PROPOSAL FOR RESEARCH STUDY

INDOT Rest Stop Constructed Wetland Evaluation: Hydrologic and Environmental Aspects

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and

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Joint Transportation Research Project

Proposed as an SPR Study
in cooperation with
INDOT and FHWA

Purdue University
West Lafayette, Indiana

1 June 2004
Project Overview

This proposed research effort was originally developed as a coordinated set of three individual ‘long-range’ research projects under the ‘Wetlands Focus Area Theme’ of the ‘JTRP-INDOT Strategic Environmental Focus Area’, as follows:

<table>
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<th>No</th>
<th>Focus Area Theme</th>
<th>Problem Statement Topic</th>
<th>Funding Request</th>
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<tbody>
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<td>1</td>
<td>Wetlands</td>
<td>Constructed Wetlands for INDOT Rest Stop Wastewater Treatment: Proof-of-Concept Research Investigation</td>
<td>$250,000</td>
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<td>2</td>
<td>Wetlands</td>
<td>Constructed Wetland Systems for Wastewater Management</td>
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<td>3</td>
<td>Wetlands</td>
<td>Hydrology of Natural and Constructed Wetlands</td>
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In short, all three of these projects were developed to facilitate a coordinated experimental evaluation of a full-scale, proof-of-concept constructed wetland at an INDOT rest stop. However, during the course of developing the individual ‘problem statements’ for each of these projects, it quickly became obvious that the optimal approach for conducting these projects would be to consolidate them into one master ‘INDOT Rest Stop Constructed Wetland Evaluation’ project with three component parts (i.e., respectively covering the additional construction of a ‘biofield’ unit plus the complementary ‘hydrologic’ and ‘environmental’ research aspects), as follows:

**Part 1:** Biofield Unit Placement at INDOT Rest Stop Constructed Wetlands

**Part 2:** Hydrologic Aspects of INDOT Rest Stop Constructed Wetlands

**Part 3:** Environmental Aspects of INDOT Rest Stop Constructed Wetlands
Several important qualifications must be emphasized in regard to this consolidation of the original three projects into a single, three-pronged project, as are described in the following synopsis:

First, the question of ‘where this experimental constructed wetland will be located’ has been given considerable thought in preparation for this project. Originally we thought that INDOT’s Centerville Rest Stop (on the Indiana-Ohio state line at the westbound side of I-74) would prove to be the optimal location, but subsequent discussions with the responsible consultant (i.e., Bonar and Associates – John Edwards) led to a conclusion that this site would not actually be built for a period of one to two years. In turn, a number of possible alternatives were considered, including the notion of building a half-scale site at an I-65 rest stop due north or south of Lafayette. Finally, after consulting with Phyllis Hockett, we decided to meld our research efforts with INDOT’s plans for installing a new constructed wetland at the Greenfield Rest Stop due east of Indianapolis on I-74. This rest stop was fairly recently built by RQAW Inc., but quickly ran into problems with an unexpectedly high concentration of effluent wastewater being discharged into the nearby municipal wastewater treatment facility due to low-flow restrictors on the rest stop toilets. As a result, this consultant (RQAW) is currently working on a feasibility report (in consort with J.F. New and Associates, Inc.) for the expedient installation of a new constructed wetland. This latter system will then provide pretreatment of the rest stop wastewater prior to discharge into the municipal sewer.

Second, the question of ‘who will be paying for this newly installed constructed wetland’ at Greenfield is currently unclear, but the circumstances appear to be such that we have an opportunity to constructively meld our research goals into a facility which INDOT was already planning on building in the immediate future. If necessary, the original ‘strategic project’ funding of $250,000 could fully be invested in this construction, but on the other hand it seems likely that these construction funds would have already been earmarked through other INDOT channels. In turn, it is our hope that we could realize a considerable savings of this $250,000, at which point we might beneficially divert some portion of these funds into the other two complementary projects.

Third, after talking with Jim New in regard to this plan for melding our research goals with the planned installation of this new constructed wetland, we came to the conclusion that it would be highly beneficial to add an additional ‘biofield’ system to the tail-end of this full-scale unit, which would creatively give us an added opportunity to experimentally evaluate its performance in regard to other INDOT rest stops which might require this type of sub-surface disposal. As such, and given that it does not appear the entire $250,000 will be required for full construction of the experimental wetland even were that necessary, we would like to expend a smaller segment of these monies (estimated at $35,000, as per engineering estimate forwarded on 31 May 2000 by J.F. New and Associates, Inc.) for the additional construction of an effluent ‘biofield’ in order to provide an additional opportunity to investigate the performance of this added component.

Fourth, at this point, therefore, the first project’s original allocation would have been reduced to an estimated $35,000 (i.e., for the added biofield), at which point we are hoping that some fraction of the remaining funds can be moved over to the remaining two project
elements (i.e., the hydrologic and environmental research components) to facilitate their commensurate expansion (i.e., to cover the added biofield).

Fifth, we are currently estimating that the **additional instrumentation required for the added ‘biofield’ will add approximately $40,000** to the ‘hydrologic aspects’ segment of this project, raising its overall budget from the originally allocated level of $180,000 to **$220,000**.

Sixth, we are currently estimating that the **additional analytical testing required for the added ‘biofield’ will add approximately $20,000** to the ‘environmental aspects’ segment of this project, raising its overall budget from the originally allocated level of $85,000 to **$105,000**.

Seventh, these latter two shifts in allocated funds, plus the designated cost for building this additional biofield unit, will still be approximately $155,000 less that the originally allocated total (i.e., for the three projects) of $515,000.

### Introduction

#### Technical Background

Over the last decade, constructed wetlands have been promoted as environmentally-friendly alternatives for wastewater treatment. Natural wetlands have long been recognized for the incredible levels of diverse plant and animal life that they support, and are important resting stops in the migratory patterns of many birds. Compared to the role of wetlands in maintaining ecosystem balance, their benefits in terms of flood-water attenuation, water quality, and recreational uses were considered to be of secondary importance.

The so-called secondary benefits of natural wetlands are currently the main reasons for preserving them, or building new ones. Their potential for offering biological diversity, as systems for economical secondary and tertiary treatment of polluted waters, and as buffers between sources of pollution and receiving waters downstream are some of the reasons for promoting their development (Perry and Vanderklein, 1996). Because of the many potential benefits that can be derived from wetlands, their design criteria are often dictated by the desired application. In particular, a wastewater treatment wetland is designed to achieve target removal efficiencies for particular constituent(s) under some pre-determined pollutant loading.

Constructed wetlands, specially subsurface ones, are now popular as a means treating wastewater. Constructed wetlands that are built for water treatment utilize natural processes involving vegetation, soils, and associated microbial populations to assist in treating an effluent or other water source. When planned properly, these systems offer the possibility of regaining the natural functions of wetlands, and offset some of the losses in wetland acreage from anthropogenic activities. With appropriate design, monitoring, operation and maintenance, these manmade systems can provide treatment benefits and, in some sense, emulate natural wetlands.

The study of wetlands requires inputs from hydrologists, water quality experts, plant ecologists, biologists, and a host of other disciplines, making it a truly multi-disciplinary problem. Wetland performance is dependent on several factors such as:
(a) wetland soils, their chemistry, and the kind of reactions that occur between the soils and the contaminants,
(b) role of macrophytic vegetation within the wetland, and
(c) microbial populations and their influence on the fate and transport of contaminants.

Even though constructed wetlands have been designed primarily for treatment of surface water, studies have shown the effectiveness of wetlands for treating runoff and non-point source pollution (Mitsch and Gosselink, 1993; Wittar, 1993; Livingston, 1989) as well. However, because of the lack of good follow up studies on constructed wetland performance, the evidence is quite weak. Intuitive ideas are often implemented for improving wetland efficiency from a hydrologic standpoint, such as:

- maximizing the distance between the wetland inlet and outlet;
- including both deep and shallow sections to promote diverse wetland vegetation;
- maximizing the treatment area;
- increasing the tortuosity of flow paths;
- minimizing slope between inlet and outlet ends to increase residence time.

Hydrology plays a major role in determining the effectiveness of wetlands. It influences the hydroperiod (the period of inundation), the establishment of vegetation and microbial populations, the diversity in plant and animal life, the loading and outflow rates, removal reaction kinetics, and the accompanying dilution. Hydrology also determines the probabilities of wetland discharges meeting or exceeding regulatory limits. Wetland hydrology has been discussed to varying degrees of detail by Kadlec and Knight (1995), Watson and Hobson (1989), Kadlec (1989), and Mitsch and Gosselink (1993). A complete description of wetlands is beyond the scope of this proposal.

For constructed wetlands, the water budget can be simplified. Generally, these structures are built so that the wetland has a single inlet and an outlet. Many constructed wetlands have plastic or bentonite clay liners to practically eliminate deep percolation.

**Modeling studies**

Mathematical models serve as valuable tools for understanding the function of constructed wetlands, quantifying pollutant removal, and developing successful management strategies. Wetland modeling efforts have ranged from attempts to describe very specific wetland processes to detailed models of wetland hydrology and nutrient cycles. Mitsch (1983) classified wetland models into seven categories: (1) energy/nutrient models, (2) hydrological models, (3) spatial ecosystem models, (4) tree growth models, (5) process models, (6) causal models, and (7) regional energy models. Mitsch et al. (1988) note significant advances in the modeling of coastal marshes and estuaries as well as modeling of shallow lakes and reservoirs and northern peat-lands. However, deficiencies exist in the modeling of subsurface constructed wetlands for the treatment of wastewater. Many modeling studies tend to be ecosystem-specific, and are of limited value for application elsewhere. For instance, the forested wetland model of
Mitsch (1988), for example, is not applicable to emergent, freshwater wetlands that are typical of stormwater applications. Similarly, models that have addressed wetlands receiving stormwater runoff tend to very site specific and are not widely applicable.

Kadlec and Knight (1995) present a detailed review of water quality modeling for wetlands since 1980. Wastewater modeling efforts include nutrient cycling (Heliotis and DeWitt, 1983); cypress dome wetland model (Jørgensen, 1986); hydrologic and nutrient cycle model (Jørgensen, 1988); compartmental dynamic hydrology and nutrient model for Porter Ranch wastewater treatment facility at Houghton Lake, Michigan (Kadlec and Hammer, 1988); phosphorus modeling (Mitsch and Reeder, 1991); simple first-order model for nitrogen and coliform (Bavor et al. 1989); phosphorus retention (Richardson and Craft, 1993); compartment generalized model for nutrients in wetlands (Johnston, 1993); and phosphorus retention (Reckhow and Qian, 1994). Light (1992) and Lung and Light (1996) study copper and phosphorus fates for Old Woman Creek wetland (Ohio). Kadlec and Knight (1995) developed a generalized model of wetland biogeochemical cycle consisting of several compartments and explicitly identified processes. Models presented were based on residence time distributions (RTDs) for continuously stirred tank reactor (CSTR) and plug flow reactor (PFR) conceptualizations. Liao (1996) modeled mechanisms of settling, diffusion, adsorption to plant and substrate, and vegetative uptake for a pollutant in dissolved and particulate forms in a two-segment (water column and substrate), two-state (completely mixed and quiescent) batch reactor system (VASWETS). This was extended by Yu et al., (1998 a and b), with kinetics similar to those of VASWETS with explicit modeling of suspended solids and inflows and outflows. Perry et al. (1996) developed a spreadsheet based model, CWFATE (Constructed Wetland Fate and Aquatic Transport Evaluation), designed for application to constructed wetlands at the Sacramento Regional Wastewater Treatment Plant in Elk Grove, CA. Bloom (1996) utilized a one or two dimension water flow and solute transport model, WETLANDS, utilizing the Richard’s water flow equation and the advection-dispersion equation, particularly suited for wetlands with significant groundwater interaction. The USEPA Compendium of Watershed-Scale Models for TMDL development presents a review of more than twenty watershed models classified by complexity ranging from “simple” methods to “detailed” methods.

**Limitations of Wetland Modeling Studies and Future Needs**

Even with the contributions of the investigations listed above, significant challenges remain in the field of wetland modeling. Kadlec and Hammer (1988) describe some of the pitfalls in modeling these complex systems. For wetland models to be useful for design purposes, site-specific information is required. However, available data is typically very sparse in terms of spatial distribution. Compartmental models require rate constants that cannot be often obtained by independent or direct measurements. For such models to be utilized at their full potential, large amounts of high quality data are required. Existing information on wetlands does not support intense modeling activity. Wagner et al. (1996) also point to data requirements as a factor limiting the use of models. Several other studies identify the need for more data to strengthen the knowledge base of wetlands (Kadlec and Knight 1995). Current approaches to using constructed wetlands for water treatment require caution due to the still emergent state of wetland research (as described by Bingham, 1994).
It appears that data collection efforts documenting performance of small-scale systems are critical due to the site-specific nature of wetland treatment systems. Kadlec and Knight (1995) also note a disproportionate focus on wetland research. Data from small-scale, detailed examinations of individual systems are far less common than data generated by long-term, large-scale research efforts. These deficiencies are symptomatic of serious gaps in knowledge of small-scale wetland systems. This project will address some of these deficiencies.

Problem Statement

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<th>Project Element</th>
<th>Respective Problem Statements</th>
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<td>Part 1: Biofield Unit Placement at INDOT Rest Stop Constructed Wetlands</td>
<td>It is anticipated that many (and perhaps most) INDOT rest stops at which constructed wetlands might be used will require sub-surface discharge of their treated effluent. In turn, it is imperative that this experimental project (i.e., at Greenfield) be amended to include one such discharge ‘biofield’ in a fashion that will then facilitate the experimental evaluation of its relative performance.</td>
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<td>Part 2: Hydrologic Aspects of INDOT Rest Stop Constructed Wetlands</td>
<td>In order to design effective subsurface wetlands, it is important to understand their performance under continuous loading and for intermittent applications. Continuous loading refers to wetland performance over a long term (time scales of months to years), where we are interested in the average performance of the wetland over a sustained period of time. Long-term performance information is required for sizing the wetlands and estimating operating and maintenance costs on an annual basis. Intermittent applications deal with practically instantaneous applications of solutes that can lead to high concentrations for short periods of time (time scales of hours to days). This information is required to understand the toxicity levels that can occur in the wetland, and to make probabilistic statements about how often a preset threshold level is likely to be exceeded in the effluent leaving the wetland. With time, it is likely that subsurface wetlands will be clogged with fine particles, organic sediments, roots, and microbial populations associated with nutrient cycling. Therefore, wetland properties change with time. It is important to have an understanding of how wetlands behave over their life span so that they can be designed effectively towards abatement of influent waters.</td>
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<td>Part 3: Environmental Aspects of INDOT Rest Stop Constructed Wetlands</td>
<td>Given that this application of constructed wetland technology is quite new to DOT rest stop locations, this research effort is needed in order to calibrate its relative utility and performance.</td>
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Objectives and Scope of the Work

The overall objective of this project is to monitor and model a newly-constructed subsurface wetland in order to understand how the wetland responds to toxic loadings over the short and
long term. Both hydrologic and environmental aspects will be studied in this research. The specific goals of this proposal are listed below.

<table>
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<th>Project Element</th>
<th>Objectives and Scope of Work</th>
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| **Biofield Unit Placement at INDOT Rest Stop Constructed Wetlands** | 1. To install an experimental ‘biofield’ at the Greenfield site in order to handle one-half (estimated at 2,500 gallons per day average flow) of this location’s constructed wetland effluent  
2. To evaluate the physical, chemical, biological, and hydrologic performance of this experimental biofield (see following two parts) |
| **Hydrologic Aspects of INDOT Rest Stop Constructed Wetlands** | 1. To monitor inflows, outflows, and water levels within a subsurface wetland at various locations as shown in the schematic in Fig. 1. This will be combined with data from infiltration studies over the wetland, and rainfall and evapotranspiration data.  
2. To use models to describe the spatial and temporal variations in water levels and effluent flows based on information on influent flows, and to evaluate the changes in permeability of the wetland as a function of time and spatial location.  
3. To conduct controlled tracer tests to determine the spatial and temporal behavior of the contaminant plumes within the wetland, and hence to determine the residence times and other important wetland characteristics.  
4. To conduct measurements on the biofield to be placed immediately downstream of the constructed wetland to determine its efficacy. |
| **Environmental Aspects of INDOT Rest Stop Constructed Wetlands** | 1. Conduct routine water quality analyses of the constructed wetland influent and effluent, as well as samples taken from the sub-surface discharge points within the downstream biofield.  
2. Conduct special track studies of environmental parameters in relation to seasonal wetland variations and high loading periods (i.e., holiday weekends).  
3. To assist the ‘hydrologic’ research team with their analysis of tracer levels (e.g., dyes, etc.)  
4. To develop an overall evaluation of the environmental behavior of the Greenfield constructed wetland  
5. To develop an overall evaluation of the environmental behavior of the Greenfield ‘biofield’ system |

**Description of Composite Project Work Plan**

This project combines a fairly intense data collection with modeling studies to understand the hydrologic as well as water-treatment performance of a constructed subsurface wetland. The overall goal of this project will be achieved through a series of tasks that are described briefly in this section.
Literature Survey

A thorough literature survey will be conducted for studies pertaining to subsurface constructed wetlands. While some preliminary guidelines on design and construction of wetlands are available in many references (for instance AASHTO MODEL, Drainage Manual, Appendix G and E; USEPA, 1988a, 1988b, 1993, 1994, 1996), this study will focus on subsurface constructed wetlands. A preliminary revealed that there is an extensive amount of material related to wetlands, but a focused study on subsurface wetlands would be useful. Results from this search will also help in preparing a document on guidelines for subsurface constructed wetlands.

Identification of study location

After several discussions among interested parties (INDOT, wetland constructors, principal investigators of wetland-related projects), it appears that a subsurface constructed wetland in Greenfield, Indiana, will be the site for this study. This wetland is located at an INDOT highway rest stop, and receives wastewater from the rest stop. One of the purposes of this wetland is to perform primary treatment of the influent wastewater from the rest stop before being released to the city sewer system. It is also proposed to construct a test-scale Biofilter facility immediately downstream of the wetland. Therefore, about half of the wetland effluent will be released into the sewer, while the other half will be directed into the Biofilter to evaluate its performance. It is expected that the wetland will be completed and ready for use by December of 2000.

Instrumentation of the wetland

Instrumentation for this project will be geared towards providing good quality data for addressing both the hydrologic and water quality aspects of the constructed wetland. Automated flow recorders will be used both at the inlet and outlet ends to determine the flow to and from the wetland. A rain gauge will be placed at the site to get accurate estimates of local rainfall at the site. Several monitoring wells will be installed within the wetland to serve as piezometers providing information about water levels at various locations within the wetland. These wells will also be used for drawing water samples. Permeameters will be utilized for measuring infiltration rates both within the wetland and for the Biofilter. These will provide information on in-situ vertical infiltration rates. One of the difficult parameters to estimate accurately is the evapotranspiration rate from the wetland surface. A small weather station will be installed closed to the site to provide this information.

Data collection

Continuous monitoring of the inflows and outflow from the wetland will be conducted using a data logger that is included with the flow-measuring device. This data will be downloaded into a computer approximately once a month. Similarly weather data (rain and ET estimates) will be automated and downloaded on a monthly basis. Water levels in the wells and water samples will be collected on a weekly basis on an average. During tracer tests when more
detailed data is required, samples will be collected twice a day, or more frequently if dictated by the existing flow rates. Infiltration measurements will be conducted at least annually. During each of these visits, infiltration tests will be conducted at several locations to get an estimate of the spatial distribution as well as the overall average surface infiltration rates of the wetland. Infiltration measurements for the biofield site will be conducted during construction, to obtain information on percolation rates (at the time of this writing, it appears that the biofield will not have a liner at the bottom).

All the data will be recorded in appropriate spreadsheets for subsequent use. This data will be made available to all interested parties on a quarterly basis or as needed.

**Description of tracer tests**

In addition to the data collection program described above, it is proposed to conduct tracer tests to get more specific information about the wetland. Three tracer tests are planned—one for each year. During each test, one conservative tracer (a bromide) will be applied along with other non-conservative tracers to be decided in conjunction with the study advisory committees for the various projects. Known amounts of these tracers will be introduced at the inlet end of the wetland, and the migration of the solutes will be observed through a fairly intensive monitoring of the samples in the monitoring wells and the effluent. The goals of these tests will be to accurately determine the residence times, adsorption rates, kinetic reaction rates, and other properties that act to transform the solutes as they move through the wetland. These data will also serve as inputs to the modeling studies described below.

**Figure 1**

*Schematic plan view showing the tentative location of monitoring wells for the proposed subsurface constructed wetland*
Model studies

Several subsurface flow and transport models have been utilized for studying the performance of wetlands in general. The following models have been identified as candidate models to be used in this study. Their selection has been based on factors such as appropriateness of the models for the current application, their general acceptability in the community, and the data collection efforts outlined earlier.

-MODFLOW (McDonald and Harbaugh, 1988) is a modular computer program that simulates groundwater flow in three dimensions. As the constructed wetland is likely to function as an unconfined aquifer for all practical purposes, this program is well suited for this purpose. Ground water movement is simulated using a block-centered finite-difference approach. It is a well-documented program and permits flexibility for various kinds of inputs and outputs. It consists of a main program and a series of independent ‘modules’ that deal with specific features of the subsurface hydrologic system. One of its major strengths in the context of this project is that MODFLOW can calculate flows and hydraulic heads under external stresses such as areal recharge and evapotranspiration. The model is capable of running both steady-state and time-dependant simulations.

-MT3D (Zheng, 1990) is a model that simulates the processes of advection, dispersion and chemical reactions of contaminant in groundwater flow in two or three dimensions. It utilizes a combined Eulerian-Lagrangian technique along with the method of characteristics for solving movement of contaminants by advection and dispersion. It was specifically designed for use in conjunction with MODFLOW. The model has the ability to simulate changes in concentrations of single–species miscible contaminants in groundwater considering advection, dispersion, and simple chemical reactions under various types of boundary conditions. The chemical reactions that the model can currently handle are equilibrium-controlled linear (or nonlinear sorption) and first-order irreversible decay or biodegradation.
- CXTFIT 2.0 (Toride et al., 1995) will be used in this study specifically in conjunction with tracer data. The problem will be converted to a one-dimensional case by averaging flow and concentration estimates perpendicular to the main flow direction. This model is utilized for estimating the parameters of transport models by fitting the model results to observed data from laboratory or field experiments. The inverse problem is solved by minimizing the sum of squared differences between observed and fitted concentrations using a nonlinear least-squares inversion procedure.

Among these models, MODFLOW and MT3D will be used for both the continuous data as well as the tracer studies. The CXTFIT 2.0 model will however be implemented for data from the tracer test alone. All the candidate models listed above have a long history of use by government agencies, private consulting firms and academicians. They have been thoroughly tested, and enjoy a high degree of credibility.

**Model calibration and validation**

Use of computer models is based on the assumption that they can reliably replicate the important physical processes, simulate historic flows, water levels, and contaminant concentrations, and that they can be used to make estimates for the future as well. For the purposes of calibration and validation of models to be used in this study, the data will be partitioned into two parts. The first data set will be used for calibration, which involves determining the magnitude and spatial distribution of model parameters that reproduce the observed hydraulic heads and solute concentrations. The primary calibration parameters will be conductivities and storativities of the subsurface wetland material, and evapotranspirative rates from the wetland. Dispersion, adsorptive capacities of the wetland, and presence of immobile regions of water will also be estimated for understanding solute movement. A trial and error procedure will be used with unknown parameters being adjusted over likely ranges in sequential model runs to match simulated water levels in monitoring wells and target effluent flows. To assist in this parameter search, an optimization procedure will be utilized.

Once the models have been calibrated, their performance will be evaluated by studying how well the model is able to replicate observations that were not utilized during calibration. This validation process utilizes the second data set, and is a true measure of how well the model represents the real system. Once the models have been reliably calibrated and validated, they can then be used to address various management related questions.

**Environmental Performance Evaluation**

One of the limiting factors with designing wetlands is that within Indiana they are currently constrained by the limited information available to designers and regulators in terms of expected process performance, reliability, stress response, etc. Specifically, water and nutrient balance models for Indiana’s temperate weather are simply not reliable. Just as simple a task as predicting the fate of water and contaminant movement through and within an Indiana constructed wetland scenario is limited by lack of information on the magnitude of the various sinks (hydraulic, chemical, and biological, etc.), particularly in relation to uncertainties regarding
evapotranspiration on a seasonal basis. The recent adoption of new groundwater quality regulations in Indiana introduces yet another important factor, whereby a mixing zone approach to the subsurface dilution of treated (i.e., constructed wetland) effluent with natural groundwater needs to be incorporated into the overall process analysis.

Influent and effluent samples routinely obtained at this site will be analyzed for their chemical (e.g., including conventional parameters such as pH, biochemical oxygen demand, and suspended solids, as well as trace metals, ammonia, nitrate, and phosphorus) and microbial characteristics (total heterotrophic plate counts and fecal coliform), with this information being tracked over time in relation to the system’s hydraulic behavior (i.e., as observed and modeled during the ‘hydrologic’ research effort). Given the projected leach field release of the treated effluent, sampling wells will also installed around the periphery of the site to facilitate parallel sampling and testing of these sub-surface waters. In turn, input-output balances will be developed over a period of three years. The three-year period will cover the initial start-up time and then extend in time through the period of plant maturation and process stabilization.

The data obtained with this project would facilitate the development of a practical understanding of this system’s incoming load (which should be distinctly different from traditional wastewater systems, and yet which is poorly understood) as well as developing effluent chemical, microbial, and nutrient mass-balance assessments. This site-specific process information will also be matched against the operating results collected at other regional constructed wetlands, resulting in the development of an overall database that documents real-world performance.

In turn, and in conjunction with the hydraulic observations, the latter database would be used to establish appropriate design guidelines which could then be used to promote the future design of similar INDOT ‘rest stop’ constructed wetland facilities. This latter effort will require a cooperative interaction of the research teams from all three of these inter-connected research efforts in order to tie together all of the involved technical aspects (e.g., plant fauna, storage capacity, hydrologic behavior and performance, chemical and biochemical behavior and performance, and finally disinfection behavior and performance).

Yet another important aspect of this project’s findings would be that of providing IDEM with a pragmatic level of confidence in the acceptability of the technology based on real-world data with ammonia removal performance. In turn, these results should validate the acceptability of surface discharge systems that might be necessary at various locations within the state (e.g., including Southern Indiana rest stop locations unsuitable for direct sub-surface discharge). This aspect of the project will entail close, routine contact with IDEM, with the intent of nurturing their future regulatory willingness to accept ‘surface’ discharge releases whenever local conditions warrant this approach. An important aspect of this ‘willingness,’ as developed through the project, should be a comparison of the existing quality of rest-stop wastewater effluent (which is likely to be extremely intermittent, and more often than not sub-standard compared to most municipal systems) against that of the field-scale research unit.

**Development of guidelines for subsurface wetlands**
This task will first start with a literature review to determine what guidelines already exist, and to see how they apply to Indiana. More specific guidelines will likely be developed for constructed subsurface wetlands based on the present study. Guidelines will be developed (or existing guidelines supplemented) in terms of important issues such as design, construction, monitoring, operation, and maintenance of constructed subsurface treatment wetlands.

**Final report and publications**

The last task of this project involves the preparation of a final report for the entire project. This report will contain the guidelines mentioned in the above-mentioned task and will cover elements of all the tasks described above.

**Timeframe:**

This projected research effort would ideally start as soon as possible, particularly given that we need to order and test a number of on-line instruments and gauges prior to their actual field installation during the construction process. In turn, our current projection is that this collective research activities will have been concluded by the end of the Spring 2003 semester. Overall, therefore, our efforts would extend over three full winter periods (i.e., extending through the winter of 2002-2003).

**Schedule of Work**

The time allocated to this project is 36 months. The last four months will be devoted to review and revision of the draft report. Table 1 presents a more detailed breakdown of the time required for the major tasks to be accomplished in this project.

| Table 1. Time line for the major tasks in the proposed work  
**(Starting date: July 1, 2000)** |
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<tr>
<td>Model calibration</td>
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<tr>
<td>Model validation</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reporting of results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final report</td>
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</tbody>
</table>
Facilities and Personnel

The principal investigator on this project will be Dr. Rao S. Govindaraju of the School of Civil Engineering. He has previous experience with field experiments involving water movement and fate and transport of contaminants in subsurface environments.

The Part #1 (Hydrologic Aspects) segment of the project will be directed by Profs. Rao S. Govindaraju, A.R. Rao and D. Lyn.

The Part #2 (Environmental Aspects) segment of the project will be directed by Profs. J.E. Alleman and R. Wukasch.

As a part of this project, one graduate student will be employed for each of the hydrologic (i.e., data collection, organization, analysis, and modeling work) and environmental research segments. In both instances, these students will be assisted by technical staff (Tom Cooper) for setting up the instrumentation and collection of the field results. Other technicians will be utilized for conducting laboratory analysis of samples.

Budget

The total budget for the proposed study is $360,000. The breakdown of the major budget items is indicated in the following three tables:

Table 2. Budget for ‘Biofield’ Research Segment
(Starting date: July 1, 2000)

<table>
<thead>
<tr>
<th>Item</th>
<th>FY01</th>
<th>FY02</th>
<th>FY03</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lump Sum Installation Cost</td>
<td>$35,000</td>
<td>0</td>
<td>0</td>
<td>$35,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$35,000</td>
<td>0</td>
<td>0</td>
<td>$35,000</td>
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</table>

Table 3. Budget for ‘Hydrologic’ Research Segment
(Starting date: July 1, 2000)

<table>
<thead>
<tr>
<th>Item</th>
<th>FY01</th>
<th>FY02</th>
<th>FY03</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries</td>
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<td>$20,709</td>
<td>$109,194</td>
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<tr>
<td>Supplies and analysis</td>
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<td>$2,306</td>
<td>$1,000</td>
<td>$5,306</td>
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<tr>
<td>Equipment</td>
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<td>$0</td>
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<tr>
<td>Travel</td>
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<td>$5,000</td>
<td>$4,000</td>
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</tr>
<tr>
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</table>
Table 4. Budget for ‘Environmental’ Research Segment  
(Starting date: July 1, 2000)

<table>
<thead>
<tr>
<th>Item</th>
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<th>FY02</th>
<th>FY03</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries</td>
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<td>$29,000</td>
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<tr>
<td>Supplies and analysis</td>
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<td>$4,000</td>
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<tr>
<td>Equipment</td>
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<td>$1,000</td>
<td>$1,000</td>
<td>$5,000</td>
</tr>
<tr>
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<td>$2,000</td>
<td>$2,000</td>
<td>$7,000</td>
</tr>
<tr>
<td>Publication/duplication</td>
<td>$0</td>
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<td>$2,000</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$34,000</strong></td>
<td><strong>$34,000</strong></td>
<td><strong>$37,000</strong></td>
<td><strong>$105,000</strong></td>
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</table>

Table 5. Total Project Budget  
(Starting date: July 1, 2000)

<table>
<thead>
<tr>
<th>Item</th>
<th>FY01</th>
<th>FY02</th>
<th>FY03</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
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<td>$0</td>
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<td>Hydrologic Segment</td>
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<td>Environmental Segment</td>
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<tr>
<td><strong>TOTAL</strong></td>
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<td><strong>$86,525</strong></td>
<td><strong>$37,000</strong></td>
<td><strong>$360,000</strong></td>
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References


USEPA (1988a), *Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment*, Contributing authors Crites et al., EPA/625/1-88/022, Cincinnati, OH.


USEPA (1993), *Constructed Wetlands for Wastewater Treatment and Wildlife Habitat-17 Case Studies*, Contributing authors Bastian et al., EPA832-R-93-005.

USEPA (1994), *North American Wetlands for Water Quality Treatment Database*, Risk Reduction Engineering Laboratory, Cincinnati, OH.


