DESIGN OF A WATERSHED-BASED NITROGEN TRADING SYSTEM FOR THE BIG AND LITTLE WOOD RIVERS WATERSHED

by

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ABSTRACT

A watershed-based nitrogen trading system was designed for the Big and Little Wood Rivers Watershed in south-central Idaho as a policy tool to help manage increasing nitrogen loads within the Watershed. The study was performed on behalf of the Blaine County Commissioners in response to concerns regarding increasing population growth and nitrogen loading in the Watershed. A trading framework was developed based on case studies and existing trading frameworks. The developed framework included selection of a trading arrangement, development of a trading cap, design of a credit distribution system, establishment of a trading ratio, and qualification of transaction costs. Potential problems with trading, including administration of the trading program, pre-quantification of transaction costs, uncertainty in data collection and source monitoring, spatial and temporal distribution of pollutants, and enforcement of the trading program, are discussed. A water balance was completed in order to understand the hydrologic conditions of the Watershed. Water inflow for the Watershed included 2.24 kg^3/yr of precipitation. Water outflows for the Watershed included 1.87 kg^3/yr of evapotranspiration and 0.33 kg^3/yr of surface water outflow. A point source/non-point source trading arrangement was set for the Watershed based on the currently high proportion of non-point nitrogen sources (e.g. agricultural lands and rangeland) and the future potential for increases in the proportion of nitrogen from point sources (e.g. wastewater treatment plants). A yearly nitrogen cap in the range of 569,300 kg/yr and 720,500 kg/yr was suggested for the Watershed. This range was based on estimates for actual nitrogen stream flow concentration and loading within the Watershed and acceptable nitrogen concentration values from EPA Ecosystem classification data, trophic states, and published data. Trading credits would be distributed to point sources in proportion to their current acceptable discharge levels and to non-point sources in proportion to the amount of land used for agriculture or ranging. The trading ratio set between point and non-point sources varied continuously between 1:1 and 1:2.6 depending on the distance of the non-point source from the river.

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1 Introduction

1.1 Background Information on the Big and Little Wood Rivers Watershed

The Big and Little Wood Rivers Valley Watershed (the Watershed) is composed of the land area that drains into the Big Wood and Little Wood Rivers. The Watershed is located in south-central Idaho (Figure 1-1), and is defined by the United States Geological Survey (USGS) Hydrologic Unit Code (HUC) boundaries 17040219 and 17040221. The Watershed covers a land area of 1.65 million acres in south-central Idaho that falls within the boundaries of five counties. The majority of the Watershed resides within Blaine County, though the Watershed does extend into the neighboring Camas, Gooding, Lincoln, and Jerome Counties (Figure 1-2). There are 16 towns and cities within the Watershed boundaries (Figure 1-3).

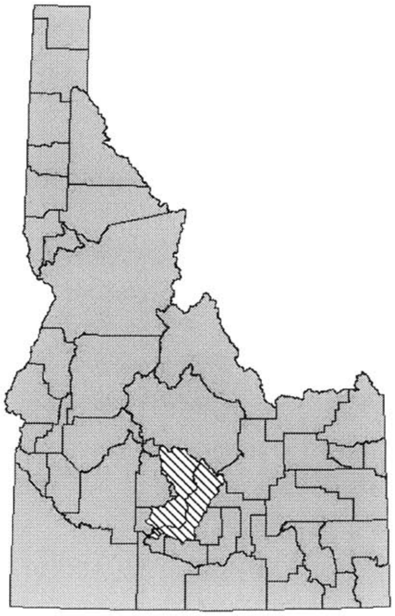

Figure 1-1. Big and Little Wood Rivers Watershed

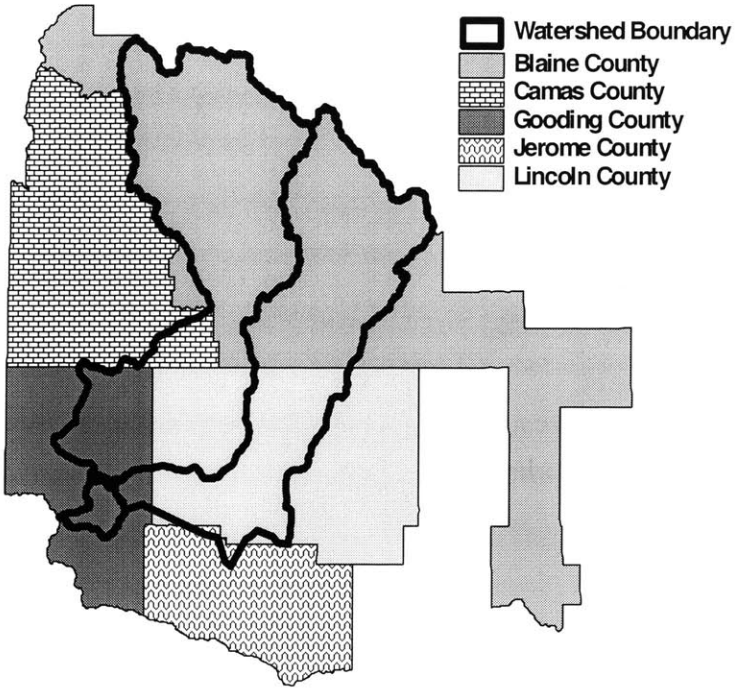

Figure 1-2. Counties within the Watershed

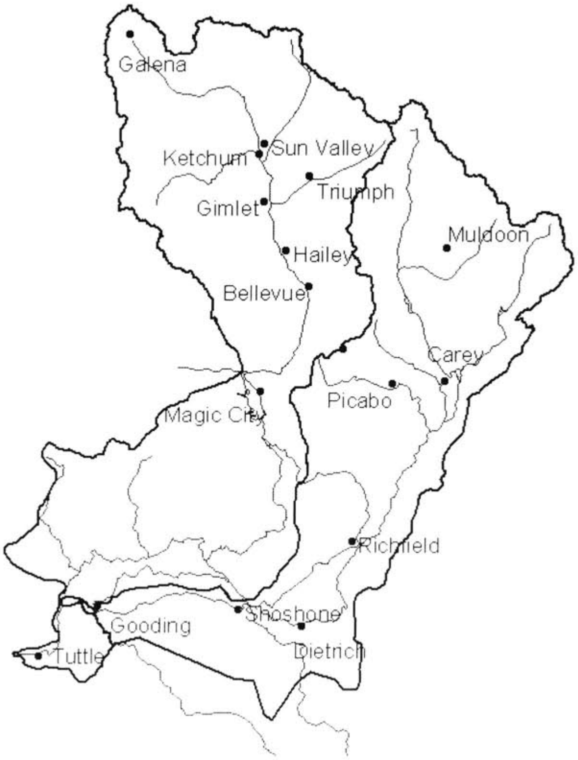

Figure 1-3. Cities within the Watershed

The major land uses within the Watershed are forestlands, agricultural lands, rangelands, and urban and suburban uses including residential and commercial development (Figure 1-4). Within the Watershed, agricultural lands, forestlands, and rangelands are being converted into residential areas, as the population of the Watershed grows (IDEQ 2002).

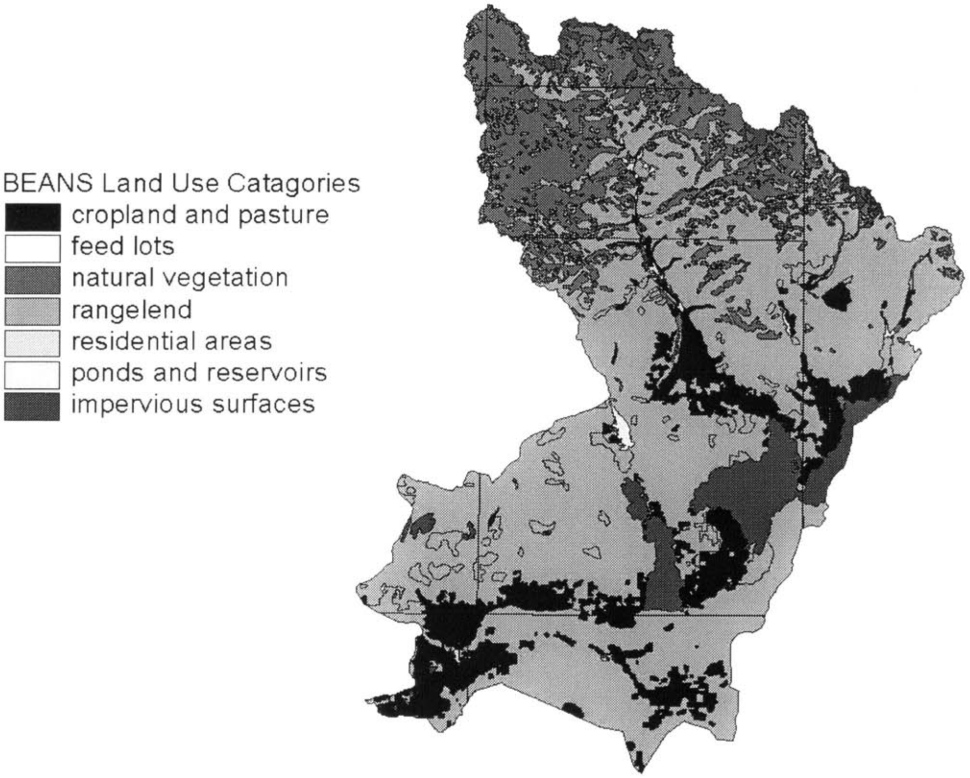

Figure 1-4. Land use estimates in the Watershed (Connolly et al. 2003)

The Watershed has undergone substantial population growth in recent decades. Blaine County's population has grown from 4,596 in 1960 to 18,991 in 2000 (Figure 1-5). Year 2000 populations in the neighboring counties are 991 in Camas, 14,155 in Gooding, and 4,044 in Lincoln. The percentage change in population from 1990 to 2000 for Blaine, Camas, Gooding, and Lincoln Counties were 40.1%, 36.3%, 21.7%, and 22.2%, respectively.

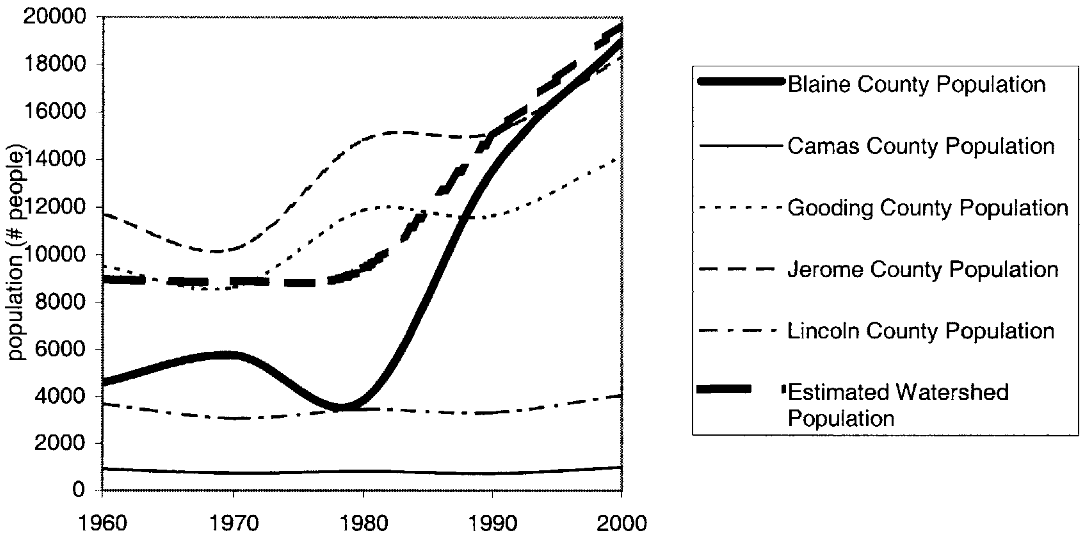

Figure 1-5. Population growth in counties within the Watershed

The USGS used the Spatially Referenced Regressions On Watershed Attributes (SPARROW) Model to estimate nitrogen loads from various land uses within the Watershed. SPARROW identifies non-agricultural sources as the largest nitrogen contributor at 48% of the total nitrogen load. SPARROW estimates livestock waste at 24%, fertilizer at 23%, atmospheric deposition at 5%, and point sources at less than 1% of the total nitrogen load (Figure 1-6) (Smith et al. 1997).

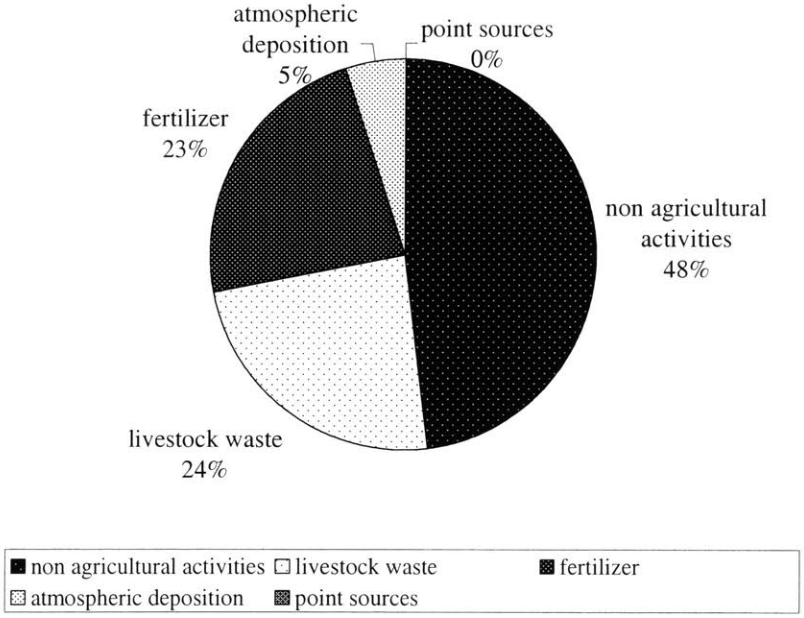

Figure 1-6. USGS SPARROW Model nitrogen source allocation within the Watershed (Smith et al. 1997)

A study by Connolly et al. estimated the current total load of nitrogen within the Watershed as about 664,500 kg/yr (Table 1-1). The study determined that the highest proportion of this load derives from inputs to cropland and rangeland (Figure 1-7) (Connolly et al. 2003).

Land Use	Nitrogen Load (kg N/yr)
Rangeland	302,200
Cropland and Pasture	276,900
Residential	37,100
Feed Lots	12,900
Impervious Surfaces	18,400
Natural Vegetation	16,500
Water	500
Total	664,500

Table 1-1. Nitrogen loads by land use within the Watershed (Connolly et al. 2003)

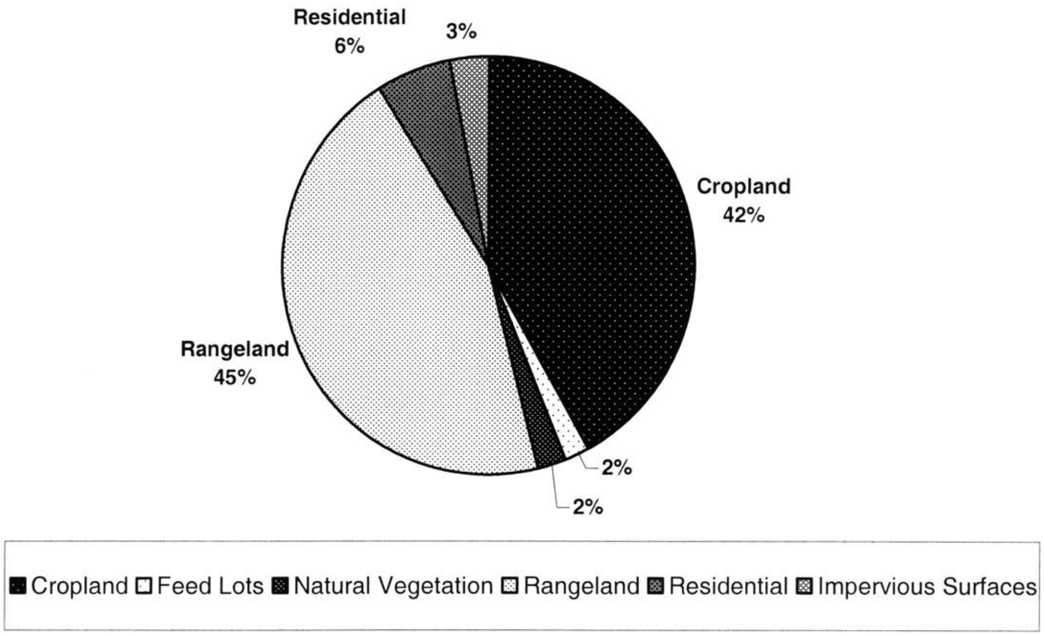

Figure 1-7. Nitrogen source allocation by land use within the Watershed (Connolly et al. 2003)

Connolly et al. also estimated that the population of the Watershed would grow by about 40,000 residents by the year 2025. This study estimates land use patterns will evolve to fit this population growth by altering agricultural lands to residential lands (Connolly et al. 2003). While this prediction is dependent on residential lot size and level of wastewater treatment, it is possible that total nitrogen load will increase and clear that residential sources will become an increasingly larger proportion of total nitrogen load (Figure 1-8).

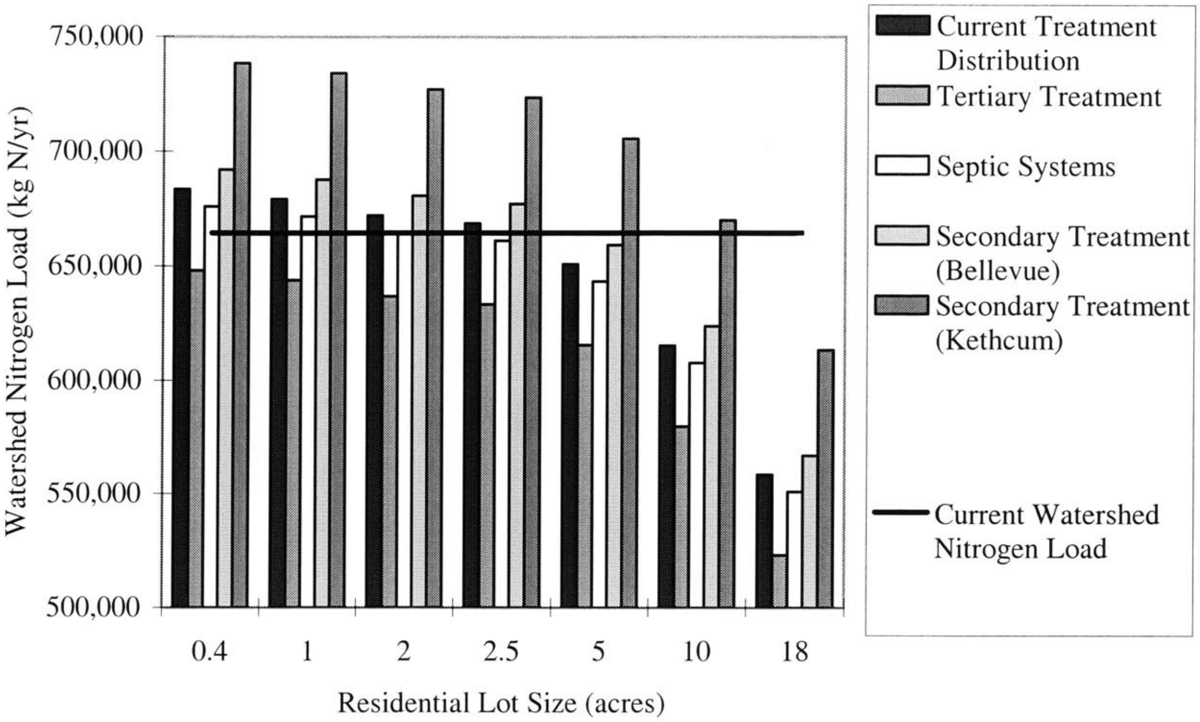

Figure 1-8. Estimated nitrogen loads in year 2025 given residential lot sizes (Connolly et al. 2003)

1.2 Overview of Water Quality Management in the United States and Idaho

Under the Clean Water Act (CWA), enacted in 1972, states and tribes must "restore and maintain the chemical, physical, and biological integrity" of national waters (IDEQ 2002). The federal government "established financial assistance for the construction of publicly owned waste treatment facilities, requirements for area-wide waste treatment management planning and major research and demonstration efforts to develop pollution control technology" (EPA 2002a). Under CWA §303, states and tribes must adopt water quality standards that are protective of fish, shellfish, and wildlife and provide human recreation in and around waters when possible. Section 303(d) of the CWA requires states to provide a prioritized list of impaired water bodies every two years.

Under CWA §303, states are required to set total maximum daily load (TMDL) requirements for waters where national "effluent limitations … are not stringent enough to implement any water quality standard applicable to such waters." The TMDL for "a particular pollutant is defined as the total amount of the pollutant that may be discharged to the water body ... without violating the water quality standard for that pollutant" (Ashford et al. 2002). Under the TMDL process, states and territories identify impaired water bodies and compile lists of these water bodies. States then establish TMDL requirements for water bodies on the list, specifying the reductions needed to meet water quality standards. States allocate these reductions among the sources in the watershed.

The CWA National Pollutant Discharge Elimination System (NPDES) permitting program has made great strides in controlling point source[1] discharges into the nation's waters. The United States Environmental Protection Agency (EPA) notes that by 1990 "over 87% of the major municipal facilities and 93% of major industrial facilities were in compliance with NPDES permit limits" (EPA 2002a). Additionally, annual point source control costs amount to about $14 billion for private firms and $34 billion for public facilities (EPA 2002a). Nonetheless, non-point sources[2] remain highly unregulated and "almost 40% of currently assessed rivers, streams, and lakes still do not support their designated uses" (EPA 2002a).

Congress passed the Safe Drinking Water Act (SDWA) in 1974 in order to protect public health by regulating drinking water sources, including rivers, streams, lakes, springs, reservoirs, and groundwater wells. The SDWA sets health-based drinking water standards for various man-made and naturally occurring contaminants, including various forms of nitrogen. The current standards for nitrate and nitrite are ten mg/L and 45 mg/L, respectively.

The State of Idaho has not set numeric water quality criteria for nutrients. Instead, it has a narrative standard which suggests that "if the designated and existing beneficial uses are not

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[1] Point sources are defined by the EPA as "any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture" (EPA 2003a)

[2] Non-point sources are diffuse sources, largely caused by rainfall and snowfall runoff. As defined by the EPA, non-point sources include: excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks; salt from irrigation practices and acid drainage from abandoned mines; bacteria and nutrients from livestock, pet wastes, and faulty septic systems; atmospheric deposition; and hydromodification (EPA 2003b).

impaired by the effects of excessive nutrients in the water body, nutrients are not exceeding the narrative water quality standard" (LBRWQP 2002).

1.3 Nitrogen Enrichment Problems in Rivers and Streams

Nitrogen is an essential element that is naturally fixed (usually by nitrogen-fixing bacteria or lightning) and used by organisms in the form of ammonium (NH_4) and nitrate (NO_3). However, during the past century, humans have increased the rate of nitrogen fixation, thus increasing the amount of available nitrogen. Human-induced nitrogen fixing processes include production of nitrogen fertilizer, increases in nitrogen-fixing crops (including soybeans, alfalfa, and legumes), and combustion of fossil fuels (Vitousek et al. 1997). Figure 1-9 provides a diagram of the nitrogen cycle.

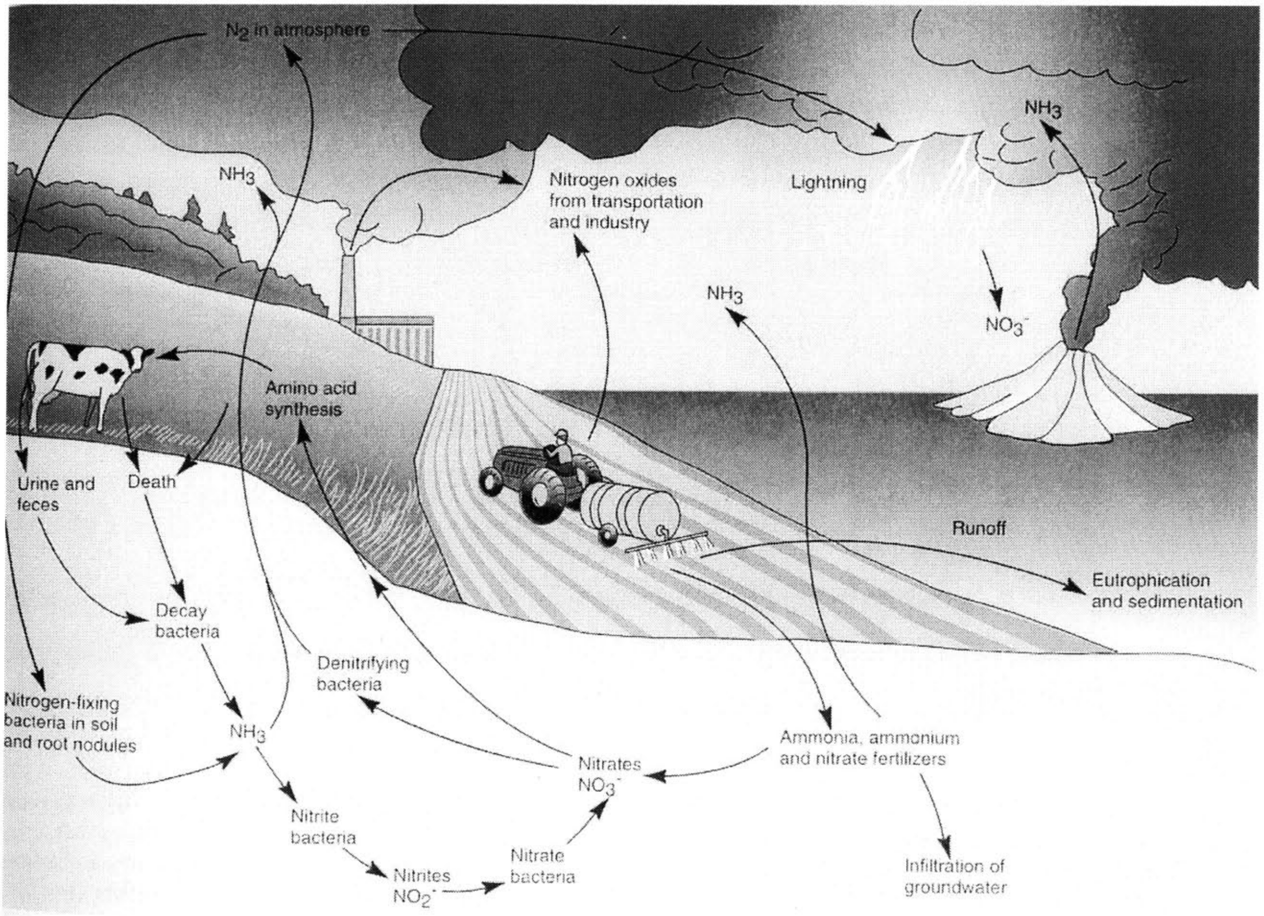
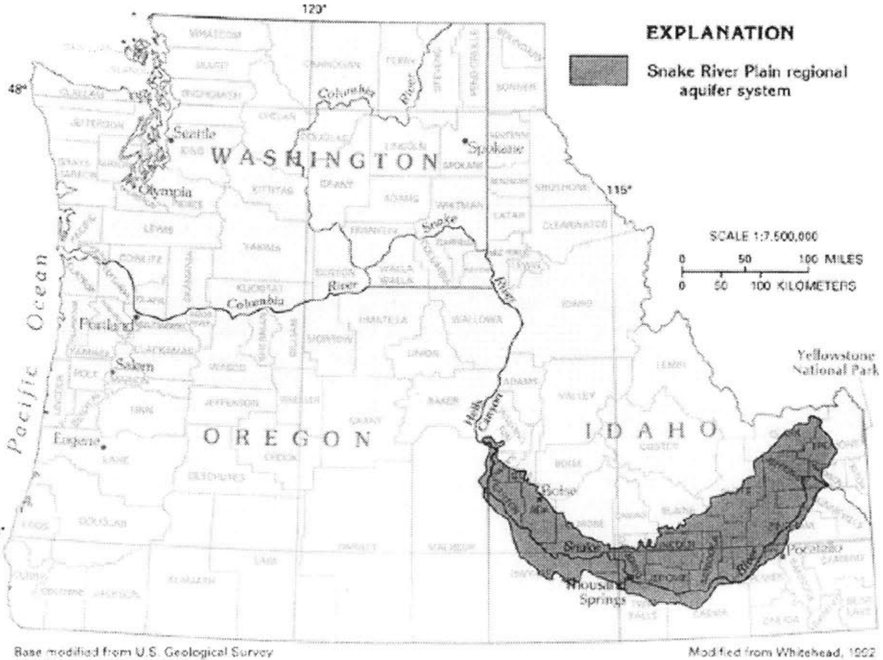


Figure 1-9. The nitrogen cycle (Miller 1994)

Due to human disturbances of the nitrogen cycle, nitrogen, and particularly nitrate, enrichment has become a major cause of water quality impairment. Impairment of a water body occurs when the water quality of a body does not meet its CWA designated use criteria. This impairment may have adverse ecological, aesthetic, human health, and economic effects.

Nitrogen affects the productivity and well being of water sources and the wildlife that lives in them. Wetzel notes, "a positive correlation has been found between high sustained productivity of algal populations and average concentrations of inorganic and organic nitrogen" (Wetzel 1983). Moreover, while phosphorus may often be the limiting nutrient in fresh water systems (including lakes, rivers, and streams), nitrogen is the limiting nutrient in marine systems. The Big Wood River is a tributary of the Snake River, which flows into the Columbia River and eventually empties into the Pacific Ocean off the coast of Washington state (Figure 1-10). Therefore, elevated nitrogen levels in the Big and Little Wood Rivers may have negative effects on a regional level.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from Whitehead, 1992

Figure 1-10. Snake River Plain aquifer (USGS 1994)

Eutrophy, a physical state that occurs in nutrient rich water bodies, can have devastating effects to aquatic habitats (Figure 1-11). Eutrophication causes the occurrence of harmful algal blooms, which can lead to decreased water clarity and reduce habitat availability for aquatic life, as algae form mats on the top of the water body and decrease the amount of dissolved oxygen available. Moreover, several species of algae may produce toxins, which can cause harm or death to marine species and illness and death to humans who come in contact with the toxins or ingest fish or shellfish with elevated levels of toxins.

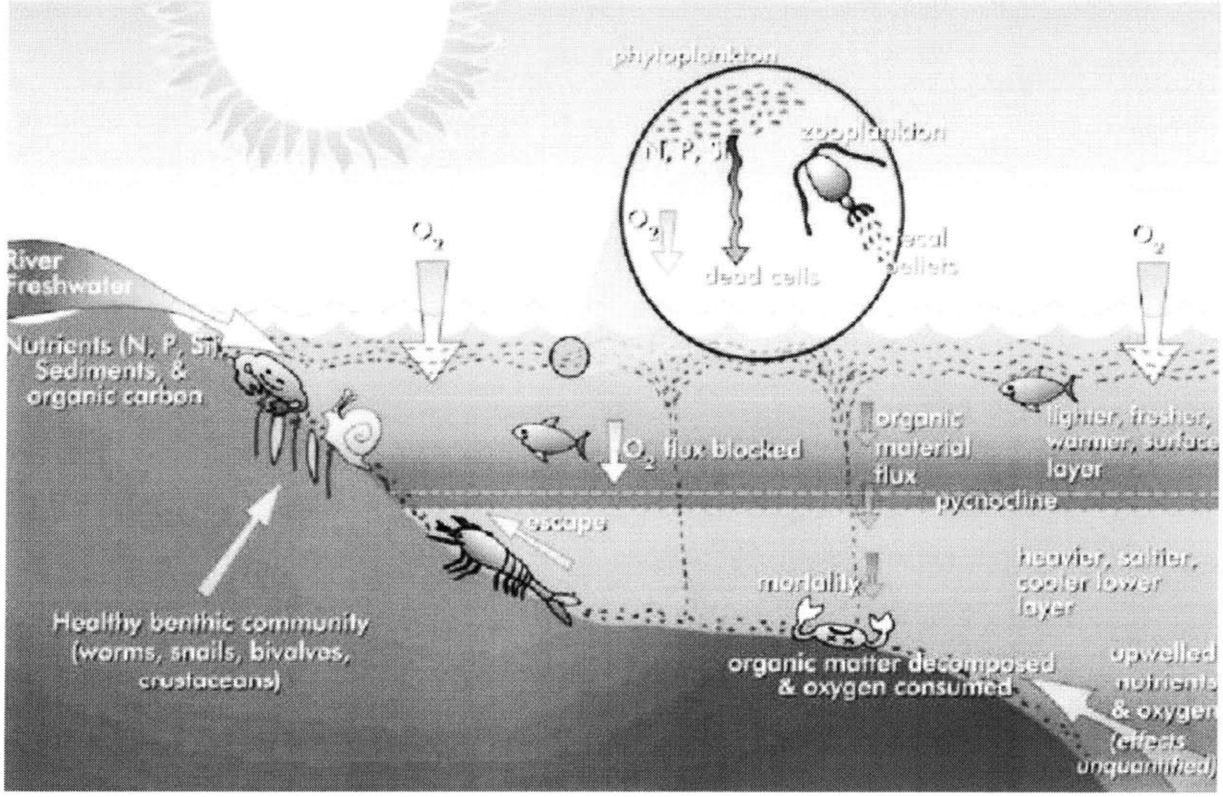


Figure 1-11. Eutrophication (EPA 2002b)

At extreme levels, eutrophication can lead to hypoxia, or an inadequacy in oxygen. In the state of hypoxia, dissolved oxygen concentrations in the river or stream become very low as the overgrowth of algae depletes the availability of dissolved oxygen. Therefore, organisms that can tolerate low dissolved oxygen concentrations tend to dominate the habitat (Wetzel 1983). Hypoxia leads to the death of fish and other wildlife that require oxygen to survive, and may lead to virtually no biological activity. This has occurred in the Gulf of Mexico at the outlet of the

Mississippi River, where nitrate levels have more than doubled since 1965 (Vitousek et al. 1997).

Eutrophication can also lead to degradation of the aesthetic qualities of the water body and interference with water body recreational uses. There may be significant economic impacts to recreational and commercial fisheries at the local level or downstream of the water body as the frequency of fish kills increases.

Dietary nitrogen sources have an important role in human health. Wolfe et al. note that a human in good health should intake about two kg/yr of biologically available nitrogen. Low nitrogen intake may lead to growth retardation, wasting of muscle, accumulation of fat in the liver, edema, changes to skin pigmentation, changes to hair texture and color, altered mental status and capacity, lethargy, fatigue, anemia, and susceptibility to infectious disease (Wolfe et al. 2002).

While nitrogen is necessary for life, intake of too much nitrogen may cause various adverse human health effects. Methemoglobinemia, or "blue baby syndrome," occurs when nitrogen preferentially binds to hemoglobin, thereby lowering the amount of oxygen in the blood system. The syndrome can be fatal in infants under the age of six months. The EPA drinking water standards for nitrate and nitrite are set to prevent this from occurring in infants (Wolfe et al. 2002).

When eutrophication occurs, *Pfiesteria piscicida*, an estuarine dinoflagellate alga, may be present. When humans are exposed to this organism, it may cause various negative health effects including memory loss, headache, skin rash, eye irritation, upper respiratory irritation, muscle cramps, and gastrointestinal upset (Wolfe et al. 2002).

Wolfe et al. also cite various studies that link nitrate to bladder, ovarian, stomach, and liver cancers and studies that possibly link nitrate to genotoxic and cytogenic effects (Wolfe et al. 2002). Nitrate concentrations of four mg/L and higher have also been linked to an increased risk of non-Hodgkins lymphoma (EPA 2000a).

Finally, elevated nitrogen levels may impose high costs to drinking water treatment facilities, as elevated nutrient levels have been shown to cause corrosion of water intake valves and algae has been shown to cause filters in the treatment plants to clog (EPA 2000a).

1.4 Watershed Water Quality History and Current Conditions

The Idaho Department of Environmental Quality (IDEQ), the Idaho State Department of Agriculture (ISDA), and the Idaho Department of Water Resources (IDWR) all identify nitrate as the "most widespread preventable groundwater contaminant in Idaho." While only three percent of sites sampled in the Statewide Ambient Ground Water Quality Monitoring Program tested higher than the nitrate MCL of 10 mg/L, 30 percent of sites tested between two mg/L and 10 mg/L. Moreover, the nitrate contamination problem is becoming increasingly severe with most sites showing increases in nitrate over an eight-year period of sampling (IDEQ 2001).

The State of Idaho has listed various sections of the Big and Little Wood Rivers as EPA CWA §303(d) impaired water bodies due to nutrients (nitrogen and phosphorus), bacteria, dissolved oxygen, flow alterations, and sediments. The IDEQ has developed TMDL requirements for the Big Wood River, for *E. coli*, total suspended solids (TSS), substrate sediments, and total phosphorus (TP). Additionally, TMDL requirements for temperature and dissolved oxygen will be set in 2003. The IDEQ has not set TMDL requirements for nitrogen for the Big Wood River because "the concentrations of NO_X in the streams [are] not considered toxic to fisheries, nor is there evidence that nuisance aquatic plant growths, algae, slimes, or molds are present to affect beneficial uses" of the streams in the Watershed. However, the IDEQ also notes that nitrogen TMDL requirements may "be seriously considered for development" in the future (IDEQ 2002). The IDEQ has not completed the Little Wood River Watershed Management Plan that would set TMDL requirements for the Little Wood River.

1.5 Scope

Currently, the Big and Little Wood Rivers are not listed for nitrogen impairment. However, future residential developmental pressures and associated increasing nitrogen loads may threaten the Watershed. Excess nitrogen may lead to eutrophication and its harmful effects in the Big and Little Wood Rivers. This study will identify the advantages and disadvantages of employing a market-based nitrogen management system and develop a watershed-based nitrogen trading system for the Watershed. Residents of the Watershed will be able to use the research completed in this document as a policy tool to ensure that nitrogen does not damage their Watershed.

2 Overview of Watershed-Based Pollution Trading

Nutrient trading is a market-based policy approach used in conjunction with a regulatory framework to protect or enhance water quality. There are three basic steps to devising a nitrogen trading plan. The first step is to set a limit, or cap, on the total amount of nitrogen entering the watershed allowable for a given period of time. This concept is similar to that of setting TMDL requirements for a body of water, and often the limit is set equivalent to TMDL values. The second step is to allocate weighted nitrogen credits to each nitrogen source within the Watershed. The final step is to allow sources within the watershed to trade so that each source manages its nitrogen outputs in a cost effective manner such that a watershed is meeting water quality goals (WRI 2000).

A closed trading program, "[o]ften called 'cap and trade,' … include[s] a mandatory 'cap' on … discharges and individual allowances to sources within a defined trading area (WRI 2000). Once a cap on discharge has been placed and pollution credits have been allocated to sources, "sources with low cost pollution reduction options have an incentive to reduce nutrient loading beyond what is required of them and to sell the excess credits to sources with higher costs" (WRI 2002). Therefore, nutrient trading is cost-effective in the sense that environmental benefits are realized at a low cost

The EPA estimates that "flexible approaches to improving water quality could save $900 million dollars annually compared to the least flexible approach" (EPA 2002a). The EPA notes various economic benefits to trading over a traditional regulatory approach. Trading "reduces costs for individual sources contributing to water quality problems." It also allows for sources to "take advantage of economies of scale and treatment efficiencies that vary from source to source." These two components allow the total cost of improving water quality to dischargers within a watershed to decrease. Moreover, some trading program analyses show that "pushing on point sources alone [is] … a relatively expensive approach when other sources contribute more to the problem" (WRI 2000). Therefore, including non-point sources in a trading program may further increase the cost-effectiveness of a trading program.

If implemented appropriately, a nutrient trading system is a flexible and cost-effective way to address water quality problems and encourage dialogue among relevant stakeholders and the public. Specifically, watershed-based nutrient trading can be an innovative way to encourage reductions of non-point sources, which are otherwise not covered under the CWA. However, it is important to note that the trading plan is not a substitute for a regulatory framework and will only work if non-point source nutrient concentrations can be quantified and monitored. Additionally, participation in trading is voluntary and must be approved by the trading regulatory agency.

2.1 Federal Support for Trading Programs

The EPA "actively support[s] and promote[s] nutrient trading within watersheds to achieve water quality objectives, including water quality standards to the extent authorized by the [CWA] and implementing regulations" and has developed a "Draft Framework for Watershed-Based Trading" in order to carry out these goals (EPA 2002c). Federally acceptable trading programs that are consistent with the CWA and other federal regulations must include "requirements to obtain permits ([CWA] §402 and 404), antibacksliding provisions ([CWA] §303(d)(4) and §402(o)), the development of water quality standards and antidegradation policy ([CWA] §303), federal NPDES permit regulations (40 CFR Parts 122, 123 and 124) and water quality management plans (40 CFR Part 130)" (EPA 2002a).

The EPA identifies that the policy is "intended to encourage the adoption of trading programs that facilitate implementation of TMDLs, reduce the costs of compliance with CWA regulations, establish incentives for voluntary reductions and promote watershed-based initiatives that result in greater water quality and environmental benefits than would otherwise be achieved under the CWA." Indeed, the EPA suggests that trading boundaries should coincide with watershed boundaries because "matching geographic trading areas with appropriate hydrologic units helps ensure that trades meet and maintain water quality standards throughout a trading area and in downstream or contiguous areas." Moreover, the EPA suggests that trading boundaries should be of "manageable size" (EPA 2002a).

The EPA identifies a need for stakeholder involvement and public participation in all stages of the trading system process. Specifically, the EPA identifies a need for additional monitoring (by the government, pollutant dischargers, or other agencies using approved sampling, analysis, and reporting methods) and public access to all data collected in monitoring. The EPA notes that "availability of data is important to all parties involved in maintaining water quality" (EPA 2002a).

2.2 Pollution Trading Components

The major pollution trading framework components that must be evaluated for any trading plan are the trading arrangements, nutrient discharge cap, initial distribution of trading credits, and trading ratios. Each of these is discussed in detail in the following sections.

2.2.1 Trading Arrangements

Pollutant trading can be arranged in various forms including, but not limited to intra-plant trading, pretreatment trading, point/point source trading, point/non-point source trading, and non-point/non-point source trading, as described below (EPA 2002a):

- Intra-plant trading: "A point source is allocated pollutant discharges among its outfalls in a cost-effective manner, provided that the combined permitted discharge with trading is no greater than the combined permitted discharge without trading in the watershed."
- Pretreatment trading: "An indirect industrial point source that discharges to a publicly owned treatment works arranges, through the local control authority, for additional control by other indirect point sources beyond the minimum requirements in lieu of upgrading its own treatment for an equivalent level reduction."
- Point/point source trading: "A point source arranges for other point source(s) in a watershed to undertake greater than required control in lieu of upgrading its own treatment beyond minimum technology-based treatment requirements in order to more cost-effectively achieve water quality standards."
- Point/non-point source trading: "A point source arranges for control of non-point source discharge(s) in a watershed in lieu of upgrading its own treatment beyond the minimum technology-based treatment requirements in order to more cost-effectively achieve water quality standards."

- Non-point/non-point source trading: "A non-point source arranges for more cost-effective control of other non-point sources in a watershed in lieu of installing or upgrading its own control."

Trading must be confined within one watershed (NWF 1999). Additionally, all point sources must remain in compliance with their NPDES permits and any technology-based limits. Moreover, "intra-plant trades must also have a technology-based floor, while the technology floor for pretreatment trading is determined by categorical standards" (EPA 2002a).

2.2.2 Nutrient Discharge Cap

Trading programs may be open market or closed market programs. In an open market program, no cap is set on the overall amount of pollution and new sources may easily enter the market. Open market programs set a cap per discharger and any pollution reduction below this cap creates a credit for the discharger to sell to other dischargers. In a closed market system, there is an overall fixed or dynamic cap set for a given area (e.g. watershed). In this system, dischargers are allotted a specific number of tradable credits, and no new credits are supplied for new sources (Powers 1988). For the purposes of this study, only a closed market program was analyzed.

"Setting a goal for the total amount of nutrients that enter waters in a watershed" is the first major step in developing a nutrient trading program (WRI 2002). A cap may be a mandatory reduction in the total amount of nutrients entering the water or may take a voluntary form, where dischargers may choose to participate. Often, nutrient discharge caps are based on TMDL requirements set forth by the state; however, trading programs may be established in impaired waters where TMDLs have not been established when the program "achieves a net reduction of the pollutant or the pollutants causing impairment as providing a direct benefit and progress towards achieving water quality standards" (EPA 2002a).

2.2.3 Initial Distribution of Trading Credits

There are various options that exist for allocating trading credits to the trading partners. The local government could auction off credits or sell credits for a set fee. This distribution system would be favorable for the government because it could keep the revenues to fund the trading program. However, as Ashford et al. note, polluters may not be accepting of either of these systems, as they would be forced to pay to emit pollution that they had previously emitted for free. Alternatively, the government could distribute credits for free in proportion to current allowable levels of emission. While this form of distribution may not bring in revenues to offset trading transaction costs, pollutant dischargers may perceive the process to be fairer (Ashford et al. 2002).

2.2.4 Trading Ratios

The EPA defines trading ratios as the number of "units of pollutant reduction a source must purchase to receive credit for one unit of load reduction" (EPA 1996). Trading ratios are used to take into account the fact that the same unit of pollution from two sources may lead to two different loads at a given receptor (Woodward 2001). For example, denitrification during watershed transport may significantly reduce nitrogen loads when sources are far from surface water, as is the case with non-point sources, but may not occur to any significant extent for point sources discharging directly to surface water. Moreover, non-point sources often employ best management practices (BMPs)[3] in order to decrease their pollutant loads. The decreases in pollutant loads from instituting BMPs may not be easily quantifiable. Thus, trading ratios address differences in distances between sources (which may lead to greater denitrification when sources are far from surface water)

EPA suggests using lower "than 1:1 point/point source and point/non-point source trading ratios necessary to provide a net water quality benefit unless it can be demonstrated that 1:1 trading ratios are consistent with achieving progress towards meeting water quality standards or a direct environmental benefit beyond pollutant load reductions results in progress towards restoring designated uses" (EPA 1996). Especially in watershed-based pollution trading, ratios are often set lower than 1:1, because "expected nonpoint loadings are imperfect substitutes for point source emissions" (Horan 2001). Indeed, environmental groups are often more likely to support a trading program if trading ratio is lower than 1:1 (Woodward 2000). A proper balance must be

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[3] BMPs should be both environmentally and economically practicable. Examples include conservation crop rotation (rotating crops on the same field), nutrient management (managing the amount, form, placement, and timing of applications of plant nutrients), mulching (applying plant residues to the soil surface to reduce evaporation and runoff), and waste utilization (using agricultural waste or other waste on land to improve soil and plant resources) (OnePlan 2003).

struck between economic practicability and environmental objectives. A low ratio may provide high environmental gains, but may not induce trades; conversely, a near 1:1 ratio may be economically optimal, but may not be environmentally stable (Woodward 2001).

2.3 Issues with Trading Programs

While trading programs have the advantage of being flexible and cost-effective, there are some issues that should be considered in designing and implementing a trading program. These include administration of the trading program, pre-quantification of transaction costs, uncertainty in data collection and source monitoring, spatial and temporal distribution of pollutants, and program enforcement.

2.3.1 Administration of Program

EPA notes that trading is most effective "when integrated into existing regulatory and management frameworks, making changes or adding new responsibilities when necessary" (EPA 1996). Therefore, local and regional government agencies – especially environmental agencies – or another trading facilitator will be required to take on a number of additional administrative duties and costs to ensure the legitimacy of any trading program. These duties include, but are not limited to, establishing guidelines for trading, dissemination of information and educational materials to stakeholders, coordination among participants and enforcement agencies, facilitation and brokering of trading deals, documentation and tracking of trades, source monitoring, and enforcement of trading guidelines (EPA 1996).

2.3.2 Pre-Quantification of Transaction Costs

Transaction costs are costs that public and private trading partners and trading facilitators incur during the trading process that they otherwise would not have incurred had trading not taken place. Because trading may not be economically beneficial in all locations, these costs must be quantified before a trading plan is put into place to determine if trading is economically viable. In other words, the economic trading benefit for an entire watershed or for an individual source may be offset by high transaction costs. The total cost of a trading plan, including transaction costs, should be compared to the total costs of applicable alternative policy actions, in choosing the most environmentally acceptable and most cost effective program. Due to uncertainties of future costs and how the nitrogen plan will develop in reality, transaction costs can not be calculated precisely. Transaction costs vary from project to project and each should be quantified and minimized as much as possible (EPA 1996).

2.3.3 Uncertainty in Data Collection and Source Monitoring

A comprehensive and reliable monitoring plan is essential to any trading system in order to minimize risks to participants and trading facilitators. Uncertainties in data collection and source monitoring can lead to added risks to some participants; these risks may play a role in whether potential trading participants will choose to enter the market or to use traditional pollution controls to decrease pollutant loads. Thus, minimization of risks is crucial for a successful trading program (Woodward 2000). Properly documenting all trades and monitoring point source and non-point source loads and load reductions can minimize risks.

Trading enforcement agencies can minimize their own risks by incorporating uncertainties into trading ratios. Moreover, agencies may be able to require extensive monitoring and reporting from traders. If agencies are not satisfied with the level of risk involved in a trade, it may choose to block the transaction (Woodward 2000).

Gathering point source data for a trading program will not differ much from a traditional regulatory program since point sources are already regulated and routinely monitored. However, non-point sources are not yet regulated under the CWA, are episodic, and cannot be easily measured (WRI 2000). Therefore, pollution from non-point sources may be difficult to quantify. It may be difficult to identify, understand the physical conditions of, and obtain reliable data from non-point sources.

The best way to deal with non-point source monitoring may be to quantify *reductions* in pollutant loading rather than loading itself. For example, if site specific data is not available, the EPA recommends estimating the effectiveness and efficiency of best management practice techniques, using runoff and soil loss equations and ecosystem modeling and simulations (EPA 1996). In this case, it may be best if traders track their own reductions, since they know what goes into the system best. Government agencies or trading facilitators would only be responsible for water quality monitoring and overall program assessments (CBP 2001).

2.3.4 Spatial and Temporal Distribution of Pollutants

All forms of trading shift pollution loads from one site to another within a watershed (EPA 1996). A pollution source that is far from surface water will have a different effect on the surface water than one that is close to the surface water. Change in distance of a source can have effects on the transport time to surface water and the level of pollutant decomposition (e.g. denitrification for nitrogen pollutant sources) reached before a pollutant reaches surface waters. While pollution trading may decrease the amount of pollutant throughout a watershed, it may cause "hot spots" of highly concentrated pollutants in particular spots within the watershed. This is especially problematic when diffuse, non-point source pollutant loads are traded with concentrated, point source pollutant loads (NWF 1999).

Changing the location of a pollutant source can also change the timing of delivery of a load to surface water due to soil properties and land use patterns. Soil properties and land use patterns can affect infiltration and runoff rates and travel times to surface water (EPA 1996). Additionally, trading that allows polluters to bank credits (hold pollution credits over a given period of time) can change the temporal distribution of pollutants (Ashford et al. 2002).

Trading programs should ensure that high pollutant loads are not concentrated over one area or period of time. Trading facilitators may do so by carefully considering spatial and temporal distribution of pollutants before trades are approved and employing distance dependent trading ratios (NWF 1999).

2.3.5 Enforcement of Program

Trading is only successful when controls placed on sources are enforceable (NWF 1999). In order to enforce standards, a trading facilitator must assess the performance of dischargers by monitoring ambient water quality, individual discharger loading, proper BMP implementation and maintenance (by non-point sources), and proper technology implementation and maintenance (by point sources) (CBP 2001). As noted above, monitoring of point sources is relatively easy because they are subject to federal regulations.

On the contrary, monitoring non-point sources may be difficult because they are not subject to federal regulations and because citizen lawsuits are not a possible enforcement mechanism. Moreover, few states have been compelled to enact non-point source control laws on their own (NWF 1999). Instead, trade facilitators may need to rely on "reasonable assurances" that sources are complying with trading rules. EPA notes that "nonregulatory, non-federal reasonable assurances are appropriate bases for trades" when "proposed controls are technically feasible" and when government agencies "have a reasonable expectation that a non-point source will implement specified controls" (EPA 1996). The National Wildlife Federation (NWF) also notes the importance of good compliance records by pollutant dischargers in assuring the stakeholders, government agencies, and the public that proposed trades will not harm water quality (NWF 1999).

Nonetheless, trading facilitators must monitor non-point sources to ensure that non-point source dischargers are complying. Trading facilitators should push for accountability and the authority to impose fines, injunction, or another type of administrative penalty if a source is found in violation of its trading agreement (EPA 1996, NWF 1999).

2.4 Trading Program Case Studies

Nutrient trading programs have been designed and implemented across the U.S. with varying success. Each nutrient trading program involves different trading arrangements (point source/point source trading and point source/non-point source trading), nutrient discharge caps (pre- or post-TMDL), and trading ratios (ranging from 1:1 to 1:9). Case studies can provide insight on what kinds of trading components have been successful under a given set of circumstances. Nine nutrient trading case studies are summarized in the following sections.

2.4.1 Chesapeake Bay Watershed Nutrient Trading Program, Multi-State

The Chesapeake Bay is the largest estuary in the U.S. The watershed encompasses 64,000 square miles in New York, Pennsylvania, Delaware, Maryland, Virginia, West Virginia and the District of Columbia (CBP 2001). Many of the Chesapeake Bay watershed's waters are listed for impaired water quality. Excessive quantities of nitrogen and phosphorus in the watershed have lead to eutrophication in Chesapeake Bay. A TMDL for the Bay is underway (EPA 1999).

In 1987, various government agencies in the bay area signed the Chesapeake Bay Agreement. This Agreement set goals to reduce nitrogen and phosphorus loading to the Bay by 40 percent of 1985 levels by 2000 and delist the Bay from the impaired water bodies list by 2010. Although many improvements were made to the Bay's water quality, in 1997, the Chesapeake Bay Program (CBP) decided to employ new nutrient reduction methods in order to meet its 2000 goals (CBP 2001). In 1998, the CBP held a workshop on trading; the CBP developed a trading framework by 2001 (EPA 1999).

The CBP trading framework used the 40 percent nutrient reduction as the basis for its nutrient cap. The framework identifies only "like" trades as allowable; this means point sources trading only with other point sources and non-point sources trading only with other non-point sources. BMPs must meet certain standards identified by the CBP. Within the framework, stakeholders that are not sources may purchase credits. Because the program encompasses such a large area, states are responsible for day-to-day management of trading, while the CBP is responsible for general baywide oversight. While trading ratios have not been set, trading ratios should take into account source losses due to attenuation, uncertainty, retirement, and any other special needs. Finally, the program identified the need for stakeholder involvement (CBP 2001). Because the trading framework is still being developed, no trades have been completed to date.

2.4.2 Long Island Sound Trading Program, Connecticut

The Long Island Sound watershed is bounded by New York and Connecticut. It is 110 miles long and 21 miles wide at its broadest point. Because it is home to over eight million people, wastewater treatment plants, atmospheric deposition from cars and industrial sources, and urban runoff account for the highest proportion of nitrogen loads in the watershed (EPA 2003c). Human activity has caused nitrogen levels to increase in the Sound, leading to increased algae growth and dissolved oxygen readings of two mg/L or lower in the summer months. In 2001, EPA approved a nitrogen TMDL analysis for the watershed. The TMDL analysis noted nitrogen trading as a possible cost-saving option for achieving nitrogen load reductions within the watershed (CTDEP 2003).

Shortly after EPA approved the TMDL analysis, the Governor of Connecticut authorized a trading framework and established a trading advisory board for a nitrogen trading program. Within the framework of this program, 79 wastewater treatment facilities must decrease their nitrogen loads to the watershed by 58.8 percent by 2014. Each facility has been assigned a nitrogen discharge cap. Facilities may come into compliance with the cap by lowering their nitrogen loads and selling their superfluous credits to the Connecticut Department of Environmental Protection (CT DEP) or by purchasing additional credits from the CT DEP. Because nitrogen naturally attenuates as it flows down the river and into the sound, trading ratios vary from 1:1 to 1:9 (point source: non-point source), based on the differential impacts that each source will have on water quality. Long-term banking of credits is not expected; nitrogen credits would likely be valid for up to one year (CTDEP 2003).

2.4.3 Fox-Wolf Basin Watershed Pilot Trading Program, Wisconsin

The Fox-Wolf River watershed is located in east-central Wisconsin and is comprised of three sub-watersheds (Lower Fox, Upper Fox, and Wolf). The basin drains over four million acres of land into Green Bay before reaching Lake Michigan. The watershed is the third largest land area draining into the Great Lakes. Point and non-point sources (including agricultural and urban runoff) have lead to increasing levels of phosphorus loading and eutrophication in Green Bay (UWEX 2003). In 1988, the State of Wisconsin established a mandatory 1 mg/L phosphorus limit on point sources and a future 0.3 mg/L limit (EPA 1999). The State has also established non-point runoff regulations for agricultural, urban, and transportation areas, effective October 2002. Specifically, these regulations require that agricultural sources meet performance standards and manure management prohibitions and for cost sharing to be available to sources not in compliance. Moreover, local officials are given the authority to implement and enforce trading rules (UWEX 2003).

In 1992, a team of stakeholders examined trading possibilities for the watershed. A study completed by these stakeholders concluded that trading would be appropriate for the Lower Fox River Basin because non-point phosphorus loads would be less expensive to reduce than point source loads. It also concluded that the Upper Fox River Basin would not be an appropriate area for trading since non-point source reductions would be costlier than point source reductions. The study's final conclusion was that the Wolf River Basin may or may not be appropriate for trading depending on future discharge limits imposed on wastewater treatment plants. The study team also completed extensive modeling and monitoring of processes in the watershed. While TMDLs have been developed for some segments of the rivers, the stakeholders suggested further application of TMDLs for phosphorus and other pollutants. To date, no trading program has been implemented, but the program is part of a statewide initiative to evaluate nutrient trading (EPA 1999).

2.4.4 Kalamazoo River Water Quality Trading Demonstration Project, Michigan

The Kalamazoo River watershed covers 2000 square miles in southwest Michigan. The area includes parts of ten counties, which is comprised mostly by cropland and pasture (57 percent), forest (21 percent), and urban areas (eight percent). Point sources of phosphorus include over 50 NPDES dischargers (mostly wastewater treatment plants and paper mills); the major non-point phosphorus source is from agricultural sources (ETN 2002).

In 1995, the Michigan Department of Environmental Quality (MDEQ) began developing a statewide, voluntary nutrient trading program in order to improve water quality. Within this program, closed trading would occur where a TMDL has been established and open trading will occur where a TMDL or other cap has not been established. The Kalamazoo River Water Quality Trading Demonstration Project became a two-year pilot program under the statewide program. A TMDL assessment has been completed for the watershed because of nuisance algae conditions due to phosphorus in Lake Allegan (EPA 1999).

In order to complete the project, the various stakeholders formed a Steering Committee, which was to provide outreach to stakeholders and promote, design, implement, and monitor the trading program (ETN 2002). Within the Kalamazoo River framework, point sources will receive credit for voluntary phosphorus load reductions by non-point sources. Half of the load reduction credits from non-point sources will be retired, while the other half will go directly to non-point sources (EPA 1999). At least six non-point sources participated in the project – reducing phosphorus loading to the river by 2,142 pounds – by implementing BMPs, including streambank stabilization and improved agricultural and livestock management. While the project was considered successful because phosphorus loadings were decreased at a lower cost than with traditional regulation, the project did identify various drawbacks, including uncertainties in credit generation, variable risks to creditors and debtors, and lack of broad-based participation (ETN 2002).

2.4.5 Lower Boise River Effluent Trading Demonstration Project, Idaho

The Lower Boise River runs for 64 miles between Lucky Peak Dam, Idaho and the Snake River, south of Parma, Idaho. Various segments of the Lower Boise River are listed on EPA's 303(d) list for multiple pollutants, including nutrients (LBRWQP 2002). Conditions for nuisance growth are present in the Boise River and actual nuisance growth is present in the Snake River watershed (EPA 1999).

The trading project is coordinating development of trading in conjunction with the completion of TMDL implementation. EPA Region 10 and IDEQ developed the trading project (EPA 1999). The trading demonstration project began in 1998 and was carried out in two phases: one to focus on the potential supply and demand for trading and a second to develop a framework for carrying out the trading process. This framework suggested a TMDL with adjustable wasteload allocations, permits with adjustable effluent limits, point/point source or point/non-point source trading, and three types of distant dependent trading ratios (IDEQ 2000). However, as of late 2002, no trades had taken place, although BMP lists had been distributed to stakeholders.

2.4.6 Town of Acton Municipal Treatment Plant, Massachusetts

The Assabet River runs for 30 miles, beginning in Westborough, MA and flowing to Concord, MA. Portions of the Assabet River, including the area around the Town of Acton, do not meet water quality standards for nitrogen, phosphorus, dissolved oxygen, and pathogens. A TMDL study is currently underway; Phase I of the TMDL found that the river is significantly impaired by nutrients, with wastewater treatment facilities contributing the highest load to the river and non-point sources contributing significantly less (OAR 2003). The Town of Acton (with a population of about 17,000) currently does not have a wastewater treatment facility and is looking to replace failing septic systems. However, new discharges of phosphorus into the river are not allowed because of already high phosphorus levels (EPA 1999).

A trading system has been proposed for the area in order to offset any discharges caused by the building of a new wastewater treatment facility in the area. The wastewater treatment plant would be allowed to discharge one unit of phosphorus for every three units of phosphorus removed by non-point sources (EPA 1999). Non-point sources would be able to reduce their loads through a variety of BMPs, including lawn fertilizer management, pet waste management, road sanding and landscaping (OAR 2003). However, connecting septic systems to the wastewater treatment facility would not be considered a possible trade, as the two sources are related (EPA 1999).

2.4.7 Tar-Pamlico Nutrient Reduction Trading Program, North Carolina

The Tar-Pamlico River runs for 180 miles from the Piedmont region to the Pamlico Sound and the Atlantic Ocean. Non-point sources, including agriculture, account for about 92% of the nitrogen loadings to the river, while point sources, primarily municipal wastewater treatment plants, contribute the remaining 8% (EPA 1996). In the early 1980s, increasing fertilizer use and development began to affect the river, causing occurrences of diseased fish, sporadic fish kills, increased sediment and nutrient loads, phytoplankton blooms, and low dissolved oxygen (DO) levels (NCDWQ 2002).

Because of the increasing nutrient loading concerns, the North Carolina Division of Environmental Management (NCDEM) implemented stricter nutrient effluent standards. Due to the high cost of compliance, a coalition of dischargers, working with government officials and non-government organizations, developed a point/non-point source nutrient trading framework. The first phase of the project allowed point sources to reduce their nutrient loads through cost-effective measures, while the second phase established a program for non-point sources to reduce their loads through BMPs, including fertilizer management programs and riparian buffering (EPA 1996, NCDWQ 2002).

The first phase of the program established an annually decreasing, collective nutrient load cap for point source nutrient dischargers. Dischargers would meet this collective load cap by allowing wastewater treatment facilities to make small, cost-effective changes to their machinery and operations in order to meet the common cap (EPA 1996). Overall, 14 wastewater treatment facilities joined the trading association and nutrient loads decreased by 20 percent. The first phase also provided one million dollars in funding to non-point sources to implement BMPs (NCDWQ 2002).

The second phase of the project runs through 2004 and includes plans to reduce non-point source nutrient loading. The second phase established a 30 percent reduction in nutrient loads from 1991 levels in the estuary, and a plan for this reduction was completed in 1995. A report in 1998 showed that while nutrient load reductions from non-point sources was great since the inception of the trading program, more BMPs would need to be implemented by non-point sources in order to meet the ultimate 30 percent reduction goal (NCDWQ 2002).

2.4.8 Lake Dillon Trading Program, Colorado

Lake Dillon Reservoir is located in central Colorado. The area is a major recreational spot and a source of drinking water for the Denver community. Major sources of phosphorus contamination include wastewater treatment plants (serving the towns of Breckenridge, Copper Mountain, Frisco, Dillon, and Keystone), septic systems, and runoff from urban and ski areas. Communities became concerned with increasing population growth in the area and its possible effects on water quality. In 1982, Colorado established phosphorus concentration standards for the reservoir. The trading program was established in 1984 and became the first point/non-point source trading program developed in the U.S (EPA 1996).

The original program set the phosphorus concentration developed by the State in 1982 as the phosphorus cap for the reservoir. Additionally a 1:2 ratio between point and non-point sources was established (EPA 1999).

Few trades have actually taken place since the program was established (EPA 1999). Nonetheless, stakeholders credit the cooperative management approach developed by the trading process with improving the area's water quality. Between 1981 and 1991, point sources within the reservoir area reduced their phosphorus loading from 3,749 kg/yr to 529 kg/yr (EPA 1996).

2.4.9 Cherry Creek Basin Trading Program, Colorado

The Cherry Creek Basin was created in 1950 to serve as an 800-acre flood basin. Since then, the Cherry Creek Reservoir has become Colorado's most visited state park. In 1984, the State enacted a total phosphorus standard in order to maintain acceptable algae levels within the basin. In 1985, Colorado established a TMDL for phosphorus and a trading program to allow point sources to receive credits for non-point source offsets of phosphorus within the TMDL framework. However, the final trading guidance document was not approved by the State until 1997 (EPA 1999).

In 1997, the State legislature established the Cherry Creek Basin Water Quality Authority to assess and support water quality projects, including Cherry Creek Basin's trading program. The trading framework allows for two types of trades: one where the Basin Authority purchases credits from sources and another where phosphorus creditors and debtors trade amongst themselves. Dischargers may only purchase credits if they show a need for increased phosphorus loads, their wastewater treatment operates at the expected phosphorus removal level, and they comply with existing effluent limits (EPA 1996). Additionally, non-point sources are required to reduce their phosphorus loading by applying BMP. Trading ratios range between non-point and point sources range from 1:1.3 to 1:3 depending on the certainty of the effectiveness of management practices (EPA 1999). Various trades have taken place for phosphorus reductions.

3 Big and Little Wood Rivers Watershed Case Study

Trading system components were evaluated for the Big and Little Wood Rivers Watershed (USGS Hydrologic Unit Code (HUC) 17040219 and 17040221). In the following sections, a trading framework for the Watershed is developed. This analysis includes selection of a trading arrangement, establishment of a nitrogen cap, description of a protocol for an initial credit distribution system, establishment of trading ratios, and qualification of trading transaction costs.

3.1 Trading Arrangements

Types of trading arrangements include intra-plant trading, pretreatment trading, point source/point source trading, point source/non-point source trading, and non-point source/non-point source trading (EPA 2002a). Intra-plant trading and pretreatment trading are not considered applicable in this study because there is little heavy, nitrogen-contributing industry in the Watershed. Point source/point source trading is not considered applicable for the Watershed because of the small number of point sources in the Watershed (wastewater treatment facilities, confined animal feeding operations, etc.) and because of the relatively small nitrogen contribution of point sources. Therefore, intra-plant trading, pretreatment trading, and point source/point source trading are removed from further evaluation.

Point source/non-point source trading was considered because non-point sources (such as agriculture) contribute a significant proportion of nitrogen to the Watershed (Figure 1-7) and the proportion of nitrogen contribution from point sources (most notably, wastewater treatment facilities) is expected to grow as the population within the Watershed increases (Connolly et al. 2003). Under a point source/non-point source trading arrangement, wastewater treatment facilities might decrease their nitrogen loads by upgrading to tertiary treatment,[4] and then trade extra credits to non-point sources. While the wastewater treatment facility in the Town of Hailey has already decreased its nitrogen load by implementing tertiary treatment, other facilities in the Watershed have yet to do so.

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[4] Primary and secondary wastewater treatments remove the majority of biological oxygen demand (BOD) and suspended solids found in wastewaters. Tertiary treatment includes a variety of techniques to remove additional BOD and suspended solids, toxic chemicals, and/or nutrients. For this case, nitrogen removal through tertiary treatment is identified as a way to reduce nitrogen loads.

Non-point source/non-point source trading was considered because the highest percentages of nitrogen loading within the Watershed currently are from cropland and rangeland sources (both non-point sources) (Figure 1-7). Non-point sources meet loading requirements by instituting agricultural BMPs. Connolly et al. identified precision agriculture[5] as a BMP that could lower nitrogen loads by up to 12.6 percent within the Watershed (Table 3-1 and Table 3-2) (Connolly et al. 2003).

Crop	Current Fertilization Rate (kg N/ha)	BMP Fertilization Rate (kg N/ha)	Reduction in Watershed Nitrogen Load (kg N/yr)	Reduction (%)
Alfalfa Hay	34	28	7,550	1.1
Barley	112	106	3,810	0.6
Corn	151	146	2,190	0.3
Potatoes	191	185	1,560	0.2
Wheat	112	106	2,260	0.3

Table 3-1. Watershed nitrogen load reductions from implementation of BMP nitrogen fertilization rates (Connolly et al. 2003)

Crop	Fertilizer Use Reduction (%)	Reduction in Watershed Nitrogen Load (kg N/yr)	Reduction (%)
Primary fertilizer crops	20	56,550	8.5
Primary fertilizer crops	25	70,690	10.6
All crops	20	67,000	10.1
All crops	25	83,750	12.6

Table 3-2. Watershed nitrogen load reductions from the implementation of precision agriculture techniques (Connolly et al. 2003)

However, because of increasing population growth within the Watershed, the relative nitrogen contribution from wastewater treatment facilities is expected to increase in the coming years (Connolly et al. 2003). While some agricultural land will be converted to residential areas, agricultural sources of nitrogen are expected to persist. Thus, given current and future land use

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[5] Precision agriculture is an "information and technology based agricultural management system to identify, analyze, and manage site-soil spatial and temporal variability within fields for optimum profitability, sustainability, and protection of the environment" (Precision Agriculture 2003)

patterns, point source/non-point source is considered most appropriate for the Watershed. There is great potential for farmers to decrease their nitrogen loads by implementing BMPs. Moreover, because not all wastewater treatment facilities in the Watershed have improved their treatment level to tertiary treatment, there is ample room for point sources to decrease their nitrogen sources as well.

3.2 Nutrient Discharge Cap

Because a TMDL has not been established for the Watershed, a yearly nitrogen discharge cap must be established. A cap is the total allowable nutrient load entering the Watershed in a given year. Trading facilitators would distribute a fixed number of pollutant credits each year, the sum of which would equal the nitrogen cap established for that year. New entrants into the market would be required to purchase credits from dischargers that have lowered their pollution loads in order to ensure that the nitrogen cap does not increase. Non-dischargers would be allowed to purchase and retire credits in effect lowering the nitrogen cap, but could only do so with permission of the trading facilitators.

The following sections describe the hydrology of the Watershed and establish a yearly nitrogen cap for the Watershed. It is important to note that understanding the hydrology and applying a nitrogen cap to the Watershed is important even if a trading system is not employed.

3.2.1 Water Balance

A water budget for the Watershed was completed in order to understand the Watershed's hydrological system (Figure 3-1 and Table 3-2). In general, water inflows include precipitation, surface water inflow, and groundwater inflow. Because mountain ranges surround the northern boundary of the Watershed, there was no surface water or groundwater inflow included in the water budget for the Watershed. Water outflows include evapotranspiration, surface water outflow, and groundwater outflow. Outflow from this Watershed includes surface water flowing out through the Big Wood River at the mouth of the Watershed and evapotranspiration from agriculture (barley, corn, wheat, sugar beets, oats, alfalfa hay, dry beans, potatoes, and pasture), water bodies, natural vegetation, and rangeland. Groundwater outflow was not considered because it was assumed that all groundwater would reach surface water before exiting the Watershed. Calculations for each of these components are described below.

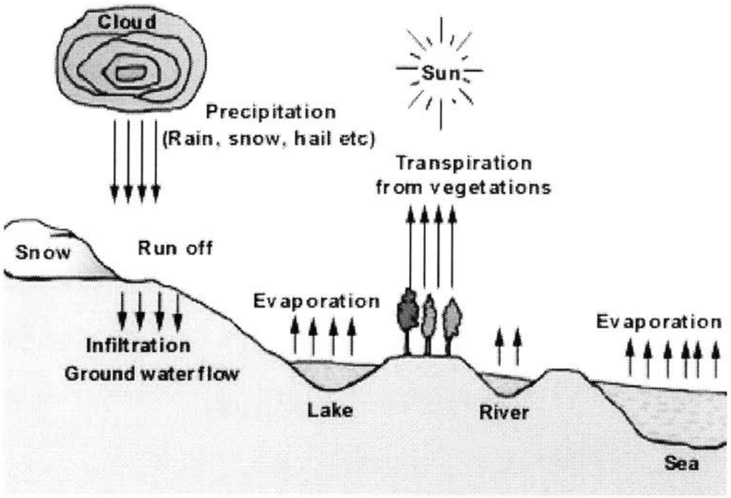

Figure 3-1. The water cycle (TERI 2003)

Inflow (km^3)	Outflow (km^3)		Balance (km^3)
Precipitation	Evapotranspiration	Surface Water	
2.241	1.873	0.326	0.04

Table 3-3. Water budget for the Watershed

The yearly volume of precipitation to the Watershed was estimated by averaging yearly precipitation data from 1981 to 2001 taken at Craters of the Moon National Park (Table 3-4) and multiplying that value by the area of the Watershed (NADP 2002). The average annual volume of precipitation per year falling on the Watershed for this time period was 2.24 km^3/yr.

Year	Precipitation (m)	Year	Precipitation (m)
1981	0.485	1992	0.188
1982	0.575	1993	0.439
1983	0.492	1994	0.230
1984	0.365	1995	0.451
1985	0.297	1996	0.336
1986	0.308	1997	0.318
1987	0.311	1998	0.456
1988	0.203	1999	0.226
1989	0.223	2000	0.222
1990	0.295	2001	0.260
1991	0.310	**Average**	**0.333**

Table 3-4. Yearly precipitation at Craters of the Moon National Park NADP monitoring station (NADP 2002)

Evapotranspiration is the sum of water loss from vegetation due to transpiration and evaporation from the soil. Specific crop evapotranspiration rates (ETc) were estimated by multiplying reference evapotranspiration rates (ETr) by specific crop coefficients (Kc). These values were then multiplied by each crop's land area within the Watershed in order to obtain a total ETc for the Watershed (Table 3-5). ETr values were obtained from the University of Idaho's *Estimating Consumptive Irrigation Requirements for Crops in Idaho* (Table 3-6). This document estimated ETr values for various weather monitoring stations in Idaho using the United Nations Food and Agriculture Organization's (FAO) method for calculating evapotranspiration. Evapotranspiration data were obtained for four cities' weather stations within the Watershed for the growing season (March through October): Hailey, Picabo, Richfield, and Shoshone (Allen et al. 1983). Kc values for crops were obtained from two sources: the University of Idaho's *Hydrologic Evaluation of the Big Wood River and Silver Creek Watersheds* and FAO's *Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements* (for crops that were not listed in the University of Idaho report) (Wetzstein et al. 2000, FAO 1998). Because the growing season in the Watershed is so short, the average Kc value chosen often reflects FAO Kc for early and late season crop stages. Kc values for natural vegetation and rangeland were estimated using FAO's estimation of Kc for light wetting events given the Watershed's ETr value and an average period of seven to ten days between significant rainfall days (WRCC 2001).

	Mar	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
ETr Hailey Station (mm/day)*	1.15	4.29	6.02	7.53	7.69	6.37	4.91	3.31
ETr Picabo (mm/day)*	1.07	4.14	6.02	7.79	8.02	6.79	5.04	3.06
ETr Richfield (mm/day)*	1.52	4.65	6.82	7.87	8.05	6.73	5.17	3.34
ETr Shoshone (mm/day)*	1.82	4.91	6.48	8.15	8.27	6.79	5.24	3.57
Average ETr (mm/day)	**1.39**	**4.50**	**6.34**	**7.84**	**8.01**	**6.67**	**5.09**	**3.32**
# days/month	31	30	31	30	31	31	30	31
Average monthly ETr (mm/month)	43.1	134.9	196.4	235.1	248.2	206.8	152.7	102.9
Average monthly ETr (m/month)	**0.0431**	**0.1349**	**0.1964**	**0.2351**	**0.2482**	**0.2068**	**0.1527**	**0.1029**

Table 3-5. Average monthly reference evapotransporation rates (*Allen et al. 1983)

			Average Monthly ETc (m/month) for Watershed									
Crop	**Land Area (ha)**	**Kc**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	Total (ha m)	**Total (km^3)**
Average monthly ETr (m/month)			0.043	0.135	0.196	0.235	0.248	0.207	0.153	0.103		
Barley	8445	0.52**	188.97	591.70	861.22	1030.78	1088.59	906.76	669.65	451.34	5789.00	**0.058**
Wheat	5043	0.52**	112.84	353.34	514.28	615.54	650.06	541.48	399.88	269.52	3456.95	**0.035**
Sugar Beets	2560	0.35*	38.61	120.89	175.96	210.60	222.42	185.27	136.82	92.22	1182.78	**0.012**
Corn	4883	0.52**	109.26	342.13	497.97	596.01	629.44	524.30	387.20	260.97	3347.27	**0.033**
Oats	2087	0.52**	46.70	146.22	212.83	254.74	269.02	224.09	165.49	111.54	1430.63	**0.014**
Alfalfa Hay	16366	0.40*	282.08	883.27	1285.61	1538.73	1625.03	1353.60	999.64	673.76	8641.72	**0.086**
Dry Beans	234	0.40*	4.03	12.63	18.38	22.00	23.23	19.35	14.29	9.63	123.56	**0.001**
Potatoes	3318	0.45**	64.95	203.38	296.02	354.30	374.17	311.67	230.17	155.13	1989.77	**0.020**
Pasture	40900	0.30*	528.71	1655.53	2409.64	2884.06	3045.81	2537.07	1873.63	1262.83	16197.29	**0.162**
Total ETc (ha m)			**847.45**	**2653.55**	**3862.28**	**4622.70**	**4881.96**	**4066.52**	**3003.13**	**2024.11**	42158.98	**0.422**
Rangeland	428675	0.2*	3694.32	11567.79	16837.07	20152.01	21282.21	17727.43	13091.73	8823.85	113176.42	**1.132**
Natural Vegetation	115457	0.2*	995.01	3115.61	4534.80	5427.63	5732.04	4774.61	3526.06	2376.57	30482.32	**0.305**
Water Bodies ***											1475.22	**0.015**
Total Evapotranspiration (ha m)			5536.77	17336.95	25234.15	30202.34	31896.20	26568.55	19620.92	13224.53	187292.93	
Total Evapotranspiration (km^3)			**0.055**	**0.173**	**0.252**	**0.302**	**0.319**	**0.266**	**0.196**	**0.132**		**1.873**

Table 3-6. Monthly specific crop evapotranspiration (*FAO 1998, ** Wetzstein et al. 2000, ***USGS 2003)

Surface water outflow from the Watershed was estimated by adding surface water baseflow, runoff over the area of the Watershed, and precipitation over the area of the Big and Little Wood Rivers. Average surface water outflow for the Watershed over the 1981 to 2001 time period was 0.326 km^3/yr (Table 3-7).

	Flow (km^3/yr)
Runoff	0.171
Rain into River	0.007
Baseflow*	0.148
Total Surface Water Flow	**0.326**

Table 3-7. Average yearly surface water outflow (*SWAT 2002)

Annual baseflow was calculated using Soil and Water Assessment Tool (SWAT) Baseflow Program, an automated baseflow filter program (SWAT 2002). This program uses daily USGS stream flow data as an input and filters baseline using recession analysis techniques (Arnold et. al 1995, Arnold et al. 1999). USGS surface water data was obtained for USGS gage 13152500, Malad River near Gooding for January 1, 1981 through December 31, 2001. This gage is located after the Big Wood River and Little Wood River confluence and is the closest monitoring station to the exit of the Big Wood River from the Watershed (Figure 3-2) (USGS 2003). Average baseflow for the Watershed over the 1981 to 2001 time period was 0.148 km^3/yr (Table 3-7).

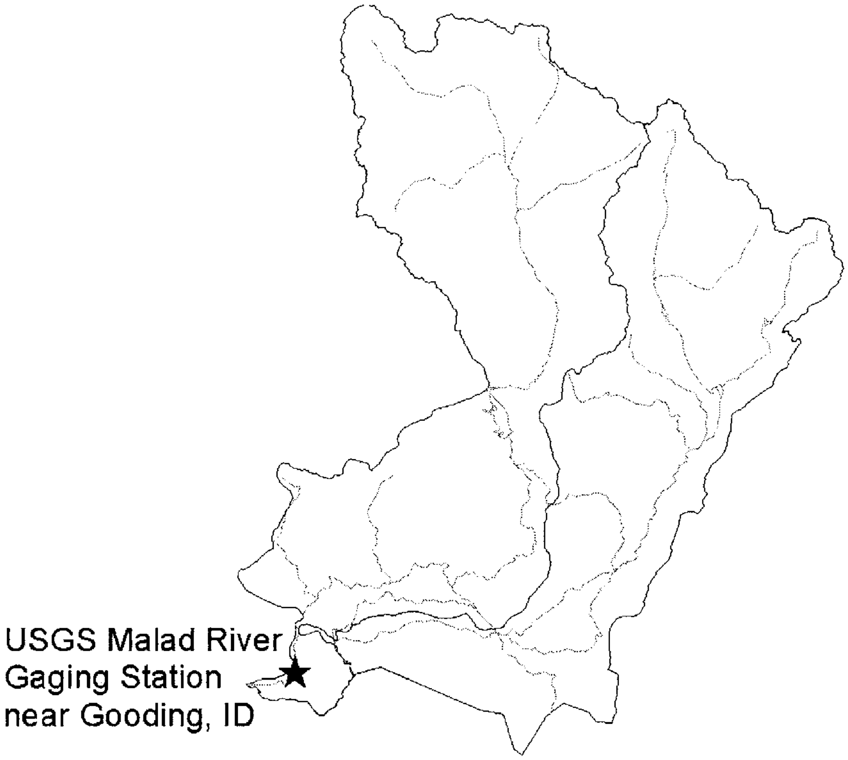

Figure 3-2. Location of USGS Malad River Gaging Station near Gooding

Runoff was estimated using the Internet Watershed Educational Tool (InterWET) runoff calculator (Parson 1999). The InterWET calculator bases its runoff calculations on the Soil Conservation Service curve number method (USDA-SCS 1986). It requires yearly precipitation, land cover, soil infiltration rate, and soil moisture as inputs. Soil infiltration rate was assumed to be high and soil moisture was assumed to be dry. Runoff was calculated for four types of land cover (pasture/crop, forest, impervious, and residential) and multiplied by each of these covers' respective land areas (Table 3-8). These four values were summed to calculate total runoff for the Watershed. The average runoff per year within the Watershed for the 1981 to 2001 time period was 0.171 km^3/yr. Infiltration rate was simply calculated as annual precipitation minus annual runoff (Saxton 2002). The average infiltration per year within the Watershed for the 1981 to 2001 time period was 2.07 km^3/yr.

	Land Area (km^2)*	**Runoff (km)****	**Total Runoff (km^3)**
Pasture/Crop	847.54	1.892E-05	0.016
Impervious	481.56	3.184E-04	0.153
Forest	5428.67	0.000E+00	0.000
Residential	22.04	8.359E-05	0.002
Total	**6779.81**		**0.171**

Table 3-8. Average yearly runoff by land use (*Connolly et al. 2003, ** Parson 1999)

Yearly precipitation into the Big and Little Wood Rivers was estimated by averaging yearly precipitation data from 1981 to 2001 taken at Craters of the Moon National Park and multiplying the value over the rivers' area (NADP 2002). The average precipitation per year over the area of the rivers for this time period was 0.007 km^3/yr.

3.2.2 Nitrogen Discharge Cap Analysis

Because nitrogen TMDL requirements have not been set for the Watershed, an assessment was completed to determine what loading level should be established for the Big and Little Wood Rivers Watershed nitrogen discharge cap. To approximate the nitrogen loading limit necessary to maintain a desired surface water nitrogen concentration, a relationship was established between actual nitrogen surface water concentration and actual nitrogen yield (load/area) within the Watershed. A linear relationship was established by comparing nitrogen surface water concentration and yield for two areas within the Watershed: the Upper Valley and the entire Watershed (Figure 3-3).

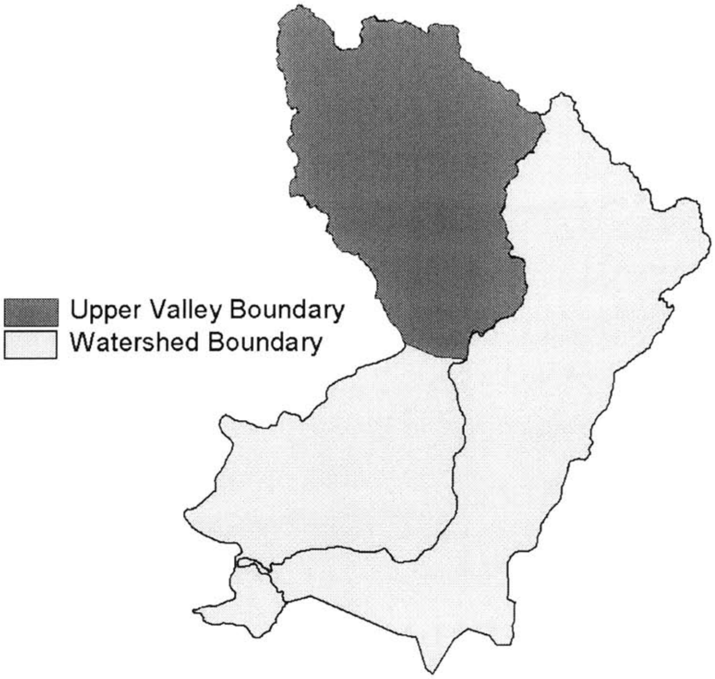

Figure 3-3. Upper Valley and Watershed boundaries

Nitrogen surface water concentration for the Upper Valley was estimated by averaging total nitrogen stream concentration data taken at the Big Wood River near Bellevue USGS gaging station (13141000) from 1990 to 1997 and the Big Wood River at Stanton Crossing near Bellevue USGS gaging station (13140800) from 1999 to 2001; nitrogen surface water concentration for the entire Watershed was estimated by averaging stream concentration data taken at the Malad River gaging station (USGS 2003). Connolly et al. estimated nitrogen loads for both the Upper Valley and the Watershed (Table 3-9) (Connolly et al. 2003).

	Actual Nitrogen Concentration (mg/L)	**Actual Nitrogen Yield (kg/ha)**
Upper Valley	0.39	0.74
Entire Watershed	0.77	0.98

Table 3-9. Nitrogen concentrations and yields for the Upper Valley and the Watershed (Connolly et al. 2003)

The relationship between nitrogen concentrations and loading for the Watershed and the Upper Valley locations is shown in Figure 3-4. The equation relating nitrogen surface water concentration and yield is: $y = 0.6316x + 0.4937$, where x is nitrogen surface water concentration and y is nitrogen yield.

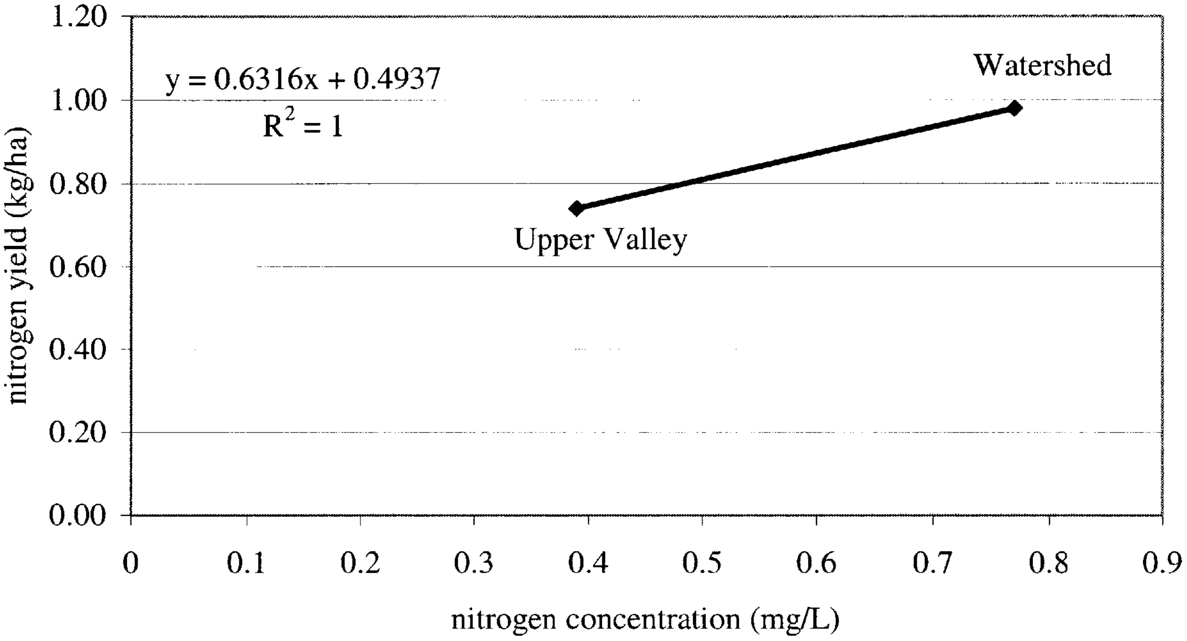

Figure 3-4. Relationship between nitrogen concentration and nitrogen yield within the Watershed

The relationship between nitrogen surface water concentration and loading was then used to estimate acceptable nitrogen loading values for the Watershed, given acceptable theoretical surface water concentrations and the Watershed's area.

In order to determine what theoretical concentrations of total nitrogen in rivers and streams would be acceptable, the EPA's *Nutrient Criteria Technical Guidance Manual: Rivers and Streams* and the EPA's *Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion III* were consulted. These documents provide "technical guidance to assist States and Tribes in developing regionally-based numeric nutrient and algal criteria for river and stream systems" (EPA 2000a).

Both documents present the criteria development process that states and tribes are advised to follow. In particular, this process includes three general approaches for nitrogen concentration criteria setting: "(1) identification of reference reaches for each stream class based on best professional judgment (BPJ) or percentile selections of data plotted as frequency distributions, (2) use of predictive relationships (e.g., trophic state classifications, models, biocriteria), and (3) application and/or modification of established nutrient/algal thresholds (e.g., nutrient concentration thresholds or algal limits from published literature)" (EPA 2000a).

Based on the *Guidance Manual*, three methods were chosen to determine the nutrient discharge cap for the Watershed:

1. Using the lower 25th percentile nitrogen concentrations of the population of all streams within the Snake River Basin subecoregion to estimate acceptable annual nitrogen loading. "The 25th percentile of the entire population was chosen by EPA to represent a surrogate for an actual reference population," where streams are likely to possess minimally impacted conditions (EPA 2000b).
2. Using trophic state classification nitrogen concentrations to determine the value of nitrogen loading per year that will likely cause nuisance growth or eutrophication in the Big Wood River.
3. Using published nutrient data on provisional permissible and dangerous concentration levels for total nitrogen to determine the level of nitrogen loading per year that is tolerable in the Watershed.

Each of these three methods and their results are described in the following sections.

CLASSIFICATION BY ECOREGION

The *Nutrient Criteria Technical Guidance Manual* divides the country "into 14 ecoregions ... based on landscape-level geographic features including climate, topography, regional geology and soils, biogeography, and broad land use patterns" (Figure 3-5) (EPA 2000a). EPA modeled the system in this way in order to facilitate stream classification and thus make it easier to set specified criteria. The Watershed falls within Ecoregion III: Xeric West, which is characterized by "unforested basins, alluvial fans, plateaus, buttes, and scattered mountains" (EPA 2000b). Moreover, EPA characterizes the area as mostly "uncultivated and used for range" with irrigated agriculture occurring "where water is available and soils are suitable" (EPA 2000b). The irrigation, coupled with a growing human population, has elevated nitrogen levels and caused various other water quality problems.

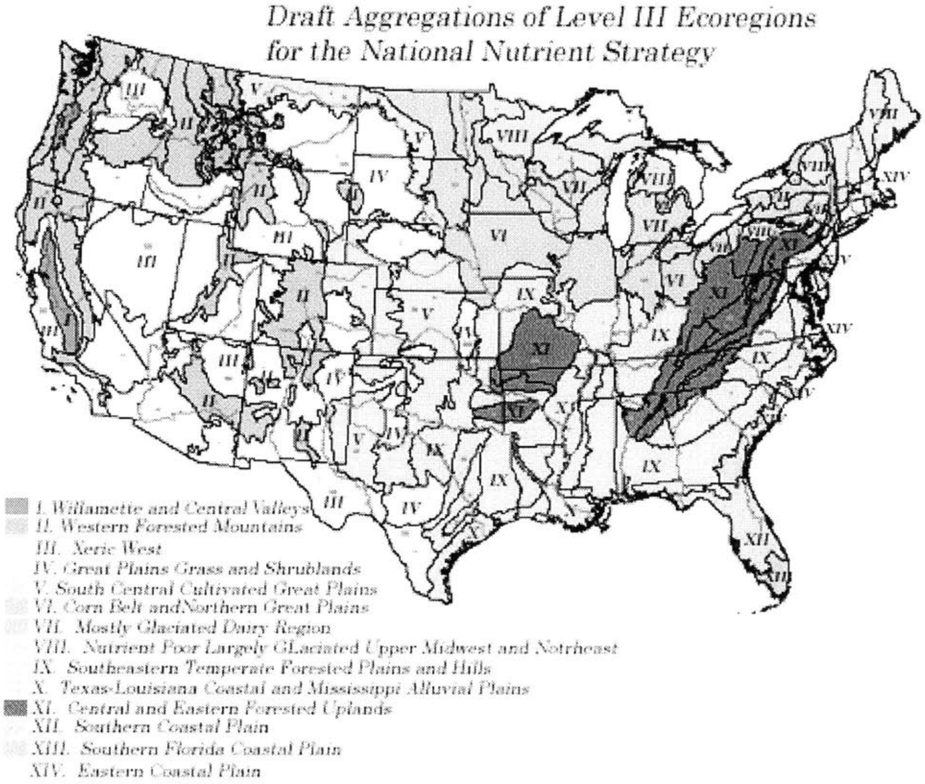

Figure 3-5. Map of Ecoregions (EPA 2000a)

Within each Ecoregion, land is subsequently subdivided into Subecoregions (Figure 3-6); the Watershed falls within Subecoregion 12: Snake River Basin. The Snake River Basin is described as more agricultural than other areas of the Xeric West and as having more cattle and dairy feeding operations. Nutrient criteria suggestions for the Snake River Basin Ecoregion can be found in EPA's *Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion III.*

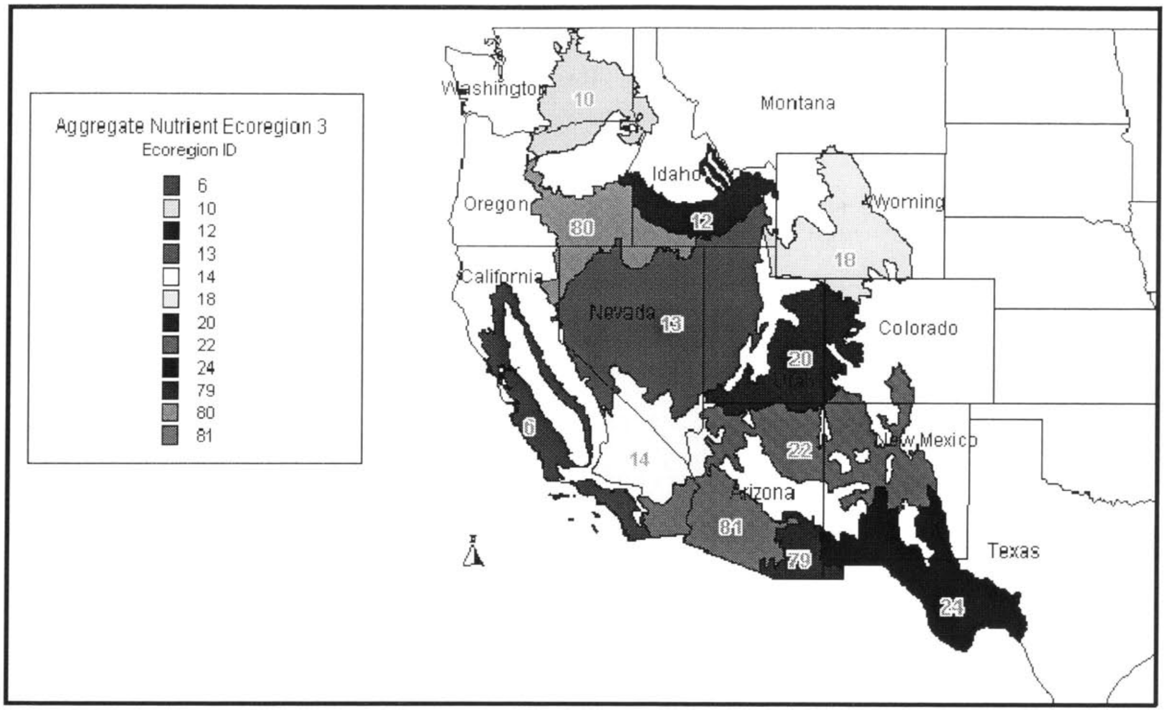

Figure 3-6. Map of Ecoregion III with Subecoregions (EPA 2000b)

In order to estimate acceptable annual nitrogen loading, the lower 25th percentile nitrogen of the nitrogen concentration of the population of all sampled streams within the Xeric West Ecoregion (Aggregate Ecoregion II) was used as the dependent variable in the equation: $y = 0.6316x + 0.4937$ (Table 3-10) to solve for the acceptable nitrogen yield for the Watershed. This value was then multiplied by the total area of the Watershed to determine the yearly acceptable nitrogen load for the Watershed.

Parameter	# of Streams	Reported Values		25th Percentiles based on all seasons data for the decade	Nitrogen cap based on P25 - all seasons (kg)
		Min	Max	P25 – all seasons	
TKN (mg/L)	733	0	13.1	0.198	
$NO_2 + NO_3$ (mg/L)	459	0	9.66	0.025	
TN – calculated (mg/L)	NA	0	22.7	0.223	**431,500**
TN – reported (mg/L)	154	0.43	10.6	0.377	**497,600**

Table 3-10. Reference conditions for Aggregate Ecoregion III Streams (EPA 2000b)

The above procedure was also appliedto the 25th percentile nitrogen concentrations of the population of all sampled streams within the Snake River Basin subecoregion (Level II Ecoregion 12) (Table 3-11).

Parameter	# of Streams	Reported Values (mg/L)		25th Percentiles based on all seasons data for the decade (mg/L)	Nitrogen cap based on P25 - all seasons (kg)
		Min	Max	P25 – all seasons	
TKN	82	0.05	2.03	0.272	
$NO_2 + NO_3$	78	0.01	7.79	0.272	
TN – calculated	NA	0.06	9.82	0.544	**569,300**
TN – reported	4	0.37	2.91	0.896	**720,500**

Table 3-11. Reference conditions for Level II Ecoregion 12 Streams (EPA 2000b)

Loading values calculated using this method estimate loading rates for pristine or minimally impacted rivers and streams. Thus, values calculated using this method should be considered a final goal, but not a starting point, for a nutrient cap.

CLASSIFICATION BY TROPHIC STATE

While there are no set criteria for trophic states[6], various sources have developed general suggested trophic classifications for rivers and streams. For this analysis, two sources were chosen: the suggested trophic classifications from the *Nutrient Criteria Technical Guidance Manual* and two suggested trophic classifications from Wetzel's *Limnology* textbook.

In order to estimate an acceptable annual nitrogen load, each trophic boundary concentration value was used as the dependent variable in the equation: $y = 0.6316x + 0.4937$ (Table 3-12, Table 3-13, and Table 3-14) to solve for the acceptable nitrogen yield for the Watershed. This value was then multiplied by the total area of the Watershed to determine the yearly acceptable load for the Watershed.

	TN (mg/L)	**Nitrogen cap (kg)**
Sample Size	1070	
Oligotrophic – Mesotrophic Boundary	0.700	**636,300**
Mesotrophic – Eutrophic Boundary	1.500	**979,900**

Table 3-12. Suggested boundaries for trophic classification of steams (EPA 2000a)

The suggested boundaries for trophic classification provided by the EPA are values calculated for lakes and other standing waters adjusted to serve rivers and streams. In this case, nitrogen trophic classifications are a good indicator of actual river and stream conditions.

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[6] Trophic classifications generally include three stages: oligotrophic, mesotrophic, and eutrophic. Oligotrophic is a term used to describe bodies of water with clear water and low levels of nutrients. Mesotrophic describes bodies of water with clear water and medium level of nutrients. Eutrophic applies to nutrient enriched bodies of water.

Trophic State	Total Nitrogen (mg/L)			Nitrogen cap based on mean (kg)	Nitrogen cap based on range (kg)
	#	Mean	Range		
Oligotrophic	11	0.661	0.307 - 1.630	**619,600**	**467,600 - 1,035,800**
Mesotrophic	8	0.753	0.361 - 1.387	**659,100**	**490,800 - 931,400**
Eutrophic	37	1.875	0.393 - 6.100	**1,141,000**	**504,500 - 2,955,500**

Table 3-13. General trophic classification of lakes and reservoirs in relation to nitrogen (Wetzel 1983)

General Level of Lake Productivity	Inorganic N (mg/L)	Organic N (mg/L)	Nitrogen cap based on Total N (kg)
Ultra-oligotrophic	<0.200	<0.200	**507,500**
Oligo-mesotrophic	0.200 - 0.400	0.200 - 0.400	**507,500 - 679,300**
Meso-eutrophic	0.300 - 0.650	0.400 - 0.700	**636,300 - 915,500**
Eutrophic	0.500 - 1.500	0.700 - 1.200	**851,100 - 1,495,300**
Hypereutrophic	>1.500	>1.200	**1,495,300**

Table 3-14. General relationship in lake productivity to average concentration of eplimnetic nitrogen (Wetzel 1983)

Trophic classification values provided by Wetzel refer to trophic classification for lakes. It is possible for rivers (especially those with high flows) to tolerate higher nitrogen levels than lakes because of higher denitrification levels in rivers due to increased aeration. Therefore, values calculated using lake trophic classifications may underestimate allowable nitrogen loading for rivers and streams.

CLASSIFICATION BY PUBLISHED DATA

In order to estimate acceptable annual nitrogen loads, published values for impairment risk in streams were assumed to be the dependent variable in the equation: $y = 0.6316x + 0.4937$ (Table 3-15), to calculate the corresponding acceptable nitrogen yield for the Watershed. This value was then multiplied by the total area of the Watershed to calculate the yearly acceptable load for the Watershed.

<table>
<tr><th colspan="4">PERIPHYTON Maximum in mg/m^2</th></tr>
<tr><th>TN (mg/L)</th><th>Impairment Risk</th><th>Source</th><th>Nitrogen cap (kg)</th></tr>
<tr><td>0.275 - 0.650</td><td>Nuisance growth</td><td>Dodds et al. 1997</td><td>453,800 - 614,900</td></tr>
<tr><td>1.500</td><td>Eutrophy</td><td>Dodds et al. 1998</td><td>979,900</td></tr>
<tr><td>0.300</td><td>Nuisance growth</td><td>Clark Fork River Tri-State Council, MT</td><td>464,600</td></tr>
<tr><th colspan="4">PLANKTON Mean in µg/L</th></tr>
<tr><th>TN (mg/L)</th><th>Impairment Risk</th><th>Source</th><th>Nitrogen cap (kg)</th></tr>
<tr><td>0.300</td><td>Eutrophy</td><td>Van Nieuwenhuyse and Jones 1996</td><td>464,600</td></tr>
<tr><td>0.250</td><td>Eutrophy</td><td>OECD 1992 (for lakes)</td><td>443,100</td></tr>
</table>

Table 3-15. Nutrient and algal biomass criteria limits recommended to prevent nuisance conditions and water quality degradation in streams (EPA 2000a)

Published data on recommended nitrogen concentrations for rivers and streams tend to be values calculated for lakes and other standing waters. It is possible for rivers (especially those with high flows) to tolerate higher nitrogen levels than lakes because of higher denitrification levels in rivers due to increased aeration. Therefore, values calculated using published data tend to be low estimates for allowable nitrogen loading for rivers and streams.

SUMMARY OF RESULTS AND NITROGEN CAP SELECTION

Nitrogen concentrations, yields, and loads for each of the three classifications are summarized in Table 3-16. Values that by best professional judgement are within the range of an initial yearly nitrogen cap for the Watershed are highlighted. The lower end of this range is about 569,300 kg/yr and the upper end of this range is about 720,500 kg/yr. These values were chosen to maintain an oligotrophic or mesotrophic water quality standard within the Watershed.

Classification	Nitrogen Concentration (mg/L)	Nitrogen Yield (kg/ha)	N load (kg)
Ecoregion 3 calculated	0.223	0.63	431,482
Eutrophy	0.25	0.65	443,078
Nuisance Growth Minimum	0.275	0.67	453,815
Nuisance Growth	0.3	0.68	464,551
Eutrophy	0.3	0.68	464,551
Oligotrophic Minimum	0.307	0.69	467,558
Mesotrophic Minimum	0.361	0.72	490,750
Ecoregion 3 reported	0.377	0.73	497,621
Upper Valley (actual)	**0.39**	**0.74**	**503,188**
Eutrophic Minimum	0.393	0.74	504,493
Ultra-oligotrophic	0.4	0.75	507,499
Oligo-mesotrophic Minimum	0.4	0.75	507,499
Subecoregion 12 calculated	0.544	0.84	569,344
Nuisance Growth Maximum	0.65	0.90	614,869
Oligotrophic Mean	0.661	0.91	619,593
Oligotrophic - Mesotrophic Boundary	0.7	0.94	636,343
Meso-eutrophic Minimum	0.7	0.94	636,343
Mesotrophic Mean	0.753	0.97	659,105
Watershed (actual)	**0.77**	**0.98**	**666,384**
Oligo-mesotrophic Maximum	0.8	1.00	679,290
Subecoregion 12 reported	0.896	1.06	720,520
Eutrophic Minimum	1.2	1.25	851,082
Meso-eutrophic Maximum	1.35	1.35	915,503
Mesotrophic Maximum	1.387	1.37	931,394
Mesotrophic - Eutrophic Boundary	1.5	1.44	979,925
Eutrophy	1.5	1.44	979,925
Oligotrophic Maximum	1.63	1.52	1,035,757
Eutrophic Mean	1.875	1.68	1,140,979
Eutrophic Maximum	2.7	2.20	1,495,298
Hypereutrophic	2.7	2.20	1,495,298
Eutrophic Maximum	6.1	4.35	2,955,523

Table 3-16. Summary of acceptable nitrogen concentrations, yields, and loads

While the nitrogen load for the Upper Valley falls well below the suggested cap range, the entire Watershed falls within this suggested range. Therefore, implementing a nitrogen cap within this suggested range would ensure that nitrogen levels within the Watershed would not increase, causing eutrophication and its associated harmful effects.

3.3 Initial Distribution of Trading Credits

Trading credits should be distributed free of charge to nitrogen dischargers in proportion to their currently allowed levels of pollution. Because the EPA and the IDEQ do not currently regulate non-point sources, this system works only for point sources. For non-point sources, credits should be distributed to dischargers in proportion to the amount of land used for agriculture or ranging.

3.4 Trading Ratios

A lower than 1:1 point source/non-point source trading ratio must be employed within the Watershed in order to incorporate distance-dependent losses from non-point sources and uncertainty in measuring non-point source loads. Calculated groundwater travel times for agricultural areas within the Watershed generally fall within a one year travel time band (Figure 3-7) (Connolly et al. 2003). Therefore, travel time to the rivers and distance from the rivers were equated in order to set trading ratios.

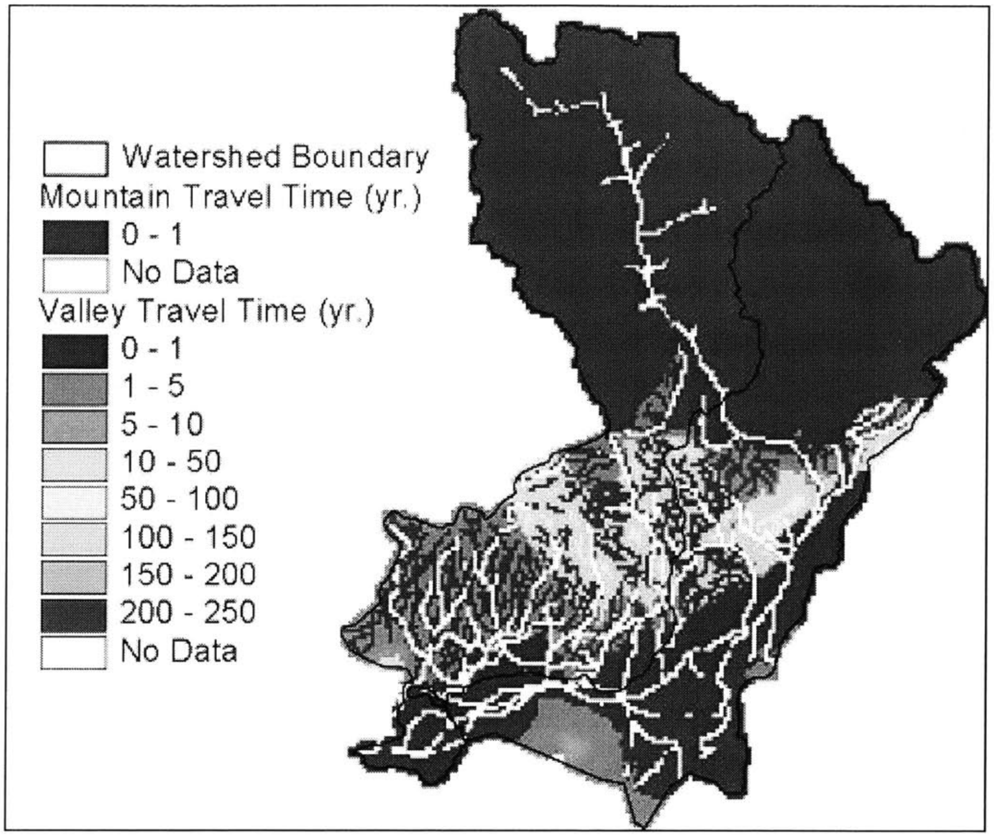

Figure 3-7. Travel times within the Watershed (Connolly et al. 2003)

To estimate distance dependent losses, a kinetics model developed by Pabich et al. was employed to predict groundwater denitrification rates (Pabich et al submitted). The model was run for all crops grown within the Watershed for a range of travel times less than one year (which was considered the longest travel time for a distance within the Watershed furthest from the rivers). At this time scale, the relationship between travel time and nitrogen losses can be linearized (Table 3-17 and Figure 3-8).

Travel Time	Barley	Wheat	Sugar - beets	Corn	Oats	Alfalfa Hay	Dry Beans	Potatoes	Total Loss
1 year	62%	62%	62%	62%	62%	63%	62%	63%	**62%**
3/4 year	47%	47%	47%	47%	47%	47%	47%	47%	**47%**
1/2 year	31%	31%	32%	32%	32%	32%	32%	32%	**32%**
1/4 year	16%	16%	16%	16%	16%	16%	16%	16%	**16%**
0 year	0%	0%	0%	0%	0%	0%	0%	0%	**0%**

Table 3-17. Nitrogen losses for specific crops within the Watershed

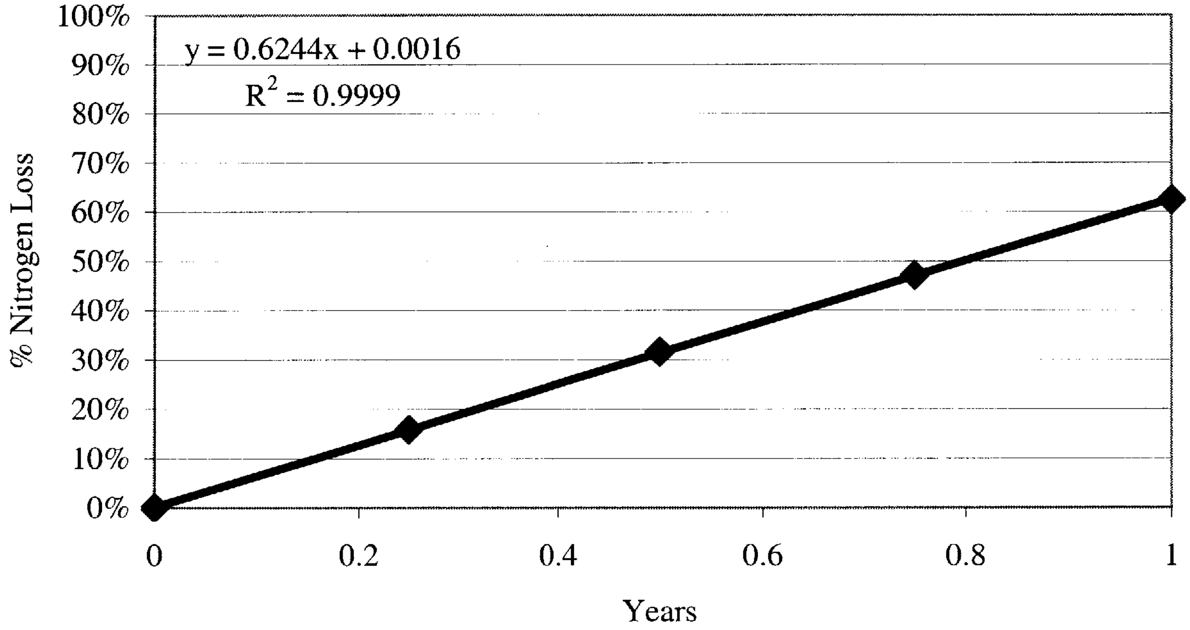

Figure 3-8. Relationship between travel time and percent denitrification within the Watershed

After this model was run, a relationship was established between travel time to the river and distance to the river. This was accomplished by assuming that nitrogen inputs from the furthest point from the river travel to the river in one year, the longest travel time within the Watershed. Figure 3-9 shows that there are land areas within the Watershed that are up to 12 km from a river. However, land areas further than six km from the Watershed are discarded from the analysis because they are impervious surfaces and cannot be used for agricultural or ranging purposes. Figure 3-10 shows the relationship between travel time and distance, so that non-point sources, given their distance from the river, will be able to calculate their given travel time.

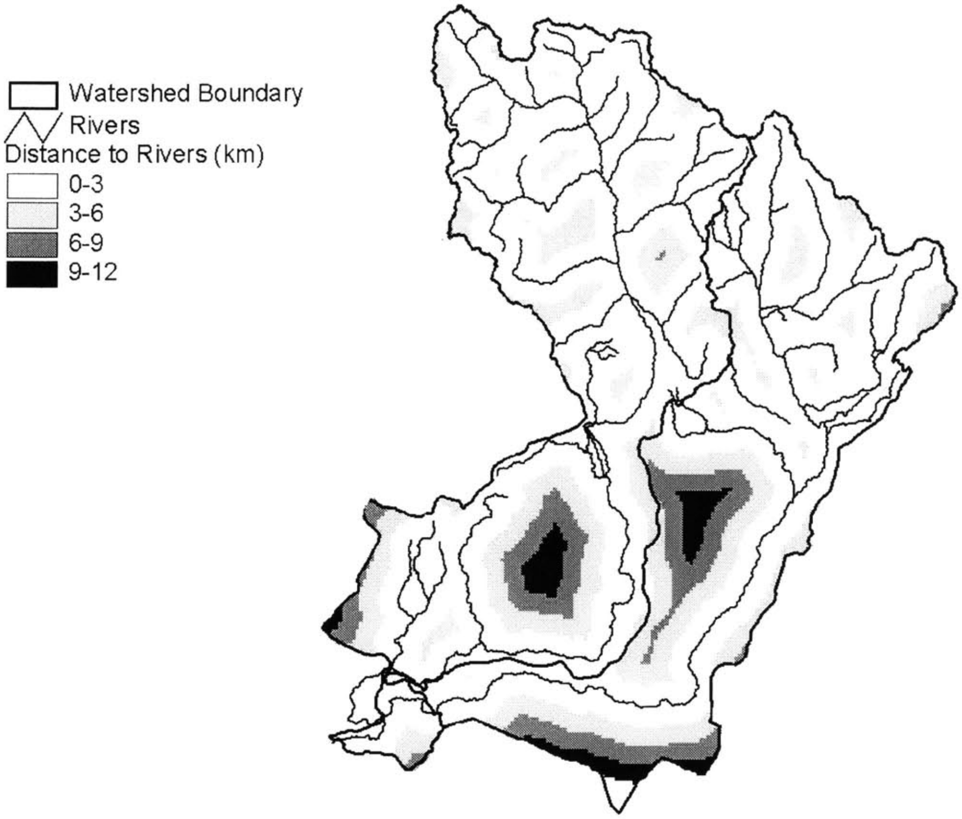

Figure 3-9. Land distances to rivers for the Watershed

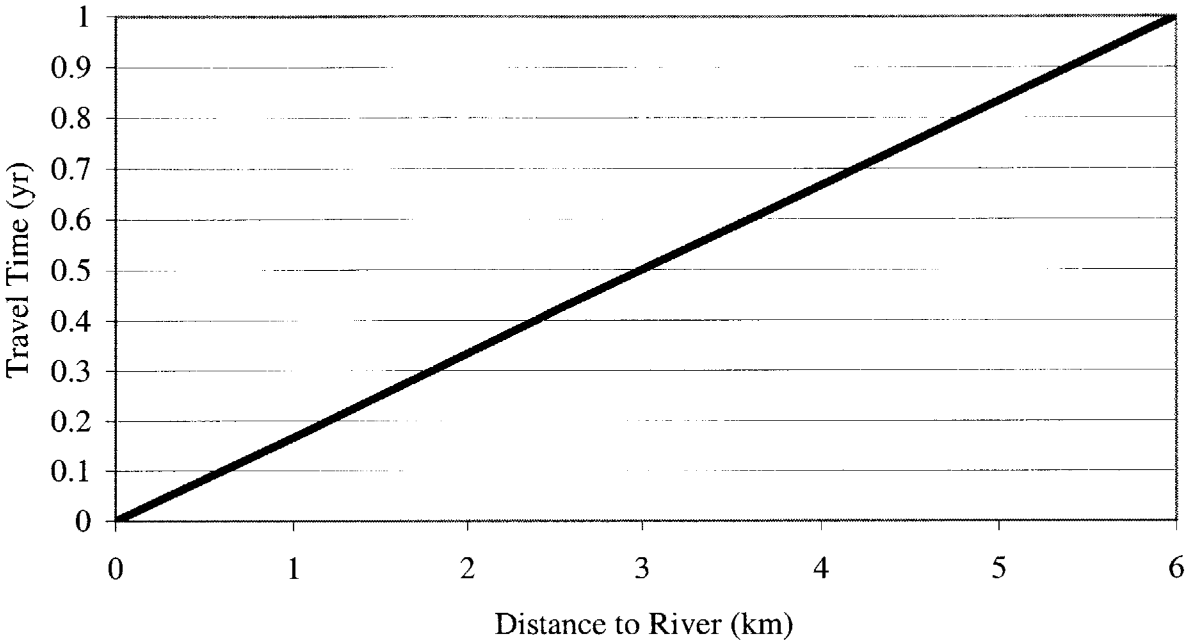

Figure 3-10. Relationship between distance to river and travel time within the Watershed

Because the Watershed exhibits a linear relationship between travel time (i.e. distance) and nitrogen loss, trading ratios for the Watershed should be continuous instead of discrete. Thus, the non-point source portion of the ratio is calculated like so: $1/(1-f_t)$, where f_t is the fraction of nitrogen lost at a given travel time (i.e. distance). For example, point sources (no nitrogen loss) should trade at a 1:1 ratio with non-point sources closest to the river (no nitrogen loss), while point sources (no nitrogen loss) should trade at a 1:2.6 ratio with non-point sources furthest from the river (about 60 percent nitrogen loss). Point sources (no nitrogen loss) should trade with a 1:1.5 ratio with non-point sources halfway to the river (about 30 percent nitrogen loss).

However, trading ratios must not only be environmentally optimal, but also economically palatable. If trading ratios are excessive, they will impede trades (Woodward 2000). Ratios for other point source/non-point source trading programs have ranged from 1:1 to as high as 1:9 (Table 3-18). In each of these situations, stakeholders were involved in setting the ratios and were accepting of such ratios (EPA 1999, Woodward 2001). Given the ratios from other trading programs, a high-end ratio of 1:2.6 between non-point and point sources does not seem extreme, especially since they are based on distance-dependent nitrogen losses. However, stakeholders must be consulted before the ratios are employed to ensure their viability.

Trading Program	Trading Ratio
Kalamazoo River Water Quality Trading Demonstration Project	1:2
Town of Acton Municipal Treatment Plant	1:3
Lake Dillon Trading Program	1:2
Fox-Wolf Basin Watershed Pilot Trading Program	1:1
Long Island Sound Trading Program	multiple, ranging from 1:1 to 1:9
Tar-Pamlico Nutrient Reduction Trading Program	1:2 and 1:3
Cherry Creek Basin Trading Program	multiple, ranging from 1:1.3 to 1:3

Table 3-18. Trading ratios for various trading programs (EPA 1999, Woodward 2001)

3.5 Transaction Costs

Transaction costs are any costs associated with conceptualizing, implementing, and enforcing a trading plan that would not exist if a trading system were not in place. An important part of a trading plan is to identify transaction costs and search for institutional arrangements to mitigate these costs. In any trading program, there are costs associated with identifying trading partners. One way to alleviate the costs of identifying trading partners is to set up a central clearinghouse through which all trades are made (Woodward 2000). A useful tool for this clearinghouse could be a website that provides information on current trading prices, available credits, interested buyers and sellers, and nitrogen load reduction plans (e.g. BMPs) (CBP 2001).

Negotiating trades, documenting trades, and government oversight of a trading program are also costs that would not be present without a trading system. These costs may be mitigated by providing a clear trading framework and implementation procedures and introducing a efficient documentation process (EPA 1996).

Transaction costs for point source/non-point source trading may be higher than for other trading arrangements. Incorporating non-point sources in trading may be more costly because non-point nitrogen source loads are not usually monitored or documented since the government does not currently regulate them. Because of this, point source/non-point source trading programs often work best when they are piggybacked on a local non-point source reduction program (EPA 1996).

In the Watershed there are substantially more non-point nitrogen sources than point nitrogen sources. However, each non-point source may only be able to reduce its nitrogen loading by a small amount. Consequently, to see big effects, many non-point sources would need to agree to trade in order to offset nitrogen loading by point sources. However, there is little regulatory incentive for non-point sources to participate in trading (EPA 1996). Simply providing potential stakeholders with information on the benefits of trading or providing financial incentives to non-point sources (e.g. funding for implementation of BMPs) may be enough to convince non-point nitrogen dischargers to participate.

4 Recommendations and Conclusions

4.1 Recommendations for Future Study

Before implementation of a nitrogen trading plan within the Watershed, an extensive monitoring plan must be developed and an analysis regarding the economic implications of trading must be completed.

4.1.1 Development of Extensive Monitoring Plan

Water quality and source monitoring is a vital component of a nitrogen trading plan in order to reduce risks to all involved in the trading program. Water quality and source monitoring must be tracked in conjunction with the application of BMPs or other management measures in order to estimate the effectiveness of nitrogen load reduction measures. However, monitoring of ambient water quality and effluent sources within the Watershed is not substantial enough to employ a trading plan at this time.

Currently, stream flow monitoring within the Watershed is completed by the USGS. The USGS measures total nitrogen concentrations consistently at only two locations within the Watershed. What is more, samples are taken once a month and samples are not collected during the winter months. If national, state, or local governments do not have the funding or technical capabilities for water quality monitoring, then local universities, community groups, or other non-profit agencies may provide this service.

The USGS, the IDEQ, and Blaine County officials complete groundwater monitoring within the Watershed. Wells monitored within the Watershed by these agencies only include very deep – usually drinking water – wells. However, nitrogen will not reach the deeper parts of the aquifer because nitrogen will travel laterally and reach surface waters before it travels vertically (Figure 4-1). Because drinking water wells are designed to be deep enough to avoid contamination from nutrients and other pollutants, they do not make very good nutrient monitoring wells. Consequently, shallow monitoring wells must be installed to properly monitor concentrations of nitrogen in the groundwater. Multi-level wells would work best to understand cross-sectional nitrogen contamination. Again, if national, state, or local governments do not have the funding or technical capabilities for water quality monitoring, then community groups, local communities, or other non-profit agencies could provide monitoring services.

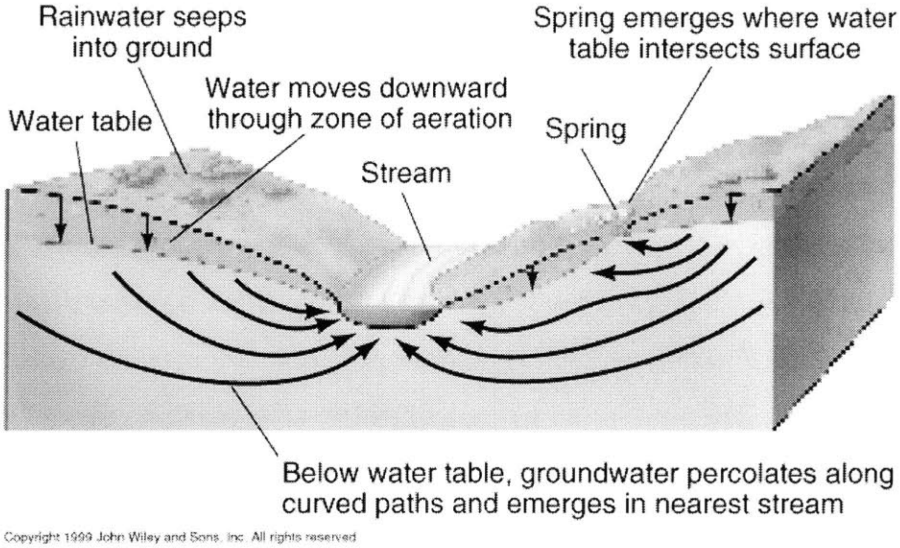

Figure 4-1. Flow paths (Skinner et al. 1999)

Point source monitoring of total nitrogen may already be required by federal, state, or local government regulations (e.g. within an NPDES permit). When it is not, trading facilitators may request that point sources, as part of participation in the trading program, add total nitrogen to its effluent parameter monitoring list.

Non-point source effluent data are hard to come by since non-point sources are not regulated and therefore not monitored. Therefore, trading facilitators must develop and fund a system to monitor non-point sources. One way to monitor non-point sources is to calculate nitrogen outflow when a particular BMP is employed in models or lab tests. This percent reduction in nitrogen would then be applied to actual conditions for a given nitrogen inflow. In this situation, the trading facilitators would distribute a theoretically-tested, approved BMP list to all trading participants. Only BMPs approved by the trading facilitators would count as valid load reduction methods. Besides load percent reductions, the BMP list would include design and construction criteria, monitoring requirements, operation and maintenance requirements, and any uncertainty discounts associated with the BMP (IDEQ 2000).

4.1.2 Economic Analysis of Trading Plan

In order to understand whether a nitrogen trading system would be environmentally beneficial and cost-effective for the Watershed, an economic analysis must be completed. This analysis would include estimating the efficiency of trading ratios, quantifying transaction costs, and estimating the number of willing trading participants (EPA 1996). It is important to remember that the cost of implementing a trading plan is important to both trading facilitators (who will have to invest public funds in the project) and trading participants (who will only choose to enter the market if trading is financially more attractive than a traditional pollutant reduction system).

Trading costs are best measured by the average cost (cost per unit over all units) or marginal cost (cost for one more unit) to reduce a unit load of nitrogen (EPA 1996). If nitrogen dischargers see that a trading plan will afford them the opportunity to lower their nitrogen loads for a lower cost than with a traditional system, they may be more inclined to participate in trading. Therefore, an economic analysis may also be a way for trading facilitators to promote a nitrogen trading plan.

This analysis could be facilitated by instituting a demonstration program where hypothetical trades take place or by implementing a pilot program for a short period of time and monitor its effects.

4.2 Recommendations for Watershed-Based Trading in the Big and Little Wood Rivers Watershed Region

The Watershed is susceptible to nitrogen-related water quality problems. Local authorities should be proactive and implement a yearly nitrogen loading cap before the Watershed's actual nitrogen load increases above the recommended cap and problems arise. Nitrogen trading is an efficient, fair, and flexible policy tool that can be used to decrease nitrogen loads in order to meet nitrogen loading goals.

Local authorities will have to decide whether a trading plan is politically feasible within the Watershed. Because trading programs are largely voluntary, potential trading partners and other stakeholders will play a major role in deciding whether a trading plan is ultimately implemented.

Moreover, the effectiveness and credibility of the program lies in the public's perception of the trading system (EPA 1996). Therefore, public meetings, outreach and education programs, and other forms of public involvement are crucial for a trading program to work.

Future population growth within the Watershed may lead to increasing nitrogen loads. Moreover, the EPA has not established a TMDL for nitrogen within the Watershed. Irrespective of the final decision by the local authorities on nitrogen trading, a yearly nitrogen loading cap within the range of 569,300 kg/yr and 720,500 kg/yr should be employed.

Before a trading plan is implemented, it is essential to set up an extensive water quality and source monitoring network and study the economic implications of implementing a trading plan.

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