PHOSPHORUS EFFECTS ON SURFACE WATER QUALITY AND PHOSPHORUS TMDL DEVELOPMENT

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INTRODUCTION

Phosphorus is essential for all life.

Phosphorus is an essential element for all life. It is part of the backbone of DNA. ATP is the fuel, or energy currency of cellular metabolism. Phosphorus at different energy states is organically bound and essential to the operation of photosynthesis, metabolism, and catabolism (the building of molecules). Because of the central role of phosphorus, when crop yields are high, phosphorus is always in adequate supply.

Desire for clean water.

We all want clean water. We desire clean water to drink, cook with, recreate, or appreciate in the landscape. Water in high mountain lakes and the headwaters of rivers is usually clear, cool, and often pure. Water in the headwaters is usually but not always very low in phosphorus. Typically many mountain lakes in the Cascades, central mountains of Idaho, and high mountain streams have less than 20 µg/L total phosphorus.

Link of Phosphorus and Poor Water Quality

Phosphorus stimulates algal growth

Plant life is the basis of food chains in aquatic systems. When algal growth is excessive, other aquatic forms of life are endangered. Algae blooms limit recreational use by reducing water clarity and aesthetic qualities. Factors that limit algal growth include available forms of nitrogen and phosphorus, sunlight, and temperature (1, 2).

How much phosphorus does it take to stimulate algae growth?

It does not take very much orthophosphate to stimulate algae growth in the Tualatin River Basin (Figure 1 (3)). Nuisance algal blooms are stimulated by an average P concentration of 80 µg/L in Lake Lowell in the Treasure Valley of Idaho. Lakes with 30 to 100 µg/L phosphorus are in the eutrophic range while those with >100 µg/L are hypereutrophic (2). Surface water concentrations often must be less than 25 µg/L to significantly improve water clarity.

Algae and low dissolved oxygen.

Algae and other microorganisms in the water greatly affect dissolved oxygen. Under algae bloom conditions, the algae have a negative effect on reservoir fisheries because of periodic oxygen depletion associated with algae respiration and decomposition.

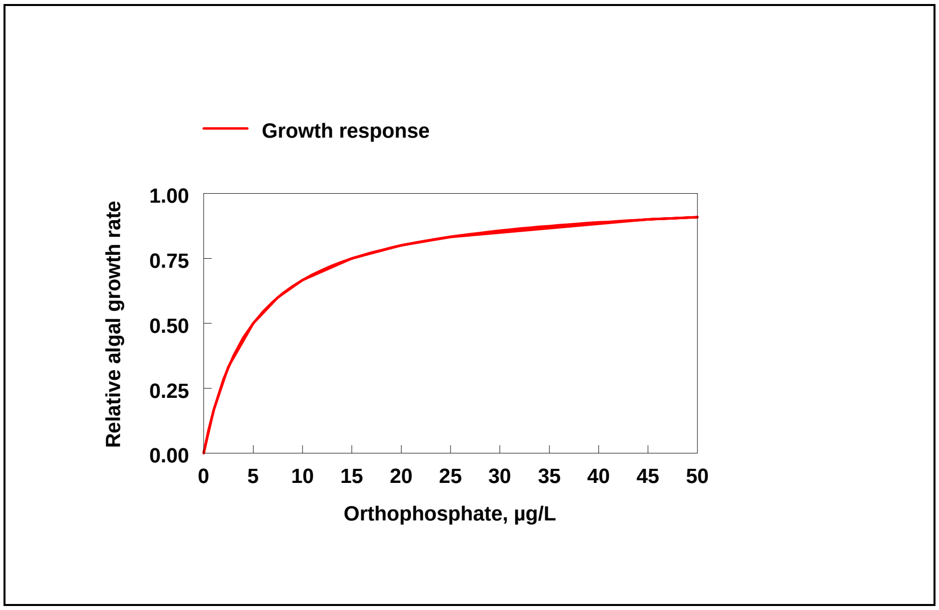


Figure 1. Algae growth in the Tualatin River, OR, has an estimated Michaelis-Menten half-saturation constant for phosphorus of 5 µg/L.

During the day algae picks up carbon dioxide and releases oxygen through photosynthesis so the dissolved oxygen in the water rises. At night their metabolism requires them to take up oxygen and release carbon dioxide. These fluctuations can be large. When an excess of algae grow and sink deeper into the water, their rate of photosynthesis can no longer be maintained, and they decompose, also at the cost of dissolved oxygen (Figure 2).

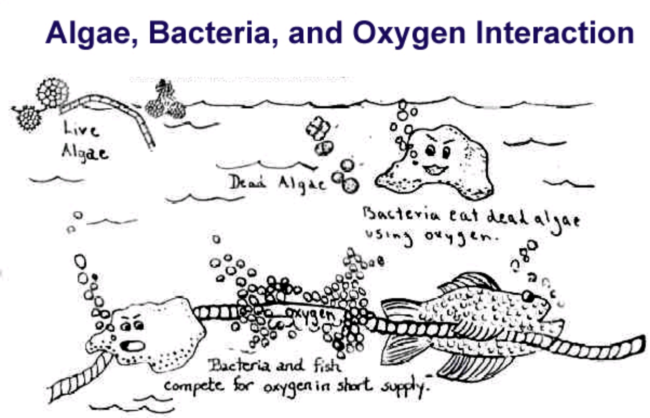


Figure 2. The decomposition of suspended algae consumes oxygen dissolved in the water. If there are large amounts of respiring or decomposing algae, their oxygen requirements compete with the oxygen needs of fish, and can lead to fish kills.

Algae and fish food chains.

Algae are also very important as a major component in highly productive fish food chains. The high productivity of fish in the Snake River, Owyhee Reservoir, and other local bodies of water is probably closely tied to algae productivity.

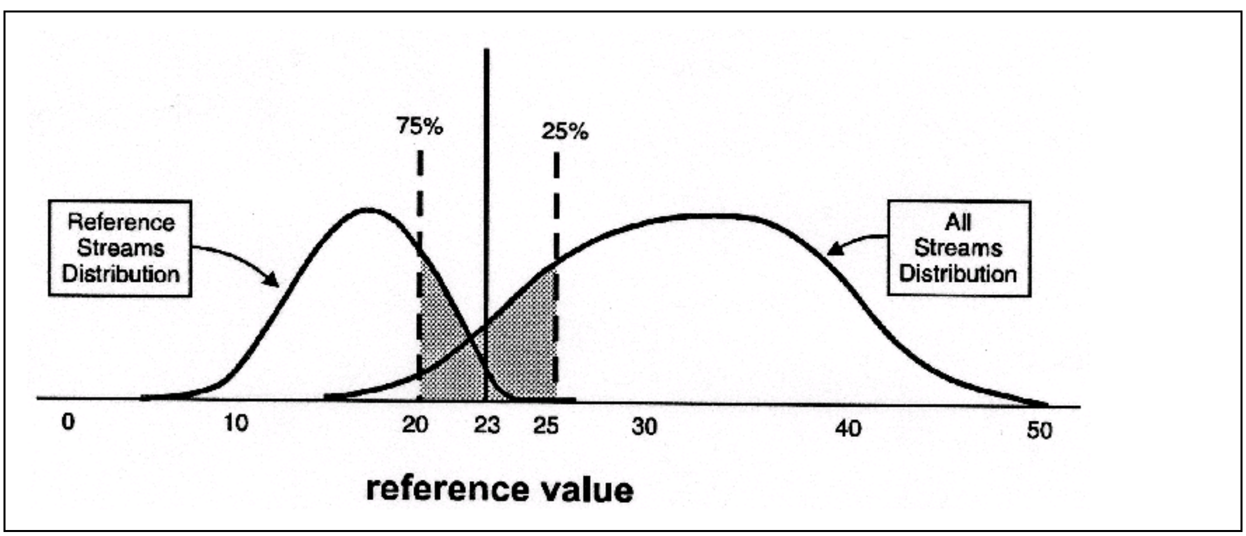
TMDL Development

A Total Maximum Daily Load (TMDL) is the calculated maximum amount of a pollutant that a water body can receive and still meet applicable state water quality standards. The applicable state water quality standards are set by the states under close guidance by the U.S. EPA (4). TMDL development is planned and has been scheduled for most of the major water bodies of Idaho, Washington and Oregon. TMDLs frequently specify the maximum total phosphorus concentration in streams and lakes due to the close ties between phosphorus and algae growth.

Typically one of the TMDL implementation goals is to reduce P losses from agriculture. P losses from agriculture can be reduced by increasing P use efficiency and reducing P losses in runoff (5). Manure can be moved from areas of excess to areas where nutrients are deficient. Parts of the landscape where the danger surface runoff losses of P are particularly high are considered for modification.

The U.S. EPA guidance compares water bodies against reference water bodies, which have low phosphorus levels (Figure 3, (4)). An assumption of TMDL development is that the frequency distribution of reference streams with low total phosphorus can be compared with the frequency distribution of all streams in the region and be used to determine a phosphorus standard. The phosphorus standards in a TMDL can be related to the water bodies with very low phosphorus (Figure 4, (4)).

Figure 3. In TMDL development the frequency distribution of reference streams with low total



phosphorus are compared with the frequency distribution of all streams in the region (4).

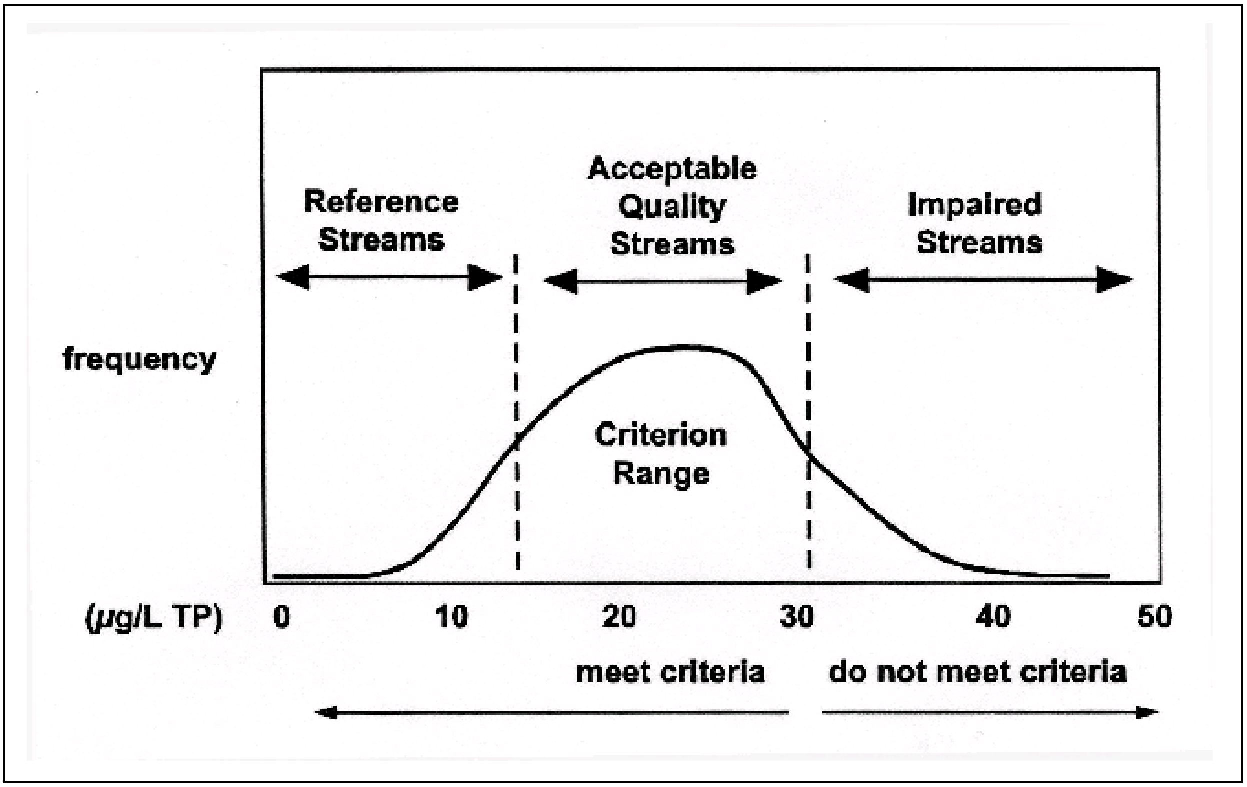


Figure 4. Approach of the U.S. EPA in choosing TMDL phosphorus criteria (4).

What is Coming for Eastern Oregon and Southern Idaho?

TMDL

The development of TMDLs for all major river segments has been scheduled. Oregon Department of Environmental Quality and Idaho Department of Environmental Quality wrote the Snake River - Hells Canyon Total Maximum Daily Load under very close supervision by the U.S. EPA. The Hells Canyon-Snake River TMDL will establish a total phosphorus standard of 70 µg/L for the main stem of the Snake River and the tributaries and agricultural drains entering the Snake River over this reach. The Boise River, Payette River, and Weiser River of Idaho and the Powder River, Burnt River, Owyhee River, and Malheur River of Oregon will all be required to meet the 70 µg/L criteria at their confluence with the Snake River.

What will "70 µg/L total phosphorus" mean for Malheur County, Oregon?

Most all runoff water from agriculture in Malheur County is two to ten times the TMDL. So runoff and return flows to rivers and streams are going to be found in violation of the TMDL.

Local Sources of Phosphorus Contamination

What are the local sources of phosphorus contamination?

Irrigation water becomes enriched in phosphorus from fertilizer and soil phosphorus through repeated use of the water in surface irrigation systems (Figure 5).

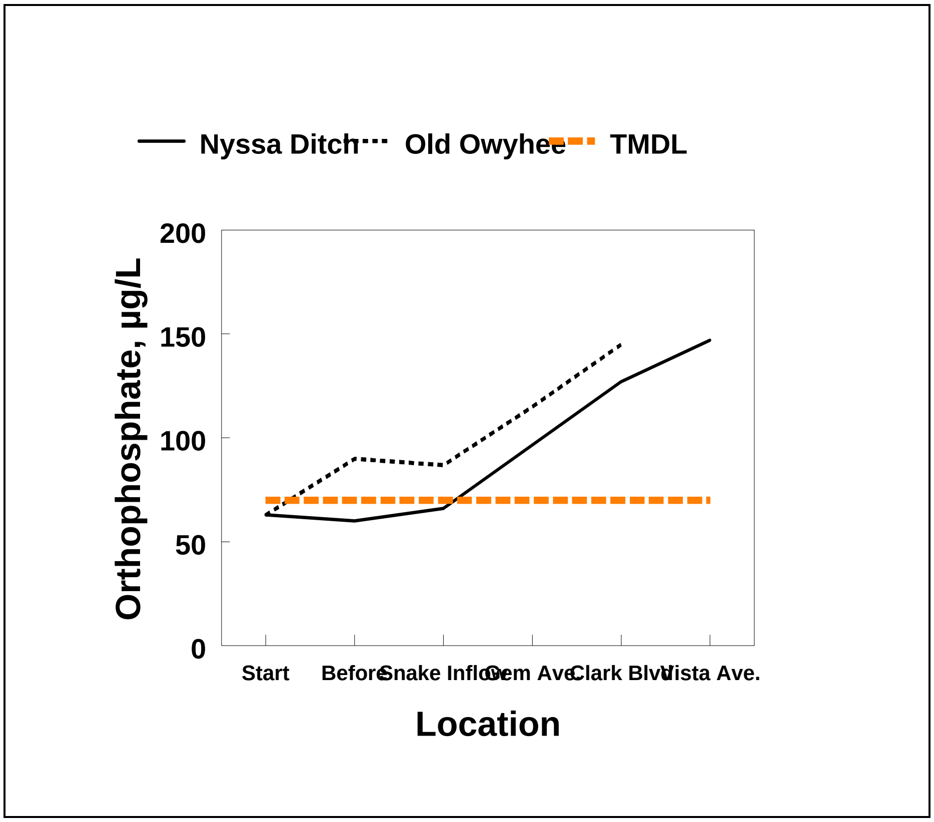


Figure 5. The irrigation water in both the Nyssa ditch and the Old Owyhee ditch become enriched with orthophosphate over their lengths. Orthophosphate is only part of the total phosphorus load in this irrigation water. The TMDL based on total phosphorus is graphed for comparison.

So clearly, repeated use of water and irrigation-induced erosion are related to phosphorus enrichment in the irrigation water. As some of this water runs off into streams and rivers, it can enrich river water phosphorus levels. The total phosphorus in the Malheur River is very high during spring runoff in February and March, after which time the phosphorus level drops in April, only to rise again with the onset of the irrigation season in May and June (Figure 6). We hypothesize that the bi-modal pattern of phosphorus loss is due to losses associated with natural background during spring runoff and irrigation-induced phosphorus enrichment.

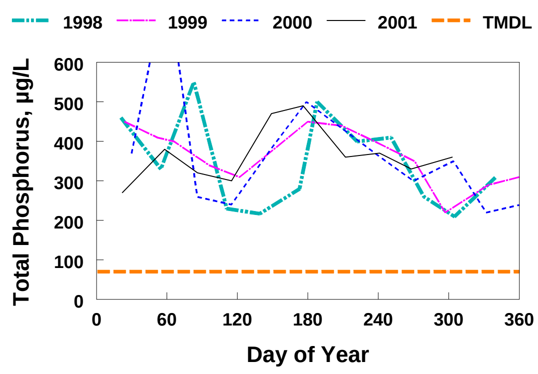


Figure 6. Patterns of total phosphorus in the Malheur River at the 36th Street Bridge in Ontario, Oregon, less than two miles from the Snake River as monitored by the Malheur Watershed Council for four years. This site is location 14 on Figure 7.

Are we close to meeting the phosphorus TMDL for the Snake River?

One of the clearly evident conclusions is that the Malheur River is nowhere close to meeting the Snake River TMDL. The river is way out of compliance averaging about 6 times the TMDL. Levels are very high both during spring runoff and the irrigation season.

Can Phosphorus Contamination Be Solved

What can be done to reduce sediment load and water phosphorus enrichment?

All changes in practices, which make irrigation more efficient and reduce erosion, will help. The less runoff, the less phosphorus load will return to the rivers.

1. Laser leveling.
2. Irrigation system conversions from furrow to surge, sprinkler, or drip.
3. Filter strips.
4. Use of PAM and straw mulch
5. More careful management of water to reduce runoff.
6. Better timing of irrigations through irrigation scheduling
7. Judicious use of phosphate fertilizers.
8. Sediment basins and pump back systems.
9. Grazing practices, which promote stream bank stability.
10. Using only the amount of phosphate fertilizers that are really necessary.
11. Better manure management.

These "Malheur County Best Management Practices" are discussed in detail on the web site at <http://www.cropinfo.net/bestpractices/Malcountybmp.html>.

Phosphorus losses can be reduced through reductions in irrigation-induced erosion and by only using the amount of phosphate fertilizers that are really necessary. Numerous places in the Malheur River drainage, stream bank stability could be improved by better grazing management. Judicious approaches need to be followed, because not all riparian sites are inherently stable. Some sites are regularly scoured by water fluctuations.

It is always possible that agencies may insist that runoff water will have to be cleaned completely through artificial wetlands or eliminated altogether.

The problem of high natural background phosphorus.

One of the complications that can occur in TMDL implementation is that background contaminate sources can be relatively high. During TMDL implementation, reductions of phosphorus contamination down to the TMDL standard may be unfeasible. It is more cost effective to discover these problems before incurring great TMDL implementation costs. In the Tualatin River Basin in western Oregon, ubiquitous sources of natural occurring phosphorus made the original phosphorus TMDL unfeasible. Vivianite, a natural occurring iron phosphate, was found.

The Malheur River and Owyhee River systems provide unsolved puzzles in the sources of phosphorus (7). The Malheur Watershed Council has been monitoring water quality in the Malheur River and its tributaries for the last five and a half years. Some of the locations are marked on Figure 7 below.

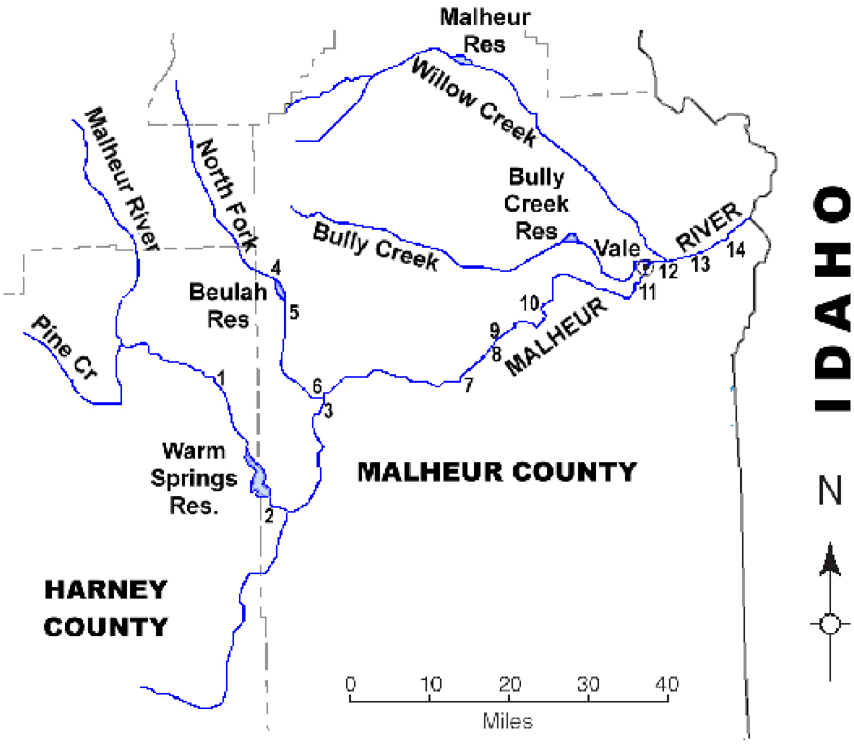


Figure 7. Simplified schematic of the major tributaries of the Malheur River. The numbered locations mark sites of the water quality-monitoring network that are regularly sampled by the Malheur Watershed Council.

Rather high in the North Fork of the Malheur River, total phosphorus regularly exceeds the Snake River TMDL (Figure 8). Below Beulah Reservoir the North Fork of the Malheur River total phosphorus averages 150 µg/L (Figure 9). Similar patterns occur on the Middle Fork of the Malheur River. These phosphorus levels are in geographic locations analogous to high in the Central mountains of Idaho that have very low phosphorus levels in spite of similar land use, suggesting geological contributions to the phosphorous loads in the Malheur drainage. Deep lacustrian deposits in the headwaters of the Malheur River and its tributaries are a suspected geological source of phosphate.

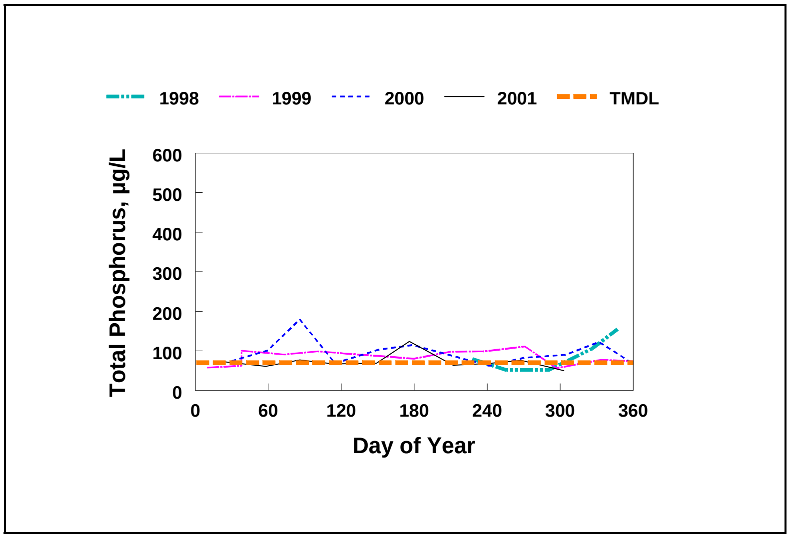


Figure 8. Total phosphorus in the North Fork of the Malheur River above Beulah Reservoir. This site is location 4 on Figure 5.

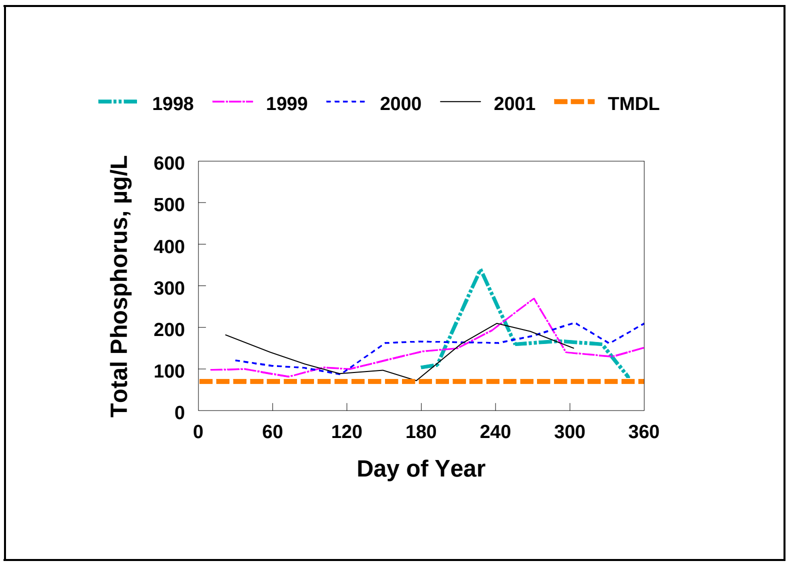


Figure 9. Total phosphorus in the North Fork of the Malheur River below Beulah Reservoir. This site is location 5 on Figure 5. Beulah Reservoir is situated in deep lacustrine deposits. Wind action on the reservoir is eroding these deposits.

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