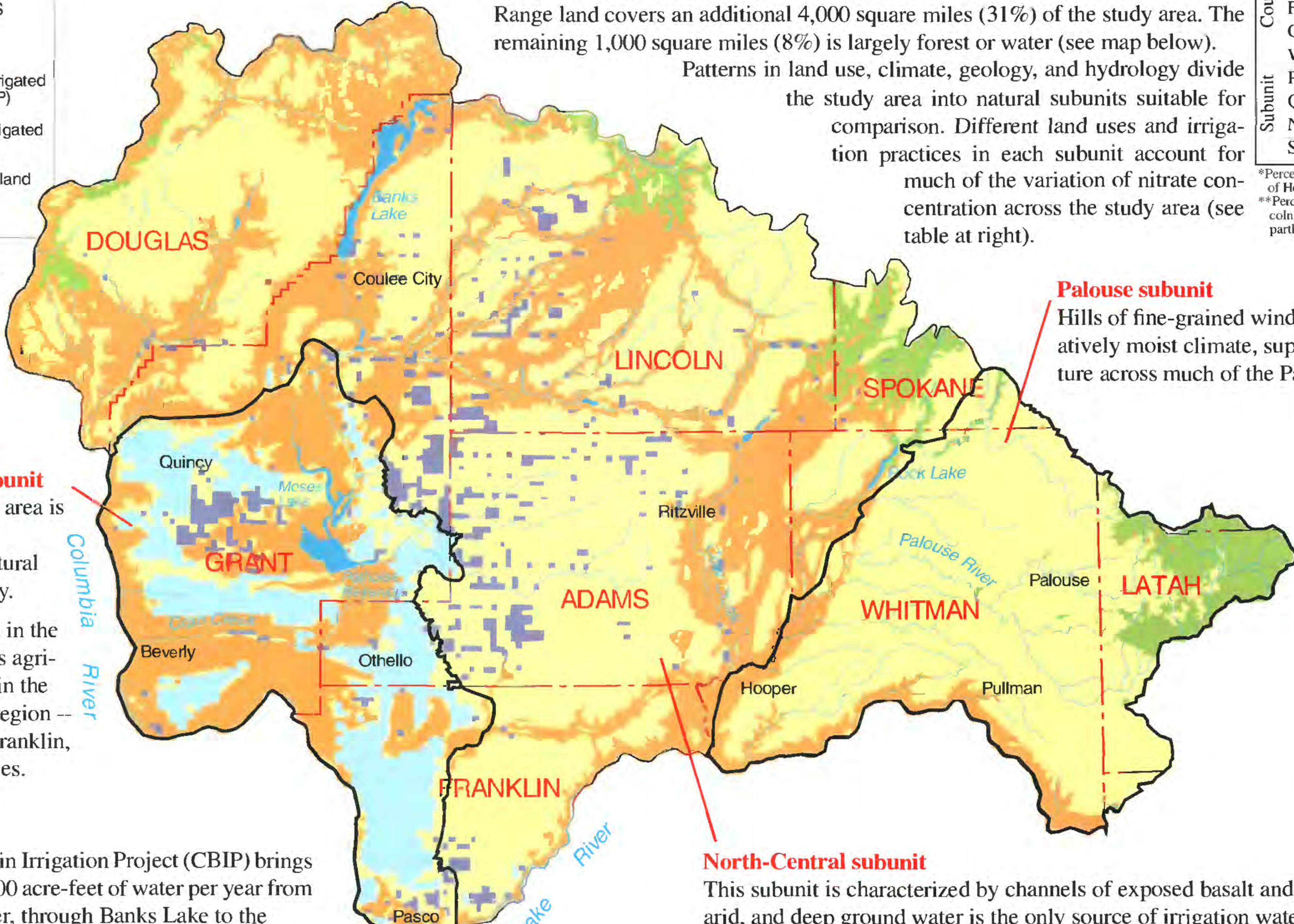
*Percentages are similar for Washington Department of Health Class A public supply wells.
**Percentages were not calculated for Latah, Lincoln, Nez Perce, and Spokane Counties, which fall partly outside the study area.

**Agriculture covers 8,000 square miles, or 61%, of the study area.** Range land covers an additional 4,000 square miles (31%) of the study area. The remaining 1,000 square miles (8%) is largely forest or water (see map below).

Patterns in land use, climate, geology, and hydrology divide the study area into natural subunits suitable for comparison. Different land uses and irrigation practices in each subunit account for much of the variation of nitrate concentration across the study area (see table at right).




Data from Jones and Wagner, 1995.




**Quincy-Pasco subunit**

The Quincy-Pasco area is one of the most productive agricultural areas in the country.

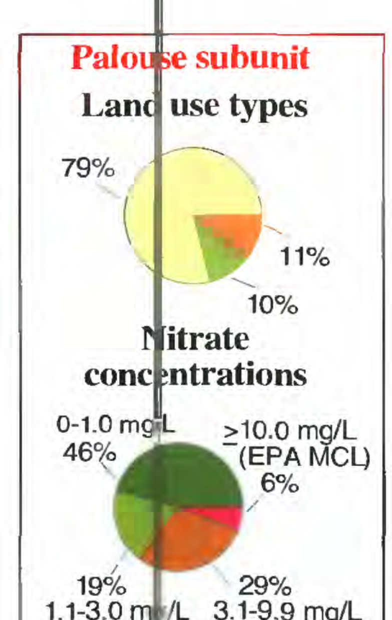
99% of water used in the study area supports agricultural irrigation in the dry southwestern region -- mainly in Grant, Franklin, and Adams Counties.

**CBIP influence**

The Columbia Basin Irrigation Project (CBIP) brings more than 2,500,000 acre-feet of water per year from the Columbia River, through Banks Lake to the Quincy-Pasco subunit.

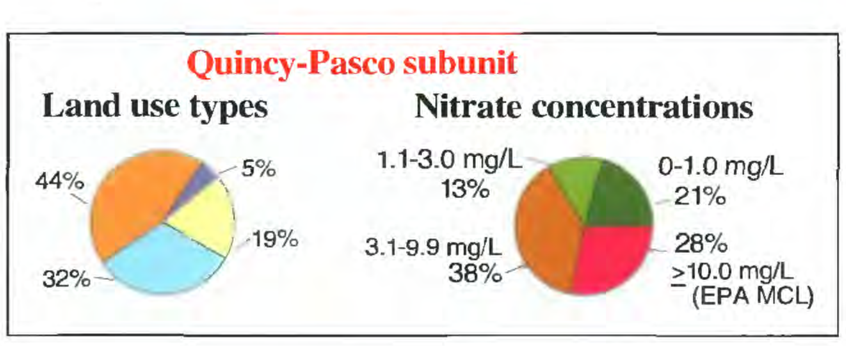
**Palouse subunit**

Hills of fine-grained wind-blown sediments, and a relatively moist climate, support non-irrigated agriculture across much of the Palouse.

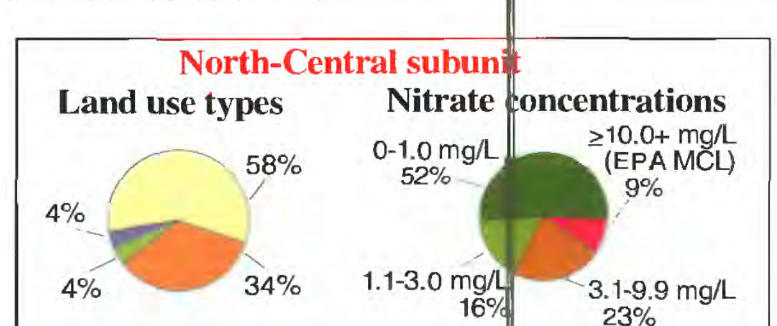



**North-Central subunit**

This subunit is characterized by channels of exposed basalt and thin, poor soil. The climate is arid, and deep ground water is the only source of irrigation water. Non-irrigated agriculture in this subunit is much like adjoining areas of the Palouse subunit.




The North-Central subunit's deep water table makes pumping expensive, but irrigated agriculture is possible in the more arable lands bordering the CBIP. High nitrate concentrations appear in the shallower ground water surrounding the CBIP.

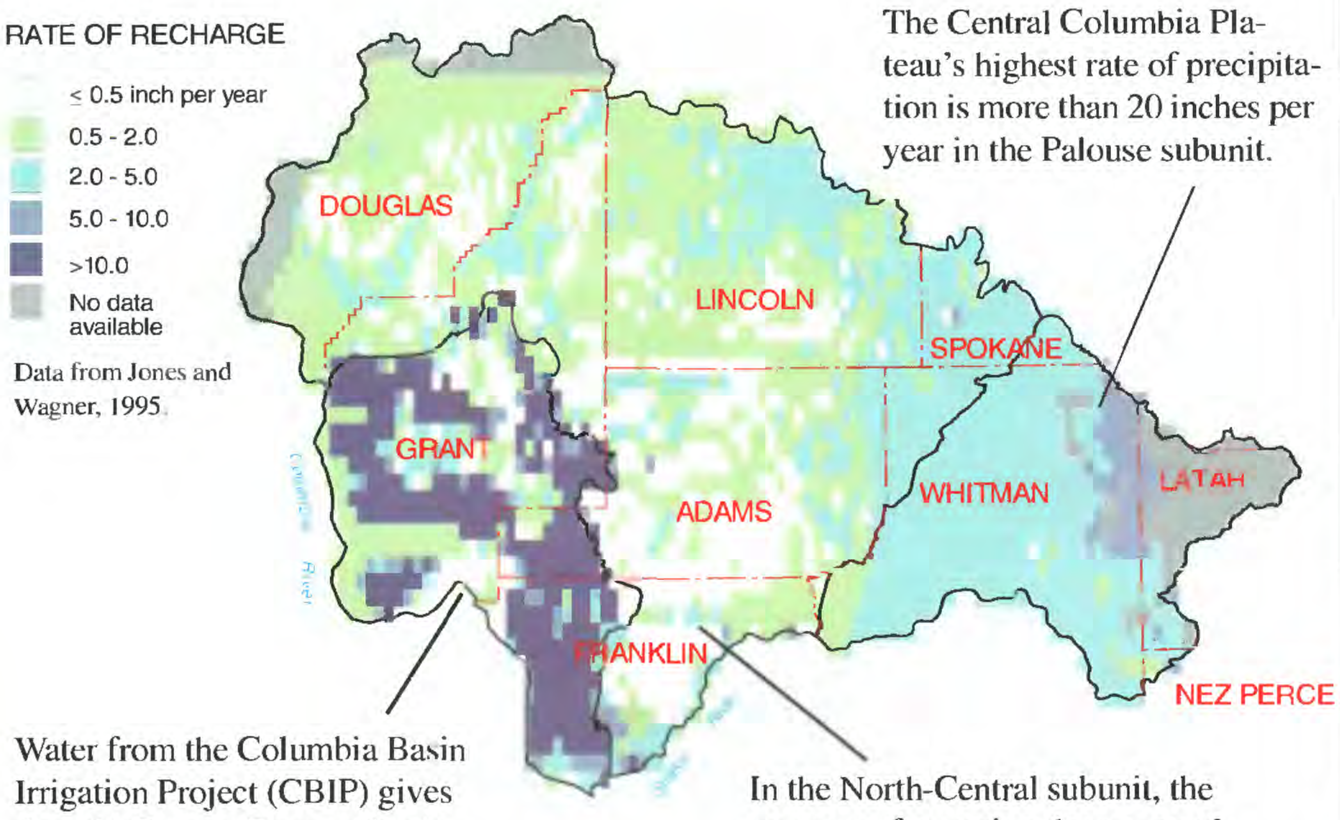


# WATER CARRIES CHEMICALS IN THE SOIL TO THE AQUIFER

## RECHARGE

### is water moving into the ground-water system.

Recharge from precipitation and irrigation may carry nitrogen compounds from the soil into the aquifer, often resulting in elevated nitrate concentrations in shallow wells.




The Central Columbia Plateau's highest rate of precipitation is more than 20 inches per year in the Palouse subunit.

Water from the Columbia Basin Irrigation Project (CBIP) gives the arid Quincy-Pasco subunit the highest rate of recharge in the study area.

In the North-Central subunit, the expense of pumping deep ground water reduces the amount of irrigation contributing to recharge.

In parts of the Quincy-Pasco subunit, water-table altitudes have been raised by several hundred feet, with both positive and negative effects. Numerous wetlands and springs have sprung up, providing new habitat for waterfowl; but along the Columbia River landslides have occurred and subsurface drains are required to prevent waterlogging of soil.

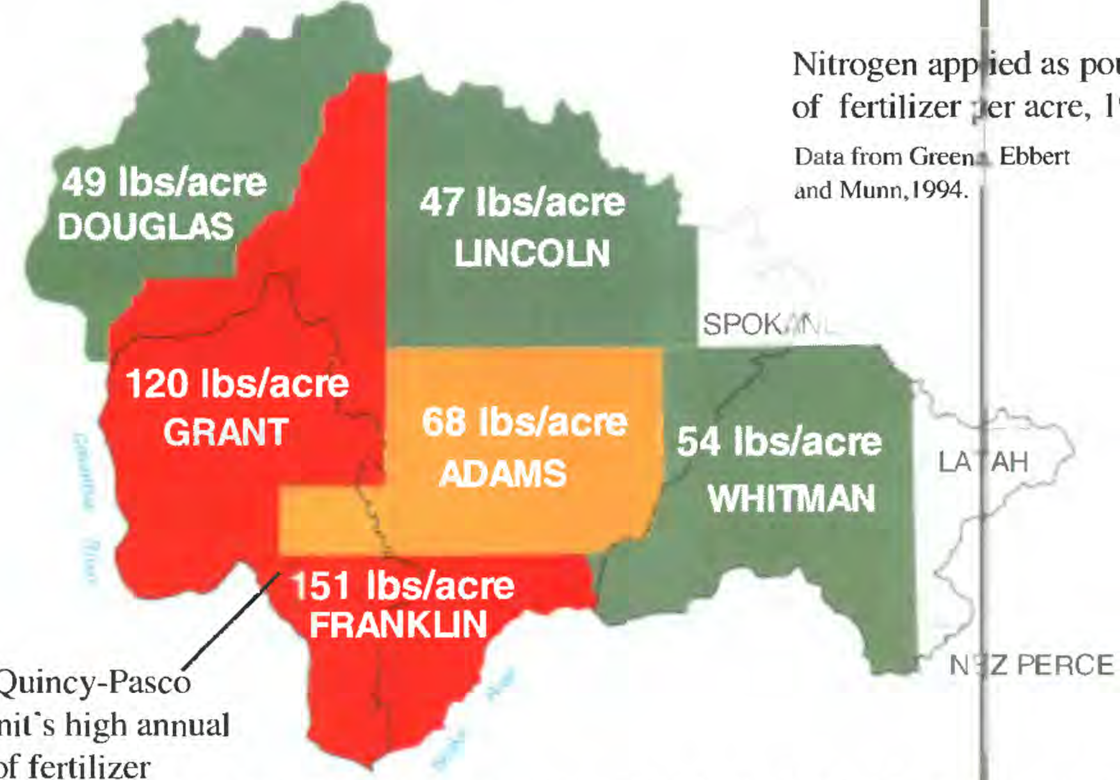
**Recharge moves nitrate primarily into shallow ground water.**

- Where irrigation has raised the water table and fertilizer application is particularly heavy, elevated nitrate concentrations can be expected, as in the Quincy-Pasco subunit (see reverse).
- On the other hand, leakage from irrigation canals may lower nitrate concentrations. Relatively low-nitrate canal water from the Columbia Basin Irrigation Project is a significant source of recharge in the Quincy-Pasco subunit.
- Nitrate concentrations in recharge are probably controlled by the amount of nitrogen fertilizer applied to the land, the chemical form of nitrogen that is applied, the rate of recharge, and the rate of nitrogen uptake by the crop.

## AGRICULTURAL FERTILIZERS

### are the main source of nitrate in ground water.

Man-made fertilizers became widely available after World War II and quickly came into use across the Nation. Today, nitrogen fertilizers (commonly nitrate or ammonium compounds) are used in large quantity in most agricultural settings.




The Quincy-Pasco subunit's high annual rate of fertilizer application coincides with high nitrate concentrations in the subunit's shallow ground water (see map on reverse).

The extent and intensity of agriculture in the Central Columbia Plateau make high annual rates of fertilizer application a particularly strong influence over water quality. Other sources of nitrogen, such as livestock production, food processing wastes, and sewage, are lesser influences at a regional scale.

**Nitrogen, ammonia, and ammonium fertilizers break down into nitrate.**

- Nitrate is the form of nitrogen that plants can assimilate.
- Nitrogen compounds naturally transform into nitrate.
- Nitrate is very water soluble, and so can be transported by water from the land surface into the soil.

**High nitrate concentrations may be an indicator of the presence of pesticides.**

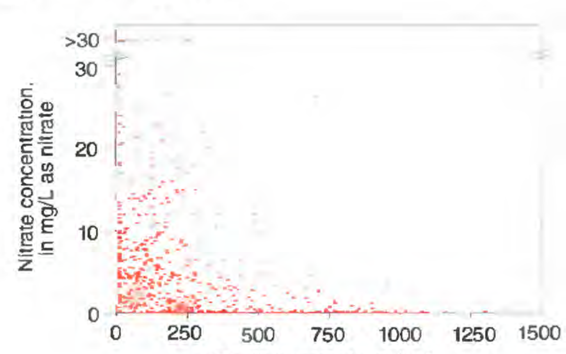
- Pesticides used in conjunction with fertilizers may be carried into ground water in the same way as nitrate. Detection of nitrate in ground water may indicate the presence of pesticides, although a number of additional factors complicate this relationship.
- Pesticides in use today contain a wide variety of chemicals. Many others are no longer in use but residues may remain in the soil and in ground water.

## NITRATE CONCENTRATIONS VARY WITH SPACE AND TIME

**Nitrate concentrations are generally lower at greater depths.**

In the Central Columbia Plateau, 26% of wells less than 300 feet deep have nitrate concentrations exceeding the EPA MCL of 10 mg/L.

Only 8% of wells deeper than 300 feet have nitrate concentrations exceeding the MCL.



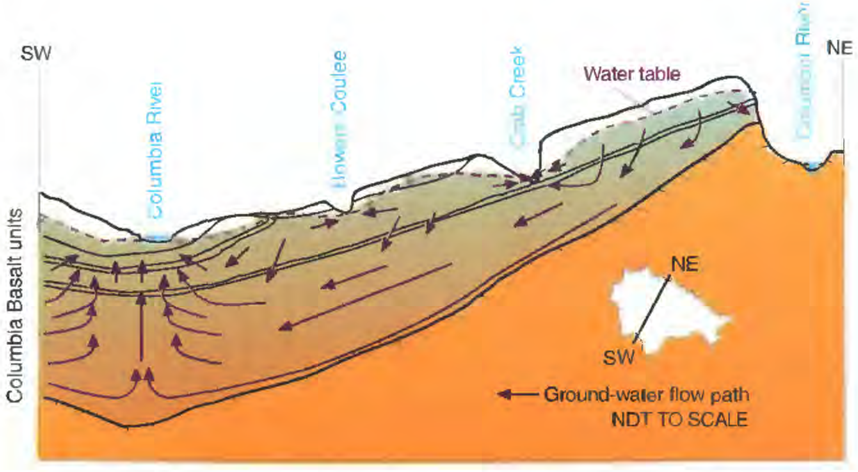

Some nitrate may be transformed into other compounds as it is carried through the ground-water system. Mixing also decreases nitrate concentrations, as water with higher nitrate concentrations enters deep ground-water systems farther from agricultural influences.

**Nitrate concentrations at the water table may vary greatly.**

Ground water moves along flow paths that vary from a few feet to hundreds of miles (shown with blue arrows, below).

Shallow flow paths tend to be influenced by land use practices at the surface, while water in deeper flow paths is farther from human influences.

Deeper flow paths also have much longer travel times, in most cases predating modern land use practices.

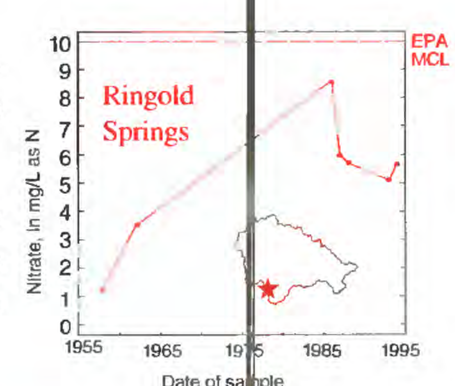



Water from different sources increases the variability of nitrate concentrations in shallow ground water. In the Quincy-Pasco subunit, recharge water carrying nitrate along shallow flow paths mixes with canal water from the CBIP. Recharge water carrying nitrate into deeper flow systems mixes with deeper, older water.

**Nitrate concentrations in the regional ground-water system have generally increased since the 1950's.**

Nitrate concentrations in the regional ground-water system vary greatly but have generally increased, due to increased irrigation and use of nitrogen fertilizers.

Single wells may show highly variable trends in nitrate concentration. A good illustration of regional trends is Ringold Springs (right), a ground water discharge point integrating an area of several square miles.




## HUMAN HEALTH EFFECTS OF NITRATE

A June 1995 Washington State Department of Health Fact Sheet states:

> **Health impacts:** High levels of nitrate in drinking water can cause a potentially fatal blood disorder called methemoglobinemia. Although methemoglobinemia can affect any age, nitrate contaminated water principally causes this illness in children under six months. Some studies have suggested a possible link between nitrate and cancer and birth defects. These suggestions, however, have not been confirmed.
>
> **Methemoglobinemia:** In order for nitrate to cause methemoglobinemia or "blue baby disease," it must first be changed in the body into nitrite. Babies less than six months old have a lower stomach acidity, which allows certain bacteria to grow in the stomach and intestines that are capable of converting nitrate to nitrite. Nitrite then changes the oxygen carrying hemoglobin to methemoglobin, which does not carry oxygen. . . . Poisonings usually occur when contaminated water is used to prepare infant formula and foods. Boiling water for infant formula is a good practice for killing bacteria, but it will not destroy nitrates.
>
> * * * * * * *
>
> **Treatment:** If the condition is not life-threatening, no treatment is needed other than a switch to uncontaminated water. The symptoms will improve within two to three days. For severely affected infants, intravenous treatment with methylene blue will convert the methemoglobin back to hemoglobin and bring rapid recovery.
>
> **Prevention:** Infants under one year of age should not drink water containing nitrate at a concentration greater than the drinking water standard of 10 parts per million (ppm) [or 10 milligrams per liter (mg/L)] as nitrogen. Although no health based standards exist for adult exposures, the following subpopulations may be at risk:
>
> - Individuals with reduced gastric acidity.
> - Individuals with a hereditary lack of methemoglobin reductase, and
> - Women who are pregnant.

For more health information, contact your water utility or county health agency, or the Washington State Department of Health: 1 (800) 521-0323.

Based on Water-Resources Investigation Report 94-4258.

References:
Greene, K.E., Ebbert, J.C., and Munn, M.D., 1994, Nutrients, suspended sediment, and pesticides in streams and irrigation systems in the Central Columbia Plateau in Washington and Idaho, 1959-1991: U.S. Geological Survey Water-Resources Investigations Report 94-4215. 64+ p.
Jones, J.L., and Wagner, R.J., [In Press], Ground-water quality of the Central Columbia Plateau in Washington and Idaho: Analysis of available nutrient and pesticide data, 1942-1992: U.S. Geological Survey Water-Resources Investigations Report 94-4258. __p.
Washington State Department of Health, June 1995, Nitrate in drinking water: Washington State Department of Health Fact Sheet. 2 p.

October 1995

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
National Water-Quality Assessment Program

For further technical information contact:

Project Chief
Central Columbia Plateau NAWQA
1201 Pacific Avenue - Suite 600
Tacoma, WA 98402

Phone: (206) 593-6530 x235 Email: akwill@usgs.gov
World-Wide Web: http://wwwdwatcm.wr.usgs.gov/ccpt.nawqa.html