Applying the Total Maximum Daily Load Process to Control Phosphorus Entering Ruzín Reservoir

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Purpose

The goal of this study is to develop a recommendation for a pollution control strategy to help protect the beneficial uses of Ruzín Reservoir. The reservoir is an increasingly important body of water in the eastern Slovak Republic. The reservoir serves to supply domestic water and is increasingly being used for recreational purposes. As tourism begins to increase in the area, maintaining acceptable water quality in the reservoir will become increasingly important. It is essential that the reservoir water quality does not become impaired resulting in driving away tourism and recreation along with the potential economic benefits these activities will bring to the people of the local area.

Pollution form excessive nutrients is the water quality constituent of most interest for protecting the beneficial uses of the reservoir. The loading of excessive nutrients causes accelerated eutrophication of waters. Phosphorus has been shown to be the primary nutrient affecting the eutrophication of freshwaters. This eutrophication impairs the beneficial uses of waters by causing excessive nuisance algal and aquatic weed growth. These growths can impair aesthetic enjoyment by forming scum's on the surface, clog water use intake structures, deplete dissolved oxygen needed for the support of aquatic life, shift to fishery communities with more undesirable coarse fish, and increase noxious aquatic weeds that tangle boat propellers and swimmers. Reversal of eutrophication is difficult since much of the phosphorus entering a lake is stored in the ecosystem and bottom sediments and is available to algae and plants for reuse. This is why it is critical to prevent eutrophication before it starts.

The main objective of the study is to create a water quality model to help prepare alternative solutions for protection of Ruzín Reservoir. A second objective is to attempt applying a different management approach to pollution control than has been used previously in the Slovak Republic. Various pollution control alternatives can be assessed using the water quality model. These alternatives can then be posed in community forums for discussion. When local acceptance of an alternative begins to form, implementation of the pollution controls should be easier to achieve than if the controls were mandated from the government.

Background

There are many different approaches used in managing water quality. Many of these are based on laws and regulations where governments enforce the same pollution controls across all polluters. This type of approach is often called "technology-based" since the controls are applied broadly. This type of approach is often found to be inadequate since it not takes into account the individual sensitivities of specific waters to pollution. Many times, the level of technology-based pollution control is not sufficient to protect the beneficial uses of sensitive waters. This approach also uses a top-down strategy for decisions on which pollution controls are put in place. There is little local public involvement in applying a technology-based pollution control strategy.

In the United States, the federal Clean Water Act (Section 303(d)) describes a "water quality-based" approach to pollution control. These "water quality-based" controls are often derived through a process defined as Total Maximum Daily Loads (TMDLs). The U.S. Environmental Protection Agency (EPA) has promulgated regulations (40 CFR 130) and developed guidance (EPA, 1991; EPA, 1992) for establishing TMDLs

The water quality-based controls derived in a TMDL process are based on a site-specific technical analysis. This analysis looks at the relative sensitivities of waters to specific pollutants. The scope of the analysis is based on one or more watershed areas so that the cumulative effects of multiple pollutant sources can be assessed together. The technical analysis offers several different alternative strategies to pollution control. The TMDL process then uses a locally driven public process to craft solutions. This grass-roots involvement in the decision making process improves

The U.S. federal Clean Water Act allows for the establishment of TMDLs on waters that are either have impaired water quality, or are threatened, good quality waters. By establishing TMDLs on good quality waters is a more proactive, "pollution prevention" approach to water quality management. It is generally easier and less costly in the long term to prevent impairments rather than retrofit controls to clean up pollution problems. In these cases, the TMDL process can plan protection of waters for pollution expected in the future from economic or development growth.

What is a TMDL Designed to Accomplish?

TMDLs for control of pollution sources are designed to address water quality problems by systematically identifying sources of pollution and carrying out mutually agreeable solutions that correct the problem. They are used as one method for addressing waterbody pollution problems.

Most larger watersheds contain a combination of point sources and nonpoint sources. The fundamental approach to addressing each situation will vary depending on the size and complexity of the problems. A combination of nonpoint source and point source control mechanisms should be integrated to meet overall goals as needed for the watershed.

It is instructive to begin with an examination of the differences between establishing controls for point source problems and those for nonpoint. Many factors used to develop controls for point sources are different from those used to develop controls for nonpoint sources. Analysis of pollutant loading from point sources involve input parameters that are generally better known, quantified and controllable to some degree than nonpoint sources. The assimilation capacity of the waterbody for one or more pollutants from point sources is generally modeled and the water quality improvement is reasonably predicted. Finally the levels of pollutants in the effluent are easier to regulate with treatment processes than the diffuse pollution coming from nonpoint sources.

Sources of nonpoint source pollution are rarely well defined. A TMDL with many nonpoint sources involves evaluation, source identification, planning, public involvement, and monitoring which may include a wide array of participants. TMDLs TMDL with many nonpoint sources are based on the assumption that designed management approaches will produce the desired water quality goals.

Progress is regularly checked against interim targets identified in a planning effort. Often the true effectiveness of management approaches is not known until programs are implemented. Thus, new programs are developed, tested and refined as workable solutions are identified. Through time, new science and adaptive management will result in better understanding of the interactions in the aquatic environment.

A recognition of the technical limitations is inherent in developing TMDLs with many nonpoint sources. In doing so, the process of TMDL development allows for progressively more stringent requirements to be "phased in" over time as needed to meet the water quality goals. This allows locally driven non-regulatory programs a chance to be successful before more restrictive measures are applied. The adequacy of nonpoint source management activities is monitored over time to determine if implementation is effective in meeting the targets.

Determining the amount of pollutant loads contributed from wide areas within a watershed is often not an effective measure of need. The concept of loading capacity is rarely used because of limited research and the need to use broad assumptions. Instead, the process relies heavily on the development of targets or identifying a desired future condition for the waterbody. TMDLs can be expressed in terms other than loads. For instance, pollutant concentrations or pool depth may be used as a target condition.

These targets must meet water quality standards at a minimum. They may also be based on a biological measure such as macroinvertebrate diversity or density. Or they can be based on a physical habitat indicator such as pool/riffle ratio or percent fines sediment in gravel that have been adequately linked to characteristic uses.

Best management practices (BMPs) are specifically mentioned as a method for addressing nonpoint sources defined in TMDLs. There are several factors to consider when evaluating whether BMPs are stringent enough to implement applicable water quality standards. They include:

- Data analysis of the controls relative to the problem;
- Mechanisms requiring implementation and maintenance of the pollution controls;
- Reasonable time frame for attaining water quality standards (waterbody responsive); and
- Monitoring to track implementation and effectiveness of controls.

A locally managed watershed plan is one of the best approaches to implementing the nonpoint source components of a TMDL. The plan should represent the needs and views of a variety of affected parties. A basic objective of the plan should be to meet or exceed water quality standards. Where applicable, other in-stream targets may be established in the plan. Management plans should address specific resource protection and restoration issues which are outlined later in this guidance.

The plan may call for short-term fixes and/or long-term rehabilitation. It may rely on activities specifically controlled by human activities or may be a combination of natural and specific restoration or management activities . Examples of short-term TMDL implementation approaches are farm plans for a situation where a single farm or small number of farms can be shown to be the primary source of water quality impairment.

Longer-term TMDL implementation strategies may involve such things as shade plans where existing shade is retained and re-establishment of shade vegetation is enhanced. Another long-term plan could involve road and/or erosion management to limit further degradation while the stream is allowed to flush excess fine sediment out over a 20 or 30 year period. Both long-term examples involve management and natural processes.

Plans developed and used as partial elements of TMDLs can address watersheds of various scales. They can be as small as a reach or as large as a whole drainage. The key is the ability to identify relationships between sources of pollution and resources that are impaired. Specific practices need to be designed to address the sources and show likely improvement in the resource.

TMDLs can be used to address existing problems or may be used to prevent problems in the future. Those TMDLs designed to prevent future problems in pristine or high quality waters are often called "preventive" TMDLs. They are established on waters not currently not impaired by water quality. Preventive TMDLs should attempt to identify all characteristic uses in the watershed, and establish targets and practices to ensure that the uses are protected.

Finally, TMDLs must include a provision for enforcement to back up voluntary plans. Noncompliance with plan provisions (i.e. no implementation of BMPs) may be grounds for enforcement action on specific individual polluters if the problem is clearly identifiable and persists in spite of local action to comprehensively address these problems. Other provisions for enforcement that may be used include inter-local agreements, local ordinances, court ordered decrees, and conditioned grant funding from government.

The Five Components of a TMDL

When a TMDL is developed specific documentation should be compiled to help affected parties understand the pollution control strategy. This documentation helps form the basis of technical recommendations and any actions that will come out of the public process. The reason for developing the documentation is to assure that institutional agreements become memorialized so that changes in affected parties do not affect implementation of the TMDL.

1. Problem formulation

Information is presented to show that a problem exists and there is a need for special management approaches. The TMDL documentation should describe the water quality problem using available information. If the TMDL is a preventive (e.g., water quality standards are currently being met), a description on why a TMDL is being done and what problem is being addressed (e.g. protection from future development, protection of a pristine water, etc.).

In describing the problem, the documentation should identify applicable water quality standards, applicable regulations or agreements, pollutants of concern, source of these pollutants, and control actions taken to date. The documentation should reference the technical reports, memorandum, and other information documenting the water quality problem(s) that the TMDL addresses.

2. TMDL data and supporting studies

Data and information that is collected as part of the planning process is presented to support assumptions needed to make resource management decisions. This includes the method and results used to establish TMDL interim targets and final goals.

The TMDL submittal needs to include technical reports with calculations used to derive the allocations of loads among pollutant sources. A TMDL study determines the loading capacity based on a water quality standard (or other quantifiable goals). Loads are allocated among pollution sources so as to not exceed the loading capacity. The loading capacity should equal the sum of the loads from point source waste load allocations plus loads from nonpoint source load allocations, and a margin of safety (MOS) to account for uncertainty (EPA, 1991). The MOS can be a specific allocation or be included into the other allocation by using conservative assumptions in the analysis (e.g. using an extreme low flow event with maximum loading during modeling). An allocation can also be set aside as a reserve for future growth.

TMDLs can also be established for water quality problems that are difficult to quantify as loads. TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. The ability to express TMDLs using other appropriate measure is a key concept in nonpoint source controls. For example, TMDLs have been established for fecal coliform using the goal of meeting a concentration goal instead of attempting to estimate billions of organisms per day.

3. Anticipated control action and implementation schedule

Control measures are designed to address the problem and a schedule for implementation is created. Several alternative pollution control strategies may be proposed for public review. After a strategy has been selected, projected dates to reach target conditions and final goals are identified.

The TMDL documentation needs to include copies of plans for the implementation of control actions. This includes permits, nutrient management plans, applicable ordinances, and intergovernmental agreements that outline roles and responsibilities for implementing the actions. The plans should also include a schedule of when such actions will be implemented.

Where nonpoint source controls are involved, it is recommended that a phased TMDL be established. A phased TMDL can be developed where uncertainty is a factor, where estimates involve best professional judgment, or where non-chemical stressors are involved. A TMDL developed under a phased approach should include a monitoring plan and a schedule of when it will be determined whether TMDL revisions are needed.

4. Public participation

This component of a TMDL includes specific interactions with the public designed to ensure adequate consultation and public involvement in decision making. This is the most important aspect of TMDL development. Without public support of the TMDL, experience has shown that the pollution control strategy derived will not be sufficiently implemented.

The TMDL documentation should include copies of materials showing that a public process has been conducted. This insures that the public commitment to agreements formed are not questioned or discounted in the future. The TMDL public participation program should consist of the 4 elements described below:

1) Information and Assistance - All information used in the development of a TMDL process must be available to the public. In addition, a list of interested and affected parties needs to be compiled and maintained.

2) Public Notification - All interested and affected parties must be notified in advance of when major decisions will be made. The notices should include a timetable in which the decision will be made, issues under consideration, alternative courses of action, and how relevant documents may be reviewed, and the name of an individual to contact for more information.

3) Public Consultation - Interested and affected parties should be consulted before any decisions on alternatives are made. Consultation may take many forms including public forums, public meetings, advisory groups, ad hoc committees, task forces, or workshops.

4) Responsiveness Summary - After an open public comment period all comments and a response should be compiled into a summary document. This document must summarize the public's views, significant comments, criticisms and suggestions. Specific responses must be set forth by modification of the proposed alternative or an explanation for the rejection of any proposals made by the public.

5. Follow-up monitoring

Monitoring is needed to assess progress toward meeting TMDL goals and targets. From the results of the monitoring, affected parties decide whether the TMDL is on track toward meeting water quality goals.

As part of the TMDL documentation, the monitoring plan must be included and the entities committing to the monitoring must be identified. All monitoring data should be evaluated periodically to assure that the TMDL implementation is effective. If future monitoring shows that the TMDL is not adequately effective, the TMDL should be modified and the control actions altered as appropriate.

Goals and Targets

Most TMDLs will use a combination of water quality standards, goals, and targets to make management decisions. Goals are related primarily to support of a characteristic use defined in the water quality standards. Targets are generally indicators of ecosystem improvement and habitat quality, but need not be a measure of characteristic use. Targets are interim steps that lead to the final goal. In some cases, final goals and targets will be the same.

All TMDLs should have specific goals for support of characteristic uses. A goal could be related to fish spawning, lake productivity, or public health. Some of these goals rely on some biological factor. In some cases the goal is represented by a numeric water quality standard (e.g. Phosphorus). The water quality standard is designed to protect beneficial uses.

Where a goal is not based on numeric water quality standards, habitat characteristics play an important role in the management strategy of a TMDL. The goal might be to increase spawning by 25%. This spawning increase is needed to meet a designated use. Certain habitat characteristics such as pool/riffle ratio may be determined as a controlling factor. A target might then be set to increase the pool/riffle ratio by 15% over the next 20 years through the implementation of a management plan designed to reduce coarse sediment (from landslides) and to increase the amount of large wood in the stream.

In the example above, circumstances outside the basin will have to be evaluated if the goal has is not met. Obviously, decisions about fish harvest levels and upstream land uses are important when numbers of spawners is concerned.

The assumption is then made that providing adequate habitat will result in the attainment of the beneficial use goal (e.g. increased spawning). However, other outside factors (e.g. harvest levels, predation) or watershed factors (e.g. fires, droughts, floods) may also influence the outcome.

To establish a goal or target, a public process is needed. Participants should identify the characteristic uses in the watershed and evaluate the factors influencing those uses. All available information from existing standards, literature, government goals, and other watershed specific data should be considered. Once this information has been evaluated, the participants should identify their goals and targets to be measured

Developing Technical Information and Making Decisions

Developing a TMDL requires a common sense approach to watershed level protection involving evaluation, decision making and follow-up. The questions outlined below are designed to assist affected parties with determining what types of information and decisions are needed for a successful TMDL. The information is presented in the form of questions:

- **What are the characteristic uses of the waters (present and future) in the watershed?**
- **Are the characteristic uses of the waters currently supported? If not, which uses in which waters?**
- **What is the nature of the impairment?**
- **What are the likely causes of the impairment of these uses? To what degree is the impairment natural and man-caused?**
- **Are there priority waterbodies in the watershed?**
- **What are the targets and/or goals for these priority watersheds?**
- **What alternative pollution control strategies will achieve standards?**
- **Which alternative pollution control strategy is acceptable to the public?**
- **What resources have been identified to implement these pollution controls?**

These questions should be addressed and discussed in a public forum. All interested and affected parties in the watershed should be represented in these discussions. Particular attention should be paid to participation and input from landowners and users of the water resources.

It is vital that the public understands the nature of the impacts to characteristic uses and the sources of impairment. Public involvement is also important in the determination of the desired future condition for the watershed (targets and goals). Public support for the plan and its implementation will largely determine the success of the TMDL.

Where established water quality standards are exceeded in a watershed, meeting the standard must become a final goal. The public should be informed of the need to meet water quality standards and the necessity to establish this goal based on the standards. Where habitat problems are resulting in non-attainment of characteristic uses, goals based on characteristic uses and targets based on narrative criteria are needed. The public must be involved in the determination of both final goals and interim targets. All available technical information pertinent to the situation should be used to make this determination. Education of some interested parties may be necessary.

Once targets are established, a very important step is to identify the activities that need to be implemented on the site to reach the goal. This may be straight forward, or it may be very complex. A best estimate of the needs should be identified and implemented as broadly as appropriate in the drainage of concern. The practices most likely to address the problem directly are the best course of action initially.

The desired future condition or target water quality condition for the watershed should be established in a public forum. Along with identifying the target condition, an approximate timetable established for reaching the target. For long-term TMDLs interim targets and monitoring should be identified to test the effectiveness of control activities.

It is important that the time frame and expectations for water quality improvement be realistic and based on good science. Some improvements can be realized in a relatively short amount of time. On the other hand, projects relying on natural processes may take a long time to reach targets and should propose interim targets for the TMDL.

The Importance of Monitoring

Monitoring to test the effectiveness of pollution controls is an important component of a TMDL. As a key part of the plan, participating parties should agree to a monitoring and feedback approach that allows for the determination of TMDL effectiveness. Timelines for achieving goals should be established and all parties involved in the planning process need to agree with the commitments.

A unique aspect of TMDLs is the recognition that many variables affect the ultimate outcome of water quality. Therefore, the process calls for long-term monitoring of the affects of management changes and an agreement by all parties to evaluate the progress through time. Monitoring provides the basis for "phasing in" management decisions as part of the TMDL process. All parties agree to long-term solutions through an iterative process. This usually means a refinement of the implementation plan for the TMDL and changes to implementation if goals are not being attained.

The primary focus of evaluations should be to determine if sufficient progress is being made toward the targets. The TMDL process does not assume that problems in a drainage will be solved with the first estimate of what is needed. Thus the phased concept kicks in and allows for interim alterations to the implementation plan. Issues likely to impact the effectiveness of the TMDL at meeting its targets include the following: Some landowners may not be cooperating (BMPs not applied); the BMPs chosen may not be adequate; an unusual climatic change or other natural event; or the watershed dynamics may not be well understood.

The key is in the monitoring and feedback loop. Once implementation begins, progress should be monitored against the desired future condition and interim targets. Data should be evaluated by the interested and affected parties, and modifications to the management plan should be implemented as needed to get the process back on target. Feedback discussions and review of data should occur at regular intervals. As in the temperature or sediment examples, the interested and affected parties should review the results and commitments in the TMDL on a regular basis. Some projects may need annual reviews. The actual review periods will depend on the time frame established for monitoring the interim targets.

Changes needed at the review time may involve any of the following: alteration of time-frames, additional education and outreach, updating BMPs, focused restoration, improved compliance inspections, and enforcement actions where necessary. In some cases, the participants may find that the target is unreasonable or unreachable. Modifications to the TMDL target will need to be discussed with affected parties.

Monitoring should be carried out throughout the life of the TMDL. Monitoring activities can be the responsibility of the local government, a local entity, or an individual or group of landowners. The responsible party should be identified in the TMDL.

An adequate monitoring program has three components:
- track implementation of BMPs or other controls;
- track water quality improvements; and
- track progress toward meeting water quality standards (targets).

Regular reports should be prepared presented to affected parties on a routine basis. Reporting dates should correspond to planned interim monitoring points in the schedule. Data for these reports should be collected and analyzed in such a manner that routine reviews of progress can be carried out by the affected parties. Responsible parties should be encouraged to present monitoring results with local participants, and a review of program adequacy and targets should be discussed.

The failure to consistently implement the agreed upon management practices is the primary cause for lack of progress in achieving goals or targets in a TMDL. This may be due to a lack of education, political support, enforcement, funding, or any combination of these factors. A second likely case is related to inadequate management measures identified in the plan. If the management measures don't work, targets will not likely be reached. Improved knowledge of the area may be cause to reassess targets. However, justification for a change to the targets should be well documented and all involved parties should be involved in the decision.

Advantages of Establishing a TMDL.

TMDLs have numerous advantages from a process, water quality and public acceptance standpoint. TMDLs provide a common sense process for evaluating watershed needs and designing activities to specifically address water quality problems. These activities have a reasonable likelihood of achieving water quality goals.

TMDLs may also address regulatory needs. For some they represent a threat; for others protection. The TMDL processes provide a handle to convince landowners and government to achieve real water quality and habitat improvement. Completion of a TMDL should provide to some a certain level of protection from additional unexpected regulatory burdens from government. Any TMDLs completed should be viewed as a major success if for no other reason than a local effort is underway to address local needs.

Efforts should be made to incorporate TMDL principles into many water quality improvement activities. Although each planning effort will be unique, a standard sequence of actions will allow government officials to work more effectively with local interest.

Local efforts are the key to a successful TMDL process. They should be fostered on a variety of scales wherever there are willing parties around the watershed. In all the planning and implementation efforts, advocates should be encouraged to adopt this approach so that their efforts will have a higher likelihood of success. Only a systematic approach such as this will provide the kind of water quality results needed to achieve broader water quality goals across the watershed.

What the public should know about TMDLs

The concept of TMDLs is difficult to explain to the public. Maximum daily loading for a nonpoint source pollutant is very difficult to visualize. In light of these difficulties, a different term should be for communicating these concepts to the public: **Water Quality Management Strategy**.

Since the objective is to move people to take action locally, some simple terminology should be used to explain what needs to happen for acceptable water quality improvements to occur. The TMDL concepts combined with water quality standards provide an excellent framework to increase the likelihood of success. The term Water Quality Management Strategy is a clearer term for describing what is going to happen.

In outreach efforts, it may be of benefit to not referring to the process as a TMDL. The focus should be on the end result (improved water quality) and making sure the TMDL steps are followed to help ensure success.

Water Quality Criteria and Beneficial Uses of Waters

Water quality criteria specify concentrations of water constituents which, if not exceeded, are expected to result in protection of the beneficial uses of the water. Such criteria are derived from scientific facts obtained studies that measure effects of different concentrations on particular water uses. Often times these criteria are adopted by governments as standards, and therefore are binding to law. However, many criteria are not officially adopted as standards and are used for advisory purposes.

Three criteria for phosphorus apply to Ruzín Reservoir and the waters in its watershed. Each of these criteria is directed at a particular beneficial use of these waters.

Aquatic Life: The following total phosphorus criteria have been adopted as standards in the Slovak Republic to protect aquatic life in rivers and streams (STN 75 72 21).

1. Below 0.03 mg/L = Very Clean Water
2. Below 0.15 mg/L = Clean Water
3. Below 0.40 mg/L = Polluted Water
4. Below 1.00 mg/L = High Level of Pollution
5. Over 1.00 mg/L = Very High Level of Pollution

Domestic Water Supply: Phosphate phosphorus concentrations in excess of 0.10 mg/L may interfere with the distribution systems of water supply facilities (EPA, 1986). Treatment processes such as coagulation and filtration may be impacted from phosphate phosphorus concentrations above this level.

Recreation and Aesthetic Enjoyment: To prevent the development of biological nuisances and control accelerated eutrophication, phosphate phosphorus should not exceed 0.050 mg/L at the point where it enters a lake or reservoir (EPA, 1986). Eutrophication can impair aesthetic enjoyment by forming scums on the surface and increase noxious aquatic weeds that tangle boat propellers and swimmers.

Ruzín Reservoir and Watershed Characteristics

The study area covers the Upper Hornád River watershed upstream of Ruzín Reservoir in the eastern Slovak Republic (Figure 1). The Hornád River accounts for 72% of the of the nutrient loading to Ruzín Reservoir. The reservoir has several other tributary streams, like the Hnilec River, entering the system which were not evaluated in this study. The total watershed size of Ruzín

Reservoir is 1929 square kilometers, where the Upper Hornád River accounts for 1146 square kilometers (59%) of that area.

Ruzín reservoir has the following characteristics:

Total capacity is 59 million cubic meters
Storage capacity is 45.3 million cubic meters
Retention capacity is 7.4 million cubic meters
Constant capacity is 6.3 million cubic meters
Maximum retention elevation is 327.6 meters
Maximum functional elevation is 325.6 meters
Minimum functional elevation is 298.0 meters

The Upper Hornád River watershed was delineated into 17 subbasins for modeling analysis (Figure 2). These subbasins were named for the purposes of this report according to the major local stream or city within that area. Land cover data were obtained from the third hierarchy CORINE geographic information system coverage developed from the European Phare Project methodology. This land cover information was intersected with the subbasin delineation's to allow modeling of nonpoint source phosphorus loads within each area (Table 1).

Point source discharge locations were identified on the rivers and streams in the watershed. Only significant sources were used in the modeling based on a total annual loads of 0.3 metric tonnes of biological oxygen demanding substances. From this information, treatments levels were estimated and expected nutrient loads were compiled from published Technical literature (table 2).

Review of Monitoring Data

Three types of monitoring data are required to develop the water quality model: climate, stream flows and concentration of water quality constituents. These data were compiled for the years of 1996 and 1997. Of the data received, the period from April 1996 to February 1997 contained sufficient data to run the model.

A review of the water quality data collected in the watershed showed that phosphorus concentrations are generally the highest at the station below the village Kluknava at Hornád River kilometer 92.1. This observation is expected since phosphorus generally acts as a conservative substance with few mechanisms for removal in stream systems. Since this station has the closest measurements of phosphorus to the reservoir, it can be used as general indication of what concentrations are likely entering the reservoir from the Hornád River at kilometers 83. These data were collected by the Bodrog and Hornád River Watershed Management Company.

The two highest value of total phosphorus measured at Hornád River kilometer 92.1 for the study period were 0.41 mg/L in July 1996 and 0.28 mg/L in February 1997. . Data collected at these date represent the most critical conditions and were used for the model calibration and validation, respectively. Even higher total phosphorus levels (0.47 mg/L) were observed in February 1996, but the lack of flow and climate data precluded using water quality data collected on this date for the modeling analysis. These high phosphorus values are considered a "High Level of Pollution" according to the official water quality standards adopted by the Slovak Republic.

Water Quality Model Construct

QUAL2E is a comprehensive, one dimensional, steady-state stream water quality model supported by the United States Environmental Protection Agency (EPA, 1987). The model has been widely used to determine pollutant loading and response in rivers and streams. The model is capable of simulating up to 15 water quality constituents in any combination. QUAL2E was used in this study to model the accumulation, assimilation and routing of phosphorus in the Upper Hornád River watershed. All other conventional constituents (e.g. nitrogen forms, BOD) were also modeled to better represent the inter-relationships between these substances in flowing waters.

The river system was divided into 18 reaches for the modeling (Table 3). Each reach was selected based on locations of tributary inflows and assumed to generally represent uniform. Each reach is further divided into computational elements with a length of 1 kilometer, which have uniform steady-state concentrations of modeled constituents.

The model was calibrated using the data collected in July 1996 and validated with February 1997. The first step in the analysis was to balance the flows for both modeled time periods. Flows within the watershed were balanced using gauged flow data from the same day as the water quality measurements were made and adjusting the incremental flow for each model reach accordingly. Climatic data from two meteorological stations were used to for specific model reaches and estimates were made for information that was not measured (Table 4).

Significant point source loading values measured and estimated (Table 2) were input into the appropriate model element according to the discharge location. Nonpoint source loading were input into each model element based on the area of land cover in each the subbasin. The third hierarchy of land covers from the CORINE geographical information system coverage was used with published studies which measured nonpoint source loading (Tables 5 and 6). Characteristics of the published study sites were matched as closely as possible to similar characteristics in the Hornád River watershed.

Model output was compared to data collected from stations at Hornád River kilometers 92.1, 100.7, 124.6, and 136.4 by the Bodrog and Hornád River Watershed Management Company.

Calibration was conducted by adjusting process parameters (e.g. algal settling rate, maximum algal growth rate) in the model using the constant state variables from July 1997 described above (Table 7). Calibration adjustments of model parameters were made within acceptable ranges until model output reasonably matched measured concentrations (Figure 4). Validation was conducted by using the same parameter values determined through calibration with the state variables for February 1997 (Figure 5). The validation data showed that model performance can has an explained variance of 81% in predict measured conditions (Table 8).

Phosphorus Loading Analyses

Development of a TMDL involves the estimation of existing loads. The calibrated water quality model was used to determine the relative phosphorus loads entering Ruzín reservoir. Loads were determined for each subbasin and various pollution source categories. Both total phosphorus and phosphate phosphorus (e.g. dissolved form) were assessed since applicable criteria apply to both.

Over two-thirds of the phosphorus load to the reservoir comes from point sources within the watershed (Table 9). Nearly half of this load comes form two subbasins: Markušovce and Richnava (Table 10). Most of the impact from point sources comes from three discharges: VK Spišská Nová Ves, VK Levoca, and VK Krompachy (Table 11). Not suprisingly, two of these point sources are in the same subbasins that contain the largest loads of phosphorus. The river does not appear to assimilate much of this loading (Figures 4 & 5).

Of the nonpoint source load contribution to the reservoir, Nearly half comes from agricultural sources (Table 12). The bulk of these agricultural loads come from areas mixed with natural vegetation (Table 13), since this is also the largest of the agricultural land cover areas in the watershed. Forested lands account for nearly a third of loading, with most of that originating from scrublands (Table 14). Urban areas contribute a quarter of the phosphorus loads, mostly from the discontinuous urban fabric (Table 15).

Phosphorus Loading Reductions

Establishing a TMDL involves assessing the reduction in loads of specific pollution control activities to achieve goal or targets. The calibrated water quality model was used to estimate the effect of various pollution controls on phosphorus concentrations entering Ruzín Reservoir.

One of the major sources of phosphorus loading to the reservoir is domestic wastewater. The water quality model was run to test the predicted effect on for two wastewater treatment scenarios. The first is to upgrade the 5 facilities that are below secondary treatment to that standard.

Secondary treatment is the level of treatment required by all dischargers in the United States. Secondary treatment involves unit operations beyond simple screening or settling of solids. Secondary treatment for domestic waste uses the activated sludge process which includes the unit operations of aeration and clarification. The model was also run to test the effect on loading to the reservoir if all significant domestic wastewater received tertiary treatment. Tertiary treatment if often used in the United States for wastewater that impact lakes and reservoirs. Tertiary treatment typically involves the unit operation of biological phosphorus removal and had a median removal efficiency of 80% (Metcalf and Eddy, 1991).

The model predicts that upgrading the 5 domestic wastewater discharges currently discharging raw or primary effluent to secondary treatment will result in only a 7% reduction in total phosphorus and a 9% reduction in dissolved phosphorus entering the reservoir (Table 16). If all significant domestic wastewater facilities were upgraded to tertiary treatment the reservoir would receive a reduction of 25% total phosphorus and 26% dissolved phosphorus. In both of these cases, the river would still fail to meet any of the criteria established for protection of beneficial uses during critical conditions.

The water quality model was also used to predict treatment approaches for the animal waste discharging from the farm near Spišská Vlachy at Hornád kilometer 109.7 (Table 16). Three separate treatment approaches were tested with the model: (1) an animal waste system incorporating methods for collecting, storing, and disposing of wastewater, (2) a diversion system to route uncontaminated storm water away from animal confinement areas, and (3) a containment structure for manure, such as waste storage ponds or treatment lagoons (EPA, 1993). The water quality model predicted that applying either of these treatment approaches alone has no effect on the phosphorus entering the reservoir. The wastewater from the farm has no direct effect on the phosphorus loading due to the small volume of discharge and the distance available for nutrient assimilation by the river (27 kilometers).

The water quality model was also used to predict the effect of agricultural best management practices on phosphorus loads to the reservoir (Table 16).Three separate best management practices were tested with the model: (1) reduced tillage systems which include practices such as conservation tillage, no-till, and crop residue use, (2) terrace systems, and (3) filter strips, which add vegetative buffer areas between crop areas and streams (EPA, 1993). The model predicted that reduced tillage systems applied to agricultural lands (CORINE codes 211, 222, 242, 243) throughout the watershed would reduce total phosphorus entering the reservoir by 13%, terrace systems by 20%, and filter strips by 23%. In each of these cases, the river would still fail to meet any of the criteria established for protection of beneficial uses during critical conditions.

The water quality model was also used to predict the effect of various urban stormwater treatment systems on the phosphorus entering the reservoir. Four different stormwater treatment systems were tested with the model: (1) use of catch basins, (2) dry ponds for flooding control modified to increase nutrient removal, (3) use of wet ponds, and (4) vegetative filter strips.). The model predicted that catch basins installed in urban areas (CORINE codes 112, 121, 142) throughout the watershed would reduce dissolved phosphorus entering the reservoir by 6%, but not reduce total phosphorus at all. For the other approaches, dry ponds would reduce total phosphorus by 12%, wet ponds by 16%, and vegetative filter strips by 13%. In each of these cases, the river would still fail to meet any of the criteria established for protection of beneficial uses during critical conditions.

Since none of the pollution control methods tested with the model is sufficient alone to meet phosphorus criteria, a combination of these must be used to achieve the criteria. The water quality model was used to predict the phosphorus concentration entering the reservoir using each of the all of the most efficient pollution controls for domestic and animal wastewater, agricultural best management practices, and urban storm water treatment (Table 16). If each of these approaches is applied throughout the watershed, total phosphorus entering the reservoir is reduced by 62%. However, the concentration at critical conditions is still predicted to be just above the Slovak Republic level 2 criterion for "clean water" which protects aquatic life uses.

An option sometimes used in the United States is the complete removal of wastewater discharges from rivers, with the wastewater applied to land for irrigation of agriculture. It is questionable whether this option is feasible, since there is not likely sufficient land areas available to receive such large volumes of wastewater if applied at agronomic rates. If the land application of domestic wastewater was not conducted correctly, the phosphorus would still find its way to the reservoir through surface runoff or groundwater loading.

The water quality model was used to test whether removal of one or more domestic wastewater discharges would result in achieving the "clean water" criterion (Table 16). Complete removal of the discharge with the largest load to the reservoir (VK Spišská Nová Ves) coupled with application of the most efficient pollution controls for the other sources still would not meet the criterion. In order to meet the "clean water" criterion, all the other significant domestic wastewater sources would also have to be removed completely (VK Levoca, VK Margecany, and VK Krompachy 1&2). With this maximum level of pollution control, the "clean water" criterion could be met, but criteria recommended for domestic water supply, recreation, and aesthetic enjoyment would not be met. There is no reasonable way to meet these criteria. The only way to achieve these levels would be to convert agricultural and urban lands back to forested areas that have a naturally low phosphorus loading.

Recommended Pollution Reduction Strategy

Since it is not likely feasible to achieve the phosphorus criteria at critical conditions without extreme management efforts, the reasonable approach would be to devise a Water Quality Management Strategy which uses a phased approach. The best way to establish this strategy is through an iterative process between technical analysis and public consultation. The process is started by proposing a series of pollution reduction measures that would when applied in combination likely produce the best results for the level of effort and cost involved. The likely results of this strategy would be predicted from the water quality model. The information could then be presented in various public forums, community meetings, or special workshops for affected parties. Suggested modifications to the strategy could be tested with the model. Through this iterative process a consensus may be formed on what is achievable politically and economically. Then, as the strategy is implemented, new information can be collected that would improve the model predictions. Water quality monitoring should also be conducted to verify that the expected results are being achieved.

The Water Quality Management Strategy proposed here should be used as only the beginning. Implementation of the proposed pollution controls will likely only occur through public empowerment. Controls that are mandated from higher authorities will likely never be actually put in place correctly. As public discussion occurs on the strategy it should be modified and improved upon. Only through environmental education and participation of affected parties and the public using the water resources can progress toward the goal of cleaner water be achieved.

The Water Quality Management Strategy proposed here is based on assumptions of what controls are economically and politically achievable in the near future that would produce the greatest results in reducing the phosphorus loading to Ruzín Reservoir. Below is a description of the strategy proposed.

1. It seems reasonable that all domestic wastewater should receive secondary treatment. This is the standards level of treatment required of all dischargers in many Western Countries. Because of this widespread use, secondary treatment standards are technically and economically easy to implement.

2. In addition, the treatment facility at Spišská Nová Ves should be upgraded to tertiary treatment for phosphorus removal since it is contributing a major portion of the load to the reservoir. Again, tertiary treatment standards have been applied to numerous facilities in Western Counties and the technology is easy to implement. The only drawback is the costs for constructing the upgrade may be higher than the local tax base can cover. Economic assistance from the national government may be needed for such an upgrade.

3. Vegetative filter strips should be established for control of stormwater and agricultural runoff. These have been shown to have the greatest efficiency at removing phosphorus from nonpoint

sources. Since it would be difficult to manage a process which could apply these controls everywhere over the entire watershed, only a few subbasins should be targeted for the first phase. Working in subbasins closer to the reservoir that have a high proportion of urban and agricultural land uses would get the most reduction in loading for the effort applied. The 3 subbasins, Olenava, Branisko, and Richnava, each have about three-quarters of their land use in agriculture and urban areas and are just upstream of the reservoir. These subbasins should be the focus of the efforts to establish vegetative filter strips. It is assumed that a 50% participation rate is a reasonable expectation for this activity.

The water quality model predicts that the above strategy will result in a total phosphorus reduction of 58% entering Ruzín Reservoir. The strategy is predicted give a total phosphorus concentration of 0.260 mg/L and a dissolved phosphorus concentration of 0.200 mg/L at critical conditions. Even though these are below the criteria for protection of beneficial uses, the reduction should reduce the amount of time uses are impaired. As improvements are observed, public interest will likely increase and more opportunities for further reductions will be accepted.

One complication to applying these recommendations is the financing structure for wastewater treatment used in the Slovak Republic. Currently, the communla management company must finance their own systems, even in rural areas. In these cases, industrial and municipal wastes are defined as toxic wastes, so financial constarints apply. This situation makes it difficult for communities and industrial facilities to obtain funding to upgrade wastewater treatment facilities.

Recommendations for Further Study

This report should be considered as the first step in the cleanup of pollution. As with all modeling exercises, the analysis presented here used many assumptions to provide results. It is simply not practical to measure every parameter needed for the model. As such, there are many improvements that could be made in the model and predictions with more monitoring data and more sophisticated techniques. Below is listed some recommendations that could be pursued:

Enhanced monitoring of streams within the watershed. Only two parties are now monitoring a limited number of stations in the watershed. The monitoring program coordinated by SOSNA does not collect data during winter months. Increasing the number of stations to include the mouths of each on the tributary subbasins could provide be used to recalibrate the model. At a minimum, the water quality from those subbasins where pollution reduction activities are implemented should be monitored to assess effectiveness of the controls.

Obtain local land use export loading values. All of the phosphorus loading estimates for nonpoint sources was obtained from data published in the literature. Even though efforts were made to select values based on similarities in other factors (e.g. weather, crop types, etc), actual export loading values are likely to be somewhat different. Local gray literature may have better estimates of these values. Also, some monitoring of specific land covers may be used to obtaining better values.

Additional monitoring data from point sources. The data obtained for the point sources was limited. Many of the effluent concentrations and treatment levels were assumed based on the information obtained. Only mean values were used for the modeling. Knowledge of daily maximum values for each of the input parameters would greatly improve the modeling estimate. A distribution of effluent concentrations and flows over time would allow assessment of risks.

Reservoir response modeling and monitoring should be conducted. Trophic state measures such as chlorophyll *a*, secchi depth, and total phosphorus should be routinely collected in the reservoir. Impairments to beneficial uses should be compiled for assessing the data against observed impacts such as excessive algal blooms. A lake response model should be developed to assess whether the measured or predicted phosphorus loads will have the assumed impacts to beneficial uses.

Trophic state needs of fisheries should be evaluated. Often use of standardized criteria in management decisions on pollution control does not match the needs of particular waters. Balancing the trophic state to support a healthy fishery and maintaining other beneficial uses can be difficult. Certain fishery stocks may improve with increased amount of phosphorus loading, while other stock decline. Reducing phosphorus to protect against filtration problems for water supply or aesthetic enjoyment may decrease certain fishery stocks that are of economic importance. Evaluating the correct phosphorus loading specific to Ruzín Reservoir for the correct balance of beneficial uses is both a technical and social challenge. These issues should be discussed in a public forum.

Stochastic modeling should be conducted to provide risk assessment of viable approaches. The results presented are given in deterministic answers. These are simple to understand, but do not reflect the variability associated with various constituents used in the model. The model used was calibrated using the worst case situation measured of the data obtained. There was other periods of time for which water quality pollutant levels were lower. Knowledge of the distribution of these variables could be used in a Monte Carlo modeling approach to give answers described in risk-based terms. This type of analysis would provide results related to the frequency that a particular criterion would be exceeded, instead of the absolute result provided by modeling steady state at critical conditions.

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Table 1. Land Cover Areas of Subbasins Modeled in the Upper Hornád River Basin

Subbasin Name	**Area**	**Urban**		**Agriculture**		**Forested**	
	hectares	hectares	Percent	hectares	Percent	hectares	Percent
Bellanovce	2,778	221	8%	213	8%	2,345	84%
Branisko	11,232	4,188	37%	5,611	50%	1,433	13%
Brusník	4,214	214	5%	530	13%	3,469	82%
Gánovský	3,344	485	15%	1,829	55%	1,029	31%
Holubnica	6,004	528	9%	501	8%	4,975	83%
Kolinovce	5,011	744	15%	1,529	31%	2,737	55%
Levocský	15,425	1,944	13%	5,197	34%	8,284	54%
Markušovce	2,206	646	29%	321	15%	1,238	56%
Matejovce	12,468	3,998	32%	5,213	42%	3,258	26%
Olenava	6,809	3,787	56%	1,361	20%	1,661	24%
Richnava	9,471	395	4%	6,350	67%	2,726	29%
Sliavnik	1,209	85	7%	272	22%	851	70%
Slovinský	7,694	411	5%	3,615	47%	3,667	48%
Tomášovce	6,651	487	7%	252	4%	5,912	89%
Vel'ká-Biela	4,512	6	>1%	466	10%	4,040	90%
Vernársky	4,089	146	4%	414	15%	3,529	86%
Vidkartovce	11,442	272	2%	2,617	23%	8,552	75%
Entire Basin	114,557	18,558	16%	36,292	32%	59,707	52%

Table 2. Characteristics of Significant Point Sources in the Upper Hornád Watershed ①

Facility Name ②	Location ②	Waste Type ⑥	Treatment Level ③	Flow (m^3/s) ②	BOD_5 (mg/L) ②	Org-N (mg/L) ④	NH_3 (mg/L) ④	NO_2 (mg/L) ④	NO_3 (mg/L) ④	Org-P (mg/L) ⑤	PO_4 (mg/L) ④
Verejná kanalizácia Spišská Nová Ves	Hornád km 127.4	Domestic	Secondary	0.2550	14.0	6.1	7.9	0.19	1.30	0.50	1.60
Verejná kanalizácia Levoca	Levocský km 15.2	Domestic	Secondary	0.0530	20.0	6.1	7.9	0.19	1.30	0.50	1.60
Farma ošípaných Sp. Vlachy	Hornád km 109.7	Animal	None	0.0009	60.0	39.2	80.0	0.08	30.80	1.00	3.30
Sp. kamenopriemysel Sp. Vlachy	Hornád km 107.2	Quarry + Domestic	Dilution of Raw 4:1	0.0003	43.7	3.8	6.3	0.02	0.05	0.80	2.50
Verejná kanalizácia Sp. Vlachy	Branisko km 1.4	Domestic	Secondary	0.0011	28.0	6.1	7.9	0.19	1.30	0.50	1.60
Zelba Solvinky Odtok z odkaliska(2pts)	Slovinský km 4.4	Mining	NA	0.0059	3.7	0.2	0.2	0.09	2.70	0.02	0.05
Verejná kanalizácia Krompachy (pt 1)	Slovinský km 0.9	Domestic	Primary	0.0025	90.0	13.0	22.0	0.06	0.19	1.60	7.70
Verejná kanalizácia Krompachy (pt 2)	Hornád km 98.8	Domestic	Raw	0.0110	140.0	15.0	25.0	0.06	0.19	3.00	10.00
Verejná kanalizácia Krompachy (pt 3)	Hornád km 97.2	Domestic	Primary	0.0025	84.9	13.0	22.0	0.06	0.19	1.60	7.70
Kovohuty Krompachy (pt 1)	Hornád km 97.8	Mining	NA	0.0231	5.9	0.2	0.4	0.04	4.20	0.03	0.15
Kovohuty Krompachy (pt 2)	Hornád km 97.5	Mining	NA	0.0319	5.9	0.2	0.4	0.04	4.20	0.03	0.15
SEZ Krompachy	Hornád km 96.6	Power Plant	NA	0.0315	5.7	0.2	0.4	0.04	4.20	0.03	0.15

Verejná kanalizácia Margecany	Hornád km 83.2	Domestic	Raw	0.0030	187.0	15.0	25.0	0.06	0.19	3.00	10.00

Footnotes to Table 2:

NA = Not Applicable for nutrients. Used background ambient water quality data provided by Bodrog and Hornád River Watershed Management Company.

① Significant is defined as point sources with a annual mean load greater than 0.3 metric tonnes per year.
② Information provided by by Bodrog and Hornád River Watershed Management Company.
③ Assumed from the BOD_5 levels (for domestic wastewater per Leo, et al. 1984 and Thomann, 1972).
④ Estimated from assumed treatment (for domestic wastewater per Mueller, et al. 1982 and Metacalf and Eddy, 1972
for swine wastewater per Gupta and Kelley, 1990).
⑤ Difference between Total P and Ortho-P (for domestic wastewater per Mueller, et al. 1982).
⑥ Information provided by Nadacia SOSNA

Table 3. Modeled Stream Geometry of the Upper Hornád Basin

Reach Number	**Reach Name**	**Length** (km)	**Begin Reach** (km)	**End Reach** (km)
1	Hornád River - Vidkartovce	18	178	160
2	Vernársky Potok	14	14	0
3	Hornád River - Spišsky Sliavnik	7	160	153
4	Gánovsky Potok	11	11	0
5	Hornád River - Bellanovce	5	153	148
6	Vel'ká Biela Voda	19	10	0
7	Hornád River - Spišske Tomášovce	13	148	135
8	Hornád River - Holbnica	5	135	130
9	Brusník Potok	19	19	0
10	Hornád River - Markušovce	7	130	123
11	Upper Levocský Potok	10	28	18
12	Lower Levocský Potok	18	18	0
13	Hornád River - Matejovce	9	123	114
14	Hornád River - Olenava	7	114	107
15	Branisko Potok	20	20	0
16	Hornád River - Kolinovce	8	107	99
17	Slovinský Potok	16	16	0
18	Hornád River - Richnava	16	99	83

Table 4. Climate Values Used in Stream Model

Weather Station	Reaches Applied to	Monthly Mean from ④	Cloud Cover (fraction of sky)	Dry Air Temperature (degree C)	Dew Point Temperature (degree C)①	Solar Radiation (Langley/hr)②	Wind Speed (meter/second) ③
Gánovce (730 m elevation)	1 through 12	June 1996	0.58	15.2	11.4	140	8
		July 1996	0.60	14.5	11.4	140	8
		Feb. 1997	0.49	-1.4	-5.4	80	8
Spišská Vlachy (388 m elevation)	13 through 18	June 1996	0.60	16.7	9.8	140	8
		July 1996	0.69	15.6	9.7	140	8
		Feb. 1997	0.57	-2.5	-5.3	80	8

Footnotes to Table 4:

① Mean of daily values calculated from daily mean relative humidity and air temperature (Linsley, et al. 1982)
② Data not available. Used monthly mean from Spokane, Washington, which has a similar continental weather and latitude.
③ Data not available. Used annual mean from Spokane, Washington, which has a similar continental weather and latitude
④ Data on Barometric pressure not available. Used median of acceptable range for the model (1000 millibars)

Table 5. Non-Point Source Loading Rates used for Phosphorus Species, Biochemical Oxygen Demand, and Total Suspended Solids

Land Cover Type	CORINE **Level 3 Code**	**Dissolved Phosphorus Loading**		**Organic Phosphorus Loading**		**BOD_5 Loading**		**TSS Loading**	
		(kg/ha/yr)	Reference	(kg/ha/yr)	Reference	(kg/ha/yr)	Reference	(kg/ha/yr)	Reference
Discontinuous Urban Fabric	112	0.63	8	0.47	8	19	12	210	12
Industrial/Commercial Units	121	2.39	1	1.78	1	19	12	210	12
Mineral Extraction Sites	131	0.87	1	9.20	1	19	12	210	12
Dump Sites	132	0.87	1	9.20	1	19	12	210	12
Sport and Leisure Activities	142	0.63	8	0.47	8	19	12	210	12
Non-irrigated Arable Land	211	0.22	3	0.43	3	18	10	450	6
Fruit Trees and Berry Farms	222	1.10	8	1.14	8	18	10	450	6
Pasture Lands	231	0.40	5	0.45	5	11	10	340	6
Cultivated Agriculture	242	0.32	2	0.33	2	18	10	450	6
Agriculture in Areas with Mostly Natural Vegetation	243	0.63	4	0.23	4	11	10	340	6
Broad-leaved Forest Lands	311	0.16	11	0.12	11	5	10	85	6
Coniferous Forest Lands	312	0.19	9	0.13	9	5	10	85	6
Mixed Forest Lands	313	0.27	7	0.01	7	5	10	85	6
Natural Grasslands	321	0.31	3	0.04	3	5	10	85	6
Schrublands	324	0.27	7	0.01	7	5	10	85	6

References:

1. Betson, 1978.
2. Burwell, et al. 1974.
3. Burwell, et al. 1975.
4. Campbell, 1978.
5. Chichester, et al. 1979.
7. Krebs and Golley, 1977.
8. Reckhow, 1980.
9. Salminen and Beschta, 1991.
10. Shahane, 1982.
11. Timmons, et al. 1977.

6. Horner, et al. 1986.

12. U.S. EPA, 1983.

Table 6. Non-Point Source Loading Rates used for Nitrogen Species

Land Cover Type	CORINE **Level 3 Code**	**Ammonia Loading**		**Nitrate Loading**		**Nitrite Loading**		**Organic Nitrogen Loading**	
		(kg/ha/yr)	Reference	(kg/ha/yr)	Reference	(kg/ha/yr)	Reference	(kg/ha/yr)	Reference
Discontinuous Urban Fabric	112	0.33	7	2.04	7	0.0408	10	3.14	7
Industrial/Commercial Units	121	0.83	1	5.62	1	0.1124	10	8.50	1
Mineral Extraction Sites	131	0.44	1	3.14	1	0.0628	10	9.20	1
Dump Sites	132	0.44	1	3.14	1	0.0628	10	9.20	1
Sport and Leisure Activities	142	0.33	7	2.04	7	0.0408	10	3.14	7
Non-irrigated Arable Land	211	0.29	3	1.57	3	0.0314	10	0.71	3
Fruit Trees and Berry Farms	222	1.35	7	1.08	7	0.0216	10	6.57	7
Pasture Lands	231	0.43	8	0.96	8	0.0192	10	2.89	8
Cultivated Agriculture	242	1.37	2	1.19	2	0.0238	10	7.08	2
Agriculture in Areas with Mostly Natural Vegetation	243	0.09	4	0.09	4	0.0018	10	1.92	4
Broad-leaved Forest Lands	311	0.19	9	0.09	9	0.0018	10	1.64	9
Coniferous Forest Lands	312	0.03	5	0.004	5	0.0001	10	0.06	5
Mixed Forest Lands	313	0.28	5	0.13	5	0.0026	10	0.82	5
Natural Grasslands	321	0.80	6	1.00	6	0.0200	10	1.67	3
Schrublands	324	0.28	5	0.13	5	0.0026	10	0.82	5

References:

7. Betson, 1978.
8. Burwell, et al. 1974
9. Burwell, et al. 1975.
10. Campbell, 1978.
11. Gosz, 1978.

7. Reckhow, 1980.
8. Schuman, et al. 1973.
9. Timmons, et al. 1977.
10. Assume 2% of Nitrate Value per mean Proportion Observed at Rudniansky Potok (not affected by a municipal point source)

12. Long, 1979.

Table 7. Input File for Calibrated QUAL2E Model

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TITLE01              Upper Hornád 7/96 Flow
TITLE02
TITLE03  NO          CONSERVATIVE MINERAL I
TITLE04  NO          CONSERVATIVE MINERAL II
TITLE05  NO          CONSERVATIVE MINERAL III
TITLE06  NO          TEMPERATURE
TITLE07  YES         5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES         ALGAE AS CHL-A IN UG/L
TITLE09  YES         PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                (ORGANIC-P; DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14  NO          FECAL COLIFORM IN NO./100 ML
TITLE15  NO          ARBITRARY NON-CONSERVATIVE
ENDTITLE
LIST DATA INPUT
NO WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
NO TRAP CHANNELS
NO PRINT LCD/SOLAR DATA
NO PLOT DO AND BOD DATA
FIXED DNSTM CONC (YES=1)=        0.          5D-ULT BOD CONV K COEF  =      1.46
INPUT METRIC            =        1.          OUTPUT METRIC           =        1.
NUMBER OF REACHES       =        18          NUMBER OF JUNCTIONS     =         7
NUM OF HEADWATERS       =         8          NUMBER OF POINT LOADS   =        11
TIME STEP (HOURS)       =         0          LNTH. COMP. ELEMENT (DX)=        1.
MAXIMUM ROUTE TIME (HRS)=       30.          TIME INC. FOR RPT2 (HRS)=         0
LATITUDE OF BASIN (DEG) =       49.          LONGITUDE OF BASIN (DEG)=       21.
STANDARD MARIDIAN (DEG) =       0.0          DAY OF YEAR START TIME  =        1.
EVAP. COEF.,(AE)        = 0.0000068          EVAP. COEF.,(BE)        = 0.0000027
ELEV. OF BASIN (ELEV)   =       500          DUST ATTENUATION COEF.  =      0.13
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)=   3.50  O UPTAKE BY NO2 OXID(MG O/MG N)=   1.00
O PROD  BY ALGAE (MG O/MG A)   =   1.60  O UPTAKE BY ALGAE (MG O/MG A)  =   2.00
N CONTENT OF ALGAE (MG N/MG A) =  0.080  P CONTENT OF ALGAE (MG O/MG A) =  0.015
ALG MAX SPEC GROWTH RATE(1/DAY)=   3.00  ALGAE RESPIRATION RATE (1/DAY) =  0.300
N HALF SATURATION CONST (MG/L) =  0.150  P HALF SATURATION CONST (MG/L) =  0.025
LIN ALG SHADE CO (1/H-UGCHA/L) = 0.0050  NLIN SHADE (1/H-(UGCHA/L)**2/3)= 0.0165
LIGHT FUNCTION OPTION (LFNOPT) =     1.  LIGHT SATURATION COEF (INT/MIN)=   0.03
DAILY AVERAGING OPTION (LAVOPT)=     2.  LIGHT AVERAGING FACTOR (AFACT) =   0.92
NUMBER OF DAYLIGHT HOURS (DLH) =  15.00  TOTAL DAILY SOLAR RADTN (INT)  = 400.00
ALGY GROWTH CALC OPTION(LGROPT)=     1.  ALGAL PREF FOR NH3-N (PREFN)   =   0.90
ALG/TEMP SOLR RAD FACTOR(TFACT)=   0.45  NITRIFICATION INHIBITION COEF  =   0.60
ENDATA1A
ENDATA1B
STREAM REACH      1.RCH=  VIDKARTOVCE      FROM        178.    TO          160.
STREAM REACH      2.RCH= VERNÁRSKY         FROM         14.    TO             0
STREAM REACH      3.RCH= SLIAVNIK          FROM        160.    TO          153.
STREAM REACH      4.RCH=        GÁNOVSKÝ   FROM         11.    TO             0
STREAM REACH      5.RCH=      BELLANOVCE   FROM        153.    TO          148.
STREAM REACH      6.RCH=     VEL'KÁ-BIELA   FROM         19.    TO             0
STREAM REACH      7.RCH=       TOMÁŠOVCE   FROM        148.    TO          135.
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STREAM REACH      8.RCH=        HOLBINCA   FROM          135.    TO          130.
STREAM REACH      9.RCH=         BRUSNÍK   FROM           19.    TO             0
STREAM REACH     10.RCH=      MARKUŠOVCE   FROM          130.    TO          123.
STREAM REACH     11.RCH=  UPPER-LEVOCSKÝ   FROM           28.    TO           18.
STREAM REACH     12.RCH=  LOWER-LEVOCSKÝ   FROM           18.    TO             0
STREAM REACH     13.RCH=       MATEJOVCE   FROM          123.    TO          114.
STREAM REACH     14.RCH=         OLCNAVA   FROM          114.    TO          107.
STREAM REACH     15.RCH=        BRANISKO   FROM           20.    TO             0
STREAM REACH     16.RCH=       KOLINOVCE   FROM          107.    TO           99.
STREAM REACH     17.RCH=       SLOVINSKÝ   FROM           16.    TO             0
STREAM REACH     18.RCH=        RICHNAVA   FROM           99.    TO           83.
ENDATA2
ENDATA3
FLAG FIELD RCH=   1.       18.          1.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.3.
FLAG FIELD RCH=   2.       14.          1.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=   3.        7.          4.2.2.2.2.2.3.
FLAG FIELD RCH=   4.       11.          1.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=   5.        5.          4.2.2.2.3.
FLAG FIELD RCH=   6.       19.          1.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=   7.       13.          4.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=   8.        5.          2.2.2.2.3.
FLAG FIELD RCH=   9.       19.          1.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  10.        7.          4.2.2.6.2.2.3.
FLAG FIELD RCH=  11.       10.          1.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  12.       18.          2.2.6.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  13.        9.          4.2.2.2.2.2.2.2.2.
FLAG FIELD RCH=  14.        7.          2.2.2.2.2.6.3.
FLAG FIELD RCH=  15.       20.          1.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.6.
FLAG FIELD RCH=  16.        8.          4.6.2.2.2.2.2.3.
FLAG FIELD RCH=  17.       16.          1.2.2.2.2.2.2.2.2.6.2.2.2.2.2.6.
FLAG FIELD RCH=  18.       16.          4.6.6.6.2.2.2.2.2.2.2.2.2.2.6.5.
ENDATA4
HYDRAULICS RCH=   1.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=   2.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=   3.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=   4.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=   5.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=   6.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=   7.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=   8.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=   9.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  10.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  11.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  12.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  13.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  14.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  15.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  16.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  17.    120.00      0.28      0.35      0.48      0.58      0.03
HYDRAULICS RCH=  18.    120.00      0.28      0.35      0.48      0.58      0.03
ENDATA5
REACT COEF RCH=   1.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=   2.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=   3.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=   4.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=   5.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=   6.      1.     0.1     0.5  3.       0       0       0
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REACT COEF RCH=   7.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=   8.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=   9.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  10.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  11.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  12.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  13.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  14.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  15.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  16.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  17.      1.     0.1     0.5  3.       0       0       0
REACT COEF RCH=  18.      1.     0.1     0.5  3.       0       0       0
ENDATA6
N AND P COEF   RCH=   1.   0.03      0    0.3      0   1.00   0.25    20.      0
N AND P COEF   RCH=   2.   0.03      0    0.3      0   1.00   0.25    20.      0
N AND P COEF   RCH=   3.   0.03      0    0.3      0   1.00   0.25    20.      0
N AND P COEF   RCH=   4.   0.03      0    0.3      0   1.00   0.25    20.      0
N AND P COEF   RCH=   5.   0.03      0    0.3      0   1.00   0.25    20.      0
N AND P COEF   RCH=   6.   0.03      0    0.3      0   1.00   0.25    20.      0
N AND P COEF   RCH=   7.   0.03      0    0.3      0   1.00   0.25    20.      0
N AND P COEF   RCH=   8.   0.03      0    0.3      0   1.00   0.25      0      0
N AND P COEF   RCH=   9.   0.03      0    0.3      0   1.00   0.25      0      0
N AND P COEF   RCH=  10.   0.03      0    0.3      0   1.00   0.25      0      0
N AND P COEF   RCH=  11.   0.03      0    0.3      0   1.00   0.25      0      0
N AND P COEF   RCH=  12.   0.03      0    0.3      0   1.00   0.25      0      0
N AND P COEF   RCH=  13.   0.03      0    0.3      0   1.00   0.25      0      0
N AND P COEF   RCH=  14.   0.03      0    0.3      0   1.00   0.25      0    80.
N AND P COEF   RCH=  15.   0.03      0    0.3      0   1.00   0.25      0      0
N AND P COEF   RCH=  16.   0.03      0    0.3      0   1.00   0.25      0    80.
N AND P COEF   RCH=  17.   0.03      0    0.3      0   1.00   0.25      0      0
N AND P COEF   RCH=  18.   0.03      0    0.3      0   1.00   0.25      0    80.
ENDATA6A
ALG/OTHER COEF RCH=   1.  50.00    0.9  0.330   0.00   0.00   0.00   0.00
ALG/OTHER COEF RCH=   2.  50.00    0.9  0.330      0      0      0      0
ALG/OTHER COEF RCH=   3.  50.00    0.9  0.330      0      0      0      0
ALG/OTHER COEF RCH=   4.  50.00    0.9  0.330      0      0      0      0
ALG/OTHER COEF RCH=   5.  50.00    0.9  0.330      0      0      0      0
ALG/OTHER COEF RCH=   6.  50.00    0.9  0.330      0      0      0      0
ALG/OTHER COEF RCH=   7.  50.00    0.9  0.330      0      0      0      0
ALG/OTHER COEF RCH=   8.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=   9.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  10.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  11.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  12.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  13.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  14.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  15.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  16.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  17.  50.00   0.10  0.330      0      0      0      0
ALG/OTHER COEF RCH=  18.  50.00   0.10  0.330      0      0      0      0
ENDATA6B
INITIAL COND-1 RCH=   1.   12.0     6.      0   0.00   0.00   0.00   0.00   0.00
INITIAL COND-1 RCH=   2.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=   3.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=   4.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=   5.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=   6.   12.0     6.      0      0      0      0      0      0
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INITIAL COND-1 RCH=   7.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=   8.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=   9.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  10.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  11.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  12.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  13.   12.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  14.   14.5     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  15.   14.5     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  16.   14.5     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  17.   15.0     6.      0      0      0      0      0      0
INITIAL COND-1 RCH=  18.   11.0     6.      0      0      0      0      0      0
ENDATA7
INITIAL COND-2 RCH=   1.      0   0.00   0.00   0.00   0.00   0.00   0.00
INITIAL COND-2 RCH=   2.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=   3.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=   4.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=   5.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=   6.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=   7.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=   8.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=   9.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  10.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  11.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  12.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  13.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  14.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  15.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  16.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  17.      0      0      0      0      0      0      0
INITIAL COND-2 RCH=  18.      0      0      0      0      0      0      0
ENDATA7A
INCR INFLOW-1  RCH=   1.  0.526    15.    6.  1.85  0.00  0.00  0.00  0.00  0.00
INCR INFLOW-1  RCH=   2.  0.243    15.    6.  2.07     0     0     0     0     0
INCR INFLOW-1  RCH=   3.  0.050    15.    6.  2.06     0     0     0     0     0
INCR INFLOW-1  RCH=   4.  0.141    15.    6.  4.05     0     0     0     0     0
INCR INFLOW-1  RCH=   5.  0.115    15.    6.  1.81     0     0     0     0     0
INCR INFLOW-1  RCH=   6.  0.363    15.    6.  1.45     0     0     0     0     0
INCR INFLOW-1  RCH=   7.  0.875    15.    6.  1.85     0     0     0     0     0
INCR INFLOW-1  RCH=   8.  0.240    15.    6.  3.52     0     0     0     0     0
INCR INFLOW-1  RCH=   9.  0.109    15.    6.  3.52     0     0     0     0     0
INCR INFLOW-1  RCH=  10.  0.098    15.    6.  4.30     0     0     0     0     0
INCR INFLOW-1  RCH=  11.  0.237    15.    6.  2.80     0     0     0     0     0
INCR INFLOW-1  RCH=  12.  0.237    15.    6.  2.80     0     0     0     0     0
INCR INFLOW-1  RCH=  13.  0.554    15.    6.  5.65     0     0     0     0     0
INCR INFLOW-1  RCH=  14.  0.302    15.    6.  6.05     0     0     0     0     0
INCR INFLOW-1  RCH=  15.  0.372    15.    6.  8.32     0     0     0     0     0
INCR INFLOW-1  RCH=  16.  0.441    15.    6. 10.78     0     0     0     0     0
INCR INFLOW-1  RCH=  17.  0.416    15.    6.  2.94     0     0     0     0     0
INCR INFLOW-1  RCH=  18.  0.833    15.    6. 12.70     0     0     0     0     0
ENDATA8
INCR INFLOW-2  RCH=   1.      0  0.286  0.065  0.001  0.063  0.023  0.088
INCR INFLOW-2  RCH=   2.      0  0.345  0.090  0.001  0.073  0.020  0.104
INCR INFLOW-2  RCH=   3.      0  0.409  0.084  0.002  0.086  0.026  0.095
INCR INFLOW-2  RCH=   4.      0  0.712  0.096  0.004  0.203  0.106  0.184
INCR INFLOW-2  RCH=   5.      0  0.292  0.079  0.002  0.098  0.021  0.080
INCR INFLOW-2  RCH=   6.      0  0.235  0.068  0.001  0.046  0.011  0.072
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INCR INFLOW-2  RCH=   7.      0  0.339  0.085  0.002  0.110  0.027  0.100
INCR INFLOW-2  RCH=   8.      0  0.540  0.136  0.004  0.182  0.043  0.151
INCR INFLOW-2  RCH=   9.      0  0.564  0.147  0.003  0.165  0.041  0.160
INCR INFLOW-2  RCH=  10.      0  0.711  0.116  0.006  0.301  0.078  0.180
INCR INFLOW-2  RCH=  11.      0  0.423  0.067  0.003  0.158  0.063  0.110
INCR INFLOW-2  RCH=  12.      0  0.423  0.067  0.003  0.158  0.063  0.110
INCR INFLOW-2  RCH=  13.      0  0.891  0.121  0.009  0.463  0.154  0.190
INCR INFLOW-2  RCH=  14.      0  0.971  0.107  0.010  0.524  0.145  0.221
INCR INFLOW-2  RCH=  15.      0  1.394  0.144  0.012  0.599  0.203  0.333
INCR INFLOW-2  RCH=  16.      0  1.469  0.218  0.011  0.572  0.231  0.434
INCR INFLOW-2  RCH=  17.      0  0.422  0.063  0.003  0.129  0.064  0.121
INCR INFLOW-2  RCH=  18.      0  1.781  0.225  0.012  0.621  0.312  0.536
ENDATA8A
STREAM JUNCTION         1     JNC=              1        18        33        32
STREAM JUNCTION         2     JNC=              2        39        51        50
STREAM JUNCTION         3     JNC=              3        55        75        74
STREAM JUNCTION         4     JNC=              4        92       112       111
STREAM JUNCTION         5     JNC=              5       118       147       146
STREAM JUNCTION         6     JNC=              6       162       183       182
STREAM JUNCTION         7     JNC=              7       190       207       206
ENDATA9
HEADWTR-1 HDW=  1.0  VIDKARTOVCE       0.076   15.    6. 0.103     0     0     0
HEADWTR-1 HDW=  2.0 VERNÁRSKY          0.027   15.    6. 0.148     0     0     0
HEADWTR-1 HDW=  3.0        GÁNOVSKÝ    0.027   15.    6. 0.368     0     0     0
HEADWTR-1 HDW=  4.0     VEL'KÁ-BIELA    0.030   15.    6. 0.076     0     0     0
HEADWTR-1 HDW=  5.0         BRUSNÍK    0.013   15.    6. 0.185     0     0     0
HEADWTR-1 HDW=  6.0  UPPER-LEVOCSKÝ    0.029   15.    6. 0.200     0     0     0
HEADWTR-1 HDW=  7.0        BRANISKO    0.029   15.    6. 0.416     0     0     0
HEADWTR-1 HDW=  8.0       SLOVINSKÝ    0.049   15.    6. 0.184     0     0     0
ENDATA10
HEADWTR-2 HDW=  1.0     0     0     0 0.016 0.0040.0000 0.004 0.001 0.005
HEADWTR-2 HDW=  2.0     0     0     0 0.025 0.0060.0001 0.005 0.001 0.007
HEADWTR-2 HDW=  3.0     0     0     0 0.065 0.0090.0003 0.018 0.010 0.017
HEADWTR-2 HDW=  4.0     0     0     0 0.012 0.0040.0000 0.002 0.001 0.004
HEADWTR-2 HDW=  5.0     0     0     0 0.030 0.0080.0001 0.009 0.002 0.008
HEADWTR-2 HDW=  6.0     0     0     0 0.030 0.0050.0002 0.011 0.005 0.008
HEADWTR-2 HDW=  7.0     0     0     0 0.070 0.0070.0006 0.030 0.010 0.017
HEADWTR-2 HDW=  8.0     0     0     0 0.026 0.0040.0001 0.008 0.004 0.008
ENDATA10A
POINTLD-1 PTL=    1VK SP. NOVÁ-    0  0.2550   15.    6.  14.0  0.00  0.00  0.00
POINTLD-1 PTL=    2   VK LEVOCA    0  0.0530   15.    6.  20.0     0     0     0
POINTLD-1 PTL=    3FARM SP. VLA    0  0.0009   15.    6.  60.0     0     0     0
POINTLD-1 PTL=    4VK SP. VLACH    0  0.0011   15.    6.  28.0     0     0     0
POINTLD-1 PTL=    5VK KAMEN VLA    0  0.0003   15.    6.  43.7     0     0     0
POINTLD-1 PTL=    6ZELBA SOLVIN    0  0.0059   15.    6.   3.7     0     0     0
POINTLD-1 PTL=    7VK KROMPACHY    0  0.0025   15.    6.  90.0     0     0     0
POINTLD-1 PTL=    8VK KROMPACHY    0  0.0110   15.    6. 140.0     0     0     0
POINTLD-1 PTL=    9VK3+KOVOHUT     0  0.0575   15.    6.   9.3     0     0     0
POINTLD-1 PTL=   10SEZ KROMPACH    0  0.0315   15.    6.   5.7     0     0     0
POINTLD-1 PTL=   11VK MARGECANY    0  0.0030   15.    6. 187.0     0     0     0
ENDATA11
POINTLD-2  PTL=    1   0.0   0.0   0.0   6.1   7.9  0.19  1.30  0.50  1.60
POINTLD-2  PTL=    2     0     0   0.0   6.1   7.9  0.19  1.30  0.50  1.60
POINTLD-2  PTL=    3     0     0   0.0  39.2  80.0  0.08 30.80  1.00  3.30
POINTLD-2  PTL=    4     0     0   0.0   6.1   7.9  0.19  1.30  0.50  1.60
POINTLD-2  PTL=    5     0     0   0.0   3.8   6.3  0.02  0.05  0.80  2.50
POINTLD-2  PTL=    6     0     0   0.0   0.2   0.2  0.09  2.70  0.02  0.05
```

```
POINTLD-2  PTL=    7     0     0   0.0  13.0  22.0  0.06  0.19  1.60  7.70
POINTLD-2  PTL=    8     0     0   0.0  15.0  25.0  0.06  0.19  3.00 10.00
POINTLD-2  PTL=    9     0     0   0.0   0.7   1.3  0.04  4.04  0.09  0.45
POINTLD-2  PTL=   10     0     0   0.0   0.2   0.4  0.04  4.20  0.03  0.15
POINTLD-2  PTL=   11     0     0   0.0  15.0  25.0  0.06  0.19  3.00 10.00
ENDATA11A
ENDATA12
ENDATA13
ENDATA13A
LOCAL CLIMATOLOGY07    96    0      140.    0.65    15.0    10.6   1000.      8.
```

Table 8. Explained Variance of Measured versus Predicted Total Phosphorus

Model Run	**Date**	**River Kilometer**	**Measured Total Phosphorus** (mg/L)	**Predicted Total Phosphorus** (mg/L)	**Coefficient of Determination**
Calibration	7/96	136.4	0.067	0.090	0.99
		124.6	0.270	0.270	
		100.7	0.410	0.360	
		92.1	0.410	0.400	
Validation	2/97	136.4	0.090	0.090	0.81
		124.6	0.330	0.310	
		100.7	0.350	0.370	
		92.1	0.280	0.400	

Table 9. Overall Relative Phosphorus Loads to Ruzín Reservoir

Source	**Total Phosphorus** (Percent of Load)	**Dissolved Phosphorus** (Percent of Load)
All Point Sources	69%	66%
All Nonpoint Sources	31%	34%

Table 10. Subbasin Relative Phosphorus Loads to Ruzín Reservoir

Subbasin Name	**Area** (hectares)	**Total Phosphorus** (Percent of Load)	**Dissolved Phosphorus** (Percent of Load)
Bellanovce	2,778	<1%	<1%
Branisko	11,232	6%	6%
Brusník	4,214	2%	3%
Gánovský	3,344	2%	3%
Holubnica	6,004	2%	3%
Kolinovce	5,011	10%	8%
Levocský	15,425	6%	8%
Markušovce	2,206	17%	19%
Matejovce	12,468	6%	6%
Olenava	6,809	4%	3%
Richnava	9,471	29%	25%
Sliavnik	1,209	<1%	<1%
Slovinský	7,694	4%	3%
Tomášovce	6,651	4%	6%
Vel'ká-Biela	4,512	2%	3%
Vernársky	4,089	2%	3%
Vidkartovce	11,442	2%	3%
Entire Basin	114,557	100%	100%

Table 11. Point Source Relative Loads to Ruzín Reservoir

Facility Name	**Location**	**Waste Type**	**Flow** (m^3/s)	**Total Phosphorus** (Percent of Load)	**Dissolved Phosphorus** (Percent of Load)
Verejná kanalizácia Spišská Nová Ves	Hornád km 127.4	Domestic	0.2550	53%	50%
Verejná kanalizácia Levoca	Levocský km 15.2	Domestic	0.0530	13%	14%
Farma ošípaných Sp. Vlachy	Hornád km 109.7	Animal	0.0009	<1%	<1%
Sp. kamenopriemysel Sp. Vlachy	Hornád km 107.2	Quarry + Domestic	0.0003	<1%	<1%
Verejná kanalizácia Sp. Vlachy	Branisko km 1.4	Domestic	0.0011	<1%	<1%
Zelba Solvinky Odtok z odkaliska(2pts)	Slovinský km 4.4	Mining	0.0059	<1%	<1%
Verejná kanalizácia Krompachy (pt 1)	Slovinský km 0.9	Domestic	0.0025	7%	7%
Verejná kanalizácia Krompachy (pt 2)	Hornád km 98.8	Domestic	0.0110	13%	14%
Verejná kanalizácia Krompachy (pt 3)	Hornád km 97.2	Domestic	0.0025	7%	7%
Kovohuty Krompachy (pt 1)	Hornád km 97.8	Mining	0.0231	<1%	<1%
Kovohuty Krompachy (pt 2)	Hornád km 97.5	Mining	0.0319	<1%	<1%
SEZ Krompachy	Hornád km 96.6	Power Plant	0.0315	<1%	<1%
Verejná kanalizácia Margecany	Hornád km 83.2	Domestic	0.0030	7%	7%

Table 12. General Land Cover Relative Phosphorus Load to Ruzín Reservoir

Land Cover Type	CORINE Level 3 Code	Total Phosphorus (Percent of Load)	Dissolved Phosphorus (Percent of Load)
Urban (all types)	100	28%	24%
Agriculture (all types)	200	52%	48%
Forest Lands (all types)	300	21%	29%

Table 13. Agricultural Land Cover Relative Phosphorus Load to Ruzín Reservoir

Land Cover Type	CORINE Level 3 Code	Total Phosphorus (Percent of Load)	Dissolved Phosphorus (Percent of Load)
Non-irrigated Arable Land	211	19%	9%
Fruit Trees and Berry Farms	222	6%	9%
Pasture Lands	231	13%	9%
Cultivated Agriculture	242	<1%	<1%
Agriculture in Areas with Mostly Natural Vegetation	243	63%	73%

Table 14. Forested Land Cover Relative Phosphorus Load to Ruzín Reservoir

Land Cover Type	CORINE Level 3 Code	Total Phosphorus (Percent of Load)	Dissolved Phosphorus (Percent of Load)
Broad-leaved Forest Lands	311	13%	14%
Coniferous Forest Lands	312	25%	14%
Mixed Forest Lands	313	25%	29%
Natural Grasslands	321	<1%	<1%
Schrublands	324	38%	43%

Table 15. Urban Land Cover Relative Phosphorus Load to Ruzín Reservoir

Land Cover Type	CORINE Level 3 Code	Total Phosphorus (Percent of Load)	Dissolved Phosphorus (Percent of Load)
Discontinuous Urban Fabric	112	75%	67%
Industrial/Commercial Units	121	13%	17%
Mineral Extraction Sites	131	<1%	<1%
Dump Sites	132	<1%	<1%
Sport and Leisure Activities	142	13%	17%

Table 16. Predicted Concentrations of Phosphorus Entering Ruzín Reservoir using Different Levels of Pollution Control

Pollution Control(s)	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)
No Further Pollution Controls	0.450	0.340
Secondary Treatment for 5 Domestic Wastewater Facilities	0.420	0.310
Tertiary Treatment for all Significant Domestic Wastewater facilities	0.340	0.250
Animal Waste System for Major Farm	0.450	0.340
Diversion System for Major Farm	0.450	0.340
Containment Structure for Major Farm	0.450	0.340
Reduced Tillage for Agricultural Lands	0.390	0.300
Terrace Systems for Agricultural Lands	0.360	0.270
Filter Strips for Agricultural Lands	0.350	0.270
Catch Basins for Urban Stormwater	0.450	0.330
Modified Dry Ponds for Urban Stormwater	0.400	0.310
Wet Ponds for Urban Stormwater	0.380	0.290
Vegetative Filter Strips for Urban Stormwater	0.390	0.300
Combined Pollution Controls: 1. Tertiary Treatment for all Significant Domestic Wastewater facilities 2. Animal Waste System for Major Farm 3. Filter Strips for Agricultural Lands 4. Wet Ponds for Urban Stormwater	0.170	0.140
Combined Pollution Controls: 1. Tertiary Treatment for all Significant Domestic Wastewater Facilities 2. Wastewater Discharge Removal from VK Spišská Nová Ves 3. Animal Waste System for Major Farm 4. Filter Strips for Agricultural Lands 5. Wet Ponds for Urban Stormwater	0.160	0.130
Combined Pollution Controls: 1. Tertiary Treatment for all Significant Domestic Wastewater Facilities 2. Wastewater Discharge Removal from 5 Domestic Wastewater Facilities 3. Animal Waste System for Major Farm	0.150	0.130

4. Filter Strips for Agricultural Lands 5. Wet Ponds for Urban Stormwater		

Figure 1. Study Area of Upper Hornád River Watershed in the Slovak Republic

Figure 2. Subbasins of the Upper Hornád River Watershed

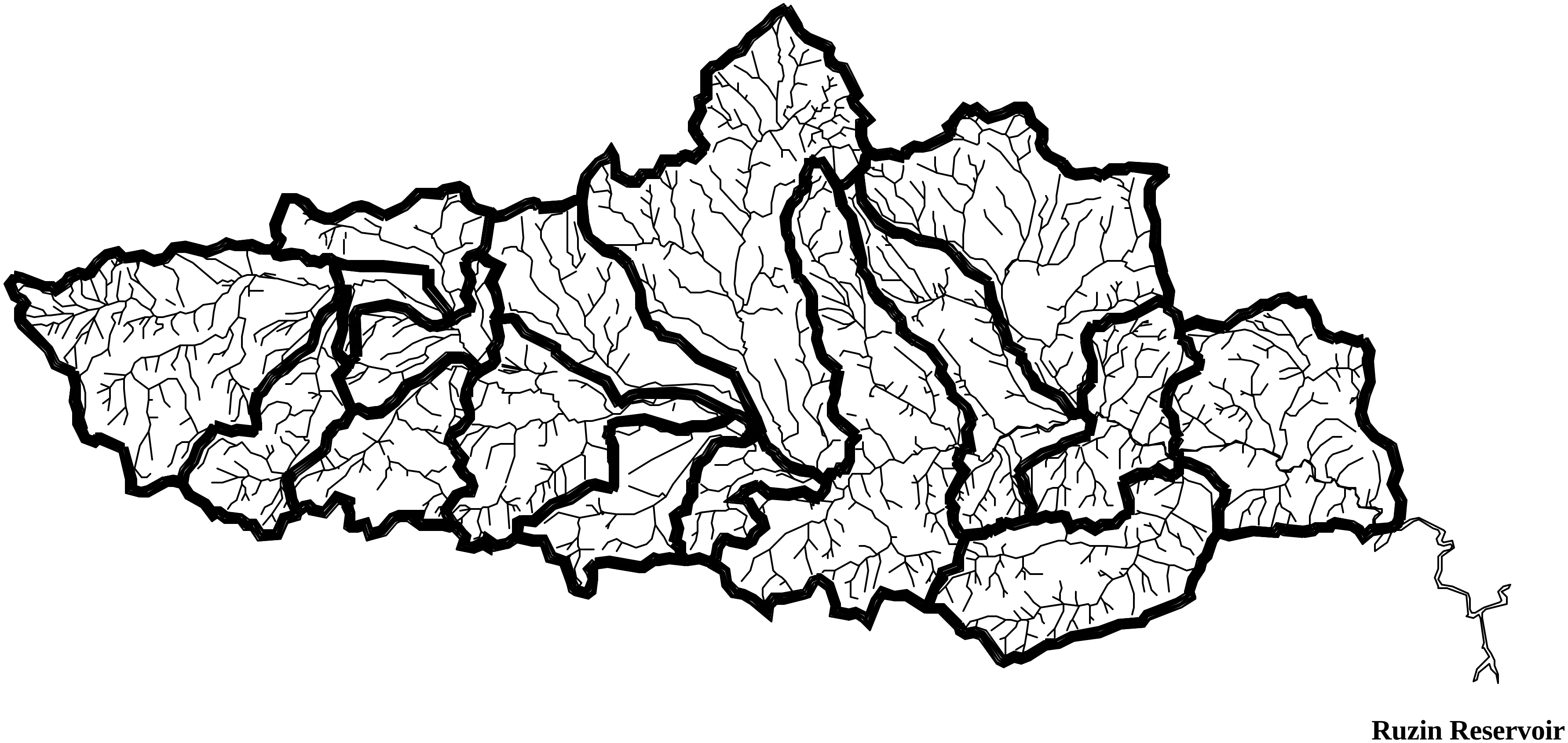

Figure 3. Schematic of the Modeled Stream Geometry

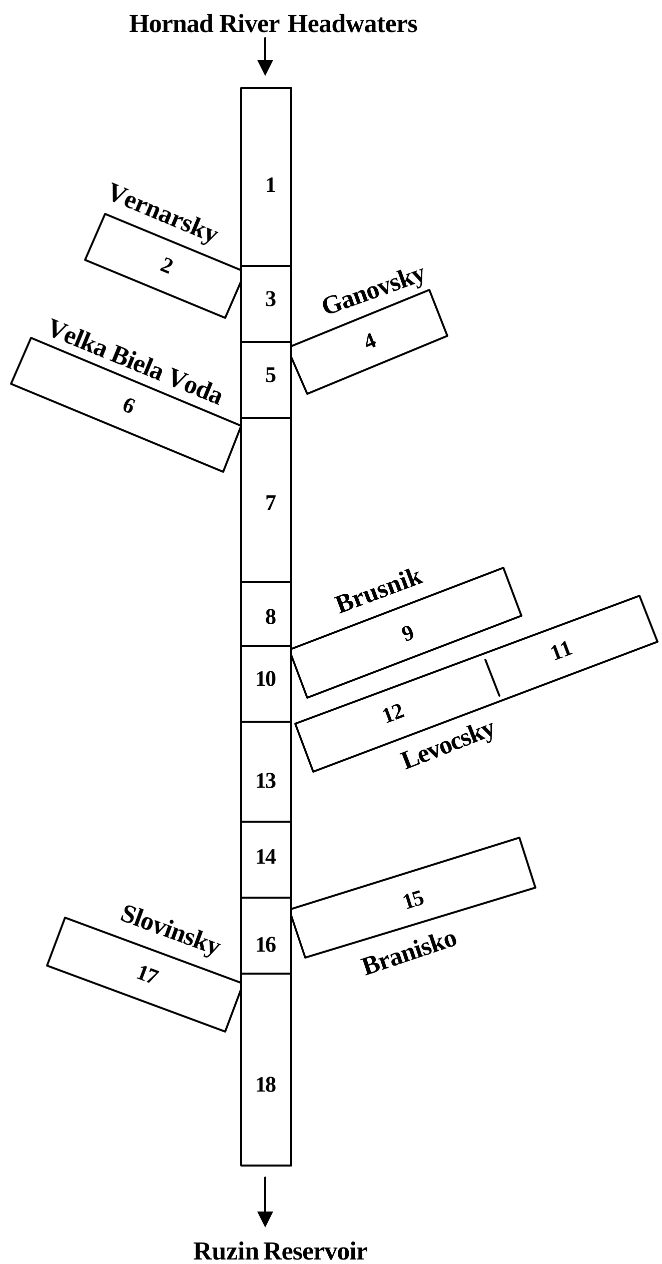

Figure 4. Calibration Run for July 1996

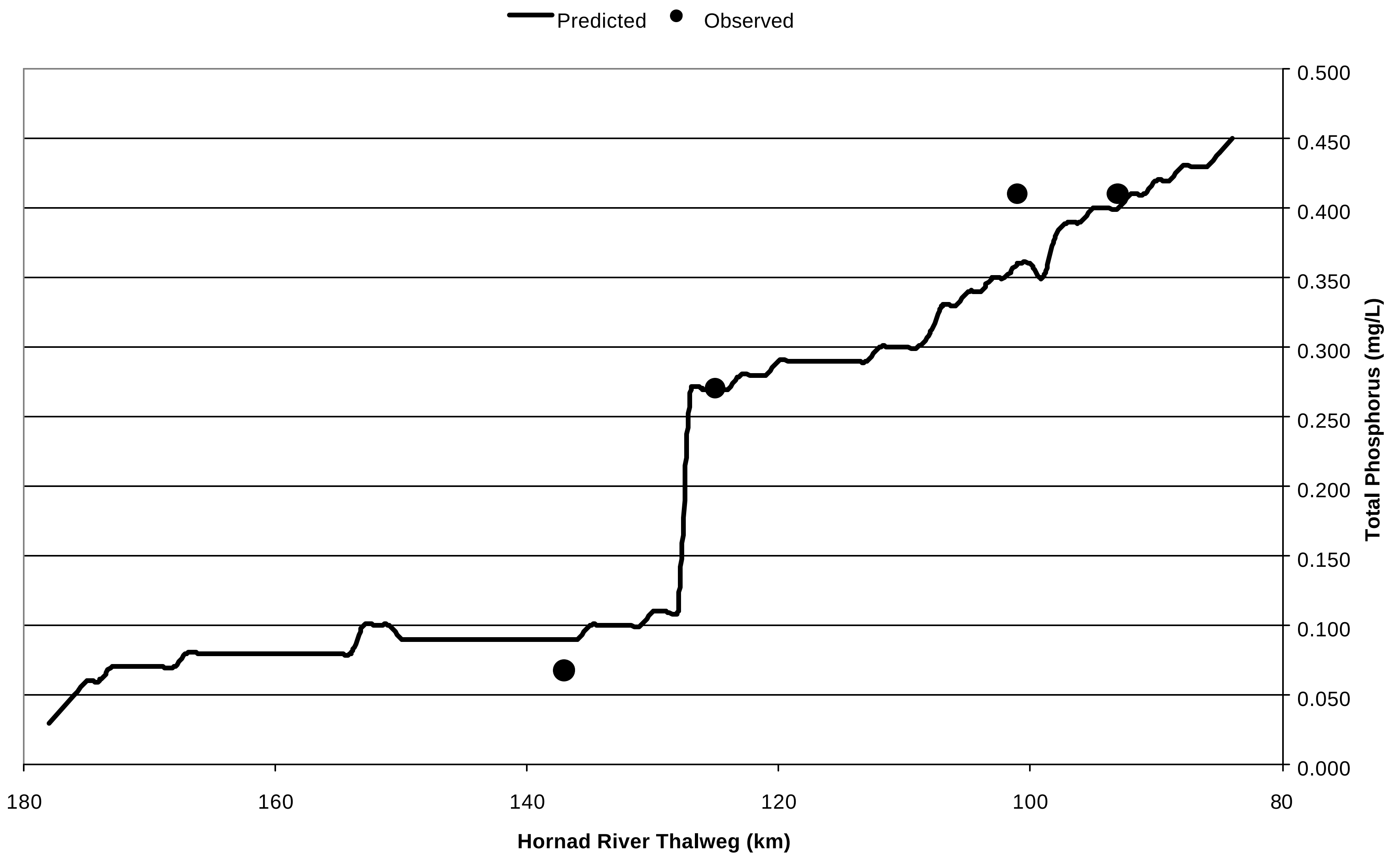

Figure 5. Validation Run for Feb. 1997