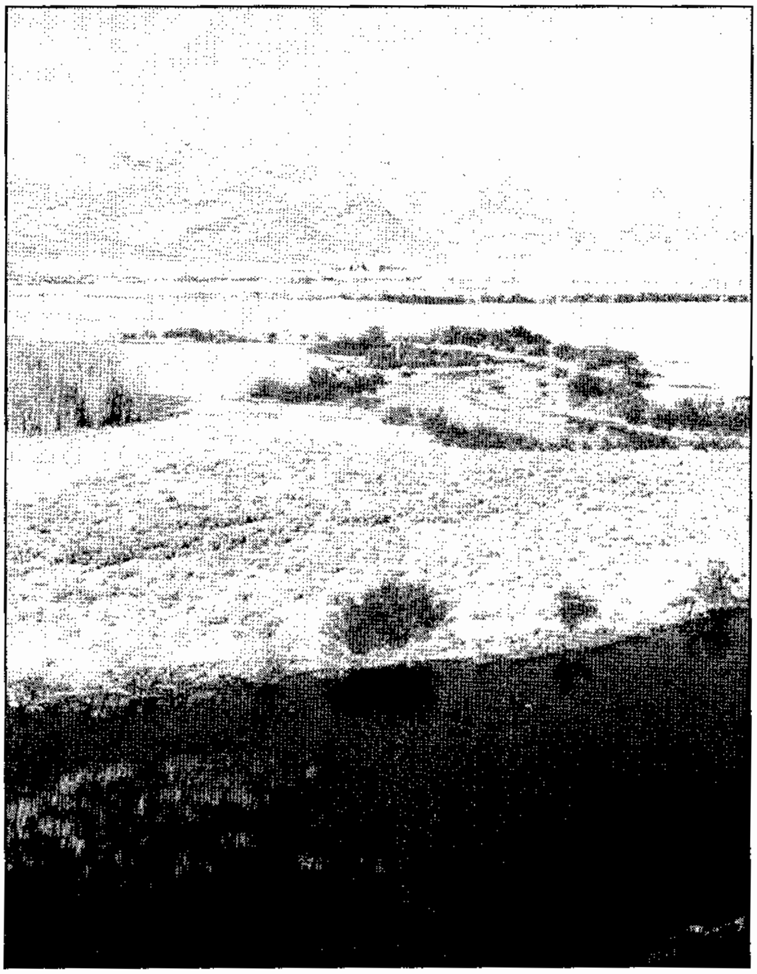
BLAINE COUNTY EVALUATION AND ASSESSMENT OF NITROGEN SOURCES



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PROJECT REPORT

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ABSTRACT

A spatially-explicit nitrogen mass-balance model for the Wood River Valley Watershed in south-central Idaho is developed (Blaine County Evaluation and Assessment of Nitrogen Sources (BEANS) model). The study is performed on behalf of the Blaine County Commissioners in response to concerns regarding increased nitrogen loading to the Big Wood and Little Wood Rivers as a result of continuing population growth in Blaine County. Nitrogen inputs incorporated in the BEANS model include atmospheric deposition, fertilizer applications, nitrogen fixation, livestock waste, and domestic wastewater from both on-site septic systems and municipal wastewater treatment plants. Nitrogen losses include ammonia volatilization, uptake by plants, retention by soils, aquifer denitrification, and instream denitrification. The magnitude of nitrogen inputs and losses are determined using basin-specific information when possible and from applicable literature when basin-specific values are not available. These values vary as a function of land use.

Nitrogen loads are calculated for the entire Wood River Valley Watershed as well as for two sub-watersheds, referred to as the Upper Valley and the Northern Valley. The majority of future population growth in the watershed is expected to occur in these two sub-watersheds. The BEANS model calculates nitrogen loads for the entire watershed, the Upper Valley, and the Northern Valley of 664,500 kg N/yr, 165,000 kg N/year, and 55,600 kg N/year respectively. The nitrogen yields are 0.98 kg N/ha for the entire watershed, 0.74 kg N/ha for the Upper Valley, and 0.55 kg N/ha for the Northern Valley. Agricultural sources, primarily cattle waste and fertilizer applications, contribute 70% of the nitrogen to the entire watershed load. Wastewater sources contribute only 5% to the entire watershed load, but the relative magnitude of wastewater sources is greater in the Upper Valley (17%) and Northern Valley (33%).

The BEANS model is used to analyze how future land use changes will affect the magnitude of the watershed nitrogen load. Reductions in agricultural nitrogen fertilizer application rates are identified as an option for reducing the watershed nitrogen load without losses in net agricultural production. Controlling the size of new residential lots and the nature of residential wastewater treatment could also provide reductions in the watershed nitrogen load without limiting the possibility of future economic development within the watershed.

A watershed-based nitrogen trading system is also designed for the Wood River Valley Watershed as a policy tool to help manage increasing nitrogen loads within the watershed. A trading framework is developed based on case studies and existing trading frameworks. The developed framework includes 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 are discussed, 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. A water balance is completed in order to understand the hydrologic conditions of the watershed. Water inflow for the watershed is 2.24 kg^3/yr of precipitation. Water outflows for the watershed are 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 is 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 is suggested for the watershed. This range is 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 distribution 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 range is recommended. The trading ratio set between point and non-point sources varies continuously between 1:1 and 1:2.6 depending on the distance from the river of the non-point source.

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- Dr. David Marks, Thesis Advisor
- Sarah Michael, Blaine County Commissioner

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11. Conclusions and Recommendations

11.1 Magnitude of Nitrogen Sources

Significant reductions in the nitrogen load to the Wood River Valley Watershed must involve reductions in nitrogen exported from agricultural sources.

11.1.1 Dominance of Agricultural Sources

Agricultural sources are the largest nitrogen contributors to the Wood River Valley Watershed. Cropland and pasture, rangeland, and feed-lots contribute 89% of the watershed nitrogen load. From these different land uses, cattle waste and fertilizer are the two largest sources. Cattle waste alone accounts for 42% of the nitrogen load to the watershed, and fertilizer and cattle waste together contribute 70%. If the more residential Upper Valley and Northern Valley sub-watersheds are considered separately, rangeland and cattle waste are still the single largest nitrogen-contributing land use and source in those sub-watersheds.

11.1.2 Achieving Agricultural Source Reductions

The primary agricultural sources of nitrogen—fertilizer and cattle waste—are directly related to agricultural production. Fertilizer use increases crop yields in the watershed, and cattle waste is a by-product of grazing and feeding operations for beef production. Because methods for maintaining production and reducing agricultural nitrogen loads are limited, significant nitrogen reductions in the Wood River Valley Watershed will involve a trade-off with agricultural production. Substantial reductions from the two primary agricultural land uses (rangeland and cropland) can be achieved by limiting production.

Rangeland: Currently, there are approximately four times as many cattle in the watershed as there are people. Unlike human nitrogen contributions in residential areas, no economically feasible methods exist for capturing and treating the rangeland cattle waste that constitutes a significant portion of the watershed nitrogen load. Nitrogen reduction from implementation of rangeland nitrogen BMPs is not easily quantifiable and may have a limited effect because of the magnitude of the cattle waste source.

Significant reductions in rangeland nitrogen loads from cattle waste must involve reducing the cattle density and related beef production in the watershed. Most rangeland in the watershed is held in the public trust by BLM and the U.S. Forest Service; consequently, animal grazing densities are not locally controlled. Local governments, ranchers, and citizens groups can encourage less dense grazing in federally-controlled lands for the reduction of the watershed nitrogen load.

Cropland: Fertilizer application rate BMPs are well researched, but the implementation of BMPs in the Wood River Valley Watershed will result in a predicted total nitrogen load reduction of only 2.5%. Precision Agricultural techniques, which represent the forefront of current agricultural nitrogen research, will achieve a predicted 12.6% reduction in total watershed nitrogen load if implemented to their full extent. Precision Agriculture represents the best-case scenario for reducing agricultural fertilizer inputs while maintaining current crop yields. More significant reductions can be achieved by changes in cropping patterns and crop yield expectations, both of which may involve producing fewer crops. Changes in cropping patterns that would reduce nitrogen fertilizer use include letting fields lie fallow or growing crops that have a smaller nitrogen requirement. Lowering crop yield expectations (and therefore nitrogen fertilization rates) can significantly reduce nitrogen yields. Whereas fertilizer BMPs and Precision Agriculture seek to maintain or improve crop yields while reducing fertilizer application, lowering crop yield expectations will lower production as a means to significantly reduce fertilization rates and subsequent nitrogen load. Attaining a voluntary reduction in the fertilizer nitrogen load requires local farmers to evaluate the costs of decreased production versus the benefits to surface water quality. Because no direct incentives exist for farmers to sacrifice their income from crop production for the benefit of local water quality, government regulation is the only realistic mechanism for reducing cropland nitrogen loads. Watershed-based nitrogen trading may provide a tool for reducing nitrogen loads from agricultural cropland sources.

11.2 Wastewater Treatment

The level of wastewater treatment is critical in determining the effects of continued development on nitrogen water quality in the watershed. Expanding the availability of tertiary wastewater treatment to a larger portion of the watershed population will accommodate future population growth with the smallest nitrogen loads to ground and surface waters. Secondary wastewater treatment plants that discharge directly to surface waters offer essentially no reduction in wastewater nitrogen concentrations, and are therefore the least efficient treatment method with respect to riverine nitrogen loads. Septic systems offer some nitrogen removal through aquifer denitrification as septic plumes travel through the subsurface; consequently, septic systems may reduce the impact of an increasing population on the magnitude of future watershed nitrogen loads. Gains in surface water quality from the use of septic systems must be evaluated in the context of viral and bacterial contamination of groundwater from these systems. Policymakers must evaluate the risks and benefits of septic system use to both public health and ecosystem health in making decisions about the nature of future residential development in the watershed.

11.3 Nitrogen Monitoring

Monitoring of nitrogen concentrations in ground and surface water should be expanded. Currently, surface water monitoring in the Wood River Valley watershed is conducted primarily by USGS, and groundwater monitoring is conducted by USGS, IDEQ, and Blaine County. In general, both of these monitoring schemes are inadequate in providing a complete understanding of the current nature and extent of nitrogen contamination in the watershed. Monitoring schedules and methods should be redesigned to incorporate monitoring during times and in areas that are suspected to have elevated nitrogen concentrations.

11.3.1 Surface Water Monitoring

As discussed in Chapter 6 of this thesis, elevated nitrogen concentrations in surface waters are likely to occur during the winter months as a result of seasonal variations and during storm events as a result of altered hydrologic dynamics that occur during storms.

In an average year, surface water nitrogen concentrations are currently measured once a month during six months of the year (April through September). Calculating the mass of nitrogen exported from the watershed in a given year based on only these six data points provides an inaccurate estimate of the true magnitude of the rivers' nitrogen load. The current monitoring schedule likely does not capture the vulnerability associated with winter and storm discharges during which the highest nitrogen concentrations are expected to occur.

Monthly, scheduled measurements of in-stream nitrogen concentrations should be expanded to include measurements during winter months, and unscheduled monitoring during storm events should be introduced to the surface water monitoring scheme. Because USGS maintains many monitoring stations within the state, it may not be feasible for this agency to expand its current monitoring. Local sources (i.e. local governments or citizens groups) may need to accept responsibility for introducing additional monitoring. USEPA provides resources for volunteer water monitoring groups, including factsheets to introduce citizens to water monitoring and manuals describing monitoring methods. National Volunteer Monitoring Conferences are also sponsored by USEPA to encourage information sharing among water monitoring volunteers (USEPA 2003). Expanding the extent of surface water monitoring in the watershed will enable better calibration of the BEANS model to observed in-stream concentration data. A broader nitrogen concentration data set that incorporates both seasonal and storm-related dynamics will also provide insight into the relationship between annual nitrogen loads and streamflow that we already observe with only a limited data set.

11.3.2 Ground Water Monitoring

While expanded groundwater monitoring is not specifically necessary to understand how accurate the BEANS model is in predicting the annual riverine nitrogen load, groundwater data are crucial in determining the magnitude of the public health effects associated with different nitrogen sources. Elevated nitrogen concentrations in groundwater are likely to occur in shallow groundwater below land uses that have high nitrogen yields (i.e. feed-lots, residential land, cropland and pasture). Groundwater flowpaths increase in depth as they travel from their source toward a receiving water body; consequently, the longer groundwater must travel, the deeper the flowpaths go (Figure 11-1).

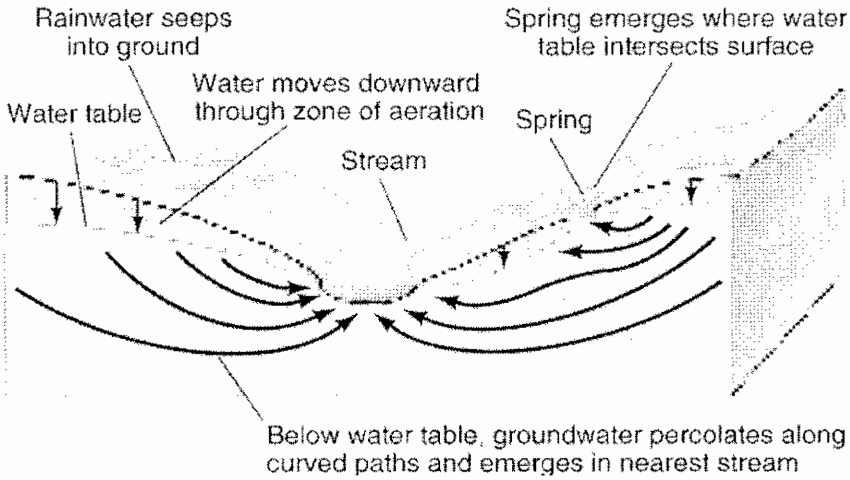

Figure 11-1: Groundwater Flowpaths from Land Surface to Receiving Water Body (source: Skinner, Porter, and Botkin 1999)

Contaminants that enter groundwater close to a river will likely not enter into deeper aquifer sections because they do not have the time to travel significant vertical distances before discharging into neighboring surface water bodies. Elevated nitrogen concentrations are not expected in deep groundwater in the Wood River Valley Watershed because of the close proximity of most nitrogen sources to river or stream channels. Currently, the Blaine County groundwater monitoring program relies primarily on relatively deep wells (usually drinking water wells) to assess the nature of groundwater nitrogen contamination. This expectation of lower nitrogen concentrations in deeper wells is observed in eastern Idaho in the Central Columbia Plateau NAWQA study unit (Williamson et al. 1998).

The groundwater monitoring network should be expanded to incorporate shallower wells. Because drinking water wells are designed to be deep enough to avoid contamination from surface sources, the construction of new shallow wells may be necessary. New shallow wells should be positioned so that they are likely to intercept nitrogen plumes from land uses with high nitrogen yields. One location that may be a good candidate for the introduction of new monitoring wells may be the cross-section of the valley at the outlet of the Northern Valley Watershed (Chapter 5). Because the aquifer is very narrow at this point, all of the groundwater from the Northern Valley is funneled through this cross-section. The installation of multi-level sampling wells across the valley at this location will provide an improved understanding of groundwater nitrogen contamination in the Northern Valley. Because residential land is the highest nitrogen yielding land use in the Northern Valley, much of the nitrogen contamination present at this cross-section likely originates from on-site, residential septic systems.

11.3.3 Monitoring to Support Nitrogen Trading

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.

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).

11.4 WATERSHED-BASED NITROGEN TRADING

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. 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. An economic analysis and understanding of the political feasibility of nitrogen trading are important to the success of a watershed-based trading program.

11.4.1 Economic Analysis

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.

11.4.2 Political Feasibility

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.

11.5 Magnitude of Future Nitrogen Loads

Watershed residents and public officials are in a position to control whether the magnitude of the nitrogen load to the Big and Little Wood Rivers increases or decreases in future years. Possibilities for nitrogen source reductions exist both in agricultural and residential sectors, and watershed-based nitrogen trading may be an effective tool to achieve nitrogen reductions. As discussed earlier in this chapter, agricultural sources are currently the largest contributor of nitrogen to the watershed, and, consequently, individuals involved in agricultural production have the greatest potential to impact the magnitude of future nitrogen loads. Alternatively, because the watershed population is expected to continue to grow in future years, residential nitrogen sources represent the largest new potential source of nitrogen to the watershed. In making decisions about future development and land use changes in the watershed, residents and policymakers should keep in mind how these decisions will affect livestock densities, the acreage of high nitrogen-demanding crops, residential densities, and the availability of different wastewater treatment technologies to watershed residents.