New York State Water Resources Institute
Annual Technical Report
FY 2001

Introduction

Research Program

The New York State Water Resources Institutes (NYSWRI) FY2001 activity under the Federal Water Resources Research Act consisted largely of eleven research projects funded during FY1999, FY2000, and FY2001. The FY 2001 Annual Report reports on a FY2000 project and a FY 2001 project from national 104G competitions, one project from a supplemental funding source, one from the FY 1999 New York State competition, and the remaining from the FY 2001 New York competition.

The FY2000 104G project, covering watershed nutrient modeling, began in late 2000 and will be completed by the end of FY 2003. The model being developed will predict nutrient loadings to coastal and inland ecosystems. The FY 2001 104G project covers the modeling of phosphorus control best management practices on a watershed scale to improve surface drinking water quality. This project went underway in November 2001 and the principal findings relate to the first half-year of the study. A simple model has already been developed for the release of P from spread manure.

One project funded from a supplemental funding source is dealing with climate and hydrologic processes relative to biodiversity in a study on Lake Ontario and the St. Lawrence River with the International Joint Commission on the Great Lakes (IJC). The work for this project did not begin until the end of this reporting period. Therefore, only a recapitulation of its goals and methods is included in this report. Substantive progress will be reported in the FY 2002 report.

One FY1999 104B project is being reported that dealt with Cryptosporidium oocysts and their risk of contaminating water. The primary objective was to develop an accurate method for the quantitative determination of the effect of watershed management practices on the risk of human health caused by the transport of C. parvum oocysts in to municipal water supplies. This goal has been achieved through development of an integrated model and risk assessment.

Seven FY2001 104B projects resulted from an in-NY competition whose topic focus reflected NYS WRIs long-term priority on nonpoint source pollutant management. The projects study methods for an internet-based, nonpoint source pollution model, filtering contaminants from stormwater, epidemiological risk analysis of Crypto in watersheds, Nitrogen, Phosphorus, and sediment attenuation capacities of wetland plants, greenhouse wastewater discharge control, assessing P eutrophication, and a web-based watershed education program.

Nine projects were completed except possibly for future journal publications. The FY 2001 104G project will be completed by the end of 2003, and the IJC project will be completed by the next reporting period.

A Watershed-Scale Biogeochemical Loading Model for Nitrogen and Phosphorus

Basic Information

Title:	A Watershed-Scale Biogeochemical Loading Model for Nitrogen and Phosphorus
Project Number:	2000NY5G
Start Date:	9/1/2000
End Date:	8/31/2003
Research Category:	Water Quality
Focus Category:	Hydrology, Models, Nutrients
Descriptors:	denitrification, ecosystems, hydrologic models, geographic information systems, land-water interactions, land use, mathematical models, rainfall-runoff processes, watershed management
Principal Investigators:	Robert W Howarth , Elizabeth Boyer , Patrick Phillips , Dennis Swaney

Publication

1. Alexander RB; PJ Johnes; EW Boyer & RA Smith, 2002, A comparison of methods for estimating the riverine export of nitrogen from large watersheds, Biogeochemistry 57, in press.
2. Boyer EW; CL Goodale; NA Jaworski & RW Howarth, 2002, Anthropogenic nitrogen sources and relationships to riverine nitrogen export in the northeastern USA, Biogeochemistry 57, in press.
3. Howarth RW; EW Boyer; W Pabich & JN Galloway, 2002, Nitrogen flux in the United States from 1961 2000 and potential future trends, Ambio, 31(2):88-96.
4. Howarth RW; R Marino; DP Swaney & EW Boyer, 2002, Wastewater and watershed influences on primary productivity and oxygen dynamics in the lower Hudson River estuary, in J. Levinton ed., The Hudson River, NY, Academic Press, In press.
5. Howarth RW; D Walker & A Sharpley, Sources of nitrogen pollution to coastal waters of the United States, Estuaries, in press.
6. Mayer B; N Jaworski; E Boyer; R Howarth; C Goodale; L Hetling; S Seitzinger; G Billen; R Alexander; N van Breemen; K Paustian; D van Dam; K Lajtha & K Nadelhoffer, 2002, On the feasibility of using the nitrogen and oxygen isotope ratios of nitrate for describing the origin of riverine nitrate and N transformations in large watersheds, Biogeochemistry 57, in press.
7. Scavia DJ; C Field; D Boesch; R Buddemeier; V Burkett; D Canyan; M Fogarty; MA Harwell; RW Howarth; C Mason; DJ Reed; TC Royer; AH Sallenger & JG Titus, 2002, Climate change impacts on US Coastal and marine ecosystems, Estuaries, in press.
8. Seitzinger SP; RV Styles; EW Boyer; R Alexander; G Billen; RW Howarth; B Mayer & N van Breemen, 2002, Nitrogen retention in rivers: model development and application to watersheds in the

northeastern US, Biogeochemistry 57, in press.
9. Van Breemen N; EW Boyer; CL Goodale; NA Jaworski; S Seitzinger; K Paustian; L Hetling; K Lajtha; M Eve; B Mayer; D van Dam; RW Howarth; KJ Nadelhoffer & G Billen, 2002, Nitrogen budgets for 16 watersheds draining to the northeaster US coast: storage and losses of nitrogen inputs, Biogeochemistry 57, in press.

Problem and Research Objectives:

Two recent reports from the National Academy of Sciences have concluded that eutrophication is the biggest pollution problem in the coastal marine waters of the United States (NRC 1993, NRC 2000). Eutrophication lowers biotic diversity, leads to hypoxic and anoxic conditions, facilitates harmful algal blooms, causes dieback of seagrass beds, and can lead to changes in ecological food webs that lower fishery production (NRC 2000). Over 40% of the estuaries in the country are degraded from eutrophication, with the problem being particularly severe in the northeastern and mid-Atlantic regions (Bricker 1999). For most estuaries in these regions, eutrophication is caused primarily from over-enrichment with nitrogen; phosphorous is a secondary contributor (e.g., Nixon 1995; NRC 2000). Most nitrogen delivered to coastal waters in the US comes from non-point sources in the landscape, with agricultural sources, human waste, and atmospheric deposition being major contributors (e.g., Howarth et al. 1996; Smith et al. 1997; Goolsby et al. 1999; Boyer et al. 2002).

In regions subject to changes in land use and to atmospheric deposition of nitrogen, the processes that control nutrient loads to the coastal zone are complex. Variability of these hydrological and biogeochemical processes is increasing as weather and climate change. Understanding how these processes affect the magnitude and transformations of the nutrient loads is necessary in order to manage the environmental resources of the coastal zone. Further, it is important for those living in and managing coastal watersheds to understand the impacts of their activities and policies on these nutrient loads. A relatively simple modeling tool that can estimate the impacts of various activities in the watersheds can greatly enhance, at low cost, our ability to manage these regions effectively and to communicate the effects of human activities and environmental processes on nutrient loads. The report of the National Academy of Sciences Committee on Causes and Management of Coastal Eutrophication concluded that no model currently available to managers fulfills this need. Our objectives are to develop such a model, targeted toward management applications.

Our model will describe flow paths of water and nutrients through landscapes to receiving waters, and will characterize biogeochemical reactions that occur as water moves along these flow paths (e.g., from an upland hillslope through the riparian zone to the river). Our goal is to create a model structure that will be used widely; thus we are developing it in spreadsheet software (Excel) and will provide an optional module to make use of spatial data to calculate model input parameters and to visualize spatial elements of the model output using GIS software (Arc View). Both Excel and Arc/View can be run on PC or Macintosh platforms, and are among the most popular software of their types.

Methodology:

Our model combines the event-based dynamics of a simple, lumped hydrologic model (Generalized Watershed Loading Function Model, or GWLF; Haith and Shoemaker 1987) with biogeochemical dynamics suggested by statistical analyses of spatially-referenced data (the Spatially Referenced Regressions On Watershed Attributes Model, or SPARROW; Smith et al.1997) and with information derived from spatially referenced data using GIS. GWLF is a parsimonious, event-based model that has been used successfully to analyze the hydrology, sediment, and nutrient loads of many mixed watersheds in the United States, including watersheds flowing into the Hudson, Tar-Pamlico, and Chesapeake Bay estuaries (e.g., Swaney et al. 1996, Lee et al., 2000). The original model used daily historic or synthetic temperature and precipitation data to simulate monthly discharge, sediment load, and nutrient transport. We used this simple model as a starting point, and are in the process of modifying it to capture the features of landscape and hydrological processes which control nutrient retention and transport. To date,

we have arrived at a 'defining equation' which will be the basis of our modified model to quantify nutrient loadings to the coastal zone. This equation, parameterized statistically, incorporates some critical ideas about sources of nutrients to the landscape and on transport and transformation processes that affect the delivery of nutrients from landscapes to the coastal zone. We consider two types of sources of nutrients, diffuse (nonpoint), for which integrated effects of landscape processes control much of the transport and attenuation, and point sources, which are attenuated by in-stream processes. In particular, we represent inputs to each watershed of interest from atmospheric deposition, fertilizer use, nitrogen fixation in cultivated crop lands, animal waste, and human waste.

Hydrological, meteorological, and nutrient load data are necessary to calibrate and validate the model. We have assembled detailed data hydrological processes, nutrient inputs, and nutrient loadings in a variety of catchments, which are available for parameterizing the model and for assessing model predictions. These include data from the USGS Hudson River NAWQA program (via co-investigator Phillips), the USGS HBN and NASQAN programs (via co-investigator Alexander), the SCOPE Nitrogen project data on large coastal catchments in the northeastern USA (via co-investigators Boyer and Howarth), and for the Mississippi River system (via colleague Don Goolsby).

Principal Findings and Significance:

The model that we are developing will allow us to understand how inputs of nutrients to the landscape are attenuated by hydrological and biogeochemical transport and transformation processes, and to predict nutrient loadings to coastal and inland ecosystems. Once the model is fully developed and evaluated, we will use it to investigate effects of environmental, land use, and land management changes on both sources of nutrients to the landscape and the resulting loadings of nutrients to the coastal zone. For example, we will consider the potential effects of changing atmospheric emissions via regulations, implementing various types of sewage treatment, implementing best management practices for agricultural, urban, and forest lands, and more. Further, we are using this tool in our own research to examine the joint effect of climate and land use change on biogeochemical processes and nutrient dynamics within watersheds. Finally, with the cooperation of the extension/outreach component of the Cornell Watersheds Program of the Center for the Environment, we plan to make our modeling tool and our modeling results available for use by watershed and coastal zone managers. We will distribute all of our materials, including data, instructions, models, and results, on a web page hosted by Cornell University's Center for the Environment. Our work will provide land managers with information relevant to mitigating nutrient pollution problems in coastal and inland waters.

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Goolsby D.A., Battaglin, W.A., Lawrence, G.B., Artz, R.S., Aulenbach, B.T., Hooper, R.P., Keeney, D.R., and Stensland, G.J. 1999. Flux and sources of nutrients in the Mississippi-Atchafalaya River Basin; Topic 3. Report for the integrated Assessment on Hypoxia in the Gulf of Mexico. NOAA Coastal Ocean Program Decision Analysis Series No. 17. NOAA, Silver Spring, MD.

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Lee, K.Y., T.R. Fisher, T.E. Jordan, D.L. Correll, and D.E. Weller. 2000. Modeling the hydrochemistry of the Choptank River Basin using GWLF and Arc/Info: 1. Model calibration and validation. Biogeochemistry 49 (2): 143-173.

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National Research Council (NRC). 2000. Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution. National Academy Press, Washington, DC.

Nixon, S. W. 1995. Coastal marine eutrophication: a definition, social causes, and future concerns. Ophelia 41: 199-219.

Smith, R.A., Schwarz, G.E., and Alexander, R.B. 1997. Regional interpretation of water quality monitoring data. *Water Resources Research 33,* 2781-2798.

Swaney, D. P., D. Sherman, and R. W. Howarth. 1996. Modeling water, sediment, and organic carbon discharges in the Hudson-Mohawk Basin: coupling to terrestrial sources. Estuaries 19: 833-847.

Microbial indicators: new tools for assessing phosphorus eutrophication

Basic Information

Title:	Microbial indicators: new tools for assessing phosphorus eutrophication
Project Number:	2001NY1081B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Nutrients, Wetlands, None
Descriptors:	Microbiology, Nutrient management, Phosphatase, Wetlands,Phosphorus
Principal Investigators:	Barbara L. Bedford

Publication

1. Wolfe, BE, 2002, Responses of extracellular enzyme activity to phosphorus addition in two calcareous fens, in The 17th annual Cornell Undergraduate Research Forum Proceedings, Spring 2002.
2. Wolfe, BE and CT Chapin, April 2002, Responses of extracellular enzyme activity to phosphorus addition in two calcareous fens, Invited seminar, Department of Crop and Soil Science, Cornell University.
3. Chapin, CT; and BE Wolfe, June 2-7, 2002, Microbial enzymatic response to phosphorus addition in two calcareous fens, Poster presentation at the Society of Wetland Scientists, Lake Placid, New York.
4. Chapin, CT and BE Wolfe, Microbial enzymatic response to phosphorus addition in two calcareous fens, Journal of Environmental Quality, in press.

Problems and Research Objectives:

Wetlands often lie at the interface between terrestrial and aquatic systems and can act effectively to buffer downstream environments from upland nutrient loading. Consequently, changes in wetland biogeochemical processes can serve as early warning signals to the potential degradation of downstream water-quality. In minerotrophic wetlands, those receiving mineral-rich waters, phosphorus (P) is often tied up in geochemical forms by mineral cations. Although minerotrophic systems are often highly buffered, continuous loading of P into a wetland will reduce the soil buffering capacity which then would increase levels of labile P. Measurement of wetland microbial processes and pool sizes may serve to alert management agencies of changes in natural nutrient cycles, and enzyme activity in particular may be a key indicator of P dynamics within a wetland. The measurement of microbial enzymes can be linked to detrital characteristics and rates of decomposition, as these extracellular enzymes serve to hydrolyze complex plant compounds into simple organic molecules that are more readily utilized by the plant community. Hence, as available P becomes more limiting, more enzyme activity is required to acquire organically-bound forms. Indeed, alkaline phosphatase activity (APA) has been reported higher in wetland soils with lower phosphate content, and has been shown to decrease after P loading in a Florida Everglades system.

We tested the efficacy of APA as a possible bio-indicator in two calcareous peatlands that have been subject to experimental phosphorus addition.

Methodology:

In situ fertilization

We have been adding an available form of nitrogen (NH_4NO_3) separately and in combination with different forms phosphorus to two calcareous wetlands in the Finger Lakes Region for the last two years (Fish Fen) and three years (Belle School Fen). The treatments include; labile P (equal molar ratios of NaH_2PO_4 + Na_2HPO_4), Fe-P ($FePO_4$), Ca-P ($CaHPO_4$), and an organic form of P (β-glycerophosphate, $C_3H_5(OH)PO_4Na_2$). Each treatment and the control consists of 5 replicates. Nitrogen is added at 6 g/m^2/yr and phosphorus at 2 g/m^2/yr.

Labile soil nutrients were monitored with ion-exchange resin bags. We used a Hedley fractionation technique modified for wetland soils to estimate pools of mineral and organic P. We measured microbial biomass C, N, and P within each plot one week after the addition of fertilizer in mid-June. Microbial P was determined by the change in quantity of inorganic P removed by extraction following a direct chloroform addition. We are also measured microbial C and N using a separate K_2SO_4 extract following chloroform addition. Microbial C (by difference) was analyzed on a Shimadzu TOC analyzer and microbial N (by difference) was analyzed by digesting the extracts with $K_2S_2O_8$ followed by analysis using a Lachat. We used methods outlined in Tabatabai (1962. Agronomy Monographs No. 9) to determine levels of alkaline phosphatase activity within soil samples from each plot at the time of microbial biomass measurements. This method is a low specificity assay which measures *p*-nitrophenol released by phosphatase activity of soil incubated with sodium *p*-nitrophenol phosphate.

Laboratory incubation

Sub-samples of the top 15 cm of the rhizosphere of Belle School Fen were homogenized into one composite sample following the removal of plant roots and rocks. We placed 30 (100g wet weight peat) samples into acid-washed mason jars and added one of five P additions or distilled deionized water as a control. We had a total of 31 jars (n=5) and one blank (no soil + water). The treatments were as follows: 0.5 g/m^2 = 39 µg P/jar, 1 g/m^2 = 78 µg P/jar, 2 g/m^2 = 156 µg P/jar (comparable field application rate), 4 g/m^2 = 312 µg P/jar, 8 g/m^2 = 624 µg P/jar. All P was applied as Na_2HPO_4 in 1 ml applications and mixed thoroughly with the soil. Jars were anaerobically incubated in the dark at room temperature for 28 days. Immediately after the incubation, we sub-sampled the peat for microbial biomass P, C, and APA activity as described above.

Principle Findings and Significance:

With respect to the Belle School Fen field samples, the only fertilization effect was a decrease in APA in N+P (all forms) treatments from that off the control at Belle School Fen ($p = 0.022$, Dunnett's test significant). The lack of an effect with the most labile form of phosphorus suggests that either the phosphorus was made unavailable due to rapid geochemical sorption, or as the response by all N+P (all forms) treatments suggests, the microbial community was not under nutrient constraints, but limited by labile carbon. Our primary concern to wetland integrity in this region is phosphorus eutrophication. However, since we did not add any carbon amendments to the soil, and soils receiving many types of effluents would also receive bio-available carbon, considering carbon as a supplement to phosphorus loading may be important in future studies of possible wetland bio-indicators. In the lab incubation of Belle School Fen soil, we did not alter APA or microbial pool sizes despite a wide range of simulated P loading in these soils. It is interesting to note that we did not see changes in extractable phosphorus until we had added P equivalent to over $1g/m^2$. This $1g/m^2$ is the theoretical threshold for P retention in many wetland soils.

Our results indicate that the response of the microbial community depends on limitations within the microbial pool and not on perceived limitation of the ecosystem as it pertains to the plant community.

Notable Achievements:

Ben Wolfe who was a junior this past year, worked extensively on this project to be used as the basis for his undergraduate research project. In conjunction with Carmen Chapin he designed a laboratory experiment to help clarify results from field sampling. His research was presented at the Undergraduate Research Symposium April 15, 2002 as well as s an invited talk at the Department of Crop and Soil Science seminar series April 30, 2002.

Nitrogen, Phosphorus, and Sediment Attenuation Capacities of Wetland Plants within the Nanticoke Creek Corridor

Basic Information

Title:	Nitrogen, Phosphorus, and Sediment Attenuation Capacities of Wetland Plants within the Nanticoke Creek Corridor
Project Number:	2001NY1141B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Wetlands, Water Quality, None
Descriptors:	Nanticoke Creek, Watershed management, Nonpoint pollution, Stormwater treatment, Sediment, Nutrients,Wetlands
Principal Investigators:	John E. Titus

Publication

1. Kao, J; JE Titus and W Zhu, Differential nitrogen and phosphorus accumulation by five wetland plant species, For submission to Wetlands, (manuscript in preparation)

Problem and Research Objectives:

The problem is that nonpoint agricultural sources of nutrients may have detrimental influences on water quality in the upper reaches of the Nanticoke Creek watershed. The primary research objective was (a) to compare the abilities of different wetland plant species introduced along the bank of the creek to reduce nutrient inputs from a dairy farm into Nanticoke Creek by accumulating nitrogen (N) and phosphorus (P) in plant tissues and by promoting sedimentation differentially. We subsequently added two related objectives: (b) to determine rates of N and P loss from decomposing tissues, and (c) to monitor plant phenology (the seasonal timing of growth, flowering, and senescence). Both secondary objectives concern the timing of nutrient accumulation by and/or loss from wetland plants.

Methodology:

(a) Eleven blocks of 900 cm^2 plots, one plot for each of five study species in each block, were planted along the creek in late April 2001. The plants were harvested near the time of peak standing crop (early August), and plant tissues were rinsed carefully, oven-dried, weighed, ground, and analyzed for N and P content with a Lachat QuikChem autoanalyzer after digestion in a sulfuric acid/hydrogen peroxide mixture. We deployed small-scale sediment traps to determine the effect of species on sedimentation, but 2001 was a drought year with no sedimentation event after plants became established.
(b) Subsamples of shoots were air-dried and placed in litterbags in a local wetland for five months, with tissues analyzed after 60, 120, and 150 days to determine rates of N and P loss from decomposing tissues.
(c) Phenological observations were made approximately three times weekly during the growing season.

Principal Findings and Significance:

(a) Sparganium americanum accumulated significantly more N and more P in aboveground tissues than Scirpus cyperinus, with Phalaris arundinacea, Juncus effusus, and Calamagrostis canadensis at intermediate values. In contrast, Juncus accumulated the most N and Scirpus the most P in belowground tissues, with Sparganium accumulating the least N and P belowground. Thus different species accumulate N and P at different rates both aboveground and belowground, suggesting that some would attenuate nutrient inputs to the creek more effectively than others.
(b) In the litterbag incubations, Phalaris lost both N and P at the highest (relative) rates. Scirpus lost N at the lowest rate.
(c) Of 16 species monitored in the field, Juncus effusus was among the first to flower and cease growing, while Sparganium americanum was among the last to flower and cease growing.
The overall significance is that different species can behave quite differently in three respects: in their relative accumulation of N and P aboveground vs. belowground, in their rates of N and P loss from decaying shoot material, and in the length of their active growth period. These are important considerations for selecting species to retain N and P from nonpoint agricultural sources, both on seasonal and longer-term bases.

An investigation into the mechanisms controlling storm water quality improvement by a large, stream-outflow wetland draining into Irondequoit Bay, Lake Ontario, New York

Basic Information

Title:	An investigation into the mechanisms controlling storm water quality improvement by a large, stream-outflow wetland draining into Irondequoit Bay, Lake Ontario, New York
Project Number:	2001NY1142B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Wetlands, Water Quality, None
Descriptors:	Irondequoit Creek, Stormwater treatment, Streams, Water quality, Wetlands
Principal Investigators:	Rebecca L. Schneider

Publication

1. Plan to have a publication in September after a full year of data has been collected.

Problem and Research Objectives:

Wetlands are now acknowledged, and utilized, as a natural, powerful mechanism for reducing NPS because of their ability to filter out sediments, trace metals, and nutrients from storm water runoff before these contaminants can enter streams and lakes. New York is unusual in having five or more large, 100+ acre, wetlands strategically located along the mouths of rivers and lakes and cumulatively draining more than one thousand square kilometers of watersheds of the Finger Lakes and Lake Ontario. Relatively little is actually known about how any large wetlands, greater than 30 ha, interact with stream surface waters to reduce contaminants. It is uncertain whether sedimentation, groundwater dilution, wetland transformation, or some other process is responsible for the improvements in water quality. Do these processes change seasonally, among years, or as regional hydrologic conditions become more extreme? Can their wetland functions be impaired with chronic or pulse loading of contaminants?

Our previous efforts looked at seasonal patterns in wetland-stream interactions by monitoring a network of two stream gauges and seven stations, each consisting of a water table well, three nested piezometers, and floating boardwalks, all established in June, 1999. This work suggests that the stream-wetland interactions are not constant through time. The proposed work will concentrate on a shorter time scale, to examine how daily factors identified in the first study, including precipitation events, cattail plant evapo-transpiration, and over-bank flood events, are affecting wetland filtering processes. The broader goal is to investigate these short-term processes and then place them in the context of the documented seasonal and interannual patterns for an overall understanding of how the Irondequoit Creek wetland functions in surface water quality improvement.

Methodology:

Intensive sampling will be made of the water table fluctuations and porewater redox conditions at hourly intervals in association with the daily pattern of evapotranspiration from the cattail stands. The evapotranspiration monitoring will be done at biweekly intervals throughout the growing season and into early fall to capture changes associated with growth and senescence of the cattails. At each sampling time, measurements will be made hourly, from pre-dawn through early nightfall to capture the diurnal cycle. Water table levels will be monitored within the existing wells and piezometers. Evapotranspiration rates will be monitored using a Li-Cor photosynthesis meter. Plant biomass and heights over the course of the study will be monitored in replicate quadrats associated with each station.

All water samples collected from the surface water, wells and porewater samplers will be analyzed for pH and conductivity in the field. Samples will be collected, filtered, and stored on ice for later analysis of total dissolved nitrogen and phosphorus, nitrate and nitrite, orthophosphate, selected cations and trace metals.

Principal Finding and Significance:

Large natural wetlands are increasingly being relied upon to improve the quality and quantity of stormwater runoff coming from upstream developments. We have been investigating the mechanisms by which a 200 acre cattail marsh is removing contaminants from Irondequoit Creek after it drains 300 sq. miles of the watershed of Rochester, New York and before it discharges into Lake Ontario. Specifically, we are examining how surface waters and groundwaters change their interactions with changes in stream inflows, precipitation, and levels of Lake Ontario. From

1999 and 2000, we determined the groundwater flow paths and hydrologic interactions in the wetland by installing and monitoring a set of seven stations, including surface water gages, water table wells and nested piezometers. This initial work indicated that there are four distinctly different phases in the wetland that differ in the direction and magnitude of surface water and groundwater interactions. These phases range from drought conditions when the stream waters move horizontally into the wetland as plant evapotranspiration draws down the wetland water table, to wet periods, when the groundwater flow reverses direction and discharges into the stream.

Over the past 12 months, we have begun to investigate how associated contaminant filtering, and specifically the wetland's removal of phosphorus, differs among these four phases. This work is being conducted at two complementary spatial scales; including microscale processes controlling phosphorus flow within the plant root zone and larger scale sequestration of phosphorus among the different parts of the wetland. Last summer, we developed and piloted an insitu lysimeter that allows us to quantify transpiration (ET) rates from whole, intact cattail plants within the marsh. These lysimeters were monitored in late summer 2001 and will continue to be monitored through the remainder of this year's growing season. In association with the lysimeter measurements, we are monitoring how the flux of groundwater due to ET is influencing soil redox chemistry and the mass flow of phosphorus to the plants. At the larger spatial scale of the entire 10 ha study site, an M.S. graduate student is developing a phosphorus budget for the wetland by monitoring groundwater chemistry and periodic sampling of the aboveground and belowground biomass, litter, and sediment phosphorus pools under the four different hydrologic phases. Later this year, we plan to link the findings from the two scales to understand how wetland phosphorus removal occurs and changes through time.

An interactive, Internet-based, nonpoint source pollution modeling system for improving landscape management

Basic Information

Title:	An interactive, Internet-based, nonpoint source pollution modeling system for improving landscape management
Project Number:	2001NY1561B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Social Sciences
Focus Category:	Management and Planning, Models, None
Descriptors:	Water quality models, Internet, Streams, Water quality management,Nonpoint pollution
Principal Investigators:	Rebecca L. Schneider

Publication

1. An Interactive, Internet-based, non-point source pollution modeling system

Problem and Research Objectives:

In deciding how to improve water quality in a watershed, managers may ask: what are the most effective BMPs for improving water quality in a given region? How would current water quality conditions change with an adjustment in landuse? How much change would implementation of a BMP create in pollutant runoff such as total nitrogen, total phosphorus, suspended solids, lead or zinc? This proposal addresses the creation of a tool for use on the Internet by both planners and community members to answers these questions. This tool will enable watershed management agencies to visualize the use of BMPs in landscape management and will help community members gain a better understanding of their watershed.

The research objective is to provide easy and widespread access to a landscape planning model and information that will facilitate stakeholder involvement and consensus building in watershed management. This project would improve a previously created watershed simulation model. Data will be available from on-going work in the Cattaraugus and Irondequoit watersheds in NY. The resulting design can potentially be applied, through additional efforts and data collection, to other watersheds in the State. The proposed interactive, Internet-based tool allows users to apply landscape changes and view model results from the basin level down to an individual stream segment.

Methodology:

This project involves literature review, data collection, water quality model enhancement and testing, and web site development. Recent work has compiled digital data layers for land use, soils, rainfall, elevation, stream segments and drainage basins for the New York tributaries to the Great Lakes. These data layers will be the basis for the surface water nonpoint source, GIS-based, pollution screening model developed by Adamus and Bergman (1995). This model calculates the volume of runoff using runoff coefficients for landuse and soil categories and predicts sediment and pollutant loading using known concentrations given each landuse type. We will use a slightly improved model to predict loading of total nitrogen, total phosphorus, lead, zinc and suspended solids to each stream segment. Predictions of the model will be tested using STORET water chemistry data available in both watersheds.

Principal Findings & Significance:

Patterns of land use have a direct linkage to downstream water quantity and quality because they act as sources of contaminants, influence the degree of filtering of these contaminants, and influence the magnitude of runoff which transports the contaminants to the receiving water body. However, often town planners, highway departments, and other local government officials may not be aware of these connections or the influence of land use planning decisions on water resources. Over the past year, we have been developing an Internet-based education tool that is readily available and easy to use by local government officials, as well as public schools and other interested stakeholders. A simple model has been developed that integrates information from 1994 remote imagery-based land use maps, soils maps, and digital elevation models for two watersheds in western New York. Using this model, we have developed rough estimates of the loadings of total phosphorus, total nitrogen, suspended sediment, and lead and zinc that result from different land use scenarios. The Internet user will be able to select among six different land use scenarios in each of the watersheds to determine the effect of changing land use or adding various best management practices. Specifically, the six scenarios are: current land use conditions (as of 1994), pre-human development as a reference condition, addition of streamside buffers

throughout each watershed, addition of constructed wetlands for controlling stormwater runoff, improvement of soil management practices in agricultural areas, and increased development for its degrading impacts on water quality. The model and its outputs are largely completed and we are currently translating this information into the Web-based format with appropriate accompanying text. We anticipate the Web site will be available in September, 2002.

Publication:

The project will provide online means for users to interactively create water quality simulations over the Internet. Users will define an area for modeling by choosing one of the two watersheds (see Figure 2). They will then have the opportunity to zoom in/zoom out or create a box around their region of interest. Larger selected regions will be modeled with coarser data to enable the model to run at acceptable speeds. The user will then choose a scenario to model:

Produce predictions of pollutants given the current state;
Apply a BMP to the selected area and model the future state;
Compare the results of one BMP with another BMP to determine effectiveness of different BMPs on different regions;

BMPs to be modeled include such pollution prevention measures as streamside buffers, changes in land use, creation of wetlands, and improved soil management practices.

The results of each model simulation will be displayed to the user on the screen in an easy to interpret format, using GIS maps and graphs.

Epidemiologic Risk Analysis of Cryptosporidium parvum in Watershed: the Role of Genetic Variation Among Isolates

Basic Information

Title:	Epidemiologic Risk Analysis of Cryptosporidium parvum in Watershed: the Role of Genetic Variation Among Isolates
Project Number:	2001NY1841B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Ecology, Methods, None
Descriptors:	Dairy Farms, Pathogens, Molecular Biology, Risk Assessment,Cryptosporidium parvum
Principal Investigators:	Hussni O. Mohammed , Susan E. Wade

Publication

1. Lindergard, G; DV Nydam, SE Wade; SL Schaff; HO Mohammed, Detection of human infective Cryptosporidium isolates by multiplex PCR in fecal and soil samples, J Vet Diag Invest 2002, (Conditional acceptance).
2. Nydam, DV; GL Lindergard; SE Wade; SL Schaff and HO Mohammed, 2002 Prevalence of Cryptosporidium parvum genotypes H and C in isolates collected from cattle within the area of New York State that comprises the New York City Watershed, Epidemiology and Infection, (Submitted).

Problem and Research Objectives:

The specific objectives of the proposed studies will focus on:

i) Expand our panel of polymorphic markers for identification of a wider range of genotype of *Cryptosporidium spp.* isolates.

ii) Using combination of deterministic and probabilistic approaches we will develop scenario path models describing the transmission of infectious *C. parvum* from the environment to the stream edge. These models will take into consideration the infectious nature of the isolates, the management practices that promote and or inhibit this rate of environmental contamination and spread on the farm. The models will based on data collected previously and methods advanced in aim 1.

iii) Design cost-effective strategies to control and manage the potential risk associated with the presence of these organisms on CAFOs. These strategies will be base on the findings in aims 2 and 3 and allow for in put form stakeholders.

Methodology:

A PCR based protocol targeting multiple loci is expected to identify differences between genotypes of isolates from many different potential hosts. DNA is being isolated directly from whole fecal samples by a method modified after Zhu et al. (7), which uses glass beads to break the oocyst wall or by a freeze-thaw method designed in our laboratory.

Samples that have tested positive for Cryptosporidium oocysts at this stage will be further analyzed with a nested multiplex PCR method to verify its genotype (3,4).

In these proposed studies, in addition to expanding our markers to include additional species of Cryptosporidium, we will reexamine the 478 samples that were confirmed by the flotation method. The reexamination will be by PCR only. By doing so, we will be able to see whether all the samples had only one genotype or were contaminated with different species of Cryptosporidium. Furthermore, we will examine an equal number of randomly selected samples from the pool of negatives.

Pricipal Findings and Significance:

The funding was used to address aim 1. We carried out studies to expand our markers to include additional species of *Cryptosporidium* and examine fecal samples that were collected from cattle in New York City watershed. These samples were confirmed by the floatation and enzyme-linked immunosorbent assay (ELISA) methods to have *C. parvum.* Furthermore, an equal number of randomly selected samples from the pool of negatives were examined using the PCR method. The purpose of examining the negative samples was to confirm that we have not miss-classified animals as the result of employing a more sensitive technique, the PCR.

DNA was isolated directly from whole fecal samples using the glassbeads method to break the oocysts' wall. A nested PCR was performed for a portion of the *Cryptosporidium* SSU rRNA gene with first set of primers SSU-1 and SSU-2 followed by nested primers SSU-3 and SSU-4. In an earlier study we fond that the SSU approach is more sensitive than TRAP-C gene for detection of the presence of Cryptosporidium sp. in fecal samples.

A restriction enzyme, *Vsp* I, that specifically cuts the human *C. parvum* type was used at this stage to differentiate it from the bovine type. Similarly, a 331 bp fragment of the TRAP-C2 gene

was amplified exclusively from *Cryptosporidium* DNA by primary primers TRAP-1, TRAP-2 and secondary primers TRAP-3. Again, both the human and the bovine *C. parvum* type were identified by digestion with specific endonucleases; *BsuR*I digests the human type only while *Eco91*I specifically cuts the bovine type.

A nested multiplex PCR approach was adapted for the simultaneous detection of four human infective genotypes of the protozoan parasite *Cryptosporidium.* Specific PCR primers were designed for the heat shock protein 70 gene of three types of *C. parvum,* human type, bovine type and dog type and for *C. felis*. These four genotypes have all been found in human fecal samples. The primers amplified DNA fragments of specific sizes each representing a unique genotype. The limit of detection of the method was found to vary between 10 and 100 oocysts per 1 ml fecal material. The results of these studies are published in the manuscript by Lindergard et al., 2002.

Fecal samples were collected from 437 calves at risk for *Cryptosporidium.* This sample represents a subset of positive and negative samples that have been previously examined by concentration/flotation microscopy and oocysts were detected in 214 of them. The DNA from whole feces from all samples was extracted. This was used to amplify fragments of the SSU rRNA and the thrombospondin-related adhesion protein C-2 (TRAP C-2) genes by nested polymerase chain reaction (PCR). Amplicons were generated for 200 of the samples. The SSU rRNA fragments were subjected to restriction digestion by the enzyme *VspI* and the TRAP C-2 fragments were digested by the restriction enzyme *Eco91I* to distinguish between the H genotype (genotype 1) and the C genotype (genotype 2) of *C. parvum.* None of the 200 samples tested by this 2 locus nested PCR-restriction fragment length polymorphism (RFLP) approach had the H genotype. We are 95% confident that the cattle in the NYCW did not harbor the H genotype. Focusing solely on methods to decrease or eliminate watershed contamination with oocysts by cattle will likely miss the important human sources of many urban drinking water outbreaks that are caused by the H genotype.

Cayuga Lake Watershed Education Program Web-linked Interactive CD-ROM

Basic Information

Title:	Cayuga Lake Watershed Education Program Web-linked Interactive CD-ROM
Project Number:	2001NY1881B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Water Quality, Education, None
Descriptors:	Education, Cayuga Lake, Computer-based training,Water quality modeling
Principal Investigators:	Daniel P. Loucks

Publication

1. None as yet. We expect to be distributing and presenting the results of this project at workshops and conferences when it is complete

Problem and Research Objectives:

The objective of this research project is to create an interactive web-linked CD that will enable all interested stakeholders to obtain the information they want and at the level they can understand on the current status of the Cayuga Lake Watershed.

Methodology:

A CD is being prepared that provides easy access to, and interactive use of, material contained in three recent publications, and to related web pages for users connected to the Internet. The three publications are "Issues in the Cayuga Lake Watershed," "Cayuga Lake Restoration and Protection Plan (RPP)" and Water Quality Study of the Finger Lakes" by C. Callinan. The Cayuga Lake Watershed Network and the Cayuga Lake Watershed Intermunicipal Organization will be distributing the CD holding informational meetings on the use of the CD. They will also be incorporating it as one of their public relations promotional tools.

This work is being carried out primarily by individuals at the Ithaca Environmental Laboratories, led by Dr. Jose Lozano, Director. Members of the Intermunicipal Organization and the Cayuga Lake Wataershed Network are contributing to the design and content of this CD.

Principal Findings and Significance:

Providing content for the CD has been the biggest and most time consuming task. The interactive structure or framework of the CD has been established, with minor modifications yet to be made. Content is now being inserted into this framework. So far about 70% of the funds have been spent. The remaining will be devoted to working on providing easy interactive access to information at various levels of understanding and detail, creating a separate web page for updated information as it becomes available and containing questions and programs and models that will make this web-linked CD more useful as an educational tool for use in schools.

Best Management: Transforming Principles into Practice in New York Greenhouses

Basic Information

Title:	Best Management: Transforming Principles into Practice in New York Greenhouses
Project Number:	2001NY1921B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Agriculture, Non Point Pollution, Water Quality
Descriptors:	Agricultural Environmental Management, Agriculture, Greenhouses,Nonpoint sources
Principal Investigators:	Jana S. Lamboy , Mary-Lynn Cummings , Thomas C. Weiler

Publication

1. NYS IPM Program, Cornell Cooperative Extension, December 2001, Protecting your business and the environment with Best Management Practices, Cornell University

Problem and Research Objectives:

Many of the 1100 commercial greenhouse operations in New York State discharge wastewater directly to the ground surface or through drains to surface water. Greenhouse wastewaters are likely to contain some contamination from the legal and appropriate use of pesticides and fertilizers in the greenhouses. In a number of counties in New York, the protection of groundwater from agricultural pollution is a key issue. The goal of this project was to increase awareness and implementation of best management practices for minimizing the discharge of nutrient- and pesticide-contaminated wastewaters from commercial greenhouses in New York State. The target audience includes extension educators, horticultural students, and commercial greenhouse owner/operators. The objectives were to develop Best Management Practices for commercial greenhouses in New York, to teach students and CCE educators how to evaluate current practices, and to reach industry leaders to enlist their support to increase adoption of BMP principles.

Methodology:

The first step in approaching commercial greenhouse BMPs was to establish the collaboration with Jeff TenEyck of the Agricultural Environmental Management (AEM) program. Once the PIs understood the way in which the project fit into the AEM Program context, terms, and organization, the next stage was to determine the environmental issues of concern to the industry stakeholders. The PIs worked with Cooperative Extension Educators in the Southern Tier (Walter Nelson) and Western (Karen Hall) regions of the state to locate greenhouse and nursery cooperators. Tom Weiler introduced his horticulture class to the principles of greenhouse BMPs., and three students selected an independent study with greenhouse BMPs. Twenty site visits to commercial greenhouse growers were conducted by a team including a CCE educator, one of the principal investigators, and one or more students. After discussions on key environmental issues, a brochure was produced to introduce the concepts of BMPs to greenhouse operators. The first AEM worksheet was created to ascertain the interests and local issues of each greenhouse operation. The concepts of greenhouse BMPs were presented to several audiences across the state and to IPM workshops outside New York.

Principal Findings and Significance:

The growers we met on site were interested in protecting their businesses from public concerns. They thought of themselves as good corporate citizens, and were very interested in pursuing how better they might steward environmental, worker, and public well-being. The students appreciated their opportunity to become informed about practical problems and environmental issues at real greenhouse businesses, beyond theoretical or classroom greenhouse situations.

Subjects identified as hot topics where education is needed included:
- water quality before, during, and after plant production
- excess fertility provided to plants leaching into the soil
- pesticide storage facilities, inventory management, safely obtaining small quantities of chemicals from large quantities, and disposal of hazardous waste
- human safety and liability issues, including customers and employees:
    - pesticide storage in worker or public spaces-inhaled fumes, etc.
    - pesticide exposures via items like aprons stored in the greenhouse
- pesticide and fertilizer knowledge: awareness of toxicology, water solubility, and modes of action

Greenhouse and nursery operators clearly were interested in the concept of continuous improvement in BMPs including: 1) risk identification and assessment (seeing themselves through the eyes of the community, neighbors, employees, the DEC, etc.), 2) prioritization of actions to improve (based on risk as well as time and financial resources available for improvement), 3) employee training, 4) inspection and record-keeping, 5) preventative maintenance, and 6) good housekeeping.

Modeling phosphorus control best management practices on a watershed scale to improve surface drinking water quality

Basic Information

Title:	Modeling phosphorus control best management practices on a watershed scale to improve surface drinking water quality
Project Number:	2001NY921G
Start Date:	9/1/2001
End Date:	8/31/2004
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Agriculture, Water Quality
Descriptors:	dissolved phosphorus, water quality modeling, best management practices, watershed management, hydrology
Principal Investigators:	Tammo Steenhuis

Publication

1. Gerard-Marchant, P., T.S. Steenhuis, M.T Walter, V.T. Mehta, M.S. Johnson, and S. Lyon, 2002, Saturated Excess Runoff Modeling in Undulating and Mountainous Watersheds, Poster EGS02-A-00665, EGS XXVII General Assembly, Nice, France, April 2002.
2. Gerard-Marchant, P., 2002, The Soil Moisture Routing Model: A User Manual, Version 1.0, Soil and Water Laboratory, Biological and Environmental Engineering Dept., Cornell University, Ithaca, NY, USA.
3. Johnson, M.S., 2001, Comparative Analysis of Two Watershed Hydrologic Models for a Central New York State Watershed: Hydrological Simulation Program - Fortran (HPSF) and the Soil Moisture Routing Model (SMR), MS Thesis, Cornell University, Ithaca, NY, USA.
4. Mehta, V.K., 2001, A Multi-Layered Soil Moisture Routing (SMR) Model Applied to Distributed Hydrological Modeling in the Catskills, MS Thesis, Cornell University, Ithaca, NY, USA.
5. Mehta, V.K., M.S. Johnson, P. Gerard-Marchant, M.T. Walter, and T.S. Steenhuis, 2001, Testing a Variable Source GIS-based Hydrology Model for Watersheds in the Northeastern US, the Soil Moisture Routing Model, Eos Trans. AGU, 82(47), Fall Meet. Suppl., Abstract H22I-05, 2001.

Problem and Research Objectives:

Non-point sources –agriculture is no exception – are one of the largest contributions of phosphorus (P) to surface waters, where excess P typically results in eutrophication. The Environmental Protection Agency (EPA) generally requires filtration for surface water supplies. New York City (NYC) was granted an exemption from filtration for surface drinking water supplies provided that an acceptable watershed program plan and protective measures can be achieved, with significant emphasis on P control. A high priority has been placed on the development and implementation of effective best management practices (BMPs) for P control. However, no effective modeling tool is available to evaluate the potential impacts of BMPs on P transport in shallow, sloping soils such as occurring in the northeastern US.

The overall goal of this study is to develop and test a model that can predict, on the watershed scale, the transport of P from agricultural and forest lands on shallow sloping soils. This will be accomplished by: 1) performing laboratory and field experiments to understand P movement on shallow soils, 2) improving the spatially distributed Soil Moisture and Distribution model (SMDR) that includes P fate and routing routines, and 3) validating the model with data collected from Town Brook and other watersheds in the Catskills.

Methodology:

In order to understand P movement on shallow soils, we decided to put more emphasis on P loss from manure and fertilizers than was originally described in the proposal. A set of experiments will be carried out on sloping artificial runoff plots in the laboratory with a rainulator. Manure and/or fertilizers will be added on the top of the slope and the P concentration will be measured as a function of time and distance along the slope. Another set of experiments will be carried out in the field with milk house wastewater strips. The advantage of these strips is that daily P is added and, therefore, ideal to study the movement of P.

Phosphorus losses are highly dependent on the distance to streams. Therefore, P transport should be simulated with a model that conserves the spatial information. Spatially distributed models are ideal for this purpose. For this project, we will adapt the spatially distributed SMDR model by incorporating P generation and transport mechanisms (SMDR has been proven suitable for the hydrologic and geologic characteristics of the Northeast).

Validation will occur in two steps. First, the simple analytical relationships between soil P content and P concentration in surface and groundwater will be validated with simple laboratory experiments described above. Then, the SMDR model with the laboratory validated P routines will be tested on a watershed scale.

Principal Findings and Significance:

The project was funded in November 2001 and, consequently, the principal findings relate to the first half-year of the study.

The field laboratory studies with the milk house wastewater filter have been completed and showed that dissolved P can move over the same distance as a chloride tracer. The data need to be analyzed further and the results will be reported in next year's progress report. Laboratory studies have just begun.

During the first part of this calendar year, we prepared two publications concerning the validation of the previous version of SMDR (called Soil Moisture Routing Model or SMR). We also compared the model with the Hydrological Simulation Program – Fortran (HSPF). Discharges were simulated equally well with both models, but only SMR was able to accurately predict the spatial distribution of water and locations of runoff- generating zones in the watershed.

Most of the time was spent on stabilizing the new SMDR code. In this new code, infiltration and drainage are simulated more realistically. This was necessary in order to implement routines for P leaching in the soil. Evaporation calculation algorithms were also modified to take better into account the development stages of different vegetation covers. Additional routines were developed to simplify the generic use of the program and to streamline the importation of input maps or the creation of input look-up tables. A user manual, incorporating a fully commented code, has been released.

In addition, a simple model has been developed for the release of P from spread manure. This model links cumulative P load released to cumulative runoff, through a simple relationship requiring the knowledge of only two parameters: percentage of water-extractable P in the manure and the volume required to wash half the P out of the manure.

Finally, we have developed a routine that allows us to calculate the loss of land-applied manure. A fully distributed modeling of manure P leaching requires the knowledge of the actual location of the land-applied manure, as well as the quantities involved. Unfortunately, such data is not available. Therefore, a semi-distributed approach is followed. The watershed is divided in a number of geographical units. Each unit corresponds to the smallest area for which some information about manure application is available: for example, a farm, or a particular field in a farm, depending on the scale of the watershed. Each of these “manure application units” is then subdivided into elementary “spreading plots”. The size of each plot is defined as the area covered during a single manure spreading. For example, when manure application units are identified with fields, the plot size will correspond to the area covered by a single spreader, that is, a stripe of approximately 2000 m^2 (723’ x 33’ with a 4’overlap).

Estimating the Risk of Water Contamination by Cryptosporidium parvum oocysts and other colloidal pollutants

Basic Information

Title:	Estimating the Risk of Water Contamination by Cryptosporidium parvum oocysts and other colloidal pollutants
Project Number:	2001NY15B
Start Date:	10/1/1999
End Date:	9/30/2000
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Solute Transport
Descriptors:	Cryptosporidium, Solute transport, Mathematical models, Animal waste, Nonpoint source pollution
Principal Investigators:	Carlo D. Montemagno

Publication

1. Yeghiazarian L.L., C.D. Montemagno, M. Walker, P. Binning and J.-Y. Parlange. Micro- and macroscopic approach to modeling the transport of pathogenic microorganisms and other colloidal particles from non-point sources of pollution (in revision).
2. Yeghiazarian L.L. and C.D. Montemagno. Application of reliability methods to the transport of colloidal pollutants in surface water. (in revision)
3. Yeghiazarian L.L., C.D. Montemagno and G. Samorodnitsky. Stochastic model of transport of colloidal pollutants in the surface water. (in revision)
4. Yeghiazarian L.L., 2001, Stochastic approach to modeling the transport of colloidal pollutants in surface water on the micro- and macroscopic scale, Ph.D. thesis, Cornell University.
5. Yeghiazarian, L. and C.D. Montemagno, 2000, Estimating the risk of water contamination by Cryptosporidium parvum oocysts, in XIII International Conference on Computational Methods in Water Resources, Calgary, Alberta, Canada, 2000.
6. Yeghiazarian, L. and C.D. Montemagno, 1999, Estimating the risk of water contamination by Cryptosporidium parvum oocysts, in International Riverbank Filtration Conference, Louisville, KY, November 1999 (invited presentation).
7. Yeghiazarian, L. and C.D. Montemagno, 1998, Stochastic model of microorganism transport from non-point sources of pollution, EOS-Transactions, American Geophysical Union, Abstract H22D-03, 1998.
8. Yeghiazarian, L. and C.D. Montemagno, 1998 Estimating the risk of water contamination by Cryptosporidium parvum oocysts, EOS-Transactions, American Geophysical Union, Abstract S152, 1998.

Problem and Research Objectives:

Many municipalities world-wide provide their citizens with finished drinking water whose source is surface waters. Recent outbreaks of cryptosporidiosis (a gastrointestinal disease caused by oocysts of *Cryptosporidium parvum*) raise grave concerns about the quality of raw surface waters, and watershed management of the risk of contamination by pathogens.

Cryptosporidium parvum is a protozoan pathogen that is found in high concentrations in animal feces. High intensity agriculture such as cattle feedlots and land application of sewage and manure may be the source of these pathogens in drinking water. The transmissive form of *C. parvum*, its oocysts, may not be eliminated by filtration and standard disinfection methods. *C. parvum* oocysts thus challenge the long-standing engineering approaches to public health risks from water supply contamination, and little is known about the transport of the oocysts in natural systems.

Our primary objective was to develop an accurate method for the quantitative determination of the effect of watershed management practices on the risk of human health caused by the transport of *C. parvum* oocysts into municipal water supplies. This goal has been achieved through development of an integrated model and risk assessment of the transport of *C. parvum* oocysts in environment risk assessment. While the study considers *C. parvum*, our strategy can be applied to any pathogenic microorganisms or colloidal particles that share the specifics and transport of *C. parvum* on the soil surface.

Methodology:

The model has the following features:

1. Two basic modes of microorganism movement in surface flow: free advection and transport via attachment to soil particles of varying sizes
2. Transport of microorganisms in the overland flow and their interactions with soil particles modeled as a discrete-space continuous-time Markov process
3. Temporal and spatial distribution of pathogenic microorganisms in runoff obtained
4. Ability to predict low probability events by incorporation of first- and second-order reliability methods (FORM and SORM)
5. Sensitivity analysis of microorganism yield with respect to environmental factors
6. The hydrologic, climate, soil, vegetation, sediment load and other parameters obtained from the Water Erosion Prediction Project (WEPP) simulations.

Principal Findings and Significance:

We have developed a new approach to modeling microorganism transport and interactions on the soil surface and in overland flow.

The heterogeneous distribution of microorganisms in surface water and on soil surface, and the uncertainty associated with the sources of Cryptosporidium, as well as the natural processes that cause its transport, lead to wide fluctuations of Cryptosporidium counts in water samples. We have created a stochastic model of pathogen transport over the soil surface to account for these phenomena. The model is based on the behavior of a single microorganism and inherently predicts the random variability of pathogen transport. The behavior of large numbers of pathogens is derived from the single-microorganism model. We found that the probability that microorganisms will form bonds with soil particles is consistently higher in the flow over the clayey soil during the first hours of runoff, then the difference between clayey and sandy soils

becomes marginal. Also, in the flow over the sandy soil the probability of being freely suspended in higher than the probability of being attached to soil particles.

A serious problem in predicting water contamination events is the low probability of the occurrence of large numbers of oocysts in surface waters. Monte-Carlo simulations therefore are not feasible due to the great deal of computational time required to simulate a single event. This problem was solved by introducing the first- and second-order reliability formulation. The reliability methods have been previously used in structural engineering and for predictions of ground water contamination, but never for the risk assessment and sensitivity analysis of surface water contamination. We found that the variations in rainfall intensity, followed by the clay content of suspended sediment have consistently had the largest impact on the outcome of the computations. We have also looked into how the failure probabilities and sensitivity measures change over time. The failure probabilities were higher at 2 hours after the rainfall commencement, as opposed to 10 hours. Also, the importance of deterministic parameters changed: at t=2 hours the most significant parameter was the one associated with the biological decay of microorganisms, whereas at t=10 hours the rate of attachment of microorganisms to soil particles acquired the highest significance.

In conclusion, we have outlined a framework for extension of single hillslope simulations and risk assessment to complex systems consisting of multiple watersheds.

International Lake Ontario and St. Lawrence River Study: 2001 Environmental Program

Basic Information

Title:	International Lake Ontario and St. Lawrence River Study: 2001 Environmental Program
Project Number:	2001NY17B
Start Date:	9/1/2001
End Date:	11/30/2002
Research Category:	Climate and Hydrologic Processes
Focus Category:	Ecology, Hydrology, Wetlands
Descriptors:	hydroecology, water regulations, hydrologic regulation criteria, biodiversity, habitat quality, ecosystem processes, wetlands
Principal Investigators:	Mark Bain , Sandra Bonanno , James Gibbs , Lee Harper , Donald Leopold , Keith S. Porter

Publication

Problem and Research Objectives:

In 1999 the International Joint Commission (IJC) informed the governments of the United States and Canada of its establishment of a binational study to review the criteria which presently prescribe the way in which Lake Ontario water levels are regulated. A Study Board was assembled by the IJC to investigate a range of benefits and consequences of the operation of control structures influencing flows and levels of the Lake Ontario - St. Lawrence system. With study results, a determination will be made as to which changes are warranted in the operating criteria of the regulatory works on the St. Lawrence River to better answer the needs of different interest groups. The Study is divided among working groups for public interests, Environment, recreational boating, commercial navigation, riparian property, hydropower, common data needs, plan evaluation, and water use.

In 2001-2002, the Environment Technical Work Group will focus on (1) wetland vegetation studies and mapping to provide recommendations on the regulation scenarios to maintain dynamic cycles and processes, (2) faunal studies to protect significant habitat in coastal waters for fish and bird communities; and (3) modeling and integration of data to obtain preliminary outcomes of different regulation scenarios on all Environmental attributes. The Technical Work Group will use the first year efforts to design subsequent investigations and analyses. This package includes all non-federal agency studies under the Environment Technical Work Group plan approved by the Study Board in June 2001.

The goal of this International Joint Commission (IJC) Environmental Work Group task is to produce an initial impact assessment model for mathematical application to the evaluation of different water regulation plans. While developing a first assessment model will require speculation on some environmental resources, this exercise will achieve the following objectives:

1. Demonstrate a specific assessment method in working form.
2. Identify information needs to support a specific assessment method in a way that can guide future efforts by the work group.
3. Demonstrate specific information needs to be developed by contractors in the current year and in future years.
4. Resolve precise relations between environmental response information and the hydrologic simulation capability of the Hydrologic and Hydraulic Modeling Technical Work Group.
5. Demonstrate outputs of the Environmental Work Group for inclusion in systemwide evaluation.

Methodology:

This proposed project is to allow a lead scientist with extensive impact assessment experience to work with an environmental specialist to design, structure, and parameterize a numeric model for expressing environmental gains and losses under different water management plans. These specialists will work with the office of the Canada Environmental Lead (C Hudon) and members of the Environmental Technical Working Group. Very close working relations will occur with 2001 contractors and the Hydrologic and Hydraulic Modeling Technical Work Group leads. In addition to one on one sharing of information and knowledge, project scientists will organize and hold two workshops of 2001 contractors (travel at their cost). The first in late winter 2002 will be held to identify the criteria for environmental resources to be in the model. For example, vegetated underwater habitat area might be a criteria for parameterization while a resource concern like fish habitat would be too general. In addition, the data and information being

collected in 2001 would be compared with available information to assess what is needed to parameterize each criteria. The product of this workshop would be a list of criteria, how they would be used together, and what information is at hand for parameterizing each criteria. The second workshop would be afterward for the purposed of parameterizing the criteria selected for modeling. Participants will again be environmental contractors and work group members. The product of this workshop will be a parameterized model with professional judgments used when no clear information exists. Afterward, the model would be made operational through interaction (small meeting of specialists) with the hydrologic simulation contractors of the Hydrologic and Hydraulic Modeling Technical Work Group. The final product of this proposed effort will be a report of the model structure, application techniques, and draft results of use in the initial assessment exercise. The most pressing information and data needs will also be identified.

Principal Findings and Significance:

The work for this project did not begin until the end of this reporting period. Therefore, only a recapitulation of its goals and methods is included in this report. Substantive progress will be reported in the FY 2002 report.

References:

None

Information Transfer Program

Basic Information

Title:	Director’s Office Information Transfer
Start Date:	3/1/2001
End Date:	2/28/2002
Descriptors:	Nonpoint pollution, Water quality management, Education,Information transfer
Principal Investigators:	Keith S. Porter

Publication

Over the past year WRI has continued to promote specifically the engagement of the wider academic community in water resource management issues in New York State. As in previous years, opportunities to pursue this aim were sought through the New York State Soil and Water Conservation Committee, the New York State Agricultural Environmental Management Committee, and the New York State Non point Source Management Coordinating Committee. With the encouragement of the three committees, WRI promoted and advanced a proposal to create a NYS Academic partnership with the inter-agency NYS Soil & Water Conservation Committee. This proposal was approved and instituted by the Committee. WRI Also promoted the idea of creating a student internship program. This was also approved by the Committee and in being pursued on a pilot basis by some Soil & Water Conservation Districts. The NYS Soil and Water Conservation Committee has now formally invited universities and colleges to form a partnership with the committee, and its member state agencies in shared research and educational ventures.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	11	0	0	0	11
Masters	4	3	0	1	8
Ph.D.	4	0	0	0	4
Post-Doc.	2	0	0	0	2
Total	21	3	0	1	25

Notable Awards and Achievements

Notable Awards and Achievements:

As a notable achievement, WRI has continued to play a lead scientific and educational role in the New York City Watershed Program. The high environmental and economic significance of this program continues to attract a high degree of national and international interest. With the assistance of WRI, Delaware County has now obtained over $2.0 million to conduct scientific and technical work on the Cannonsville Reservoir Basin. A particular success is the innovative integrated nutrient management program that WRI has facilitated through these funds. This program, led by faculty at Cornell University, is developing and applying integrated models for animal nutrition, field crops, soil and water. By using the models, imports of phosphorus can be reduced by up to 50% and the amount of phosphorus in manure reduced by 25%. This environmental gain is accomplished with economic benefits to the farmer. The models also improve the recycling of nutrients on the farm and promote more efficient applications of manure resulting in greatly reduced losses of the nutrients to watercourses.

WRI is also assisting in extending the adoption of the management methods elsewhere in New York State through the NYS Agricultural and Environmental Management Program. It may also be noted that the Cannonsville Reservoir Program conducted through Delaware County is receiving a high level of acknowledgement. The recognition is due in large part to the solid scientific credentials upon which the watershed program is based. This is now an excellent example of how the academic scientific community: faculty, staff and students, can assist in meeting a critical water resources challenge.

Non-USGS Projects

The Hudson River Estuary Program

One of Governor Pataki’s highest environmental priorities is the Hudson River Estuary Program (HREP). Fran Dunwell has directed the Hudson River Estuary Program since its inception in 1996. The Program has received $30 million in state funds over the past five years ($6.0 million/year). The HREP has just updated its strategy adopting three primary themes:

- Conserving Natural Resources - Promoting Use and enjoyment of the River - Cleaning up Pollution

The Hudson River Estuary Program is expanding to deal with issues in the greater Hudson River watershed. Thus the WRI Faculty Advisory Committee is considering establishing a Hudson Estuary Watershed Support Group, initially chaired by Peter Loucks, to foster closer relations between Cornell and HREP.

At the suggestion of its Faculty Advisory Committee, the NYS Water Resources Institute invited Fran Dunwell and Scott Cuppett from the HREP to visit Cornell and meet with several faculty members to discuss potential research ideas. The outcome of the meeting was the plan to work on developing a support group for the Hudson River Estuary Program based on solid science with a research component for decision making. Two main issues will be focused on:

- Developing a regional water budget within a climatological framework

- Emphasizing public health and water supply issues

WRI is presently working on developing a discussion paper with key faculty members for presenting to the Hudson River Estuary Program.

Publications from Prior Projects

None