TABLE ROCK LAKE WATER QUALITY DECENTRALIZED WASTEWATER DEMONSTRATION PROJECT

FINAL TECHNICAL REPORT

By

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GLOSSARY OF TERMS

Advanced OWTS	Treatment or removal of contaminants beyond the conventional quality for OWTS
Basin	The area which drains all precipitation or other sources of water to a particular location
BOD	Biochemical oxygen demand
CIG	Community Involvement Group
Drip Irrigation	Dispersal of pre-treated wastewater through small-diameter tubing over a large area
E. Coli	Eschericia coli, a common bacteria that live in the intestines of warm-blooded mammals
EPA	The U. S. Environmental Protection Agency
FAST	Fixed activated sludge treatment
Fecal coliform	Bacteria that come from the digestive tracts of humans, livestock and wildlife
GIS	Geographic Information System (digital, spatial database used for mapping and data collection)
JRBP	James River Basin Partnership
LMVP	Lakes of Missouri Volunteers Program
MDHSS	Missouri Department of Health and Senior Services
MDNR	Missouri Department of Natural Resources
MSO	Missouri Smallflows Organization
MSU	Missouri State University
NRCS	Natural Resources Conservation Service
OCWC	Ozarks Clean Water Company
Onsite	Located or contained on a particular property or site
OWTS	Onsite wastewater treatment system
PAB	Project Advisory Board
RME	Responsible Management Entity
RSF	Recirculating Sand Filter
Septic	Wastewater and solids in an anaerobic environment or conventional water-tight tank
SPI	Soil Potential Index
TRLWQ	Table Rock Lake Water Quality Inc.
TSS	Total suspended solids
UWRB	Upper White River Basin
Wastewater	Refuse liquid from house or business use such as from sink drains, toilets and other uses
Watershed	Drainage area of a particular stream or water body
WTP	Wastewater treatment plant

EXECUTIVE SUMMARY

Increasing population and development in the Table Rock Lake watershed threatens water resources by increasing sources of nutrient pollution, not the least of which is failing septic systems. The largely rural population uses onsite wastewater treatment systems (OWTS) to treat wastewater, although these systems are often not suitable to the thin existing soils in the region to treat wastewater. The Table Rock Lake National Demonstration Project tested different types of advanced technology for OWTS. The Demonstration Project also utilized the U. S. Environmental Protection Agency's (EPA) management models for proper maintenance of OWTS. This project planned to find solutions to the many failing and inadequate OWTS in the Table Rock Lake area. Three main goals were:

1. Install and test different types of advanced wastewater treatment technologies to evaluate effectiveness in the unique geological setting around Table Rock Lake.

A number of excellent decentralized treatment technologies including advanced OWTS (or systems with pre-treatment components before dispersal into the soil) had been field-tested elsewhere and were commercially available. The focus of the Demonstration Project was to compare technology and test performance in treating wastewater and phosphorus removal using the BioMicrobics FAST and RetroFAST, Premier Tech Ecoflo and ZABEL SCAT wastewater treatment systems in the Table Rock Lake area and match the treatment units to a lateral dispersal field suitable for the existing soils.

2. Develop a management program following the EPA's recommended management models for OWTS.

With advanced OWTS regular maintenance is needed to ensure proper functioning. Advanced OWTS had received a bad reputation nationwide due to failures from lack of maintenance by system owners. A responsible maintenance entity (RME) was needed to remove maintenance responsibilities from developers or homeowners.

3. Identify legal impediments to widespread adoption of advanced OWTS by changing the regulatory and the wastewater industry's perceptions of these systems and gaining their acceptance in Missouri.

In the past, advanced OWTS technologies have not been widely accepted as feasible or practical and most contractors in the area were unfamiliar with such systems. The few installers that had experience with advanced OWTS, such as drip dispersal, did not generally recommend these systems or install them due to maintenance concerns. With adoption of renewable operating permits requiring maintenance, an answer to this concern would be presented.

Twenty four sites were installed/remediated through this Demonstration Project. Criteria for acceptance into the project included environmental need, installation feasibility, cost share potential and the owner's willingness to cooperate with project goals. Different types of advanced OWTS installed included constructed wetlands, aeration/fixed film, media filters using foam cubes and peat moss and recirculating sand filters. All of these systems highly pre-treat wastewater before dispersal into surface stream or soil.

Monitoring systems were installed on four sites to measure treatment success. Samples were taken from septic tank effluent (raw sewage), treatment effluent (pre-treated, filtered liquids) and sub-surface liquids (after passing by drip irrigation through the soil). Analysis of samples produced evidence of successful treatment with effluent BOD_5 (biochemical oxygen demand) and TSS (total suspended solids) values from three of the monitored systems consistently below 20 mg/L. The fourth monitored system was a much higher restaurant-strength waste, which had median treatment BOD_5 and TSS of 59 and 32 mg/L respectively. Median sub-surface phosphorus concentrations ranged from 0.5 to 1.2 mg/L demonstrating the soil's capacity for phosphorus removal.

Average septic effluent, treated effluent and subsurface concentrations

Parameter	Septic Tank	Treated	Sub-surface
BOD_5(mg/L)	162	26.8	3
TSS(mg/L)	46	17.7	NA
Ammonia(mg/L)	5.6	4	0.41
Phosphorus(mg/L)	3	2.7	0.93
Fecal Coliform (colonies/100 mls)	271,000	19,488	140

The major results from the Demonstration Project are:

1) **Acceptance by State/County regulatory agencies and installers of advanced OWTS as a solution to failing conventional systems and the use of drip irrigation in imported soil for pre-treated effluent dispersal.**
2) **Remediation of over 25 OWTS near Table Rock Lake and influencing numerous installers and homeowners to seek advanced OWTS options.**
3) **Formation of Ozarks Clean Water Company (OCWC) as a RME to remove maintenance responsibilities (EPA management level 5) from developers and homeowners in cluster systems (subdivisions & apartment complexes that use a decentralized OWTS).**
4) **Changes in the wastewater ordinance by local regulatory agency, the Stone County Health Department, to require renewable operating permits for advanced OWTS (EPA management level 3).**
5) **Demonstration of phosphorus removal achieved through advanced OWTS and drip irrigation in imported soil around Table Rock Lake.**

Data from this project will provide regulatory agencies with scientific evidence necessary to accept advanced OWTS as standard systems removing them from experimental status. Project partners and participants gained applied knowledge of advanced OWTS and alternative treatment technology to help protect water quality resources. Education and outreach through numerous local, statewide and national meetings helped to focus attention on the potential water quality implications of failing wastewater systems and successful remediation systems in the Table Rock Lake watershed. An outstanding benefit of the Demonstration Project includes a change in the way OWTS are installed in southwest Missouri, along with a change in the public's perception of advanced OWTS. Another applied achievement of the project was the formation of OCWC which will continue to grow and provide service to benefit residents of Missouri particularly residents of the Table Rock Lake watershed. This project may serve as a national action model for other lake communities facing similar problems that need effective solutions.

This Project funded through U. S. Environmental Protection Agency by Cooperative Agreement (XP8309301).

1 STUDY BACKGROUND AND OBJECTIVES

Table Rock Lake is located within the Upper White River Basin watershed, in the heart of the Ozarks. Formed by Table Rock dam in the 1950's, Table Rock Lake is the second largest of five reservoirs in the Upper White River. It is located primarily in Taney, Stone and Barry counties in Missouri, but about a third of the lake's watershed resides in Arkansas (Figure 1).

The lake, which is widely considered to have the best water quality of any in Missouri, is quite clear and supports a variety of fish species including bass, crappie and sunfish. The excellent water quality has led to a booming tourism business, with many resorts catering to fishing, boating and swimming activities, principally during the summer months. The region draws tourists from throughout the Midwest and around the country. The U.S. Army Corps of Engineers estimates that the recreational use at Table Rock Lake ranges between 30 and 40 million visitor hours annually. Along with the Branson tourism industry, Table Rock Lake and other reservoirs on the White River are responsible for the hundreds of millions of dollars annually pumped into the local economy.

Ozark landscape is characterized by karst topography made up of highly porous carbonate, limestone bedrock overlain by very thin, rocky soils. This region also contains many caves, sink holes, and subterranean channels which convent flow directly from surface run-off into ground water systems through a system of highly dynamic hydrological networks. This karst geological structure makes water resources extremely vulnerable to infiltration of contaminated waters from human activities. The Swiss-cheese-like structure of the karst terrain was formed when rainwater and surface run-off eroded the carbonate rock over millions of years and dissolved channels in the primarily limestone and sandstone formations. Most of the land is forested or pasture with areas of rapidly expanding industry and urbanization.

During the 1990's, local residents, concerned by diminishing lake clarity and explosive population growth, formed Table Rock Lake Water Quality (TRLWQ) to address the declining water quality. This organization received a $2 million cooperative agreement administered by EPA in 2002 to demonstrate management models for installation and long-term management of advanced, decentralized treatment alternatives to failing septic systems.

This report summarizes the results of the $2 million cooperative agreement with EPA known as the Table Rock Lake Water Quality National Onsite Demonstration Project. This project initiated and built institutional and structural requirements for comprehensive methods to replace and maintain failed septic systems. Further, the project team identified changes needed in current regulatory climates to ensure that decentralized wastewater systems installed today do not fail and pollute water resources in the future.

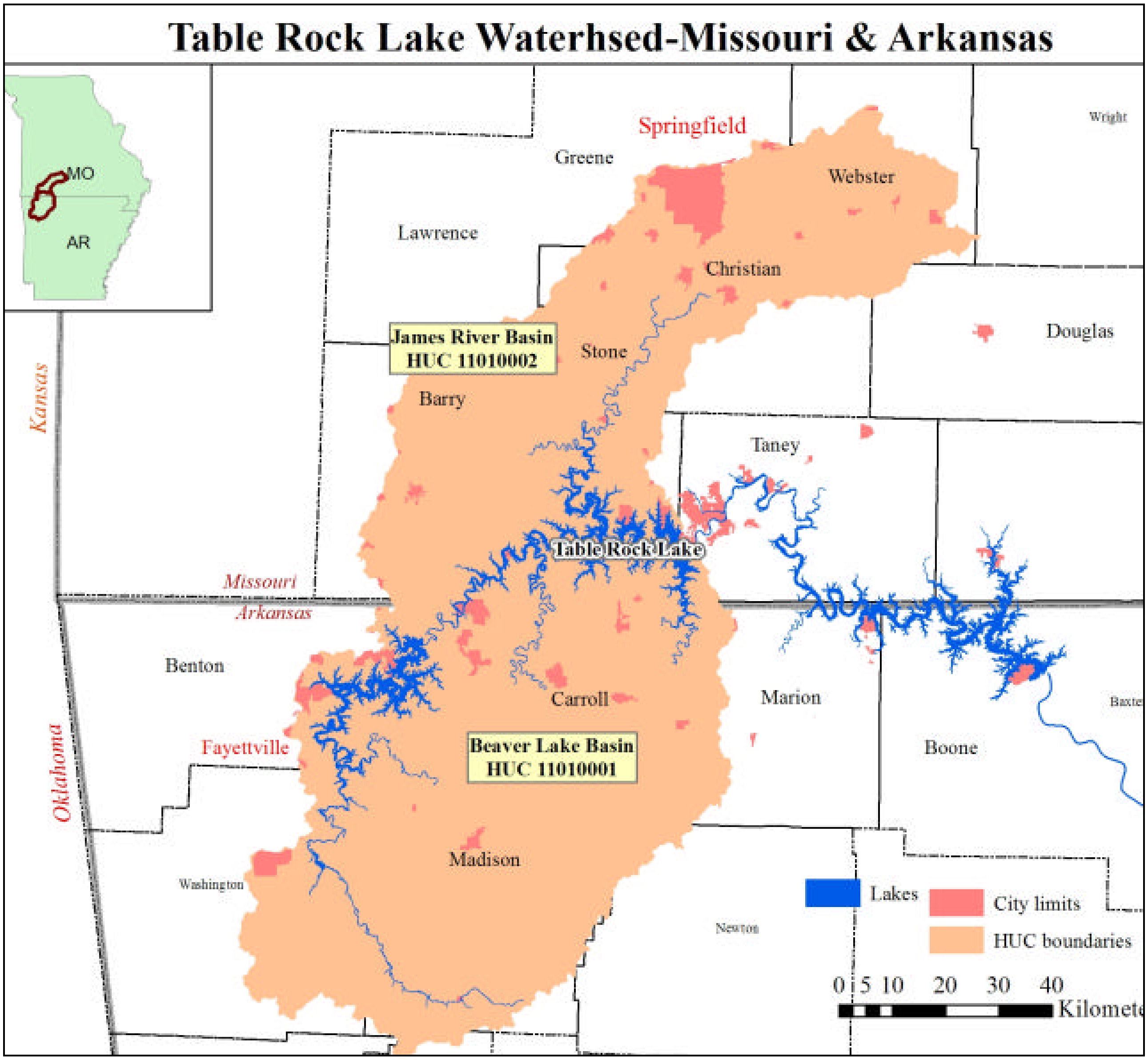


Figure 1: Location of the Table Rock Lake watershed, Missouri and Arkansas

Water Quality Trends in Table Rock Lake

The James River is one of the main tributaries to the White River that flows into Table Rock Lake. It flows south into the lake from its headwaters northeast of Springfield, Missouri. Historically, the James River arm of Table Rock Lake has had the lowest clarity and the highest levels of suspended algae due to its receiving stormwater and run-off from the larger metropolitan areas of Springfield, Missouri. This arm has also been one of the most productive fisheries out of the many tributaries of the lake. The greatest point-source of nitrogen and phosphorus to Table Rock Lake, the Springfield Southwest Wastewater Treatment Plant (WTP), discharges 45 million gallons of treated wastewater per day into the James River. Since 1998, upgrades to the plant have lowered phosphorus outputs in the discharge to below 0.5 mg/L.

Localized, excessive eutrophication (excessive algal growth) and the resulting increases in phytoplankton and lower water clarity in Table Rock Lake have been a cause for concern for some time. According to the USGS, water clarity directly above Table Rock Dam decreased by an average of 0.82 meters in the period from 1974 to 1994. The MDNR identified three probable sources of excessive nutrient loading, including the James River with municipal sewage discharges from Nixa, Ozark, and Springfield WTP, residential septic systems associated with increasing populations, and livestock and poultry wastes from northwest Arkansas and the western portion of the watershed. In fact, University of Missouri researchers identified septic systems as a problem for Table Rock Lake's water quality in the early 1980's.

After an August 1998 public meeting, the Missouri Department of Natural Resources (MDNR) formed an advisory committee to focus on assessing the impact of nutrients, particularly phosphorus, entering the James River and Table Rock Lake. Committee members came from a variety of stakeholder groups, including private sewer companies, city and county governments, tourism industry officials, and environmental organizations. Over a two month period in late 1998, the committee met with a variety of experts in watershed/water quality management. The group also attended a variety of seminars, meetings and field trips to learn more about the unique benefits of Table Rock Lake and threats to its water quality. One of the experts this stakeholder committee met with was Dr. Jack Jones, a professor and limnologist with the University of Missouri. He has studied changes in the water quality of Table Rock Lake since 1978. He published a final report in 1999 which summarized his analysis of water quality trends in Table Rock Lake from 1978 through 1998, with heavy emphasis on data collected in the 1990's (Jones and Perkins, 1999).

The analysis from the University of Missouri shows that there has been a significant drop in lake transparency (i.e. lake clarity) and a corresponding increase in density of algae. Prior to 1995, samples were taken only near the dam for Secchi transparency, total phosphorus, and algal chlorophyll during the summer of each year. From November 1995 to January 1999, measurements for these parameters were taken at five locations along the White River arm (i.e. the main body) and at fifteen locations along the James River arm of the lake. A simple trend analysis shows that the Secchi transparency dropped from 4.5 meters in the late 1970's to near 3.0 meters by 1998. During this period, total phosphorus and algal chlorophyll rose from 7 to 12 µg/L and 3.8 to 6.0 µg/L, respectively.

The possibility was considered that the water quality trends were due to either the increased nutrients from various sources (increased agricultural and human development) or the result of periodic cyclical changes in climate and hydrology. However, by comparing water quality trends from Table Rock Lake with other lakes in the region, researchers determined that trends in Table Rock Lake were not due to periodic cycles of weather and hydrology, but rather from increased nutrient loading. It was this conclusion that prodded the DNR to form the phosphorus advisory committee in 1998.

Advisory committee efforts led to the enactment of a rule by the Missouri Clean Water Commission to limit phosphorus concentrations from point-sources discharge in the Table Rock Lake Basin to 0.5 mg/L (MDNR 1). Existing point sources discharging more than 22,500 gallons per day were required to meet this limit by Nov. 30, 2007. New facilities constructed after November 30, 1999 must meet the phosphorus limit regardless of flow.

MDNR concerns with Table Rock Lake did not end with the phosphorus advisory committee. The agency continues to monitor water quality in the lake through efforts by the University of Missouri Extension's Lakes of Missouri Volunteers Program (LMVP). This program assesses lake water quality throughout the state using volunteers trained in water sample collection and water quality analysis.

Based on data from the LMVP, MDNR estimated that Table Rock Lake receives about 675 lbs of phosphorus per day from point sources and about 1,500 lbs per day from non-point (land area contributions) sources (MDNR 2). Of the point source total, over 90 percent of that load came from the City of Springfield's Southwest WTP. MDNR also points that an important aspect of the threat comes from failed septic systems. Table Rock Lake and surrounding communities do not have municipal sewer service and therefore rely on individual septic systems for treatment of sewage and gray water.

In addition, the Table Rock Lake watershed lacks the Northview Shale geologic formation that is present in some nearby watersheds. This layer is an aquitard and thus can prevent the downward movement of contaminated surface water into groundwater, the source of drinking water for much of the region as shown in Figure 2. Thus, widespread failure of septic systems is not just a threat to Table Rock Lake, but is also a threat to drinking water supplies.

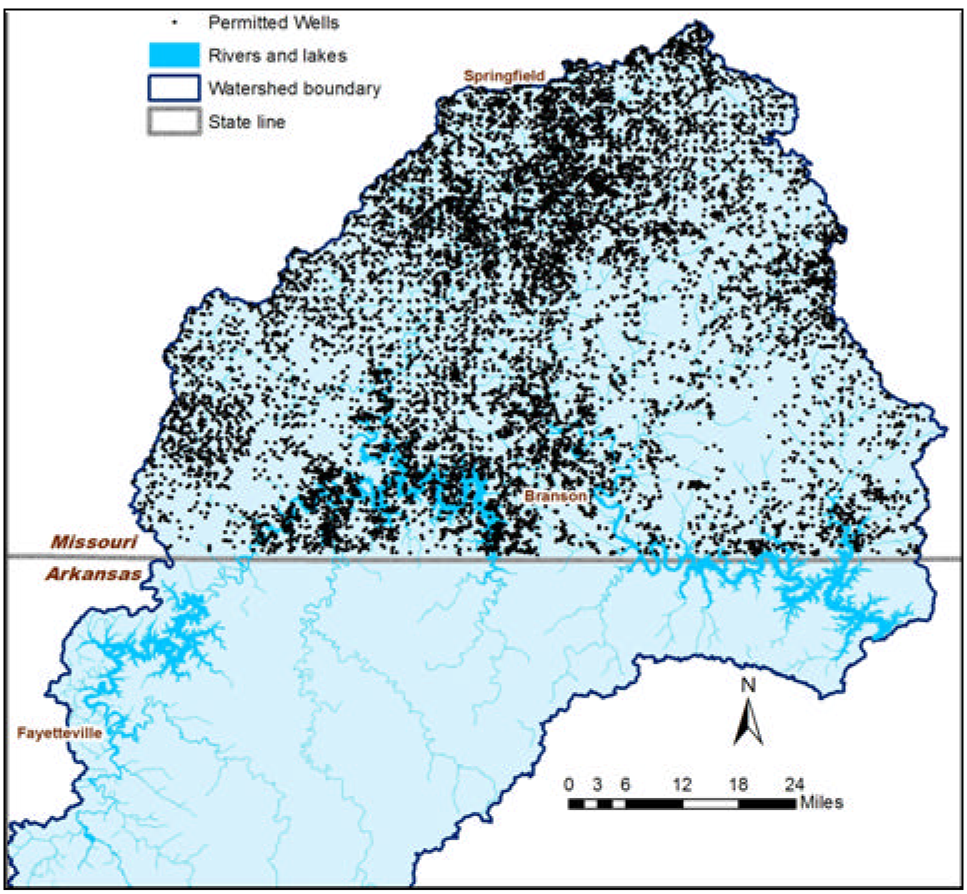


Figure 2: Permitted wells in the Missouri portion of the Upper White River Basin

Formation of Table Rock Lake Water Quality, Inc.

Recognizing the potentially devastating impact that a drop in water quality could have on the region's tourism industry, the Table Rock Lake Area Chamber of Commerce formed Table Rock Lake Water Quality (TRLWQ) an independent, 501(c)3 non-profit corporation in 1998. TRLWQ's mission is to improve and maintain water quality in Table Rock Lake. The Chamber of Commerce provided start up funding and administration costs for TRLWQ while staff aggressively pursued outside funding. In 2001, TRLWQ was awarded a Section 319 water quality grant from the Missouri Department of Natural Resources. This grant, which was used to gauge the impact of septic discharges on near-shore water quality around the lake, is described in detail in the next section.

TRLWQ is governed by a volunteer Board of Trustees consisting of eight local citizens and businessmen: Richard Meyerkord, President; W. K. Lewis, Vice-president; Tony DeLong, Secretary; Bob Simmons, Treasurer; and board members James Sandberg, Pat Connell, Ken Foersterling, and Lefty Evans. The board members provide contractors of TRLWQ guidance on the execution of various projects. The board members, most of whom have been with TRLWQ since its inception, are not paid; yet, they have shown extraordinary dedication through attending meetings, participating in public education seminars, identifying potential demonstration sites, and assisting in all aspects of the study. In many ways, the board members of TRLWQ exemplify the unique attitude of many local citizens, who have a fierce allegiance to maintaining the beauty of Table Rock Lake. Without their unwavering dedication and support, this project would not have been possible.

The experiences of TRLWQ and its volunteer Board of Trustees carries a lesson for others interested in this field: only with a motivated populace can significant changes be made. Local citizens can be motivated, but they must first be educated about the problem and potential solutions. The hard work of public education is therefore crucial to a project's success.

2001 Septic Study

Today the greatest phosphorus loading to the Table Rock Lake watershed comes from non-point sources, including a very large agricultural industry (primarily poultry farms) and septic systems from significant urban and suburban development throughout the region. Failing septic systems are a significant threat to Table Rock Lake. A section 319 grant through MDNR and administered by TRLWQ in 2001 suggested septic discharges were entering the lake. Enforcement of septic system regulations had been lax and with the characteristic steep slopes, fractured limestone and thin soils of the Ozarks, septic tank effluent received little if any treatment from the natural environment. Thus remediation of failing, and potentially polluting, septic systems has become a vital requisite to maintaining water quality in Table Rock Lake.

MDNR estimates of phosphorus loadings were calculated based on reported water quality data and estimated flows. As such, they were strictly "paper studies" with little empirical evidence to back up the estimates. The point source estimates (from WTPs and permits) are based on verified data and thus reasonably accurate. On the other hand, the non-point portion of the loading estimates are much more difficult to verify since this type of pollution comes from a wide region rather than from the end of a pipe. Thus, TRLWQ proposed conducting a study to attempt to confirm the presence of untreated septic effluent in the lake.

The study, which was funded by the EPA and administered by MDNR through Section 319 of the Clean Water Act, was based on a similar approach used by researchers on several small reservoirs in Indiana (Grant, 2000). In the study, the researchers slowly trolled along the shoreline pumping water through a portable fluorometer. The fluorometer measured the fluorescence of the water within a wavelength typical for optical brighteners, which are commonly found in laundry detergents. Optical brighteners can be an excellent surrogate for septic effluent because they are not broken down chemically as they pass through a septic tank or as they migrate through the soil profile. Spikes in the water samples measured by the fluorometer are assumed to be from the optical brighteners in laundry detergent, and thus indicate a plume of septic system effluent.

Researchers conducted the survey along three different shorelines, including two that are heavily developed with home septic systems and, as a control, one that had little development. They performed the survey on two different days during the summer of 2001, including during the week after the July 4th holiday, one of the busiest times for the local tourist industry.

The study team concluded that localized impacts of septic systems along the shores of Table Rock Lake appear to be significant, particularly in developed coves. It was felt by the researchers that the septic systems contribute sizeable amounts of ortho-phosphate (inorganic phosphorus) and ammonia, which can be used by algae for growth. In fact, the study concluded that septic systems were the most dominant source of nutrients for algae in developed coves. The team also found that water clarity in the developed coves was only 50 to 60 percent of the clarity in the undeveloped coves, reinforcing the data collected by MDNR and others. The study called for more effective long-term management of onsite wastewater systems. The complete study can be found on the web at: http://www.trlwq.org.

Current Conditions

Subsequent site visits and observations around Table Rock Lake have backed up the conclusions of the 2001 septic study and monitoring by MDNR and Dr. Jones, mentioned earlier. Soils around the lake were found to be inadequate for providing treatment for wastewater with conventional systems. Additional observations made while identifying locations for potential septic remediation demonstrations also suggested that septic system failure is widespread. Lack of records on failing septic systems means there is not sufficient data to accurately quantify the extent of the problem, but 75 to 90 percent of existing systems over 5 years old are estimated to be failing today. Given the fractured nature of the local geology and the large number of metal, rusted tanks used as septic tanks, it is likely that many of the failures will not even surface, but run straight into groundwater. The lack of past oversight on the part of local regulatory agencies, developers and home builders ignorant of our unique hydrological situation has caused widespread contamination of drinking water wells.

A large algae bloom in 1999 in the James River arm motivated many to become concerned about the water quality problem. However, the lack of any problems since then combined with the large drop in phosphorus due to changes at the Springfield WTP could lead many to become more complacent. Also, with many failed systems percolating down (rather than surfacing) it is a challenge to arouse local residents and convince them of the problem.

Nevertheless, there are reasons for optimism. As part of the Demonstration Project, a Community Involvement Group (CIG) was formed that met enthusiastically for more than two years to address the water quality problem. In addition, the Stone County Health Department has become much more vigorous in their enforcement of the existing septic system regulations. Many local citizens are discussing water quality, and considering the need to fix the current state of wastewater treatment infrastructure. This project has helped push water quality issues and concerns to the forefront where they have gotten the attention of representatives, governmental officials, the local media and the local citizenry.

This section describes the objectives of the Demonstration Project including a description of the project tasks. These are presented as they were conducted, rather than as they were originally planned in the scope of the project.

Project Objectives

The objectives of the Demonstration Project were:

1. Demonstrate advanced onsite wastewater treatment technologies for Table Rock Lake region. This would be done through installation of advanced treatment systems and observation of their effectiveness through monitoring the performance of these systems.

2. Demonstrate management solutions for advanced systems following EPA's recommended management levels 3 and 5 for onsite wastewater treatment systems. This project was designed to be a learning process that would provide invaluable experience and expertise in the field of wastewater management for alternative systems. This experience is only possible through field testing of systems, which is considered one to the most valuable data and information products of this demonstration project.

3. Identify and address legal impediments to a widespread implementation of advanced systems. This Project also seeks to change the status and acceptance of the alternative, ecologically safer onsite wastewater treatment systems in Missouri which are currently considered only experimental systems at the beginning of the project.

The project's scope of work was developed based on these objectives and a rough sense of the current practices in the region. Early in the project, however, it became obvious to the team that some adjustments in tasks were needed.

Advanced onsite wastewater treatment systems (OWTS) have tremendous potential for protecting water resources in the Ozarks, given the soil limitations in this region for conventional systems. However, the dismal track record of maintenance on even the simpler, conventional septic systems indicated that without some mechanism for adequate maintenance, simply putting advanced systems in the ground was a recipe for their eventual failure. The team therefore realized that an organization to provide maintenance for advanced OWTS systems was needed.

The project team also determined that a massive public education effort was needed with various events aimed at public participation from homeowners, installers/maintenance providers and regulatory officials, and realtors. In order to facilitate public outreach activities, the Board authorized the development of a Community Involvement Group (CIG). A CIG was appointed to communicate project activities to various community groups. The committee was made up of a broad variety of local citizens and stakeholders representing the public interest in areas such as home owners, realtors, bankers, septic tank pumpers, resort owners, developers, educators, senior citizen groups, environmental groups, and others. The committee met twice a year for 2 years with the Program Coordinator serving as the committee chair. CIG members included Tim Schnakenberg, Richard Nierman, Dorothy Polk, Doug Louk, Fern Langston, Gail Kendall, Glenn Phillips, Greg Evans, Jeff Justus, Jerry Hageman, Pat Barnett, Paul Schafer, Ray Jones, Rod Taylor, Steve Welko, Terry Priest, Tim Hoehn and Paul Hoback. Committee members communicated project information to other interested parties within the local community and provided feedback from the local community to the Program Coordinator.

The Demonstration Project Team also saw the need for a committee of well respected leaders in the scientific and onsite industry to review and recommend methods for installation, maintenance and monitoring. A Project Advisory Board (PAB) was established consisting of five members: Dr. Randall Miles, Dr. Bobby Wixson, Daryel Brock, Dr. Mark Gross and Wally Miller. These members represented the educational, scientific and regulatory communities.

2 PROJECT TASKS

This chapter presents the 6 major tasks undertaken by this project to accomplish its objective; demonstrate various types of advanced onsite wastewater treatment systems (OWTS) in the Table Rock Lake area. The tasks are broken up into objectives, methods, and results.

Task 1 – Create soil suitability map for OWTS

Wastewater treatment for onsite systems largely depends on the suitability of the soil where the system is installed. Silty loam soils can provide excellent treatment of septic effluent for a long time while some clays and sands provide almost no soil treatment. Of course in all cases the solids must be removed from the tank routinely, but treatment of the effluent or liquids is traditionally accomplished through soil absorption an action by microorganisms.

Objectives:

The initial objective of Task 1 was to develop a system which could be used by county health department official to determine the suitability of soils for conventional or advanced OWTS systems on any given location. The ideal solution would have been a table or flowchart that leads the user to identify a short list of three to five technologies suitable for any given piece of property.

Regulation of individual wastewater systems is most often left to the local jurisdiction; usually the county health department. Given the many different job responsibilities of the local county sanitarian, it is no wonder that these officials, who were not usually trained in wastewater treatment principles in the past, often could provide little or no advice to homeowners on advanced OWTS systems. Choosing a system (or fixing a failed one) became the homeowner's responsibility and, with little guidance, the homeowner was at the mercy of manufacturer's claims. Thus, the objective behind Task 1 was to develop a methodology that could be easily understood by county sanitarians to guide homeowners into an appropriate treatment technology for onsite wastewater systems. Ideally, the method would be easily understood so that a homeowner would have independent guidance in selecting an appropriate treatment method.

Methods:

In cases where soil does not provide treatment, higher levels of pre-treatment such as with advanced OWTS systems, ought to be required. The method for accomplishing Task 1 was therefore based foremost on soil characteristics. After much discussion with soil scientists, engineers, and other knowledgeable people, the project team determined that creation of a flow chart or matrix was unreasonable since there were too many soil and land characteristic variables to include in a simple chart.

The Demonstration Project team decided to hire an engineering firm, Ayers and Associates, that had experience working with the decentralized industry and contracted with them to develop a GIS-based program that produced a simple color-coded map of soils potentials based on the many variable conditions of the landscape and geology

A Geographic Information System (GIS) is an excellent aid in addressing the nearly infinite number of possible soil characteristics. In a GIS, spatial data is layered over a base map. In the case of this task, the project team used soils mapping from the Natural Resources Conservation Service (NRCS) as the base map. The project team then used the GIS to develop a composite map based on a series of quantitative scores used to judge various soil and land characteristics. The map details areas within given ranges for particular composite scores.

The approach is similar to one used by the NRCS in previous years to ascertain septic system suitability (SW Missouri RC&D, 1997). In their approach, all soils started with a score of 100 and then were de-rated depending on the existence and probability of certain features, including slope, flooding, permeability, depth to bedrock and depth to high water table. The final number is referred to as the soil potential index (SPI). Soils with a SPI lower than 44 have a low or very low potential to perform adequately with conventional septic systems.

Results:

The NRCS approach to quantifying soil suitability for septic systems by scores was valuable but the project team felt it was not sufficiently user friendly. Thus, the project team took the concepts developed by the NRCS and refined them into a visual guide. The map shown was the result and can be printed and used for reference proposes (Figure 1.1).

However, the precision of the soil map or scoring system does not replace a soil survey and field investigation when installing a septic system. A soil profile study is needed to determine site-specific septic requirements while the soil potential map provides a general idea of what types of conditions to expect for areas in Stone County.

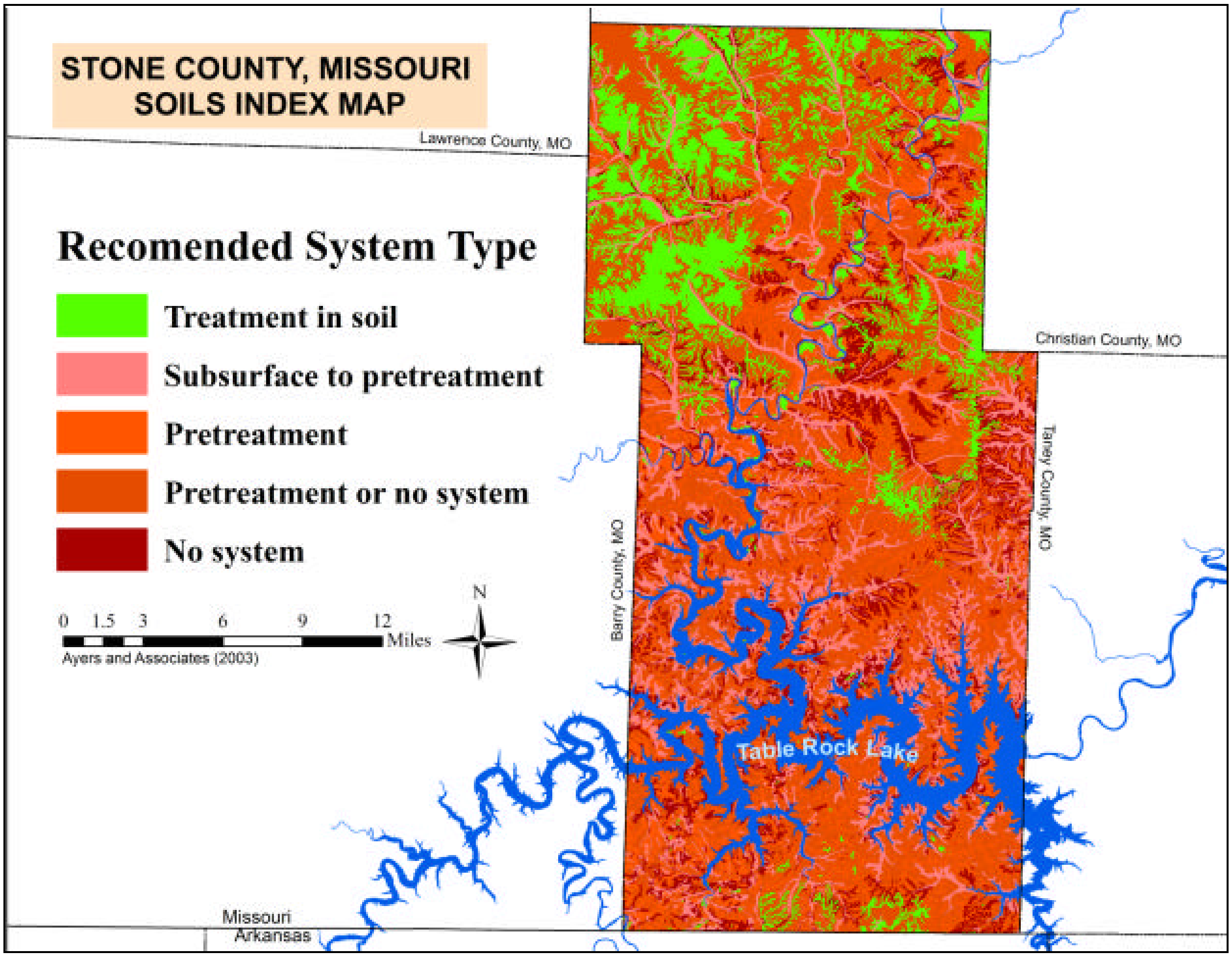


Figure 1.1: Stone County, Missouri soil potential map

Task 2 – Review existing ordinances & establish legal framework for responsible management entity

A key component of implementing advanced OWTS includes updating regulations that govern these systems. Without regulations requiring the proper installation and maintenance of systems the decision to implement these is at the discretion of the property owner, installer or developer who may not have proper education/training to make the best decision. In addition, maintenance of these systems is critical to their success and must be included in any implementation plan.

Objectives:

The objectives of Task 2 were to: (1) review existing ordinances by the local county health department and determine the need for revisions to reflect needed changes to wastewater treatment requirements and policies and (2) Establish the legal framework necessary for the formation and operation of a responsible management entity (RME) to ensure the proper maintenance of advanced OWTS and other types of wastewater treatment systems.

Methods:

The Demonstration Project's Program Coordinator, David Casaletto, Project Manager, John Murphy and Board of Directors discussed the feasibility of updating Stone County regulations which had not been updated since their initial adoption in 1993. A consultant with extensive experience in the onsite industry, Tom Yeager of Kennedy/Jenks Consultants, was hired for the task of assessing the existing Stone County Department of Health ordinances and assembling a list of best management practices and recommendations for inclusion in a revision of the ordinance. The assessment was also compared to state regulations which were developed in 2002. There were significant discrepancies between the County Health Department ordinance and state regulations since the ordinance had not been updated to reflect changes in the state laws. The requirement for installation and maintenance of different types of advanced OWTS was also vague and inconsistent at best.

A proposal for changes to the Stone County Health Department ordinance was submitted by the Demonstration Project in December of 2004. A revised ordinance effective September 1, 2007 was passed by the Stone County Commission that incorporated most of the suggested changes.

To address the problem of maintenance and management of onsite systems, the Demonstration Project examined the possibility of forming an RME to provide maintenance services. The Voluntary National Guidelines for Management of Onsite and Clustered Wastewater Treatment Systems, published by EPA, state that more than half the (onsite wastewater) systems in the United States were installed more than 30 years ago when OWTS rules were nonexistent or poorly enforced. In addition, the guideline states that few systems receive proper maintenance because homeowners are either unaware of the need for maintenance or find it a distasteful task. Lack of maintenance is the main cause of failing septic systems which can become clogged with solids, releasing the liquid waste without it being treated. The EPA guidelines outline 5 different models for the management of OWTS with varying degrees of responsibility by the homeowner or an RME.

Management Model 1 is simply where the local public is made aware of the need for proper maintenance of their OWTS but no regulations are used to enforce maintenance. Management Model 2 suggests maintenance contracts be obtained by the property owner and an inventory kept of all OWTS by the local County or regulatory authority. The regular maintenance can be carried out by any licensed maintenance provider chosen by the homeowner. Model 3 requires owners of OWTS to obtain renewable operating permits on their systems. To renew these permits require proof of regular maintenance. Maintenance Models 4 and 5 are similar in that the operation and maintenance requirements are met through an RME or company that in turn collects a fee for services. In Model 4 system the homeowner retains ownership of the OWTS while in the Model 5 the RME takes on ownership of the OWTS, maintains it and upgrades it while charging the system user a service fee similar to a city sewer utility.

Ozarks Clean Water Company (OCWC) was created through the Demonstration Project with the sole objective of owning and operating individual and clustered wastewater systems as the RME, thus eliminating the requirement of the individual property owner to take on this responsibility. The Management Model 5 Program was considered the most feasible model for OCWC since it is most comparable to a city sewer program where the homeowner or property owner is only responsible for the monthly bill payment.

EPA Model 5 Program Overview:

- The wastewater system is owned by RME (OCWC)
  - Comparable to centrally sewered management
  - Monthly fee paid to RME
- Allows area-wide management
- Reduces oversight by regulatory agency
- RME assumes all wastewater liability

Another step in the process of establishing OCWC was the adoption of a rate of charge for maintenance of OWTS and cluster systems. To arrive at a comparable and justifiable rate, OCWC hired an engineering firm to complete a detailed study of sewer rates within the southwest Missouri area. The fee covers all necessary operation, maintenance and repair work. The initial fee for a single family home was $28.53. Commercial rates are also offered, but are defined on a case by case basis.

Results:

Since the initial attempts at revising Stone County wastewater regulations in 2004, there have been significant changes in the Stone County Health Department. The new director of Stone County Health Department, Angela Ford, has placed greater emphasis on wastewater concerns and has hired a full-time sanitarian, Todd Fickbohm, dedicated entirely to wastewater regulation. The Demonstration Project's Program Coordinator has been invited to serve on the Stone County Health Board Variance Committee and the Health Department has drafted and passed a new ordinance incorporating many of the changes suggested in 2004.

Demonstration Project personnel found that legal framework for establishing an RME for maintenance of wastewater treatment systems was already in place in the Missouri state statutes. OCWC was formed as a non-profit corporation in March of 2004 by the Demonstration Project to take ownership and responsibility for the maintenance of advanced OWTS and other wastewater systems.

OCWC was formed in accordance with sections 393.825 to 393.861 of the Missouri Revised Statutes and is governed by a Board of Directors. The initial Board of Directors consists of the six incorporators, with two serving a one-year term, two serving a two-year term and two serving a three-year term. Future Directors selected from the members will be elected to three-year terms by the members at the Annual Membership Meeting in June of each year. OCWC was designed as a non-profit corporation with voluntary membership which is gained by applying for and receiving services from OCWC. The Company falls into IRS tax category 501(c) 12.

OCWC does not have a defined service area, and can offer services anywhere in the State of Missouri. The Missouri Department of Natural Resources has given written notice that OCWC is recognized as a viable Continuing Authority and an acceptable entity to receive funding from the State Revolving Fund, which is a low interest loan program. Individual homeowners contracts include the services provided by OCWC, the billing rate and ownership status of the System. Contracts for developers include the services provided by OCWC, the ownership status of the system and the contract requirements of individuals who will occupy the development and pay a fixed sewer rate for maintenance.

Below is an illustration of the design of a cluster system such as those for a property owner's association (POA) or development (Figure 2.1). Each individual home has a septic tank that collects the initial wastewater and solids. This tank still needs to be pumped occasionally to remove the solids. The liquid is sent to a shared pre-treatment unit located within the development on shared land. The treated effluent is then dispersed either into a drip field, lateral field or surface discharge as permitted by MDNR.

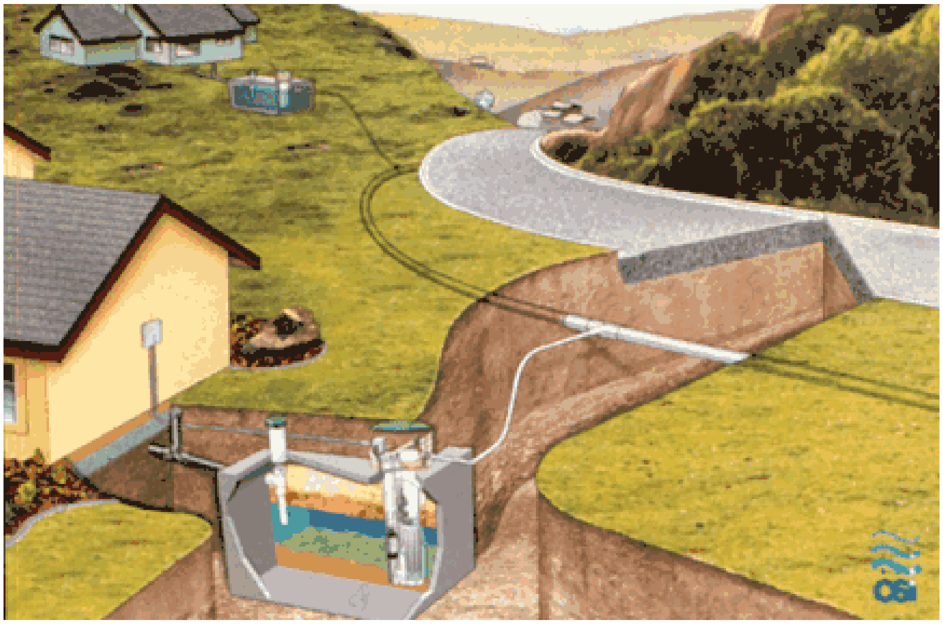


Figure 2.1: Basic design of a Cluster System for POAs or subdivision developments

Some of the system types included in the OCWC service plan that have been installed as part of the Demonstration Project are:

- 3 Single family homes (fixed film pretreatment in drip irrigation & imported soil)
- 1 Single family home where advanced treatment was added to existing septic
- A 2 Home cluster (fixed film – drip irrigation in new soil)
- A 5 Home cluster (fixed film – drip irrigation in new soil)
- A 10 Home cluster (Septic tanks – Recirculating Sand Filter (RSF))
- A 30 Home cluster (Septic tanks – RSF)
- 3 Resorts (fixed film pretreatment – drip irrigation in new soil)
- 1 Restaurant (fixed film pretreatment – drip irrigation in new soil)
- 2 Multi-unit cabins (RSF/fixed film – drip irrigation in new soil)

At the end of the Demonstration Project OCWC is billing over 300 service connections, mostly new construction, including several new cluster systems listed below:

- 200 unit apartment condo complex WWTP
- 1000 lot subdivision WWTP
- 25 lot subdivision (RSF)
- 10 lot subdivision (RSF)
- 1000 unit condominiums WWTP
- 50 lot subdivision (RSF)

In the future OCWC expects to own operate and maintain hundreds of treatment plants with thousands of connections (members). The plan is to operate very similarly to a rural electric coop.

A major accomplishment of the Demonstration Project has been a change in the way OWTS are installed in southwest Missouri. In the past advanced OWTS for individual or clustered systems were not widely accepted as feasible or practical and contractors in the area did not install these systems. They had received a bad reputation due to failure when in reality the failure was on the part of the property owner to maintain the system.

OCWC has provided a way for these systems to be properly maintained for a simple, flat fee that is comparable and many times less expensive than that a homeowner would expect to pay for city sewer fees. Now the rural areas of southwest Missouri and any other part of the state have been offered the privilege to choose an alternative and environmentally friendly wastewater treatment system and have it maintained for a flat fee.

Task 3 – Selection, Installation and Maintenance of Advanced OWTS

Advanced OWTS have the potential to adequately treat wastewater in areas with limited soils, such as the Ozarks, but have received a bad reputation in the past due to system failure. Failure is caused by lack of proper maintenance, traditionally the responsibility of the property owner.

Objectives:

The objectives of the installation phase of the Demonstration Project were to: 1) replace selected failing or onsite wastewater treatment systems by installing more appropriate treatment technologies and 2) demonstrate management solutions by creating a responsible management entity to ensure proper maintenance.

Methods:

Steps undertaken for this part of the project included site selection, determination of appropriate alternative systems needed, installation of the system as well as installation of monitoring components. Sites were chosen for onsite demonstration based on specific criteria and surveys of individual homeowners. An example of the evaluation criteria is shown in Table 3.1.

Table 3.1: Site evaluation criteria

Criteria	*Score Descriptions*	*Score*	*Weighted Score*
Attitude. Does the applicant show a willingness to participate in the project and work with project team? Is the applicant motivated more by concern for the lake or more by the potential matching funds?	5 = helpful & willing to share 3 = neutral 1 = unhelpful		
Environmental Need. Does the applicant have a pressing problem that needs immediate attention? Will the lake water quality benefit from the project's participation? Lakefront property or removed from lake?	5 = extreme; new system will produce immediate benefits 3 = small flows or removed from lake 1 = relatively minor problem		
Expense. Is there reasonable potential for significant cost sharing?	5 = good potential for significant cost share 3 = some potential for cost sharing 1 = applicant unwilling or unable		
Feasibility. Is a cost-effective solution possible for this site? Are there especially challenging site characteristics, even considering typical problems of southern Stone County?	5 = simple solution readily available 3 = typical for Stone County 1 = site presents unique challenges		

Flow & Design Issues	**Field Notes:**

List actual flow and design flow

Describe site and soil conditions.

Regulatory Issues

Are the County Health Department or MDNR aware of any problems?

Cost Issues

Will property owner still put in new system without benefit of project participation?

Recommended percentage of cost share

Press releases advertised the project seeking to cost share on remediation of failing septic systems for area homeowners. Once individuals applied to be a part of the project, Demonstration Project personnel visited homeowners and conducted extensive site visual evaluations to obtain an indication of the environmental need at the site and the interest level of the homeowner or property owner.

During the site visit, Demonstration Project personnel also assessed the level of cooperation this individual exhibited and their level of enthusiasm for maintaining the system. In addition to these criteria, the property was evaluated to determine if there was adequate area to install a septic system with an appropriately sized effluent dispersal field. Once a property was selected for remediation, the installation was contracted to a septic system installer and excavator with specific engineered installation instructions and plans.

The various types of advanced OWTS used in the Demonstration Project included constructed wetlands, BioMicrobics FAST and RetroFAST, Zabel SCAT, Premier Tech Ecoflo peat moss and recirculating sand filters which are further discussed as follows.

Wastewater Treatment Options

Constructed Wetlands Treatment System

Constructed wetlands simulate natural wastewater treatment systems and are designed to provide clean water discharge and prevent pollution to Table Rock Lake. These systems use raised flow beds to support water-loving plants. The roots of these plants help provide an aerobic environment to break down contaminants and absorb nutrients (Figure 3.1). Constructed wetlands can offer an affordable solution to wastewater for sites with failed conventional absorption fields or low soil absorption and percolation.

Figure 3.1: Constructed wetlands systems treatment system

Wetlands treatment systems can be custom designed for all projects ranging from a single family home to a larger municipal or commercial facility. The wetlands system installed during the Demonstration Project was for a residential complex. The components of a wetlands treatment system include: a septic tank and settling tank, an impermeable liner, a gravel substrate, mulch and water-loving plants, a distribution system, collection systems and a water level control device. Water leaving the wetland is often treated with a chlorinator or ultraviolet light (UV) to control bacteria levels. Treated water is high quality and could, in the right conditions, be directly released to a river or aquifer.

Constructed wetlands are site-specific and expert design and calculations must be used to determine the requirements of a given site. Because year-round flow is necessary to sustain the plants, constructed wetlands are not appropriate for seasonal residences. On steep slopes, terraced systems may be necessary to keep the effluent flow slow enough for proper absorption. Constructed wetlands systems also require maintenance such as mowing around the wetlands pools, weed pulling, and regular checks of the chemical and UV injection system. The constructed wetlands approach is also very cost effective, at estimated 60 percent less construction cost than conventional treatment systems for a similar size development. For small towns and areas around the Ozarks where money is tight and improperly treated wastewater can have serious environmental consequences, wetland systems could be a viable solution.

BioMicrobics FAST Wastewater Treatment Systems

Fixed Activated Sludge Treatment (FAST) wastewater treatment systems are a fixed film media, aerated system utilizing a combination of attached and suspended bacteria growth. FAST systems can be designed to treat wastewater from residential, commercial, high strength and small community applications and are capable of removing high concentrations of nutrients in a single tank. The stable surface of the fixed film media in a FAST system allows for the cultivation of large volumes of microorganisms on the honeycomb-like structure (Figure 3.2). The FAST treatment chamber is aerated to encourage the growth of aerobic bacteria and the wastewater coming from a residence is digested by these microorganisms which use it for food and turn it into a clear, odorless, high-quality effluent (Figure 3.3). The attached growth system also assures that more microorganisms remain inside the system rather than being flushed out during peak flows.

The first compartment of the two-compartment septic tank can be used as the primary settling zone. The second compartment houses the FAST treatment insert and is the aerobic zone. Two separate tanks can also be used as the settling tank and treatment tank. Once installed, the FAST system is low maintenance, clean, and odorless. The FAST wastewater treatment system is located below ground level and the aerating blower is placed in housing above ground. FAST technology is well suited for high strength waste, residential development, remediation of failing systems and severely limited sites such as those with poor or thin soils around Table Rock Lake. The innovative combination of the stability of fixed film media and the effectiveness of activated sludge through aeration treatment make FAST wastewater treatment reliable and environmentally sound.

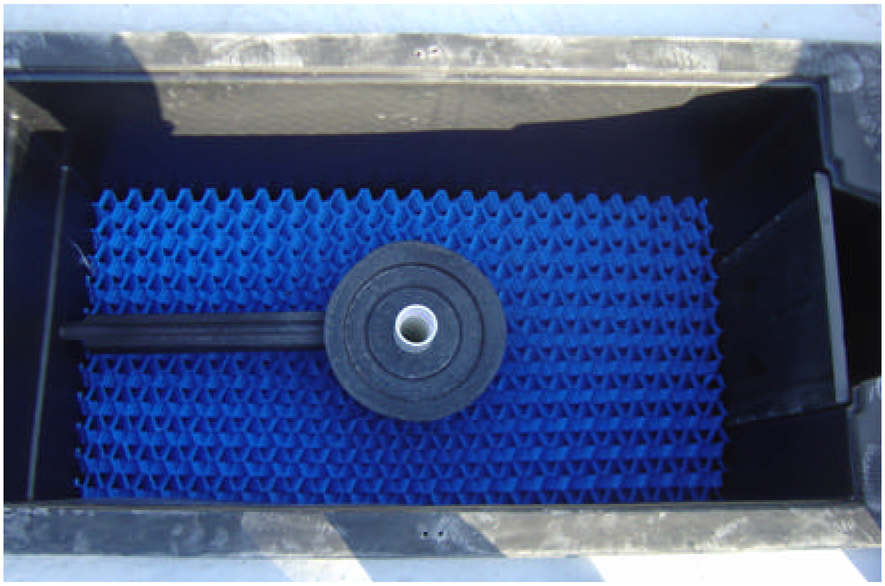


Figure 3.2: Fixed film media for bio-microbial treatment colonies

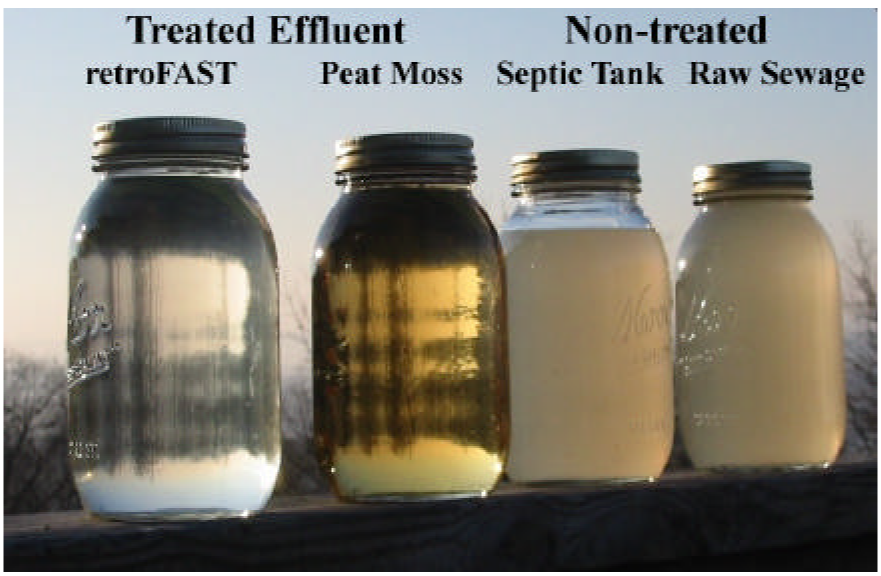


Figure 3.3: Comparison of treated effluent and non-treated effluent. Treated septic effluent shows a much higher clarity than untreated (Peat moss treated effluent is stained by tannins in the peat as it is filtered) (photo courtesy of the Upper White River Basin Foundation)

BioMicrobics RetroFAST Wastewater Treatment Systems

A RetroFAST treatment system adapts conventional onsite systems by inserting a RetroFAST unit and aeration blower into an existing watertight and properly sized septic tank (Figure 3.4). This not only enhances wastewater treatment performance but may also be used to remediate failed onsite soil absorption fields or lateral fields. Conventional systems utilize a septic tank to hold solids and a lateral field to disperse the wastewater and provide the majority of treatment. Over time, the lateral field can become clogged with microorganisms called biomatt which find this area conducive for growth. This can eventually prevent wastewater from moving away from the system causing overflow, soggy lawns, plumbing system back-ups and surfacing.

Replacement of the soil absorption system is a drastic form of repair can be costly as well as cause damaging to the existing property. RetroFAST wastewater treatment units can be adapted and inserted into the existing tank to promote the growth of aerobic bacteria on the fixed film media in the tank. This helps remove more of the pollutants that originally fed the biomatt that formed the clogging layer in the failed lateral field. RetroFAST systems oxygenated effluent also promotes the development of aerobic bacteria in the soil which digests the existing clog and helps to renovate the failed lateral field.

Many conventional systems or failed systems due to clogged lateral fields are good candidates for RetroFAST units. Upgrading an onsite wastewater treatment system with a RetroFAST unit may not only help prevent system failures, but may also greatly increase the treatment value of the system, protect the environment and increase the value of the property.

Figure 3.4: RetroFAST unit installation in an existing septic system

ZABEL or Quantics SCAT Wastewater Treatment Systems

The Zabel SCAT treatment system, now know as the Quantics system is a bio-filter system that uses a tank or series of tanks containing media such as foam cubes which house the microorganisms and have the wastewater effluent sprayed over them to treat the water. These bio-filters can be installed on a variety of sites from single family residential to large commercial applications.

Two-inch polyurethane cubes are placed into a container to form a packaged septic media filter system which is used in either single pass or recirculating system. Packaged foam cube wastewater treatment systems may be placed entirely above ground (Figure 3.5) in areas that do not have a hard freezing climate. A septic tank collects the septic solids while the effluent is passed into the foam filter in small doses (1/10 gallon to 1 gallon per cubic foot per dose) using spray nozzles which dose the filter from its top. The treated wastewater is then recirculated for further treatment or discharged to the soil.

The design of the foam cube filter systems in alternative wastewater treatment systems is dependent upon equal distribution of the wastewater effluent over the entire surface of the foam cube filter units. However, the spray nozzles can become clogged in these systems which reduce the effectiveness of the filter by providing uneven effluent distribution. An advantage of the foam cube septic media system for wastewater treatment is its relatively easy maintenance with the clog prone top of the filter and nozzles easily accessible for removal or and replacement. Another advantage is that this type of system can facilitate wastewater treatment on very small lots or even completely above ground where space or soil conditions do not permit a conventional tank system.

Figure 3.5 ZABEL units and Foam cube filter. Each lid opens up to a foam cube media filter and spray nozzle in the ZABEL wastewater treatment unit.

Premier Tech Ecoflo Peat-moss Filter Wastewater Treatment System

The Premier Tech Ecoflo Peat-moss filter is an attached growth pre-treatment system that reduces the amount of nutrients and contaminants in the septic effluent before it is discharged into the soil absorption field. The peat filter consists of a fiberglass shell containing peat-moss. The wastewater from the septic tank is piped into the shell where it flows over and throughout the filter by means of gravity. Naturally occurring fungus and bacteria live and breed within the peat moss and it is these microorganisms that treat the wastewater to a very high degree (Figure 3.3). The pre-treated wastewater is then discharged by infiltration into the soil. A peat moss bio-filter may be used as an advanced treatment unit in conjunction with a conventional lateral or drip irrigation disposal system. It may also be used in conjunction with existing onsite wastewater treatment systems. On adverse sites, where the use of conventional subsurface soil adsorption systems does not provide acceptable levels of treatment, peat-moss may be used as an economical method of onsite wastewater treatment.

Recirculating Sand Filter Wastewater Treatment System

Recirculating Sand Filters systems (RSF) provide another alternative to conventional methods of treatment when soil conditions are not conducive to proper treatment and disposal of wastewater. RSF are aerobic, fixed-film bio-filters that also physically strain and remove suspended solids from the wastewater within the pores of the filter media. As the wastewater percolates through the sand filter chemical adsorption and removal of nutrients occurs through digestion by microorganisms. The basic components of a recirculating sand filter include a recirculation/dosing tank, pump and controls, distribution network of pipes, the sand filter bed with bottom draining system, and a return line to recirculation tank. The return line splits the flow to recycle a portion of the filtrate back to the recirculation/dosing tank while a small volume of wastewater and filtrate is dosed to a soil lateral field.

Recirculating filters must use a coarser media than single-pass filters because recirculation requires higher hydraulic loadings. Washed pea gravel is the most common media used (Figure 3.6). Some modifications to the basic RSF design include the type of distribution system, the location and design of the recirculation tank, the means of flow splitting the filtrate between discharge and return flows, and enhancements to improve nitrogen removal.

Recirculating sand filters can be used for a broad range of applications, including single-family residences, large commercial establishments, and small communities. They are frequently used to pre-treat wastewater prior to subsurface infiltration on sites where soil has insufficient unsaturated depth above ground water or bedrock to achieve adequate treatment. RSF are primarily used to treat domestic wastewater, but they have also been used successfully in treatment trains to treat wastewaters high in organic materials such as those from restaurants and supermarkets. Sand filters are used on sites that have shallow soil cover, inadequate permeability, and limited land area. An advantage to RSF is that they provide very good effluent quality with over 95% removal of biochemical oxygen demand (BOD) and total suspended solids (TSS), along with significant reduction in nitrogen levels. A disadvantage to the sand filter is that maintenance on this type of system is needed frequently.

Figure 3.6: Recirculating sand filters. Large systems like the ones pictured can treat wastewater from a subdivision or housing complex.

Discharge and Dispersal Options

Existing Lateral Field

Most existing lateral fields around Table Rock Lake consist of the conventional perforated pipe buried 1 to 3 feet deep that disperses the septic liquids into the soil and surrounding environment. However, the characteristic thin, clay soils with a high percentage of rock fragments and the highly porous bedrock found in the Ozarks and around Table Rock Lake are not conducive to conventional septic lateral fields. Inadequate soil provides little treatment while fracture bedrock allows for contamination of surface and ground water systems. Only in very few instances were the existing lateral fields accepted where there was adequate soil depth and absorption capability.

Drip Irrigation Effluent Dispersal System

All soil dispersal systems must have uniform distribution of effluent in order to properly treat wastewater. Drip irrigation systems use small-diameter plastic tubing (about ½ inch) and drip emitters placed two feet apart and 6 to 9 inches below the surface to distribute the effluent evenly. Effluent is taken up and processed by the roots of grass or other plants growing at the surface over the drip irrigation field. Evapotranspiration (combined effects of evaporation from the soil surface and transpiration of moisture through plant leaves) is a significant factor in removing effluent water from the drip irrigation field.

This technology is designed to disperse filtered, pre-treated septic tank effluent in to the soil absorption field. In a Drip Irrigation system, the main septic tank receives the raw waste, and an additional tank houses the biomat and microbiotic aeration chamber through which the liquid is filtered and cleaned. A holding tank collects the pretreated wastewater and, with a pump and timing system, doses the drip field. This drip dispersal field can be either pre-existing on the site or be brought into the site to provide adequate soil absorption capacity.

Drip irrigation systems may be used in place of conventional lateral lines where there is insufficient soil depth to absorb and treat effluent. The wider dispersal area of drip irrigation systems allows for the absorption of more effluent in a shallower soil matrix. In cases where there is adequate soil with a less amount of rock and gravel fragments, the drip dispersal tubing can be trenched into the ground, as shown in the Figure 3.7. More often than not, there is not sufficient soil volume in the Table Rock Lake area to provide adequate depth for drip dispersal. In these cases, soil may be imported to create an absorption field and suitable conditions for vegetative growth and uptake of nutrients. In these cases a soil bed is constructed (Figure 3.8) and drip tubing is laid down and covered with more soil to form an absorption zone. This system should not be used if there is any chance of vehicles crossing the field as this will compact the soil and prevent soil absorption. Additional pretreatment is necessary, and filtration is essential to ensure proper functioning. Pre-treatment through a properly installed and functioning wetlands treatment, sand filtration, FAST, RestroFAST or peat moss system combined with an adequate conventional or drip irrigation system can provide very effective individual onsite wastewater treatment.

Figure 3.7: Trenching in drip irrigation lines. Adequate soil at this site allowed drip lines to be installed directly into the existing soil.

Figure 3.8: Imported soil for drip irrigation lines. Lines can be installed between soil bed and covering layer in imported soil.

Maintenance of advanced systems, such as drip irrigation requires some additional considerations such as ensuring good vegetative cover and regular checks of the dispersal and aeration components to evaluate proper operation and treatment. Periodic back flushing of the tubing is sometimes necessary to clear out solid material from the effluent deposited in the piping. Like any pump-operated system, a reliable source of power is required.

Surface Discharge

Surface discharge to a stream or to the lake is only recommended with the highest quality effluent. All surface discharges in the Table Rock Lake area are required by Missouri State law to meet phosphorus limits of 0.5 mg/L. Additionally these discharges must disinfect for bacteria through chlorination, UV or other treatment system. Surface discharges from individual onsite wastewater treatment systems are currently prohibited by Missouri State law.

Results:

The Demonstration Project installed or Retrofitted 25 onsite wastewater treatment systems (OWTS) using advanced treatment options including FAST, RetroFAST, and other media filters. These systems and their locations, treatment types, property types and maintenance arrangements, either done by Ozarks Clean Water Company (level 5) or other, are summarized in Table 3.2 and shown in detail in Appendix I.

Drip irrigation was considered the best treatment alternative for wastewater systems in the Table Rock Lake area due to the fact that this treatment design not only pre-treated the septic effluent using aeration and microbial activity, but also dispersed the liquid effluent over a wider area allowing for maximum absorption by the thin soils.

As the Demonstration Project developed, it was further determined that the thin soils that existed around the Table Rock Lake area were often not adequate for filtering the wastewater even from drip dispersal. Therefore drip dispersal in imported soil was demonstrated to evaluate its performance. In addition to improved wastewater treatment and protection of the water quality of Table Rock Lake the success of this treatment system has helped allow for the acceptance of drip irrigation as a plausible alternative to failing conventional systems in the thin soils near Table Rock Lake in southwest Missouri.

To address the problem of maintenance and management of onsite systems, Ozarks Clean Water Company (OCWC) was formed in March of 2004 with the help of Table Rock Lake Water Quality and the Demonstration project. This non-profit company was formed to provide homeowners with OWTS the option of having a third party provide all maintenance services for their system for a monthly fee.

The Voluntary National Guidelines for Management of Onsite and Clustered Wastewater Treatment Systems, published by EPA outlines 5 management levels for OWTS. Further discussion on the EPA Management Models or Maintenance Levels can be found in Task 2. OCWC operates on the EPA level 5 management guidelines.

Table 3.2: Summary of completed installations

Site Name	Maintenance level	Treatment type	WTS type	Property type
Joe Bald Rd Subdiv	Five	Recir Sand Filter	NPDES Surface Discharge	Cluster
Kimberling City Subdiv	Five	FAST	Imported Soil Drip Dispersal	Cluster
DD Hwy Subdiv	Five	Recir Sand Filter	New Lateral Field	Cluster
Shell Knob Apts	Five	FAST	Imported Soil Drip Dispersal	Cluster
Shell Knob Subdiv	Three	Wetlands	NPDES Surface Discharge	Cluster
Galena Apts	Five	Recir Sand Filter	NPDES Surface Discharge	Cluster
Kimberling City Campground	Three	FAST	Existing Soil Drip Dispersal	Shower house
Shell Knob Restaurant S	Five	Comm FAST	Imported Soil Drip Dispersal	Restaurant
Shell Knob Restaurant N	Three	Wetlands	NPDES Surface Discharge	Restaurant
Galena resort	Three	Zabel SCAT	Drip Dispersal	Resort
Reeds Spring Resort	Three	Recir Sand Filter	NPDES Surface Discharge	Resort
Hwy OO Resort	Three	FAST	Existing Soil Drip Dispersal	Resort
Lampe Resort	Three	Zabel SCAT	Imported Soil Drip Dispersal	Resort
Cape Fair Resort	Three	FAST	Imported Soil Drip Dispersal	Resort
Hwy DD resort	Three	Zabel SCAT	Imported Soil Drip Dispersal	Resort
Reeds Spring residence	Five	FAST	Existing Lateral	Single family
Shell Knob, Owl Pt residence	Five	Peat Moss	Imported Soil Drip Dispersal	Single family
Lampe residence	Three	FAST	Existing Lateral	Single family
Kimberling City residence	Five	RetroFAST	Existing Lateral	Single family
Ozark residence	Three	FAST	Existing Soil Lateral	Single family
Hwy H residence	Three	FAST	Imported Soil Drip Dispersal	Single family
Campbell Point residence	Three	FAST	Imported Soil Drip Dispersal	Single family
Galena residence	Three	FAST	Imported Soil Drip Dispersal	Single family
Ridgedale residence	Five	FAST	Imported Soil Drip Dispersal	Single family

Task 4 - Treatment System Monitoring

Objectives:

The Demonstration Project contracted with Midwest Environmental Consultants, (MEC) to conduct monitoring to evaluate the performance of four onsite systems that were included in the demonstration project. The four systems were selected to demonstrate how advanced treatment technologies popular in other areas of the United States could be installed and operated in challenging site conditions in the Table Rock Lake area. These challenging conditions commonly consist of shallow soils and limited lot sizes.

The four sites included the Cape Fair Resort, the Lampe Resort, the Shell Knob Restaurant South (S) and the Kimberling City Residence (Table 4.1). The Cape Fair Resort, Lampe and Shell Knob Restaurant S treatment systems included drip dispersal into imported soil. Imported soil was considered to be a potential means of improving effluent dispersal for sites with shallow, rocky soils. Therefore, it was a priority to include these systems in the monitoring program. The Project Advisory Board (PAB) suggested that subsurface water quality monitoring be included at all four sites. Therefore, the project included innovative subsurface monitoring approaches to collect water quality data below the dispersal fields. These data were not intended to be compared to specific standards, but rather were intended to provide specific water quality information to better understand subsurface dynamics at each site monitored.

Table 4.1 Monitoring Locations, System Characteristics, Monitoring Parameters and Testing Frequency

Owner	Bedrooms/ Flow (gpd)	Type of Treatment System	Type of Subsurface Monitoring System	Samples to Collect	Rainfall	Water Chemistry Analyses	Water Chemistry Sampling Frequency
Cape Fair Resort	16 bedrooms 1,920 gpd	Bio-Microbics FAST® with drip dispersal into imported soil	Plastic sheet and half-pipe lysimeters	Septic tank effluent, FAST effluent, plastic sheet and half-pipe lysimeters	Daily	Total Suspended Solids, Biochemical Oxygen Demand, pH, Total Phoshorus, Fecal Coliform,Temperature, Conductivity, Dissolved Oxygen, Ammonia, Nitrite/Nitrate, Total Nitrogen	Monthly (August 2006 through July 2007)
Lampe Resort	1,560 gpd	Zabel SCAT® biofilter with drip dispersal into imported soil	Half-pipe lysimeter	Septic tank effluent, SCAT effluent and half-pipe lysimeters	Daily	Same as above	Monthly (November 2005 through July 2007)
Shell Knob Restaurant South	1,500 gpd	Restaurant wastewater discharging into a Bio-Microbics FAST® unit with drip dispersal into imported soil	Plastic sheet and half-pipe lysimeters	Septic tank effluent, FAST effluent, plastic sheet and half-pipe lysimeters	Daily	Same as above	Monthly (November 2005 through July 2007)
Kimberling City Residence	3 bedrooms 360 gpd	Bio-Microbics RetroFAST® with existing Infiltrator dispersal system	Piezometers	RetroFAST effluent, subsurface piezometers	Daily	Same as above	Monthly (November 2005 through July 2007)

Methods:

Data were collected from each of the selected systems to evaluate system conditions, treatment unit process performance and dispersal system performance. Monitoring was conducted at Lampe Resort, Shell Knob Restaurant S. and the Kimberling City Residence from November of 2005 through July 2007. The Cape Fair Resort monitoring began when the onsite system began operation in August 2006 and continued through July 2007. Unit process and water quality data were collected to evaluate the performance of the treatment systems and dispersal field. Phosphorous removal in the soil was of special interest. Dispersal fields along Table Rock Lake shorelines are typically constructed in one to two feet of soil above limestone bedrock sloping toward the Lake. Therefore, dispersal field subsurface water quality represents an important aspect of maintaining lake water quality.

Monthly sampling was conducted for each of the four systems (Figure 4.1). Electronic rainfall gauges were installed at each site to provide information on how rainfall may affect subsurface sample concentrations. Sampling locations consisted of septic tank effluent, treatment system effluent and dispersal field effluent from subsurface sample collectors. Laboratory water quality measurements included 5-day biochemical oxygen demand (BOD_5), total suspended solids, ammonia nitrogen, nitrate nitrogen, total nitrogen, total phosphorus and fecal coliform. Field measurements included pH, dissolved oxygen, conductivity and temperature. Monitoring approaches, quality control and quality assurance activities were conducted in accordance with the project Quality Assurance Project Plan (QAPP) (August 2004) and Revised Monitoring Plan (November 2005).

Septic Tank and Treated Effluent Monitoring

The procedure for analyzing ammonia nitrogen had a maximum detection limit of 5.0 mg/L. Ammonia measurements above 5.0 mg/L are reported as “greater than 5.0 mg/L”.

The evaluation of the mechanical treatment systems involved collecting samples from septic tank and process effluent sample points (Figure 4.2). A peristaltic pump was used to obtain tank effluent samples. New tubing was used for each sample location. The sample line was purged with the sampled matrix for approximately 30 seconds prior to filling the sampling containers. Approximately 2,000 milliliters (mLs) were collected and split accordingly into the appropriate containers (glass or HDPE bottles) issued from the laboratory. Duplicate samples were taken at a frequency of one per 10 samples collected. Field blanks were collected during each sampling trip. Temperature, conductivity and dissolved oxygen were measured using a YSI 85D or a YSI 6 series multiparameter sonde. pH was measured with an Orion 200 Series portable meter.

Shell Knob Restaurant S.

Lampe Resort

Cape Fair Resort

Kimberling City Residence

Figure 4.1: Photographs of properties included in the onsite monitoring program

Figure 4.2: Typical septic tank effluent and treated effluent sampling locations

Subsurface Monitoring

Subsurface water collection devices were installed to collect and characterize subsurface water quality in the treated effluent dispersal fields at the four sites. Subsurface monitoring devices were also installed at each site in areas unaffected by the onsite system effluent to serve as experimental controls.

Subsurface monitoring systems included lysimeters and piezometers. A lysimeter is a device for the collection of water moving through the soil. Lysimeters are typically classified into two categories: gravity lysimeters and suction lysimeters. The demonstration project utilized gravity lysimeters for subsurface sample collection. A gravity lysimeter, as the name implies, collects soil water as it percolates via gravity through saturated soils. Piezometers are vertical pipes inserted into the soil at varying depths typically to measure groundwater levels, but they can also be used to collect groundwater samples.

Half-pipe and plastic sheet gravity lysimeters were used to collect subsurface samples. Both types of lysimeters were installed underneath drip lines at Cape Fair Resort and Shell Knob Restaurant S. during the installation of the drip fields (Table 4.2). Half-pipe lysimeters were installed into the Lampe Resort drip field several months after the drip field was installed. The drip tubing was cut and reconnected following the lysimeter installation. A plastic sheet lysimeter was not installed at Lampe due to the large area of the existing drip field that would need to be excavated and re-installed.

Table 4.2: Subsurface Monitoring Devices Installed

Location	Half-pipe Lysimeter	Plastic Sheet Lysimeter	Piezometer
Cape Fair Resort	✓	✓	---
Lampe Resort	✓	---	---
Shell Knob Restaurant S.	✓	✓	---
Kimberling City Residence	---	---	✓

The half-pipe lysimeters consisted of 12-inch PVC pipe that was cut in half lengthwise to create a 15 to 20 foot long trough under the drip tubing (Figure 4.3). The half pipe drained to a 24-inch corrugated polyethylene riser installed at the edge of the drip field. The bottom of the riser was open and filled with 3 to 6 inches of washed clean river gravel. The 12-inch pipe invert was approximately 18 inches above the gravel bottom of the riser. The pipe was inserted approximately one foot into the riser with a slope of approximately 0.5% to 1%. Once in place, the cracks around the 12-inch pipe (inside and outside of the riser) were sealed with silicone to keep soil from entering the riser. The half-pipe trough was filled with 3 inches of washed river gravel and covered with leach field fabric, which acts as a barrier layer keeping soil from entering the lysimeter. The fabric was cut large enough to overlap the ends and sides and clamped to the pipe at approximately two foot intervals. Half of a 5-gallon bucket was placed over the solid section of pipe near the riser to protect leach field fabric from being punctured. Drip lines were installed over the lysimeter following the addition of dispersal field soil. Figures4.4 shows the installation and riser assembly of a half-pipe lysimeter.

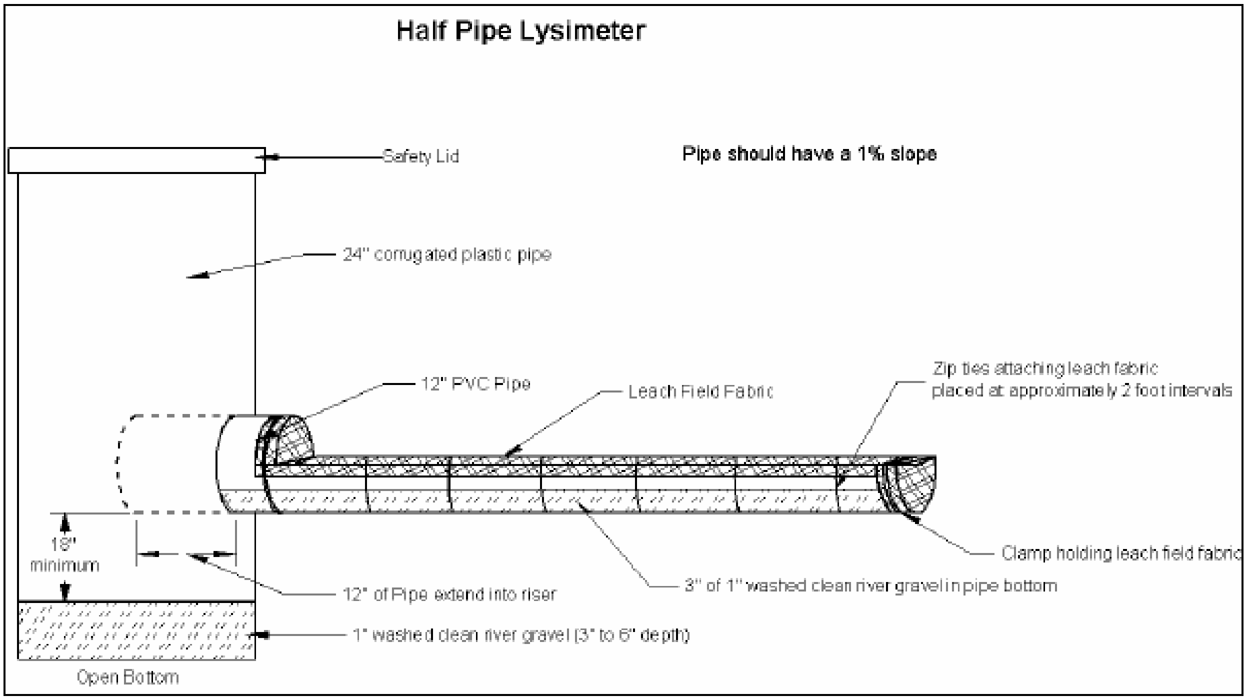


Figure 4.3: Half-pipe lysimeter sketch

Figure 4.4: Half-pipe lysimeter photographs

The plastic sheet lysimeter was a unique subsurface monitoring approach designed by the Demonstration Project personnel. The plastic sheet lysimeter uses the same principles as the half-pipe lysimeter but collects effluent from a larger area under the dispersal field. Installers cleared a 50-foot long, 5-foot wide area over which the plastic sheeting was placed (Figure 4.5). A 4-foot wide, 4-inch deep water collector trough was then excavated on the downslope end of the plastic sheet trough. A 4-inch PVC perforated lateral line was installed in the trough to collect and direct runoff to the sample container. The collector channel was lined with 1-inch diameter clean river gravel to allow water movement and protect the plastic liner from being punctured.

The bottom of the collector channel was below the original grade to create a depressed area to pool subsurface water. Leach field fabric was wrapped around the pipe with extra fabric extended beyond the perforations and beyond the capped end. The excess plastic was wrapped around the pipe and attached to the apex with rubber weather stripping and screws. The remainder of the plastic was wrapped over the capped end of the perforated pipe and securely fastened around the solid wall pipe with the weather strip. Another piece of leach field fabric was laid over the pipe and sheeting and clean river gravel was poured over it to secure it in place prior to backfilling. The 4-inch collector pipe drained into a 24-inch corrugated polyethylene riser pipe where a sample container was placed to collect sample.

Figure 4.5: Photographs of plastic sheet lysimeter installation

Piezometers were used for collection of subsurface samples at the Kimberling City Residence (RetroFAST site). A piezometer is a small diameter PVC pipe perforated near the bottom and used for ground water monitoring and water infiltration monitoring. Three piezometers were installed at the Kimberling City Residence dispersal field where a chambered, gravity dispersal (Infiltrator®) had been installed prior to the demonstration project. The Kimberling City dispersal field was well landscaped and the piezometer method was considered the least invasive approach to collect subsurface samples. Borings were augered into the soil and the piezometers were placed to the depth of bed rock in order to gather any water that may be following the rock layer down gradient. A control piezometer was also placed at the site in a location that would not receive leachate from the dispersal field.

Subsurface Sample Collection Methods

Subsurface sampling was conducted during each monthly site visit if sufficient sample volume was present in the sample containers. Monthly monitoring runs were conducted soon after rain events to best assure fresh samples. Subsurface samples were collected using two methods. Lysimeters samples were collected in containers that remained inside of the riser portion of the monitoring device. Samples were extracted from piezometers using a peristaltic pump.

Subsurface Sampling Device Installation and Performance

The project team recognized the experimental nature of collecting subsurface water samples and the absence of standardized methods for dispersal field subsurface water sample collection and data interpretation. Therefore, the ability of a given method to merely generate samples was considered equally as important as the water chemistry data conducted on the samples collected. A properly operating drip dispersal field does not create saturated soil conditions and should not generate free water that can be collected in a gravity lysimeter. Therefore, samples would be expected to be generated only during rain events. Sample volume and parameter concentrations are affected by several variables such as rainfall amounts, frequency and intensity; the depth of soil fom the drip tubing to the lysimeter; the location and number of drip emitters over the lysimeter; soil structure; and temperature. The data collected from subsurface samples were not intended to be compared to specific standards, but rather were intended to provide specific water quality information to better understand subsurface dynamics at each site monitored.

One of the most important variables in the drip field subsurface monitoring systems was the depth of soil between the drip tubing and the lysimeter. Site constraints such as depth to bedrock did not allow for standard depths between the drip tubing and the lysimeter. Soil depths ranged from 9 inches to less than one inch (Table 4.3).

Table 4.3: Soil depth and drip tubing placement information

	Cape Fair Resort	Lampe Resort	Shell Knob Restaurant S.
Approximate soil depth above drip tubing	12 inches	12 inches	12 inches
Approximate soil between drip tubing and lysimeters	5 inches	< 1 inch	9 inches
Drip tubing placement over lysimeters	Parallel	Perpendicular	Parallel

Samples generated from all lysimeters are summarized and shown in Table 4.4 and Figures 4.6, 4.7 and 4.8. Lampe generated the greatest number of samples which was attributed to the minimal soil present between the drip tubing and the lysimeters. Very few samples were collected in the Shell Knob Restaurant S. control lysimeters. The cause was not determined. The piezometers at the Kimberling City Residence did not perform as well as the gravity lysimeters, yielding only two dispersal field samples and no control samples. The plastic sheet lysimeters for Cape Fair Resort and Shell Knob Restaurant S. produced the greatest number of samples and were considered more effective than the half-pipe lysimeter.

Table 4.4: Subsurface samples collected at each monitoring site

Monitoring Site	Dispersal Field	Control
Cape Fair Resort		
Plastic Sheet Lysimeter	5	9
Half-Pipe Lysimeter	3	7
Lampe Resort		
Half-Pipe Lysimeter	14	9
Shell Knob Restaurant S.		
Plastic Sheet Lysimeter	18	1
Half-Pipe Lysimeter	14	2
Kimberling City Residence		
Piezometers	2	0

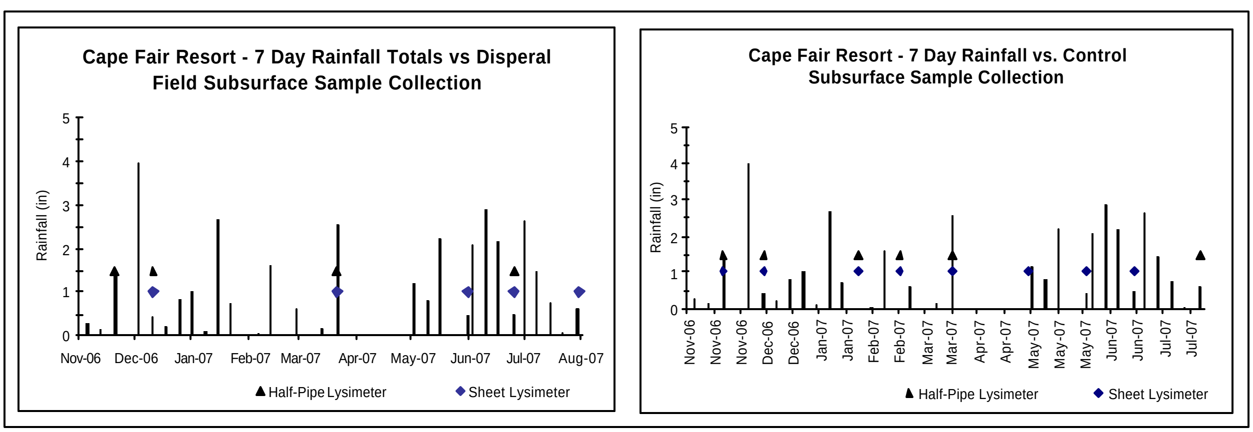


Figure 4.6: Cape Fair Resort 7-day rainfall for subsurface collection. Total rainfall versus dispersal field sample and control sample

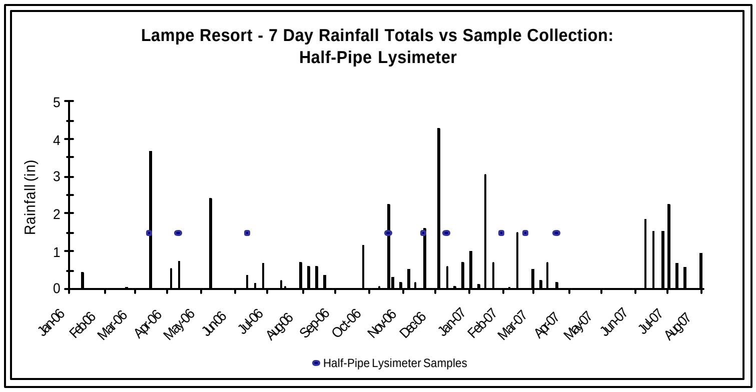


Figure 4.7: Lampe Resort 7-day rainfall total versus sample collection

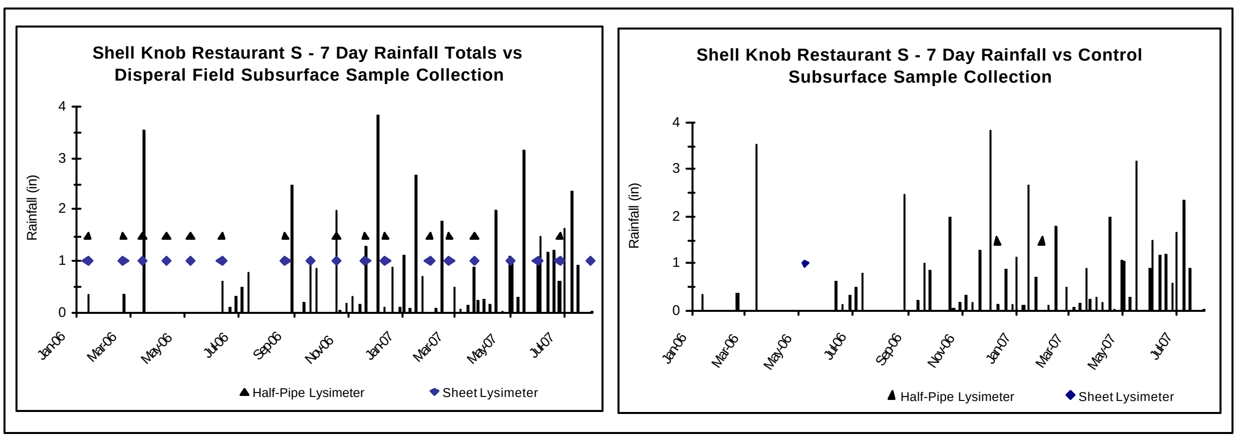
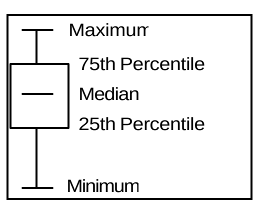


Figure 4.8: Shell Knob Restaurant S 7-day rainfall for subsurface collection. Total rainfall versus dispersal field sample and control sample

A comparative analysis of dispersal field and control water quality measurements for the three sites with gravity lysimeters was conducted using box plots. The box plots provide a graphic representation of the following dataset values:



The median value is the 50th percentile of the dataset. Median values best reflected the dataset as a whole and therefore were used in the comparative analysis as a single number to represent the dataset. Control sample concentrations were generally lower than dispersal field samples (Figures 4.9, 4.10 and 4.11). There were intermittent spikes in control datasets, such as fecal coliform concentrations for Cape Fair Resort half-pipe lysimeter. All median concentrations in control datasets were at/below dispersal field concentrations (Table 4.5)

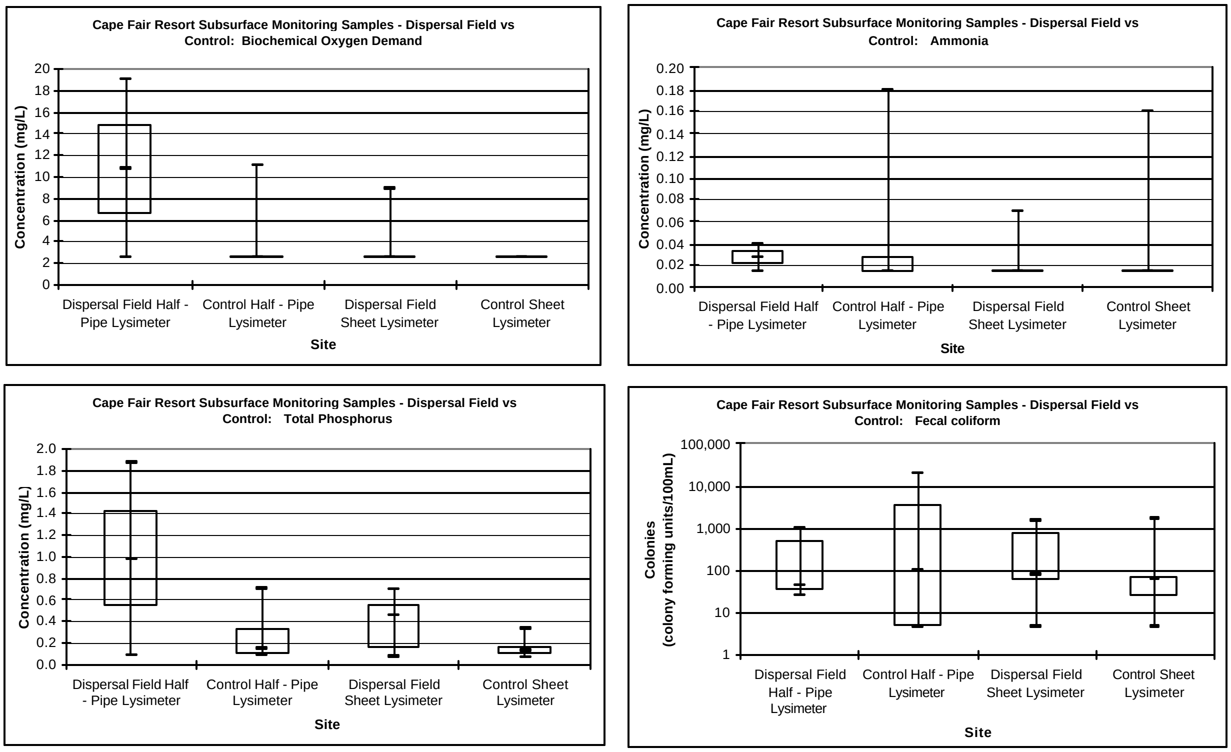


Figure 4.9: Cape Fair Resort subsurface box plots. Dispersal field versus control concentrations

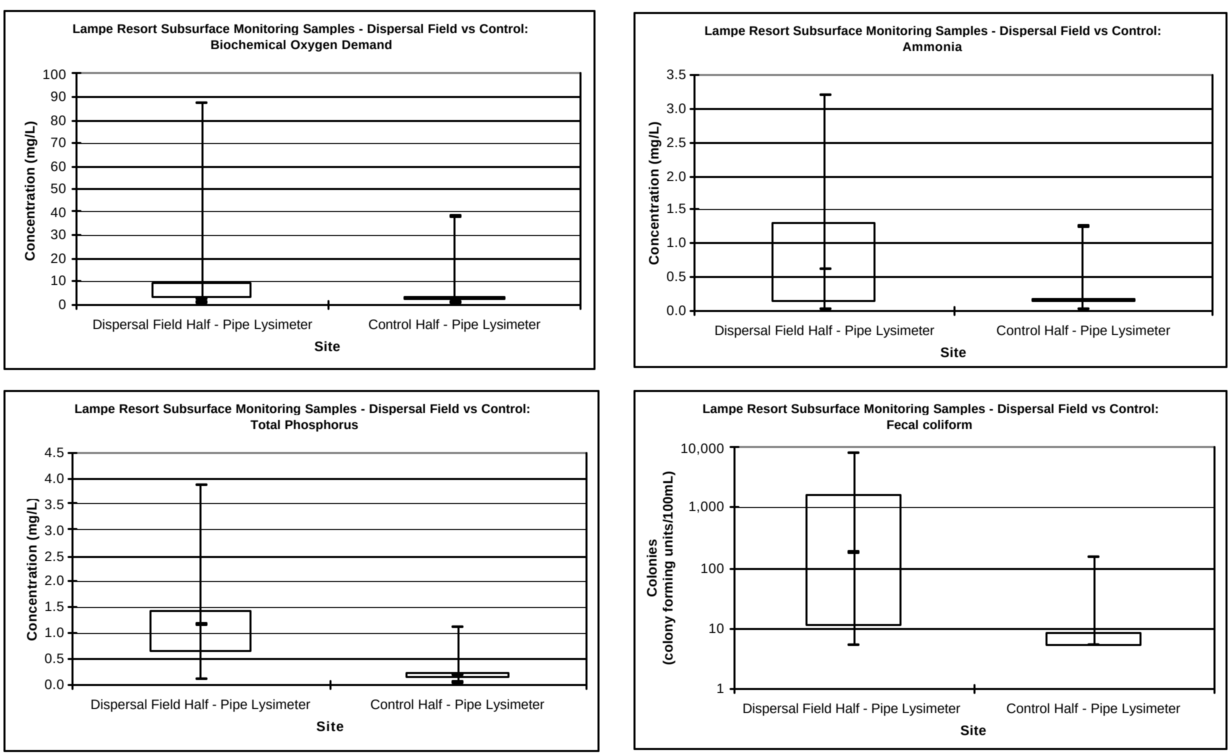
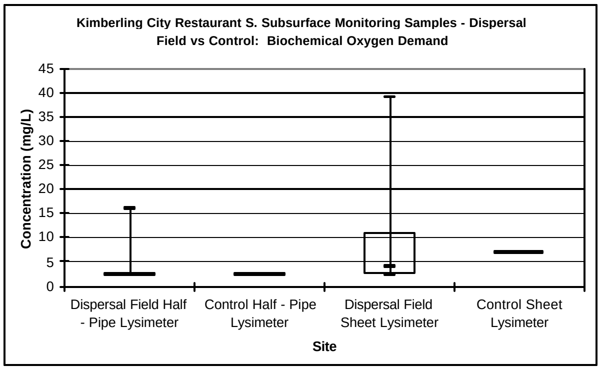
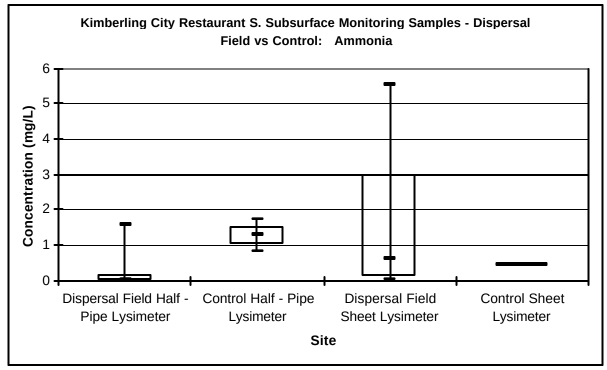
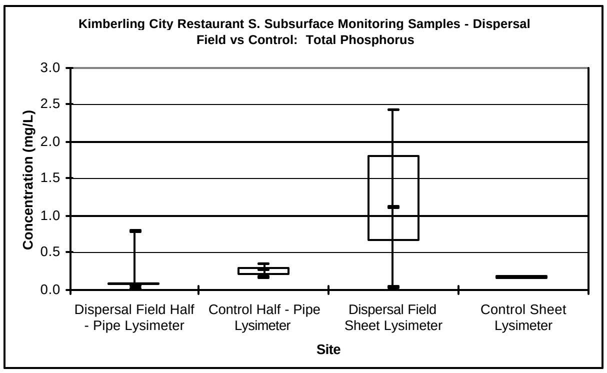


Figure 4.10: Lampe Resort subsurface box plots. Dispersal field versus control concentrations







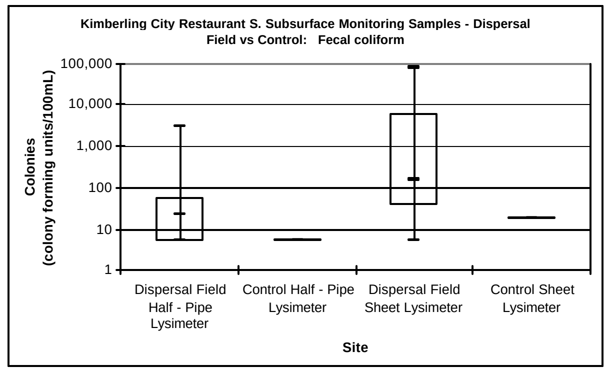


Figure 4.11: Shell Knob Restaurant S. subsurface box plots. Dispersal field versus control concentrations

Table 4.5: Median sample concentrations of dispersal field and control lysimeter samples

	Cape Fair Resort	Lampe Resort	Shell Knob Restaurant S.
	BOD5 (mg/L)		
Plastic sheet lysimeter			
Dispersal Field	3	----	3
Control	3	----	3
Half-pipe lysimeter			
Dispersal Field	11	3	4
Control	3	3	7
	Ammonia (mg/L)		
Plastic sheet lysimeter			
Dispersal Field	0.02	----	0.02
Control	0.02	----	1.28
Half-pipe lysimeter			
Dispersal Field	0.03	0.62	0.61
Control	0.02	0.14	0.44
	Phosphorus (mg/L)		
Plastic sheet lysimeter			
Dispersal Field	0.46	----	0.06
Control	0.14	----	0.25
Half-pipe lysimeter			
Dispersal Field	0.98	1.17	1.10
Control	0.15	0.19	0.16
	Fecal Coliform (mg/L)		
Plastic sheet lysimeter			
Dispersal Field	81	----	23
Control	63	----	5
Half-pipe lysimeter			
Dispersal Field	45	186	153
Control	99	5	18

Relationship between Rainfall and Lysimeter Sample Concentrations

The relationship between rainfall amounts and subsurface sample concentrations was evaluated by comparing subsurface phosphorus and fecal coliform concentrations to the total rainfall that occurred 7 days prior to sample collection of each sample (Figures 4.12, 4.13 and 4.14). In general, there was little if any observed correlation between rainfall amounts and sample phosphorus and fecal coliform concentrations.

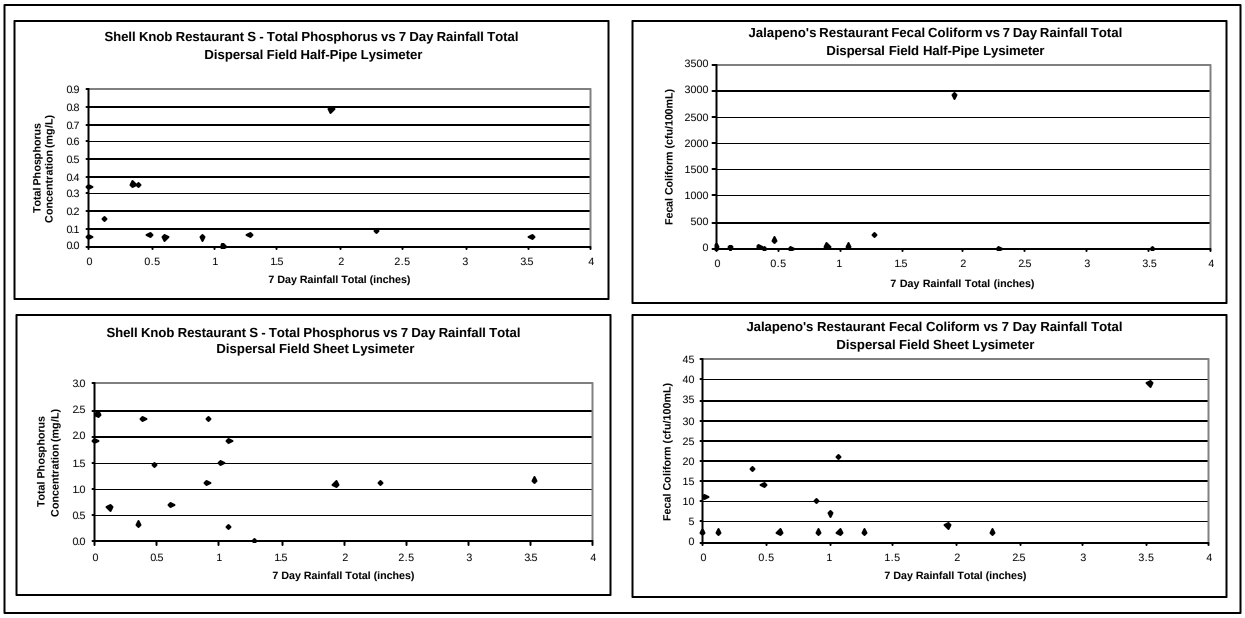


Figure 4.12: Cape Fair Resort subsurface phosphorus and fecal Coliform. Concentrations versus 7-day preceding rainfall

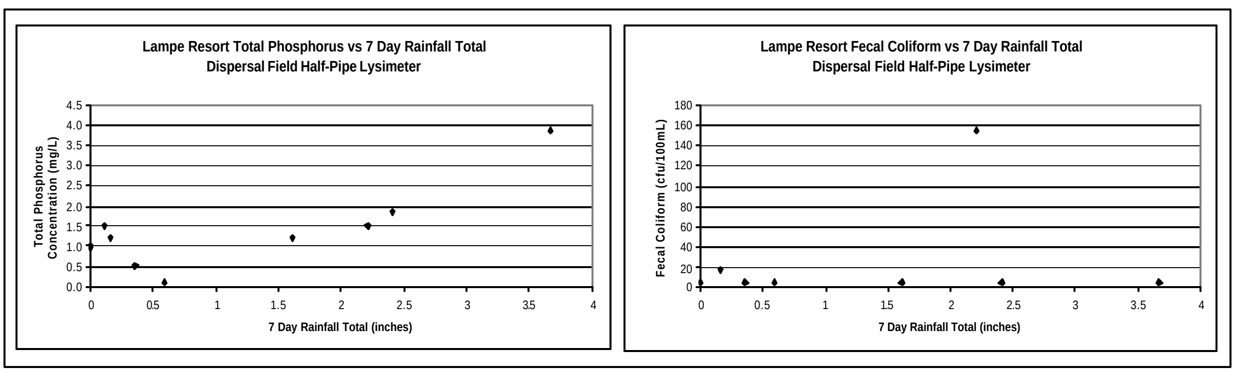


Figure 4.13: Lampe Resort subsurface phosphorus and fecal Coliform. Concentrations versus 7-day preceding rainfall

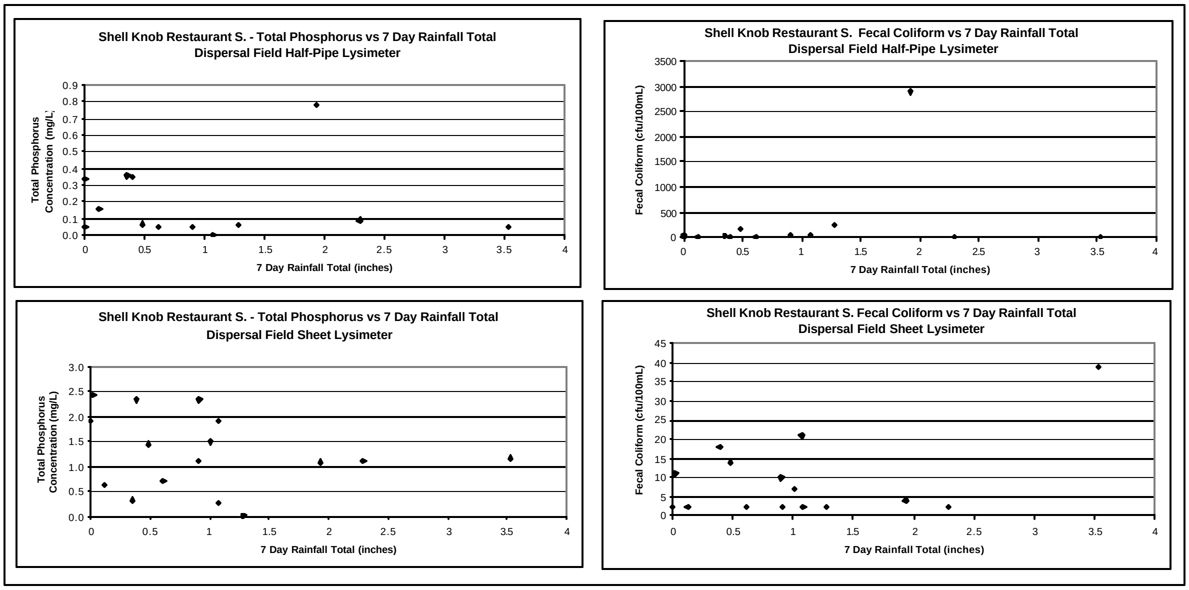


Figure 4.14: Shell Knob Restaurant S. subsurface phosphorus and fecal Coliform. Concentrations versus 7-day preceding rainfall

Subsurface Data Selection for Results and Discussion Section

Subsurface monitoring datasets were reviewed for each of the four monitored sites to determine how the data would be included in the results and discussion section of the project summary report. For Cape Fair Resort and Shell Knob Restaurant S., the plastic sheet lysimeter datasets were considered most representative of subsurface water quality. At Cape Fair Resort, the plastic sheet lysimeter produced sufficient samples for analysis of all parameters for five discrete samples, as compared to two with the half-pipe lysimeter. At Shell Knob Restaurant S., the half-pipe lysimeter samples potentially included potable water due to a water line break that occurred near the site. Until further site investigations are conducted, the plastic sheet lysimeter dataset will be used exclusively for the Shell Knob Restaurant S. dispersal field. The two samples collected from the Kimberling City dispersal field piezometers were not included in the discussion of results due to the small size of the dataset and high concentrations of total suspended solids in the samples (Appendix II).

Task 5 – Monitoring Results and Discussion

Objectives:

This section provides monitoring results for the four onsite systems selected for detailed evaluation. These monitored systems included the Cape Fair Resort site, the Lampe Resort, Kimberling City Residence and Shell Knob Restaurant S. site. A comparison of the four systems, a post-monitoring period soils evaluation and a discussion of important findings is also included.

Methods:

Cape Fair Resort Monitoring Results

1. **Operating Conditions**

The Cape Fair Resort treatment system consisted of a septic tank, a BioMicrobics FAST® unit and drip dispersal into imported soil. This system operated with no significant operational or mechanical disruptions during the evaluation period other than intermittent pump tank filter plugging which was easily corrected.

2. **Treatment System Loading Rates**

Loading rates at the Cape Fair Resort were proportional to room occupancy which was greatest during the summer months and tapered to minimal occupancy during the off-season. Estimated hydraulic loading rates during the off-season were typically at or below 500 gallons per day (gpd) (Figure 5.1). Flows increased during the busy summer season with estimated hydraulic loading rates for June and July 2007 of 1,400 and 1,100 gpd, respectively. All system loading rates were below the system design loading rate of 1,920 gpd. Drip field estimated loading rates were also below the design maximum hydraulic loading rate (0.2 gpd/ft^2) with a peak hydraulic rate of 0.15 gpd/ft^2 in June 2007 (Figure 5.2).

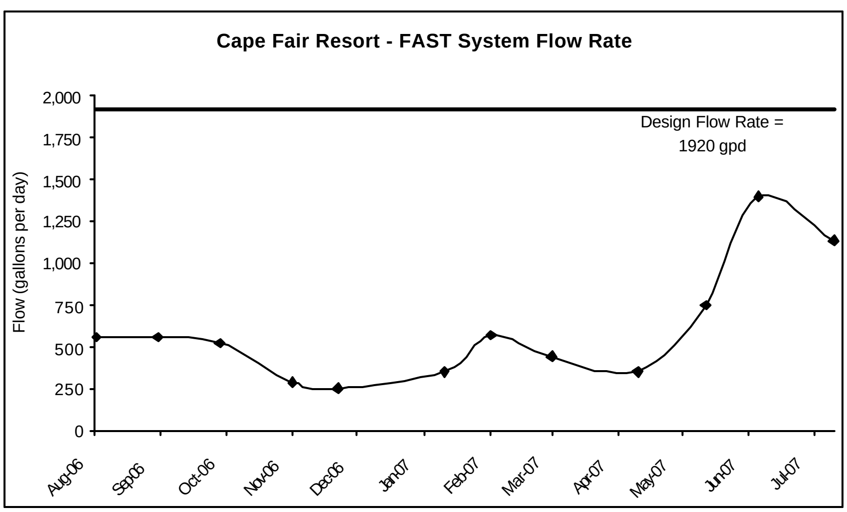


Figure 5.1: Cape Fair Resort FAST system flow rate

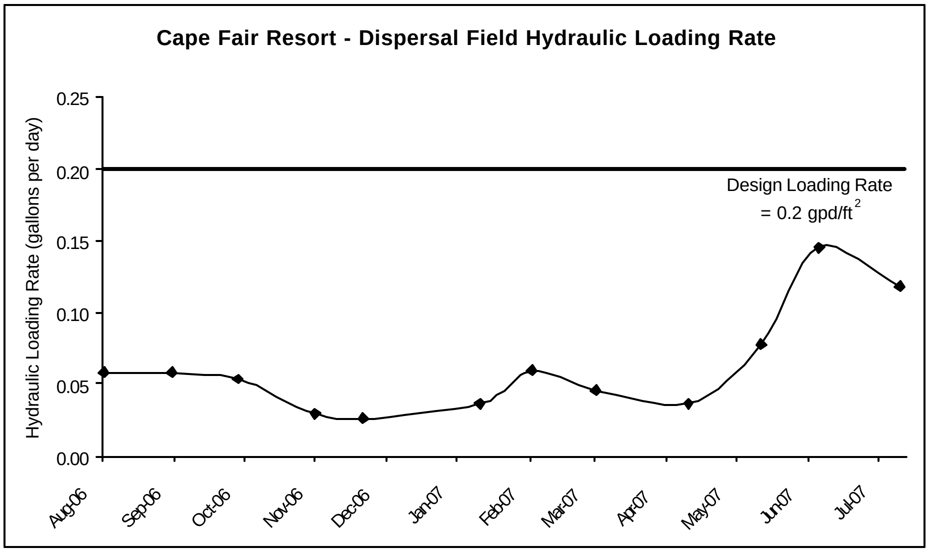


Figure 5.2: Cape Fair Resort dispersal field hydraulic loading rate

Septic tank effluent BOD_5 and TSS concentrations were low (near or below 50 mg/L) during the off-season months (Figure 5.3). BOD_5 increased markedly during the busier summer season with concentrations ranging between 123 mg/L and 335 mg/L. TSS concentrations remained below 100 mg/L during the summer season which indicated good settling conditions in the septic tank system.

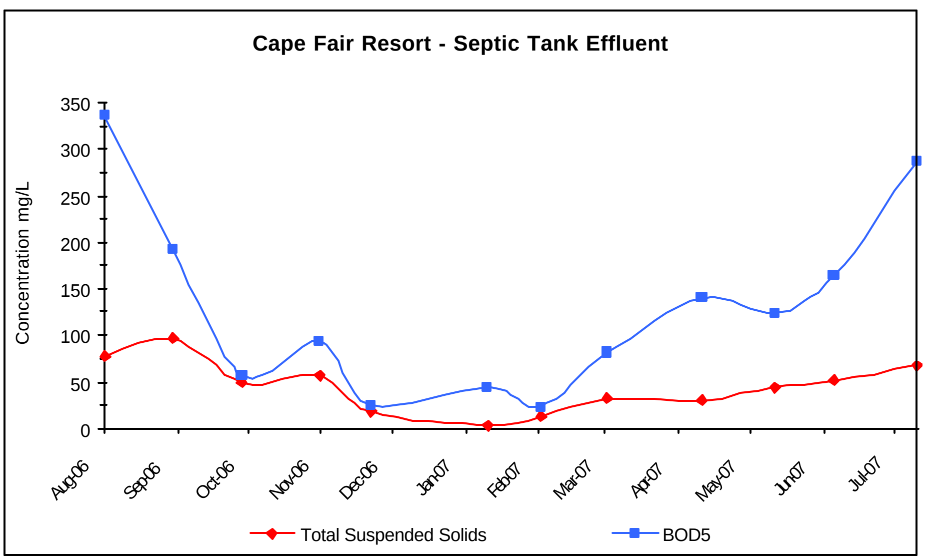


Figure 5.3: Cape Fair Resort – TSS and BOD5 in septic tank effluent

3. Effluent Quality

a. BOD_5, TSS and Ammonia

Effluent quality from the FAST system correlated with hydraulic loading rates. The lowest BOD_5 and TSS concentrations occurred during the off-season low-flow period and increased as flow increased during the summer months (Figures 5.4). Ammonia concentrations were below 1 mg/L during the fall and winter months (October through February) and greater than 5.0 mg/L during the busier warm-season months.[1] Percent removal of septic tank effluent BOD_5 and TSS decreased during the summer months (Figure 5.5). Dissolved oxygen concentrations in the FAST system effluent also decreased during the summer months which indicated that the biological treatment was being limited by aeration (Figure 5.6). This observation was supported by the low summer nitrate concentrations (Figure 5.7) which indicated insufficient dissolved oxygen for nitrification during the summer months.

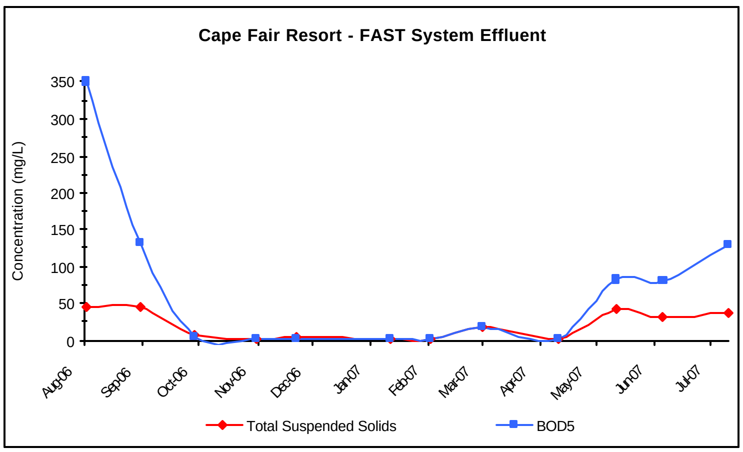


Figure 5.4: Cape Fair Resort – TSS and BOD5 in FAST system effluent

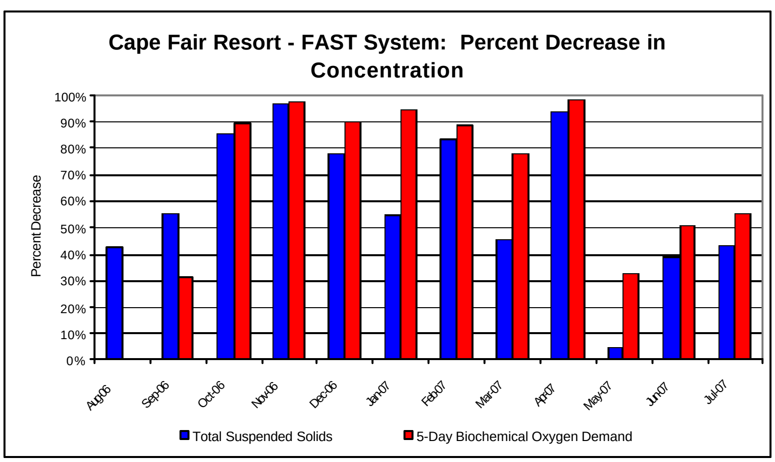


Figure 5.5: Cape Fair Resort – decrease in percent TSS and BOD5 concentrations

[1] The procedure for analyzing ammonia nitrogen had a maximum detection limit of 5.0 mg/L. Ammonia measurements above 5.0 mg/L are reported as “greater than 5.0 mg/L”.

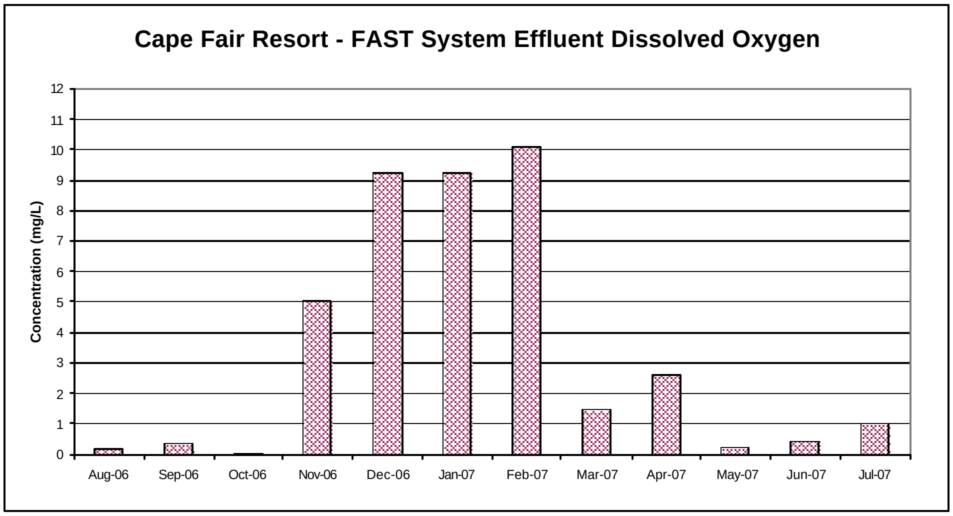


Figure 5.6: Cape Fair Resort – dissolved oxygen concentrations in FAST system effluent

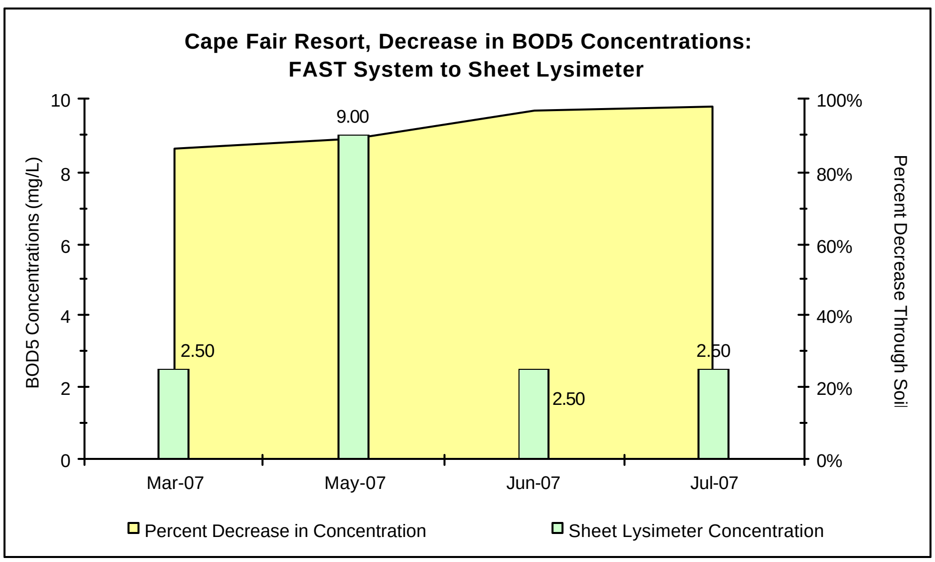


Figure 5.7: Cape Fair Resort – decrease in BOD5 concentrations from FAST system to plastic sheet lysimeter

BOD_5 and ammonia concentrations in the plastic sheet lysimeter subsurface samples were near or below minimum detection limits which indicated consistent and thorough (80 to 100%) decreases in concentrations of these constituents as the treated effluent migrates through the soil column (Figures 5.7 and 5.8).

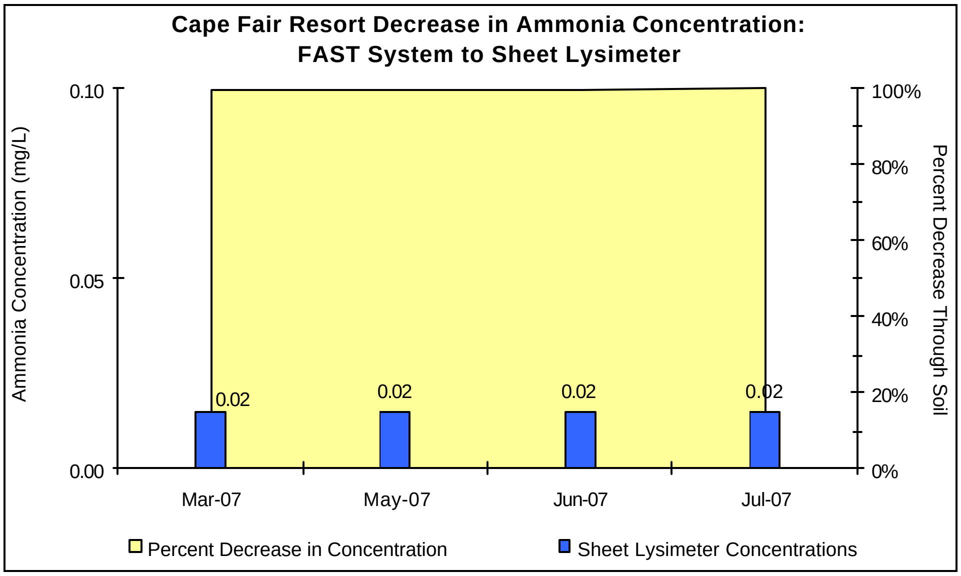


Figure 5.8: **Cape Fair Resort – decrease in ammonia concentrations from FAST system to plastic sheet lysimeter**

b. Phosphorus

Onsite biological treatment systems are not designed to significantly remove phosphorus. As expected, there was little if any reduction in phosphorus observed through the FAST system (Figure 5.9). However, the subsurface samples indicated appreciable reductions in phosphorus concentrations through the soil (Figure 5.10). Plastic sheet lysimeter samples ranged from 0.08 mg/L to 0.7 mg/L total phosphorus, with most sample concentrations being less than the 0.5 mg/L total phosphorus effluent limitation for domestic treatment plants discharging into the Table Rock Lake watershed [2]. Phosphorus concentration reductions in the lysimeter samples were consistently greater than 80% (Figure 5.11).

c. Fecal coliform

The Cape Fair FAST system is not equipped to disinfect wastewater. Fecal coliform concentrations through the FAST system were reduced appreciably during the low-flow off-season months, but only marginal reduction was observed during the active summer months (Figure 5.11). As with all previous parameters, fecal coliform concentrations were consistently reduced in subsurface samples, ranging from less than detection limits to 1,530 colonies per 100 mLs (Figure 5.12). For comparison, these concentrations were less than the Missouri secondary whole body contact criterion of 1,800 colonies per 100 mLs, with three measurements less than the primary whole body contact criterion of 200 colonies per 100 mLs.

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[2] Table Rock Lake watershed phosphorus effluent limitations are found in Missouri Code of State Regulations 10 CSR 20-7.015 (3)(g). These regulations do not apply to onsite systems with subsurface effluent dispersal but are referenced as a comparison.

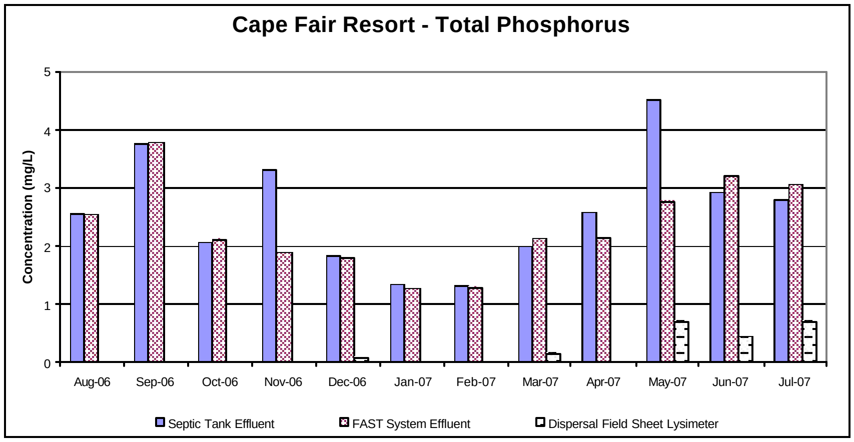


Figure 5.9: Cape Fair Resort - monthly total phosphorus in septic tank, FAST effluent and plastic sheet lysimeter

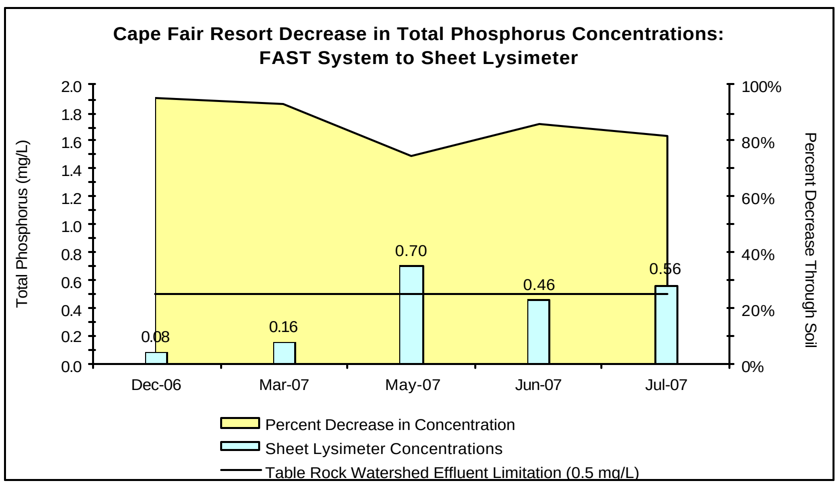


Figure 5.10: Cape Fair Resort – decrease in total phosphorus from FAST to lysimeter

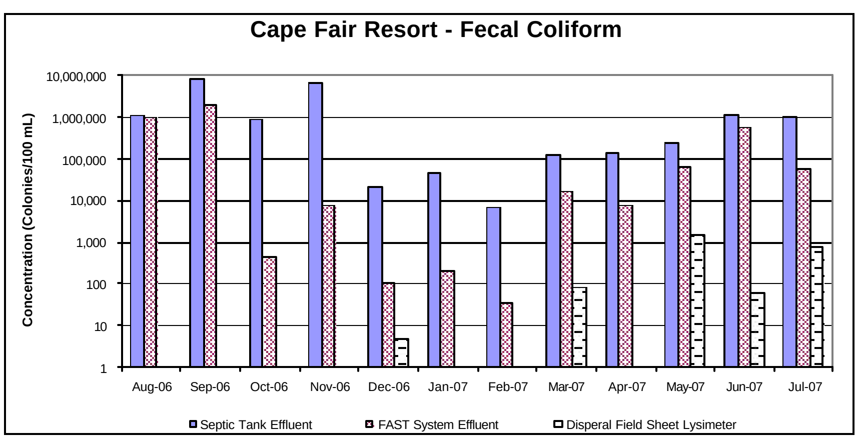


Figure 5.11: Cape Fair Resort – fecal Coliform in septic tank, FAST and lysimeter

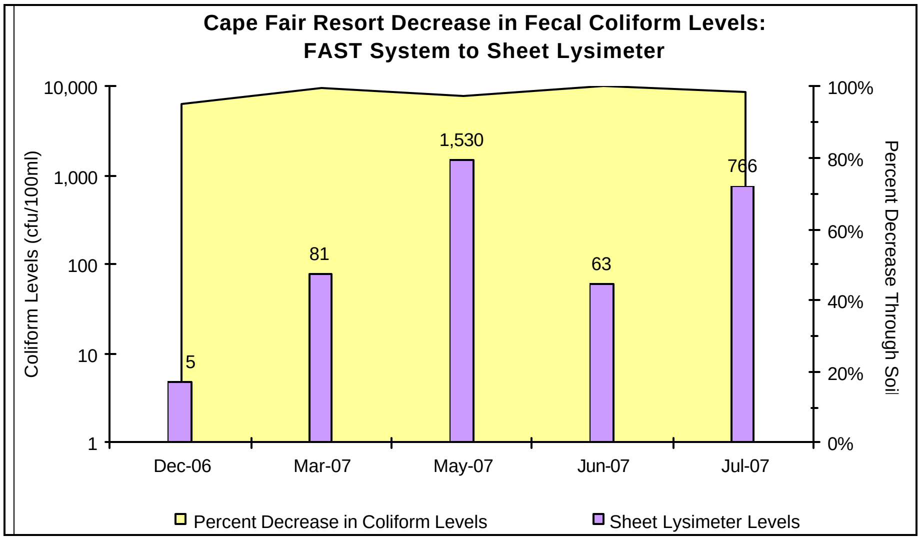


Figure 5.12: Cape Fair Resort – decrease in fecal Coliform from FAST to lysimeter

<u>Lampe Resort Monitoring Results</u>

1. Operating Conditions

The Lampe Resort treatment system consists of two septic tanks, followed by three Zabel SCAT units operated in parallel, and drip dispersal into imported soil. Septic tank filter plugging problems occurred in the first several months. Drip pump filter plugging also occurred intermittently in the summers of 2006 and 2007.

2. Treatment System Loading Rates

As with the Cape Fair Resort, Lampe Resort loading rates were proportional to room occupancy which is greatest during the summer months and tapers to minimal occupancy during the off-season. Lampe Resort hydraulic loading rates during the 22-month monitoring period were typically at or less than 200 gallons per day (gpd) during the off-season (Figure 5.13). Flow rates increased steadily during the active summer season with a peak flow of 1,400 gpd in 2006 and 1,200 gpd in 2007. All treatment system loading rates were below the design loading rate of 1,560 gpd. Drip field loading rates were also below the design maximum hydraulic loading rate (0.1 gpd/ft^2) with a peak hydraulic rate of 0.9 gpd/ft^2 in July 2006 (Figure 5.14). Off-season loading rates were typically less than 0.02 gpd/ft^2.

In the first half of the study, septic effluent BOD_5 concentrations fluctuated widely, typically in the range from 20 to 300 mg/L. From July 2006, septic tank effluent BOD_5 concentrations generally remained below 50 mg/L (Figure 5.15). TSS concentrations were most often less than 50 mg/L in septic tank effluent samples, which indicated favorable settling conditions.

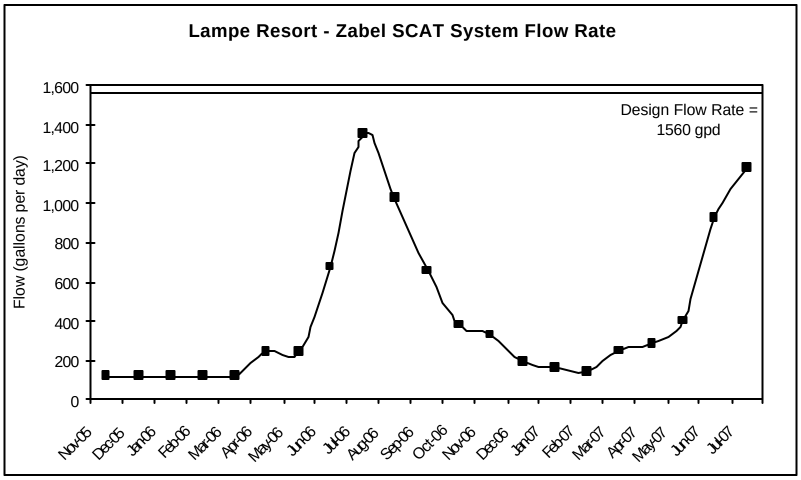


Figure 5.13: Lampe Resort – Zabel SCAT system flow rate

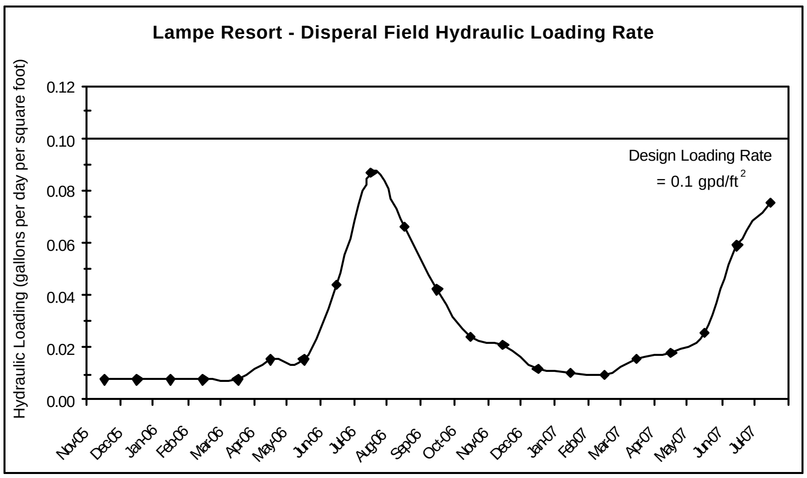


Figure 5.14: Lampe Resort – dispersal field hydraulic loading rate

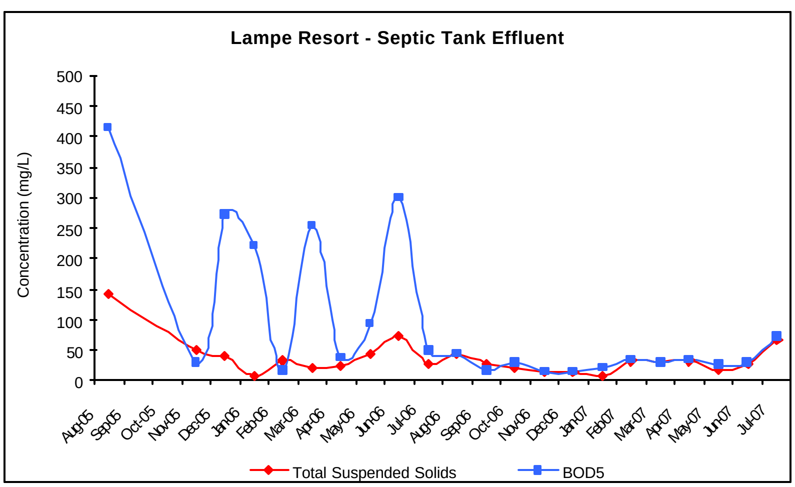


Figure 5.15: Lampe Resort – TSS and BOD5 in septic tank effluent

3. Effluent Quality

a. BOD_5, TSS and Ammonia

SCAT effluent BOD_5 concentrations correlated with septic effluent measurements, with wide fluctuations in the first half of the study and more stable, lower concentrations in the second half. BOD_5 measurements in the first half of the study fluctuated between concentrations of less than 10 mg/L BOD_5 to peak concentrations just below 100 mg/L (Figure 5.16). In the second half of the study, BOD_5 concentrations generally remained at or below 30 mg/L. TSS concentrations were typically below 20 mg/L, indicating the system achieved consistent and thorough suspended solids removal.

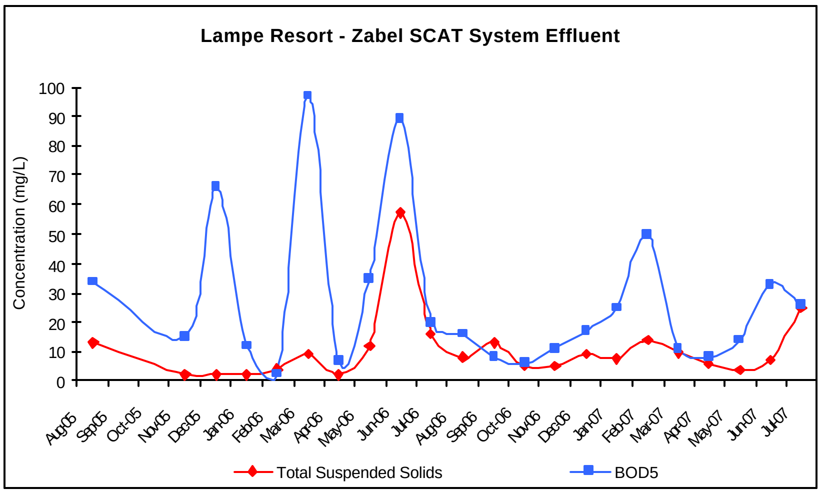


Figure 5.16: Lampe Resort – TSS and BOD5 in Zabel SCAT system effluent

SCAT effluent ammonia concentrations were generally greater than 5.0 mg/L throughout the study with consistently high nitrate concentrations typically ranging from 10 to 25 mg/L. Decrease in TSS concentrations from septic effluent to Zabel SCAT system effluent ranged from 20% to 95% with an average decrease of approximately 60%. The decrease in BOD5 form the SCAT filter was also high with and average of over 55% (Figure 5.17).

Low septic tank effluent BOD_5 and the favorable recirculation rates created sufficiently high dissolved oxygen concentrations to enable nitrification. Dissolved oxygen concentrations in the SCAT effluent were generally above 2 mg/L (Figure 5.18).

Even though there was a minimal soil depth between the drip tubing and the half-pipe lysimeter, the BOD_5 in subsurface samples collected in the half-pipe lysimeter were generally lower than the Zabel SCAT effluent (Figures 5. 19) Ammonia concentrations were generally below 1.0 mg/L (Figure 5.20).

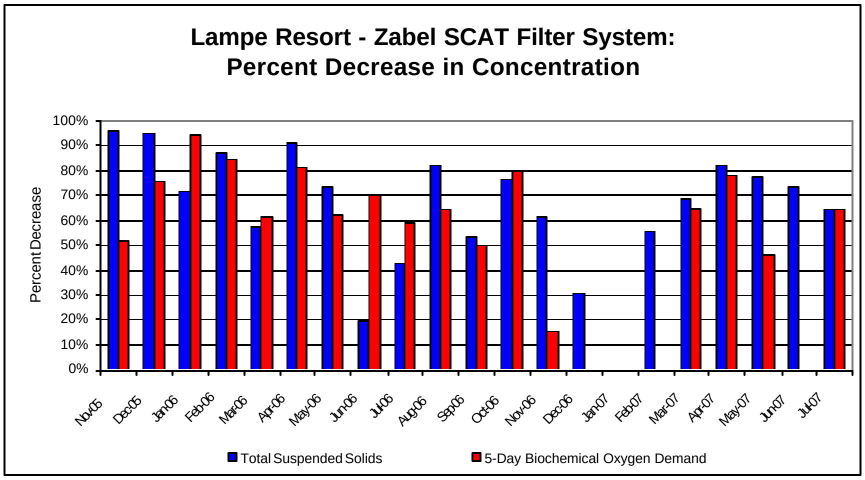


Figure 5.17: Lampe Resort – percent decrease in TSS and BOD5 in Zabel SCAT effluent

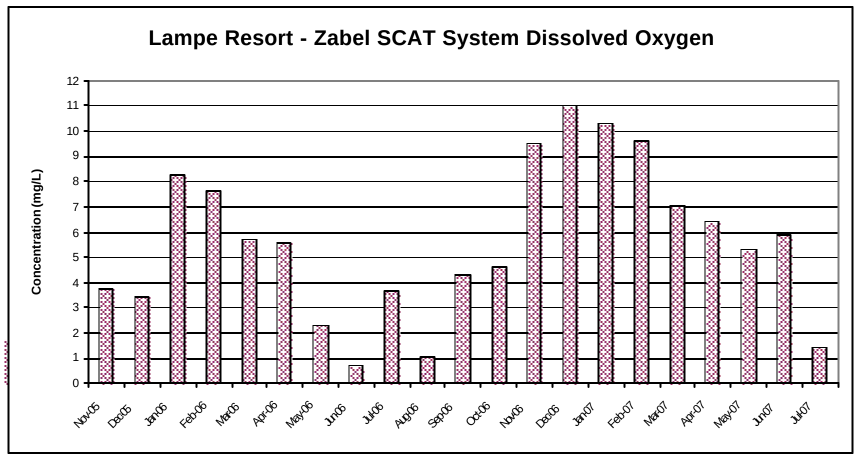


Figure 5.18: Lampe Resort – dissolved oxygen in Zabel SCAT effluent

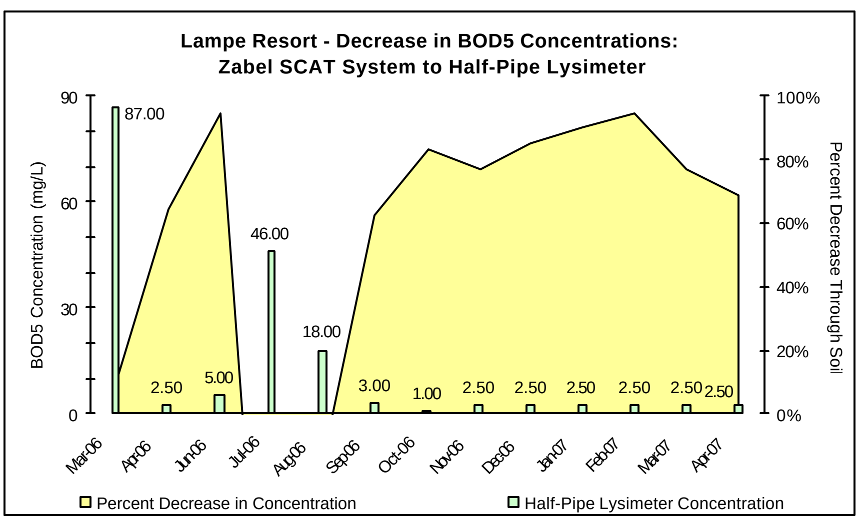


Figure 5.19: Lampe Resort – decrease in BOD5 from Zabel SCAT to lysimeter

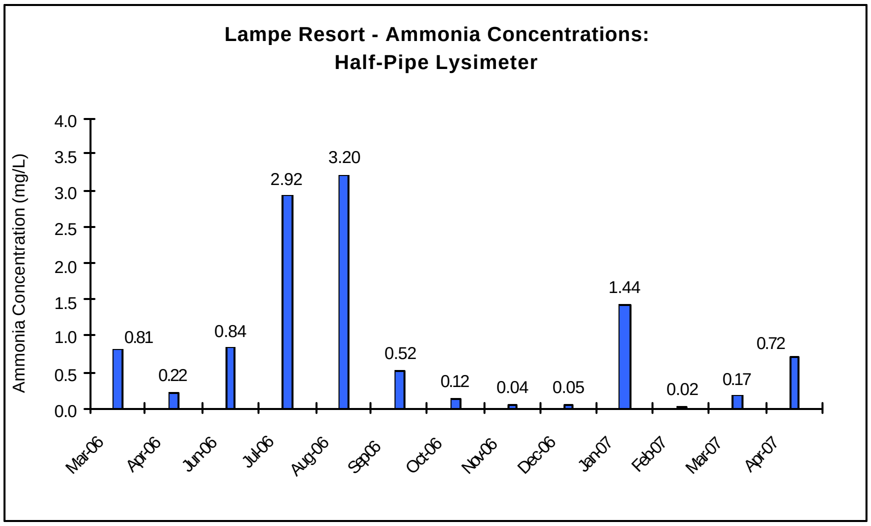


Figure 5.20: Lampe Resort – ammonia concentrations in lysimeter effluent

b. Phosphorus

There was little if any reduction in phosphorus observed through the SCAT system at the Lampe Resort (Figure 5.21). However, the subsurface samples indicated appreciable reductions in phosphorus concentrations through the soil as the effluent made its way from the Zabel unit to the half-pipe lysimeter (Figure 5.22) even though the soil layer between the drip tubing and half-pipe lysimeter was minimal. Lysimeter sample total phosphorus, concentrations were generally below 1.5 mg/L representing phosphorus concentration reductions consistently over 40% (Figure 5.22).

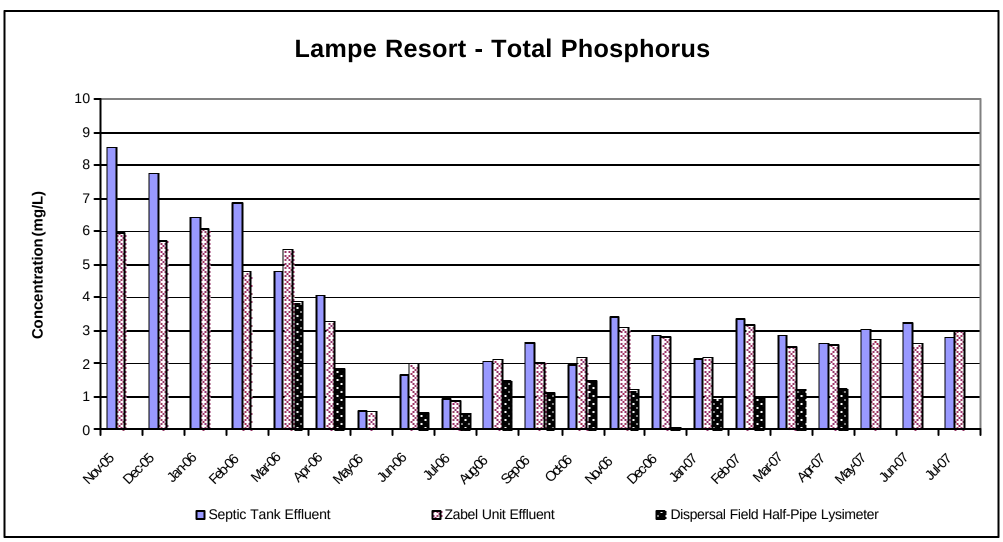


Figure 5.21: Lampe Resort – total phosphorus in septic, Zabel SCAT and lysimeter effluent

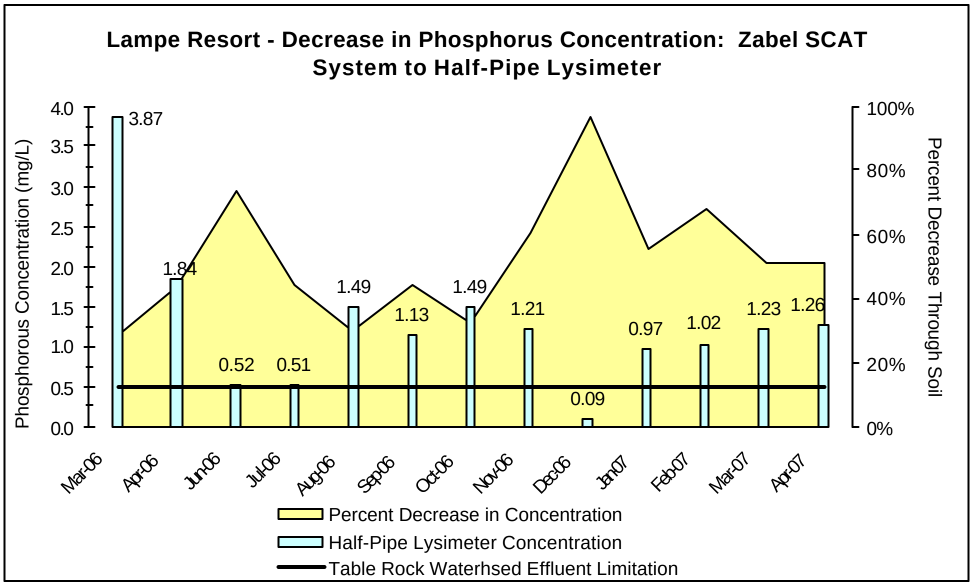


Figure 5.22: Lampe Resort – decrease in total phosphorus from Zabel SCAT to lysimeter

c. Fecal Coliform

Fecal coliform densities were reduced marginally by the SCAT system, with effluent concentrations generally above 10,000 colonies/100 mLs (Figure 5.23). Subsurface fecal coliform densities were generally at or less than 1,000 colonies/100 mLs with concentrations below 100 colonies/100 mLs in winter months. Concentration reductions approached 100% for most of the study, despite the thin soil layer between the drip tubing and the lysimeter (Figure 5.24).

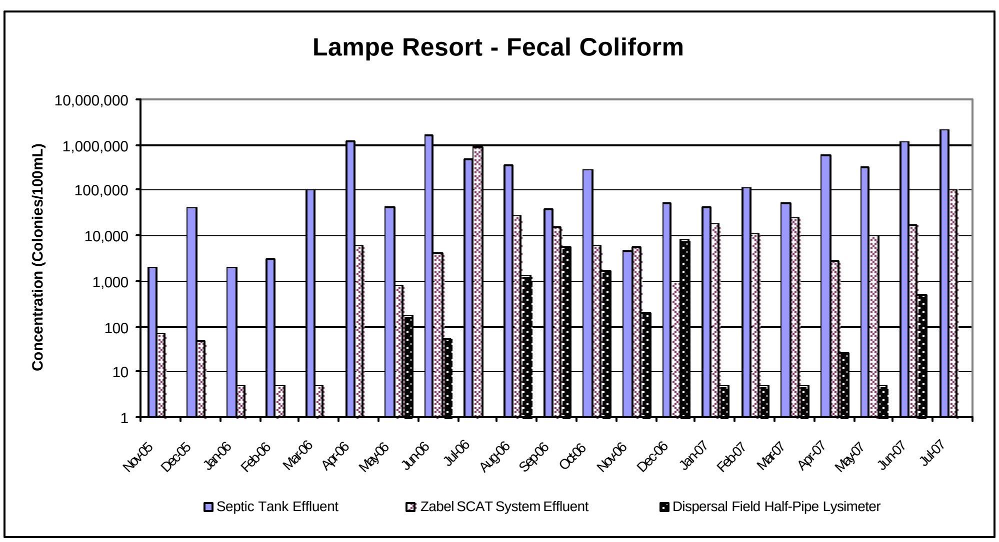


Figure 5.23: Lampe Resort – fecal Coliform in septic, Zabel SCAT and lysimeter effluent

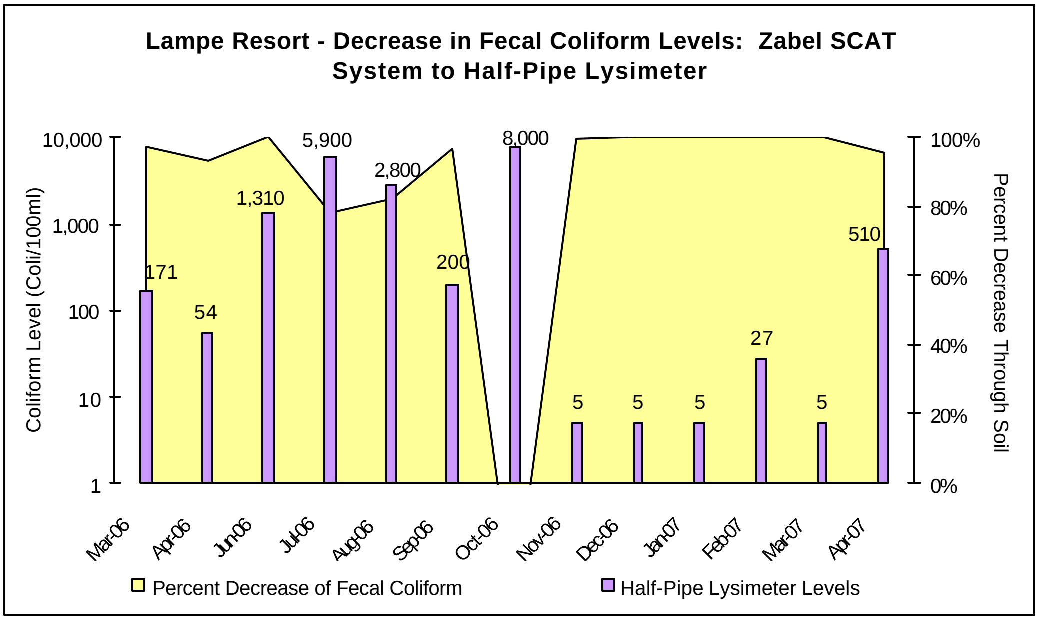


Figure 5.24: Lampe Resort – decrease in fecal Coliform levels from Zabel SCAT samples to half-pipe lysimeter samples

Shell Knob Restaurant S. Monitoring Results

1. Operating Conditions

The Shell Knob Restaurant S. treatment system consists of a series of three septic tanks, a FAST biological treatment unit and drip dispersal. After system startup, foaming problems were encountered in the FAST unit vent pipe but quickly remedied. The new owners of the restaurant opted to discontinue blower operation for the remainder of the study period which lowered effluent quality.

2. Treatment System Loading Rate

The peak hydraulic loading rate of 1,100 gpd occurred in April 2006 (Figure 5.25). Restaurant ownership changed in May 2006 and hours of operation were reduced as were treatment plant loading rates. Business activity increased in the spring and summer of 2007 as reflected by increasing hydraulic loading rates which approached 800 gallons per day in July 2007. All hydraulic loading rates were below the treatment system design flow of 1,500 gpd. Drip dispersal hydraulic rates ranged from 0.02 to 0.17 gpd/ft^2 and were below the 0.2 gpd/ft^2 design hydraulic loading rate (Figure 5.26).

Septic tank effluent BOD_5 were highest in the first half of 2006 (500 to 1,100 mg/L) and decreased as restaurant activity decreased through the remainder of 2006 to less than 300 mg/L (Figure 5.27). BOD_5 concentrations rose just above 300 mg/L in the spring of 2007. Septic tank effluent TSS were consistently less than 200 mg/L indicating favorable settling conditions in the septic tank system.

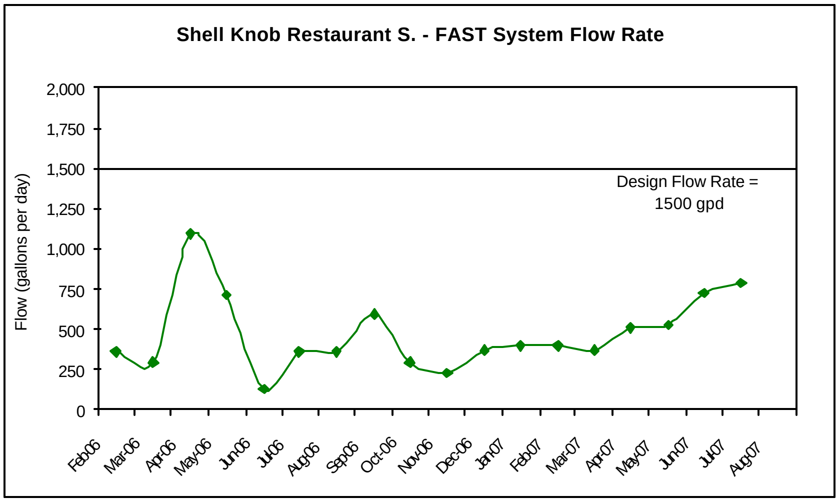


Figure 5.25: Shell Knob Restaurant S. – FAST system flow rate

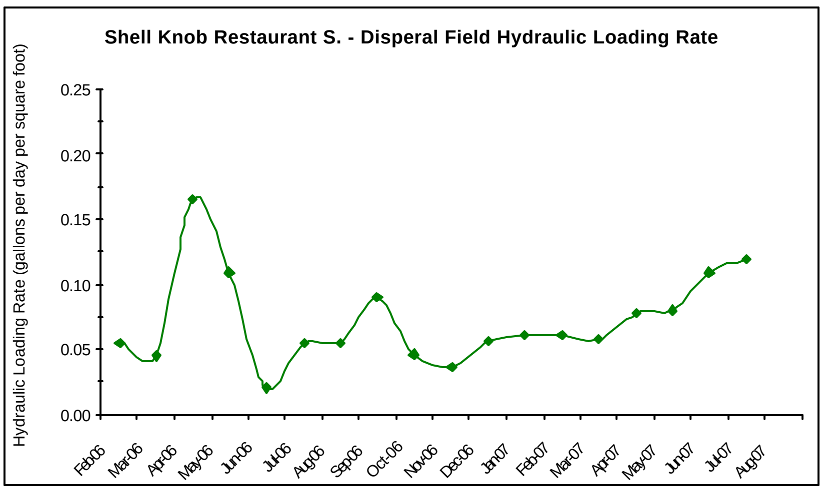


Figure 5.26: Shell Knob Restaurant S. – dispersal field hydraulic loading rate

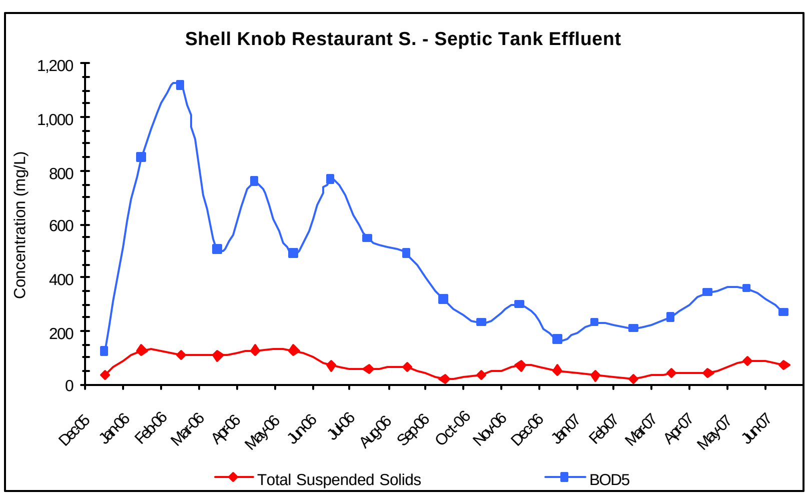


Figure 5.27: Shell Knob Restaurant S. – TSS and BOD5 in septic tank effluent

3. Effluent Quality

a. BOD5, TSS and Ammonia

FAST system BOD_5 concentrations (Figure 5.28) were generally less than 100 mg/L with only one measurement greater than 150 mg/L (350 mg/L in June 2006). TSS concentrations were generally less than 50 mg/L. BOD_5 percent concentration reductions through the FAST system were typically between 70 and 95% which indicated the system was capable of assimilating most of the restaurant organic load (Figure 5.29). TSS percent removals were not as great due to the low septic tank effluent TSS concentrations, which were already close to typical biological treatment system effluent concentrations before FAST treatment.

FAST effluent ammonia concentrations were generally above 5.0 mg/L throughout the study. Nitrate concentrations were near zero indicating little if any nitrification. This was expected due to the low aeration unit dissolved oxygen concentrations (Figure 5.30). Dissolved oxygen concentrations were typically less than 1 mg/L due in part to the FAST blower being inoperable in accordance with the facility owner's discretion.

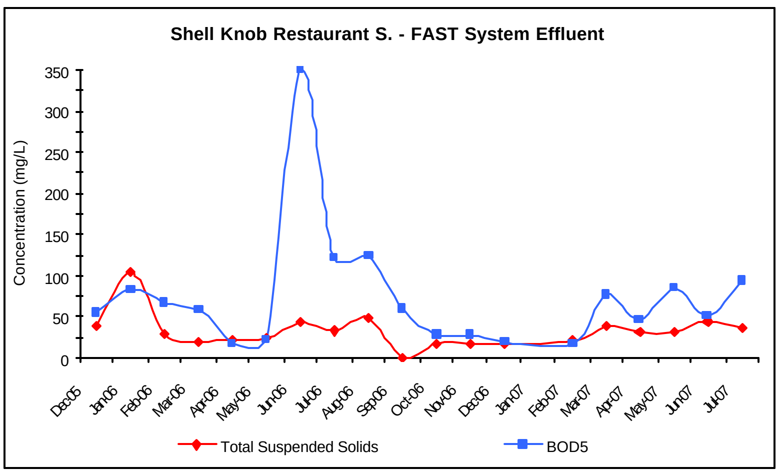


Figure 5.28: Shell Knob Restaurant S. – TSS and BOD5 in FAST system effluent

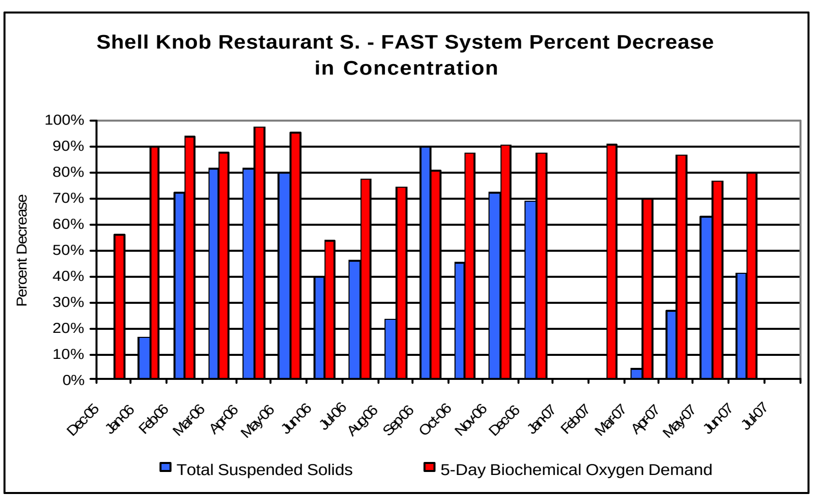


Figure 5.29: Shell Knob Restaurant S. – decrease in TSS and BOD5 from FAST system

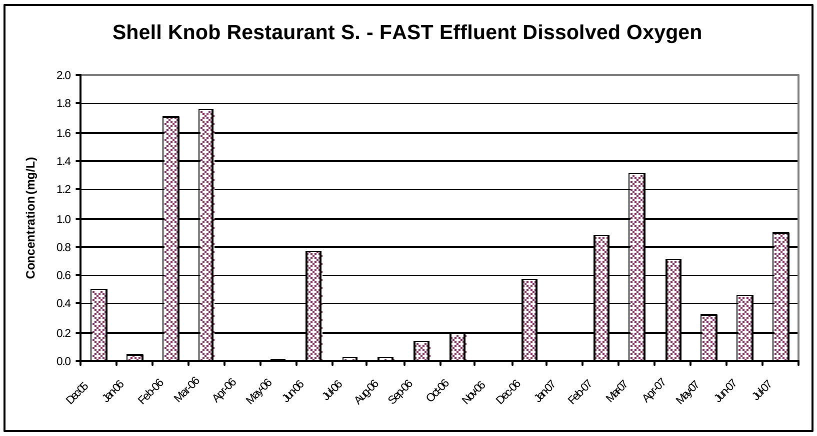


Figure 5.30: Shell Knob Restaurant S. – dissolved oxygen in FAST effluent

BOD_5 concentrations in the plastic sheet lysimeter subsurface samples were consistently lower than pump tank effluent samples (Figures 5.31). BOD_5 concentrations were generally below 20 mg/L with concentration reductions consistently greater than 80%. Winter and spring ammonia concentrations were typically below 1 mg/L but summer and fall concentrations increased to between 3 and greater 5.0 mg/L (Figure 5.32). Concentration reductions of above 80% during the winter and spring months decreased to less than 20% in the summer months.

b. Phosphorus

Total phosphorus reduction was consistent, but marginal with concentration reductions varying between 0.5 to 2.0 mg/L lower in FAST effluent compared to septic tank effluent (Figure 5.33). Subsurface lysimeter concentrations were generally less than FAST effluent samples, but to varying extents. Total phosphorus concentration reductions were greatest in January through June 2006 with reductions greater than 60 percent compared to FAST effluent concentrations (Figure 5.34). Subsurface phosphorus concentrations were typically between 1 and 2 mg/L for the remainder of the study with measurements increasing up to 2.4 mg/L in July 2007. Percent phosphorus concentration reduction also lessened during this period.

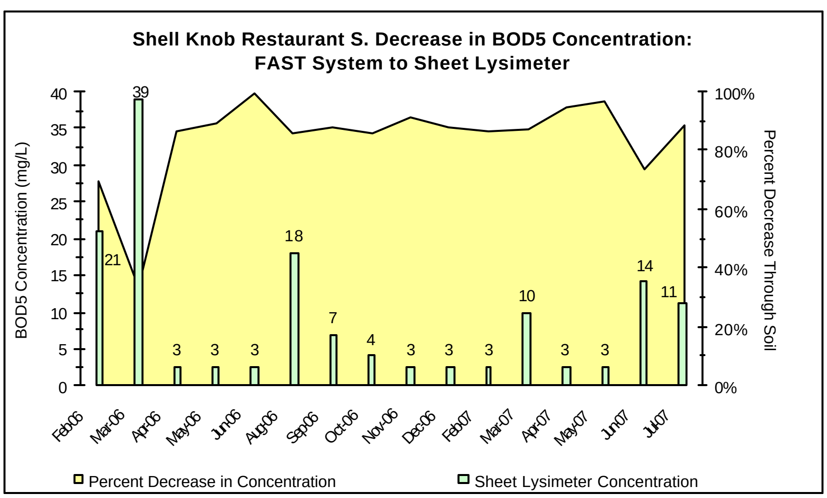
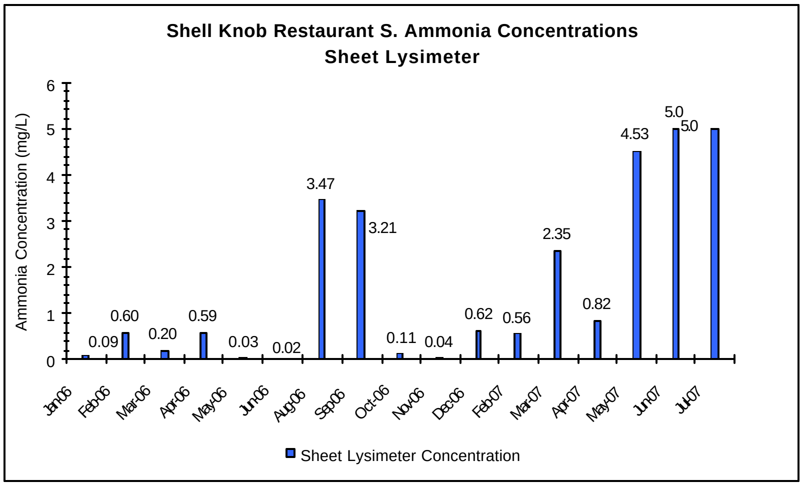


Figure 5.31: Shell Knob Restaurant S. – decrease in BOD5 from FAST to lysimeter samples



* June and July 2007 concentrations are denoted as "greater than 5.0 mg/L").

Figure 5.32: Shell Knob Restaurant S. – ammonia concentrations in lysimeter samples

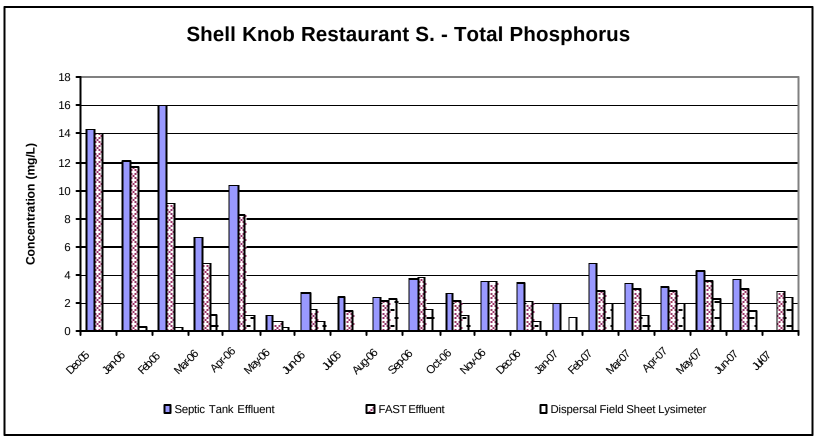


Figure 5.33: Shell Knob Restaurant S. – total phosphorus from septic tank, FAST and lysimeter samples

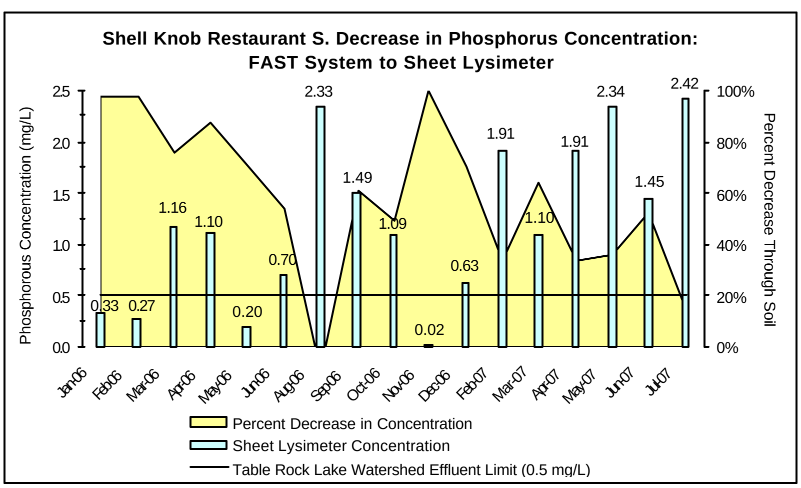


Figure 5.34: Shell Knob Restaurant S. – decrease in total phosphorus - FAST to lysimeter samples

c. Fecal coliform

As with total phosphorus, fecal coliform reductions through the FAST system were consistent but marginal, with typically less than one log reduction observed (Figure 5.35). Subsurface concentrations were also lower, but to varying extents (Figure 5.36). Greater than two log reductions were observed for several events.

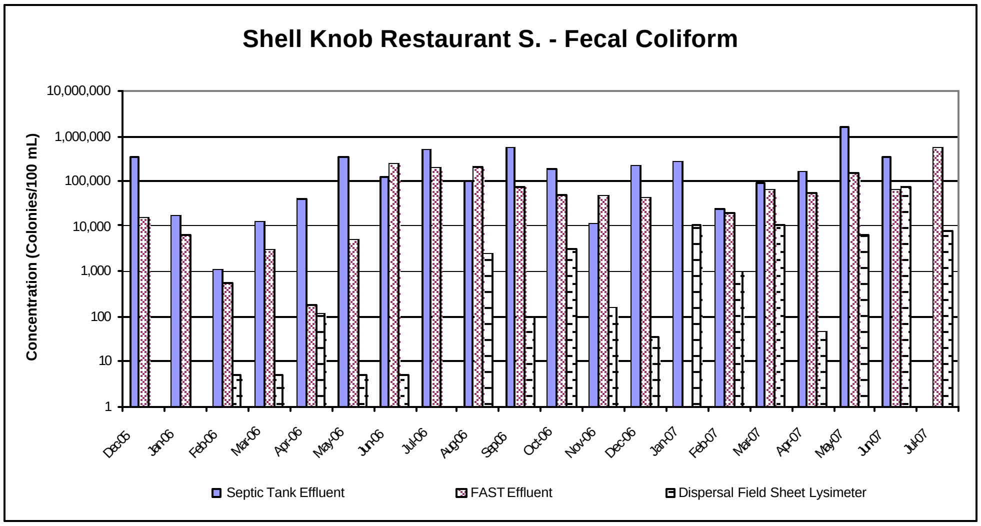


Figure 5.35: Shell Knob Restaurant S. – fecal Coliform concentrations in septic, FAST and lysimeter samples

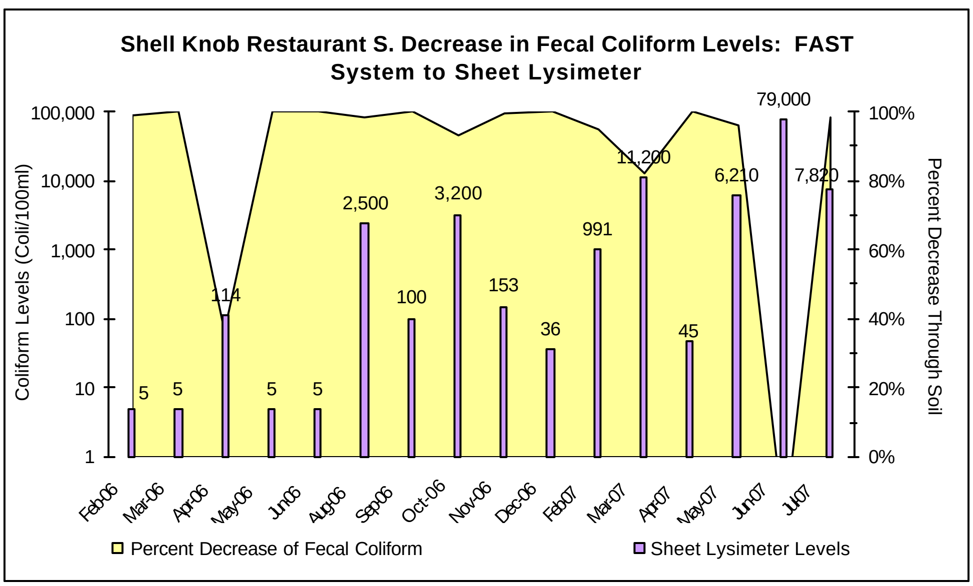


Figure 5.36: Shell Knob Restaurant S. – decrease in fecal Coliform through soil

Kimberling City Residence Monitoring Results

1. Operating Conditions and Hydraulic Loading Rates

The Kimberling City Residence RetroFAST system (Figure 5.37) operated dependably through the study with no known blower malfunctions. Hydraulic loading was estimated based on days of occupancy per month for a one bedroom home with the two adult residents.

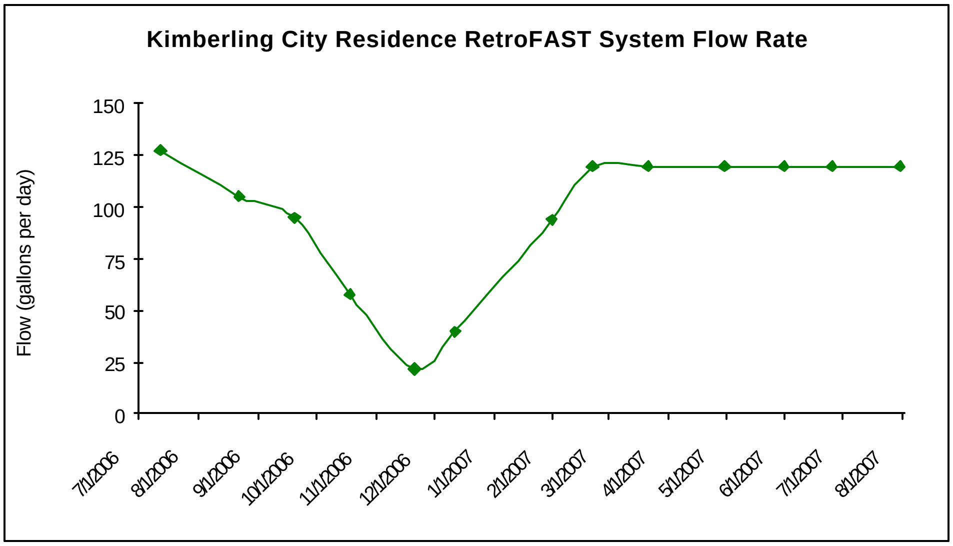


Figure 5.37: Kimberling City Residence – RetroFAST system flow rate

2. Effluent Quality

The Kimberling City Residence RetroFAST system modification consisted of inserting tube bundles and aeration diffusers into the outlet cell of the existing septic tank. The septic tank effluent is aerobically treated in contrast to the previous three onsite systems which have separate biological treatment units. Therefore, the Kimberling City Residence site had only one system sampling point, which was the RetroFAST system effluent collected from the septic tank discharge piping.

RetroFAST effluent BOD_5 concentrations ranged between 50 and 225 mg/L during the first half of 2006, but stabilized to concentrations consistently below 30 mg/L for the remainder of the study (Figure 5.38). TSS concentrations also stabilized beginning in mid-2006 and indicated good settling conditions in the RetroFAST settling zone.

Ammonia concentrations were typically less than 1.0 mg/L which demonstrated consistent nitrification (Figure 5.39). Nitrate concentrations, which typically exceeded 10 mg/L, confirmed the high level of nitrification occurring in the system (Figure 5.39). Dissolved oxygen concentrations, generally above 2 mg/L (Figure 5.40), were sufficient to activate nitrifying bacteria.

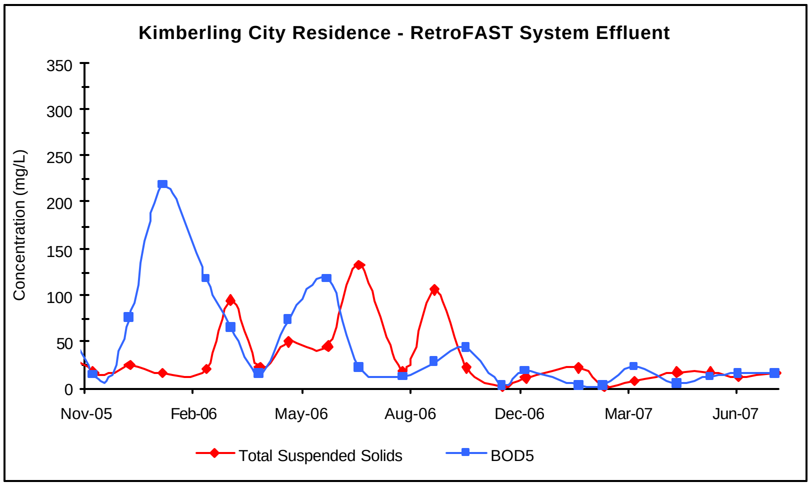


Figure 5.38: Kimberling City Residence – TSS and BOD5 in RetroFAST system effluent

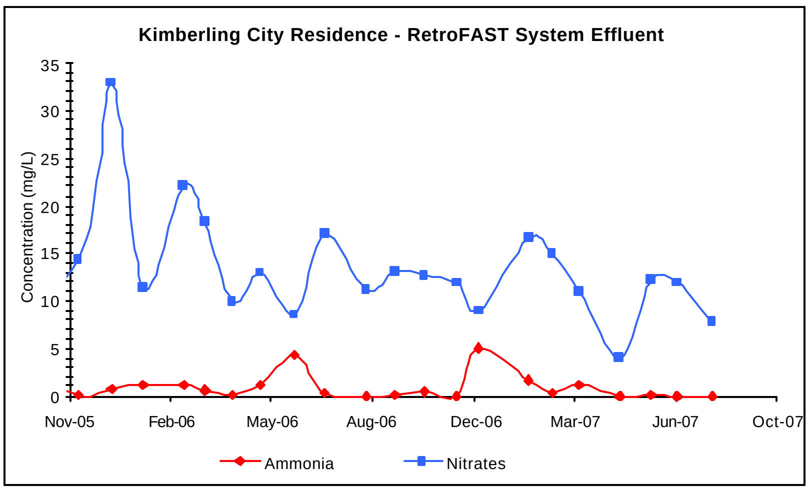


Figure 5.39: Kimberling City Residence – ammonia and nitrates in RetroFAST system effluent

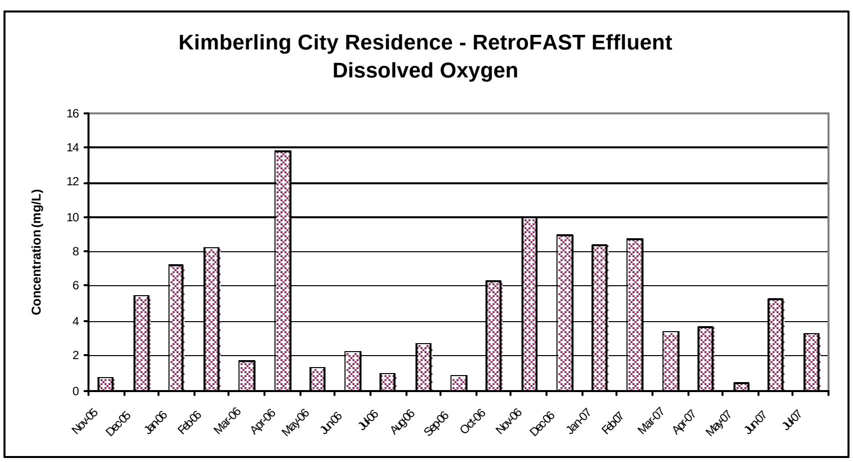


Figure 5.40: Kimberling City Residence – dissolved oxygen in RetroFAST system effluent

3. Drain field Rehabilitation Measurements

The Kimberling City Residence onsite treatment system was an existing system originally installed when the home was built. The system consisted of a septic tank followed by Infiltrator® chamber gravity subsurface dispersal laterals. TRLWQ staff conducted an initial assessment of the system and observed 8 inches of standing water in the drainfield. The standing water indicated a flow restriction potentially due to biomass buildup in the drainfield. The system was selected to demonstrate if the suspected biomass restriction could be reduced with the addition of an aerobic process to treat septic tank effluent before being discharged to the gravity dispersal field. This approach has been identified as a potential method to rehabilitate drainfields.[3]

The Bio-Microbics RetroFAST® unit was installed in the existing concrete watertight septic tank. Beginning in November 2005, monitoring staff measured water levels in a vertical PVC pipe inserted through the soil into a dispersal pipe chamber. Standing water depths of up to 0.9 inches were measured in the spring of 2006 during a period of heavy rainfall (Figure 5.41). No standing water was detected in subsequent measurements which included periods of comparable rainfall. These data indicated favorable flow distribution in the lateral field compared to initial conditions. The improvement may have been attributed to reduced biomass buildup in the drainfield following the RetroFAST unit installation. The RetroFAST unit's high-quality, aerobic effluent was favorable for minimal biomass production in the drainfield.

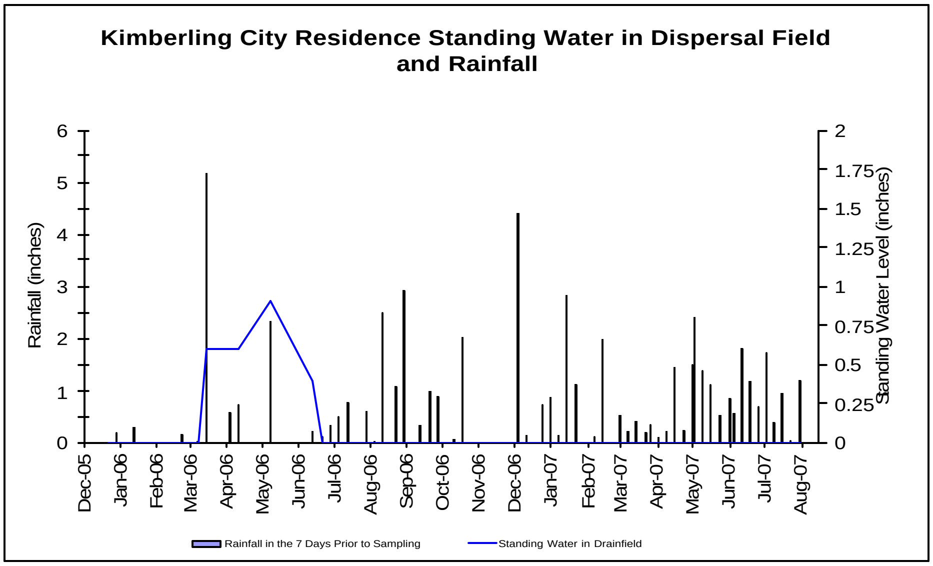
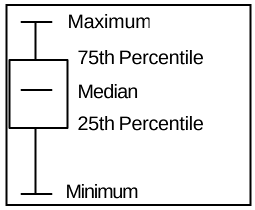


Figure 5.41: Kimberling City Residence – rainfall and standing water in dispersal field

[3] Noah, M., "Investigating Drainfield Rehabilitation", *Water & Wastes Digest* April 2006 Volume: 46 Number: 4.

Comparison of Water Quality Measurements for the Four Onsite Systems

A comparative analysis of water quality measurements for the four onsite systems was conducted using box plots that provide a graphic representation of the following dataset values:



The median value is the 50th percentile of the dataset. The median value was considered to best reflect the dataset as a whole and therefore was used in the comparative analysis as a single number to represent the dataset.

1. Septic tank effluent water quality concentrations

Ammonia, total phosphorus and fecal coliform median concentrations were similar for all three system septic tank effluent samples (Table 5.1). Septic effluent BOD_5 and TSS concentrations were highest for Shell Knob Restaurant S. and lowest for Lampe Resort. (Figure 5.42).

Table 5.1: Septic effluent, treated effluent and subsurface median concentrations

	Cape Fair Resort	Lampe Resort	Shell Knob Restaurant S.	Kimberling City Residence
BOD5 (mg/L)				
Septic Tank Effluent	108	36	343	----
Treatment System Effluent	12	17	59	19
Subsurface Samples	3	3	4	----
TSS (mg/L)				
Septic Tank Effluent	46	29	64	----
Treatment System Effluent	12	7.8	32	19
Ammonia (mg/L)				
Septic Tank Effluent	>5.0	>5.0	>5.0	----
Treatment System Effluent	4.8	>5.0	>5.0	0.4
Subsurface Samples	0.02	0.62	0.61	----
Phosphorus (mg/L)				
Septic Tank Effluent	2.6	3.0	3.5	----
Treatment System Effluent	2.1	2.8	3.0	2.9
Subsurface Samples	0.5	1.2	1.1	----
Fecal Coliform (colonies/100 mLs)				
Septic Tank Effluent	551,000	103,000	160,000	----
Treatment System Effluent	12,060	8,290	50,000	7,600
Subsurface Samples	81	186	153	----

---- Samples not obtainable

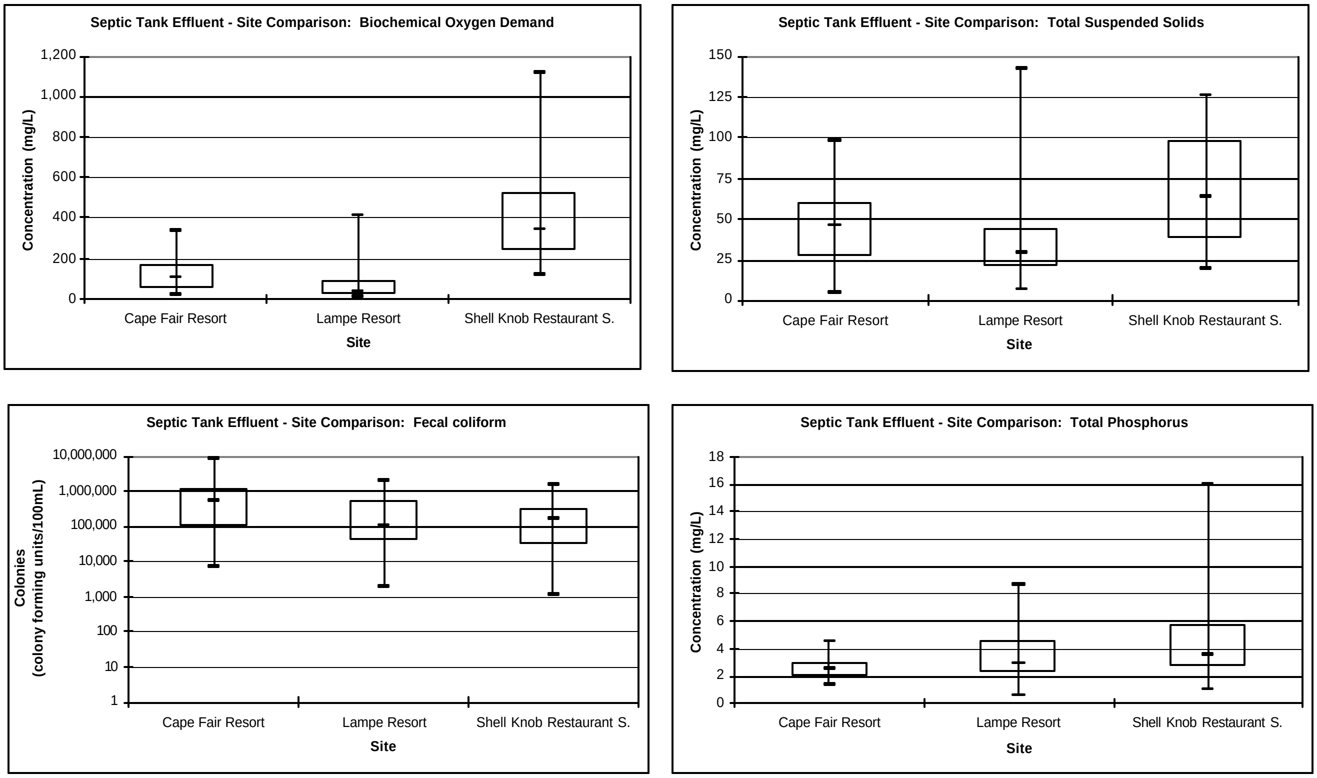


Figure 5.42: Box Plots of septic tank effluent concentrations at each site

2. Biological treatment system effluent water quality concentrations

Biological treatment system effluent BOD_5 and TSS data ranges varied for each site (Figure 5.43). However, median concentrations for Cape Fair Resort, Lampe Resort and Kimberling City Residence were below 20 mg/L, which indicated high levels of organic and solids removal. Median concentrations for BOD_5 and TSS at Shell Knob Restaurant S. were 59 and 32 mg/L, respectively. These higher concentrations were attributed to the higher strength restaurant waste coupled with the intermittently inoperable blower.

Median treatment system effluent ammonia concentration for Cape Fair Resort, Shell Knob Restaurant S. and Lampe Resort was 4.8 mg/L. Shell Knob Restaurant S. and Lampe resort were greater than 5.0 mg/L (Table 5.1). The Kimberling City Residence median concentration of 0.4 mg/L demonstrated the consistent and thorough nitrification in the residential RetroFAST unit.

Total phosphorus concentrations were comparable in all four systems with median concentrations ranging between 2 and 3 mg/L (Table 5.1). Median fecal coliform concentrations in the Cape Fair Resort, Lampe Resort and Kimberling City Residence were similar, ranging from 7,600 to 12,000 colonies/100 mLs. Fecal coliform concentrations were greater in the Shell Knob Restaurant S. treated effluent with a median concentration of 50,000 colonies/100 mLs.

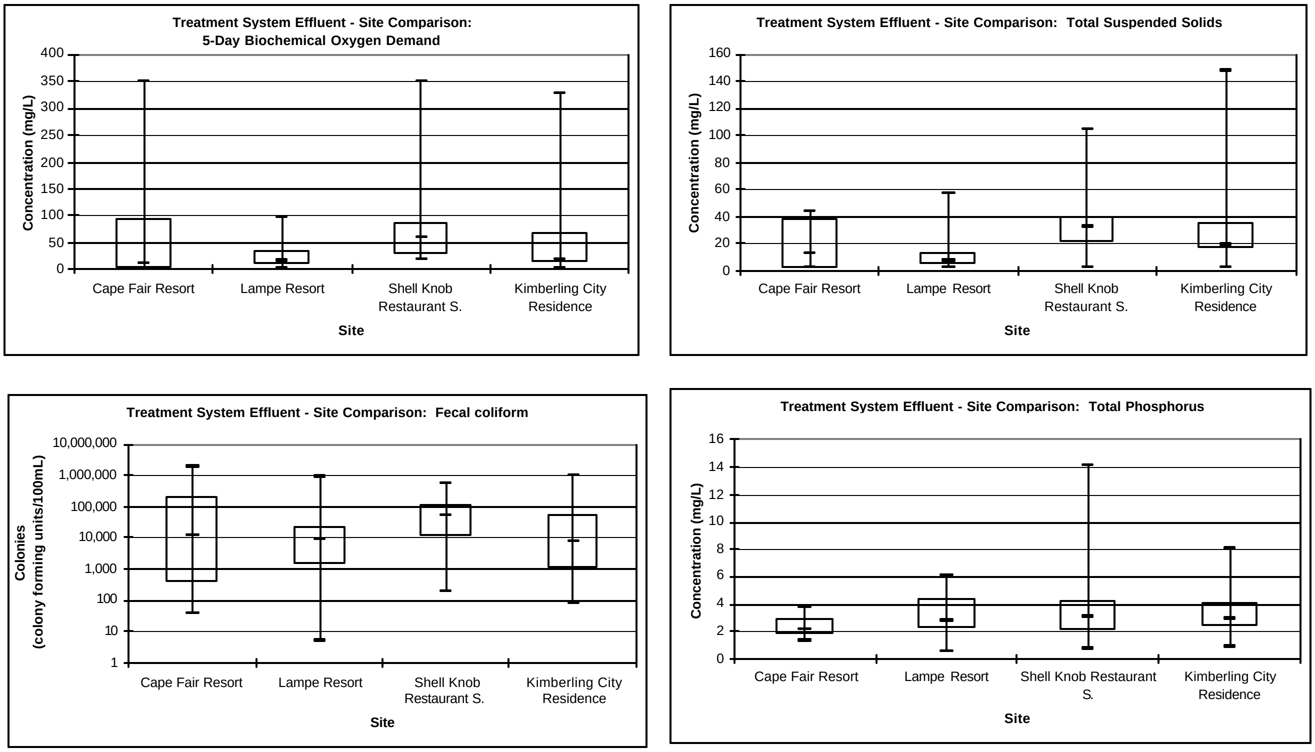
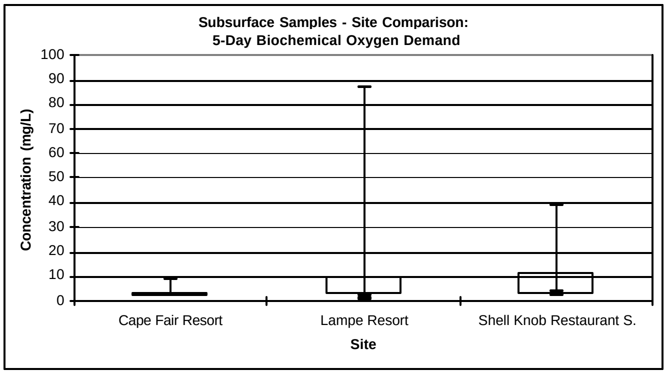
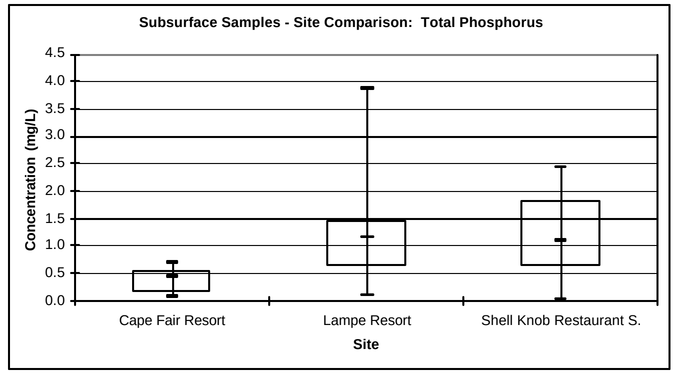


Figure 5.43: Box plots of treatment system effluent concentrations at each site

3. Subsurface water quality concentrations

Subsurface concentrations for all parameters were lowest at Cape Fair Resort (Figure 5.44). BOD_5 and ammonia concentrations were frequently at or below method detection limits. Median total phosphorous and fecal coliform concentrations were at or below water the water quality criteria for surface discharging mechanical treatment plants in the Table Rock Lake watershed (Table 5.1). Wide ranges in all parameters were observed in the Lampe Resort and Shell Knob Restaurant S. subsurface samples. However, median BOD_5, ammonia and fecal coliform concentrations for these two sites were all less than typical surface water discharge effluent limits for a disinfected effluent. Median total phosphorus concentrations for Lampe Resort and Shell Knob Restaurant S. were 1.2 and 1.1 mg/L, respectively.





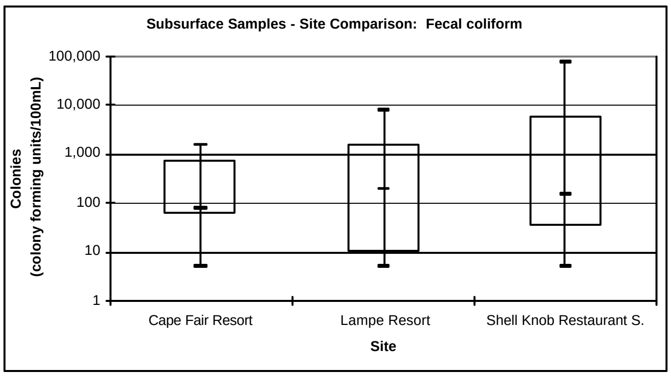


Figure 5.44: Box plots of subsurface sample concentrations at each site

Post-monitoring Drip Dispersal Field Soil Evaluation

After the project monitoring period was completed, Harold James, PhD, Missouri State University, conducted soil evaluations of the three drip dispersal systems (Appendix II). The evaluation provided additional information on the performance of the three drip dispersal systems installed into imported soil. The evaluations were conducted in August 2007 following several weeks of dry and hot weather conditions and peak system flow rates. His findings for each site are summarized as follows:

Cape Fair Resort

The Cape Fair Resort drip dispersal field was well vegetated with grass. The drip field was installed on a 14 to16 percent slope. A six foot wide wet area was observed along the low end of the field. The wet area could potentially be remedied by pumping a greater percentage of the effluent into the upper drip field zone.

Lampe Resort

The Lampe drip dispersal field was well vegetated with grass. Two small wet areas were observed with limited grass growth. In one area, bedrock was found at a depth of 11 inches with the drip tubing 7 inches below the soil surface. As with the Cape Fair Resort drip field, the wet area could potentially be solved by pumping a greater percentage of the effluent to the adjacent (upper west side) zone.

The Lampe drip field also has an eroded area that was attributed to the installation of the half-pipe lysimeter. This problem area is scheduled for repair and is not reflective of the drip dispersal system performance.

Shell Knob Restaurant S.

The Shell Knob Restaurant S. was well vegetated with mostly weeds. There were no wet areas observed in the dispersal field.

Summary of Study Results

The following are the key conclusions and observations based on this study:

- Effluent BOD_5 and TSS concentrations from three of the four advanced systems were consistently below 20 mg/L indicating thorough and reliable organic and solids removal typical of surface discharging mechanical treatment systems. The fourth system treated restaurant waste and had median BOD_5 and TSS concentrations of 59 and 32 mg/L respectively.

- Plastic sheet and half-pipe gravity lysimeters are effective in collecting subsurface samples. Plastic sheet lysimeters are preferred if the lysimeters can be installed during the drip field installation. Piezometers were not effective in collecting subsurface drip field samples.

- Dispersal field subsurface sample concentrations were consistently lower for all water quality parameters measured. For all three systems with gravity lysimeters, median BOD_5, ammonia and fecal coliform concentrations were below effluent limitations typically issued to mechanical surface discharging systems with nitrification and disinfection unit processes. Median subsurface phosphorus concentrations ranged from 0.5 to 1.2 mg/L, demonstrating the soils capacity for phosphorus removal.

- Subsurface sample concentrations for phosphorus and fecal coliform indicated little if any correlation to rainfall amounts.

- Effluent BOD_5, TSS and ammonia concentrations in the residential RetroFAST system were low indicating effective treatment of organic materials, suspended solids and ammonia.

- Absence of standing water in the residential system drainfield several months following RetroFAST installation indicated potential rehabilitation of the drainfield. The rehabilitation was attributed to the reduced biomass production from the high-quality RetroFAST effluent.

- Median septic tank effluent TSS concentrations were below 64 mg/L indicating favorable settling conditions in septic tank systems.

- The primary operational problem at two sites was septic tank and drip field pump tank filter plugging.

- Two of the three drip dispersal fields had wet areas on the downslope zones of the drip field during peak flow. The wet areas were limited and potentially corrected by adjusting flows between zones.

Task 6 – Share the information

Objectives:

The Demonstration Project success can only be realized if information is imparted to interested parties including the public, the onsite industry, the regulatory community, and others. TRLWQ staff, supporters and project participants all helped disseminate the information and lessons learned through the Demonstration Project throughout their constituents and contacts. This information sharing has proven invaluable to the project's accomplishments as word of this work has reached many areas of the Country.

Methods:

A combination of various methods was used to spread public education on the Demonstration Project. These included the CIG, numerous public meetings, web sites, newspaper and magazine articles and printed brochures and flyers. Over 50 public meetings were held during the project period where the Project Coordinator presented Demonstration Project information and findings.

Results:

Results of the education and outreach associated with the Demonstration Project are listed below:

- A 24 page full-color brochure featuring the project, its purpose, design, implementation strategies and lessons learned was printed for public distribution.

- An 8 page TRLWQ projects brochure featuring the Demonstration Project.

- Presentations of the Demonstration Project and its findings were also given to the following groups shown in Table 6.1.

Table 6.1: Presentations of the Demonstration Project

Presentation Event	Date
Public meeting on Demo Project at Shell Knob, MO	11-17-03
MDNR Nonpoint Source Coordinating Team meeting at Springfield, MO	7-19-04
SW Missouri State water resources class	7-24-04
Environmental conference at Missouri Chamber of Commerce & Industry	8-19-04
Arkansas Watershed Advisory Group (AWAG) conference in Little Rock, AR	9-9-11-014
Tour of Demonstration Project sites for county officials in SW Missouri	12-21-04
Missouri Smallflows convention at Columbia, MO	1-17-19-05
Watershed initiative advisory meeting at Berryville, AR	1-24-05
Shell Knob Lions Club	1-24-05
Demonstration Project at meeting at Gainesville, MO	3-10-05
Public meeting at Cape Fair, MO	3-10-05
Rotary Club at College of the Ozarks, Point Lookout, MO	Na
Lakes Area Leadership council	Na
Missouri State University (MSU) Water Resources class	5-20-05
Kimberling City, MO Lions Club	6-15-05
Stone County Soil and Water Conservation District, Crane, MO	5-10-05
Cassville, MO rotary club	Na
College of the Ozarks Conservation of Natural Resources class	8-15-05
MSU graduate class at request of Dr. Robert Pavlowsky	8-21-05
Tri-Lakes area board of realtors meeting	8-22-05
MSU water resources class	8-29-05
Nonpoint Source Coordinator, EPA region 7 Kansas City, MO	8-30-05
EPA region 6 water quality summit, Dallas, TX	Winter 05
Watershed Committee of the Ozarks monthly meeting	10-18&19-05
TRL Neighbors and Friends monthly meeting	11-14-05
Bella Vista property owners association	11-17-05
Lakes area leadership council	12-23-05
DNR public meeting to form a water quality group at Lake of Ozarks, MO	5-16-06
Branson Sunrise Rotary Club	5-18-06
Master Gardeners Club	6-12-06
Branson West, MO Rotary Club	8-18-06.
EPA region 7 water quality forum, Kansas City, MO	9-26&27-06
MSU class on water quality and Demonstration Project	10-16-06
WEFTEC decentralized breakout session at Dallas, TX.	10-21&25-06
EPA regional decentralized wastewater gulf coast workshop, Biloxi, MS.	12-5&6-06
National Onsite Wastewater Recycling Association Convention in Baltimore, MD. Two sessions: drip in imported soil and formation of RME (OCWC)	3-12&15-07
New water quality group at the Lake of the Ozarks, Missouri (Lake of the Ozarks Watershed Alliance)	3-29-07
Group of citizens and business owners at Bennett Springs, MO facing water quality and wastewater issues at this Missouri state park.	4-23-2007

Filmed for water quality video “White River Heritage, Guarding the Treasure” which covers the water quality efforts underway in the Upper White River Basin watershed including the TRLWQ Projects.	6-21-2007
Stone County Onsite Installers, Stone County Health Department.	7-19-2007
Annual membership meeting of the Kings River Watershed Partnership at Berryville, AR.	08-30-2007
Testified at hearing before the Arkansas Health Board on Drip Dispersal of Septic Tank Effluent, Little Rock, AR.	10-25-2007

- Article published at the National Onsite Wastewater Recycling Association’s onsite journal (winter 2005) entitled “Onsite Management a Priority at Table Rock Lake”

Many additional meetings and presentations were given to the following groups:(unknown dates)

- Septic Tank Demo Days-Pumpout. Equipment on display, educational talks, etc.
- TRL Chamber of Commerce membership luncheons
- Stone County Health Department Board of Directors
- Stone County Commissioners
- Southwest Power Commission
- James River Basin Partnership Board of Directors
- Carol Jones Realtors

Another result of the Demonstration Project was recognition by local and state regulatory and environmental officials of the significance of the Demonstration Project and its accomplishment. In addition, the Program Coordinator for the project was elected or appointed to the following positions and licenses:

- Member of the Board of Directors & Officers of Ozarks Clean Water Company.
- Member of the Board of Directors & Officers of Missouri Smallflows Organization
- Stone County Health Department Onsite Wastewater Variance Commission
- Member of the Board of Directors & Officer of Upper White River Basin Watershed Improvement District
- Licensed Onsite Advanced Installer in Missouri
- Licensed Onsite Inspector in Missouri

3 RESULTS AND RECOMMENDATIONS

Rapid population growth and increasing rural development in southwest Missouri watersheds, especially the James River and Table Rock Lake watersheds is causing concern about the maintenance of water quality in the reservoirs and streams. In addition to the increased impervious area and wastewater treatment plant discharge, there are concerns that individual onsite septic systems are contributing an increasing amount of nutrient pollution through failed systems. This nutrient pollution is exacerbated by the overall inadequacy of the thin soils in this region to support most conventional septic systems.

From 1990 to 2005 the population of Stone County increased by over 60% while the average population growth for the entire state during this time was approximately 13%. In neighboring Barry County the population has increased by 30% since 1990. The vast majority of this new population is moving into rural developments that use onsite septic systems to treat wastewater. Home remodels and add-ons rarely upgrade existing septic systems to accommodate extra waste treatment needs. Newly built homes on older sites often use available existing systems without any consideration of this system's capacity to treat the new waste water volume.

Regulation Changes

The soil potential map of Stone County illustrates the large area of the watershed that is characterized by high potential for infiltration. As shown in the Stone County soils potential map, the majority of the area around the Lake is unsuitable for conventional septic systems. This is due to the fact that soils in this area, which are the main treatment media for conventional septic systems, are very thin and composed of a high percentage of rock and gravel fragments. The subsurface or bedrock throughout the Table Rock and James River watersheds is very close to the surface and is composed principally of the carbonate rocks, limestone and dolomite. The Burlington limestone formation is found in the uplands while Jefferson City-Cotter Dolomite predominates in the valleys. The fractured Burlington Limestone formation is very close to the surface and is characterized by numerous springs, caves and sinkholes, and extensive movement of groundwater from one area to another. Failing septic systems therefore are a significant threat to the water quality in the Table Rock Lake and its tributaries as the wastewater is virtually unfiltered and free to flow throughout system. Thus, septic tank effluent receives little if any treatment from the natural environment, and contributes to the pollution of the Lake.

The major result of this project has been a change in the way onsite septic systems are installed in southwest Missouri as well as a change in general public perception about the use of alternative onsite wastewater systems for the Table Rock Lake area. In the past these systems were not widely accepted as feasible or practical and contractors in the area did not install these systems. Even those few installers that had some experience with drip irrigation systems did not generally work with imported soil as done in this Project.

Another result which is ongoing and will be seen in future reports is the acquisition of data on the effectiveness of these types of systems for treating wastewater effluent. This data is being collected from the lysimeter sampling systems installed throughout selected onsite drip system sites. This data will help provide regulatory agencies with information and sound evidence to accept these alternative systems as standard rather than experimental.

Maintenance is Key

This project has also provided a vehicle to remove the responsibility of maintenance and ownership of these onsite systems from the developer and homeowner to ensure proper operation and maintenance by forming the Ozarks Clean Water Company. Advanced wastewater systems had received a bad reputation in the past due to system failure when in reality the failure was on the part of the property owner to maintain the system. If we are to improve water quality with advanced treatment wastewater systems we must insure these systems will be maintained in proper working order.

As the project attempted to find phosphorus removal technologies for onsite systems, it became increasing clear that given the high cost of any technology that can be utilized to remove phosphorous for a single family home and the fact that current regulations do not require phosphorous removal, it would be unlikely many homeowners would choose to incur this added cost. The project team concluded that phosphorus removal in onsite wastewater treatment systems is best achieved around Table Rock Lake by utilizing drip irrigation for dispersal of treated effluent. Given our difficult conditions, many sites require the drip tubing be placed in imported soil. The nutrients are bound in the growing zone of the soil and available for plant uptake. Thus, the project focused their efforts on this method of phosphorous removal.

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APPENDIX-I

INDIVIDUAL SITE INSTALLATIONS

Joe Bald Road Subdivision

Reason Chosen: Joe Bald Road Subdivision is located on Little Aunts Creek road in Stone County, Missouri. It is approximately 20 miles from Branson and approximately 55 miles from Springfield, Missouri. The subdivision is less than 0.25 mile from Table Rock Lake.

A cluster system was already in place, making it the first pre-existing system cluster system that became part of the demonstration project. There was a failed liner on the recirculating sand filter (RSF). The liner was replaced in warranty and the project covered the labor other materials.

RSFs are an alternative to conventional methods of treatment when soil conditions are not conducive to proper treatment and disposal of wastewater. Sand filters are used on sites that have shallow soil cover, inadequate permeability, and limited land area. An advantage to RSFs is they provide very good effluent quality with over 95% removal of biochemical oxygen demand (BOD) and total suspended solids (TSS) along with significant reduction in nitrogen levels. A disadvantage to the sand filter is that maintenance on this type of system is needed frequently.

Technology: The RSF at the Wildflower subdivision was already in place. A septic tank is located at each home and the effluent flows or is pumped to the treatment site. The system has the capacity for 55 homes with over 30 homes currently utilizing the system at the end of the project.

Management: The Wildflower Homeowners Association owned and operated the recirculating sand filter. A unanimous vote of all property owners was obtained to allow the project RME (OCWC) to assume ownership and operation of the treatment system. Under this agreement this site became an EPA Level 5.

Lessons Learned: Even though it is much more difficult to take ownership of a sewage system this is already in place when a unanimous vote is needed, it is possible with the help of a Homeowners Association (HOA) and people living in the subdivision. HOA officers were willing to take the necessary steps to get the property owners to agree to turn over the ownership to Ozarks Clean Water Company. The homeowners realized that maintenance is an important part of keeping a system functioning at its highest capacity and that Ozarks Clean Water Company is a viable alternative to private ownership of wastewater treatment systems.

Old liner is inspected

New gravel and piping with new liner in place

New gravel being installed during repair

Pump tank positioned outside of filter

Pipes are examined

Distribution pipes ready for installation

Kimberling City Subdivision

The Kimberling City Subdivision location is near Kimberling City, Missouri. The site is composed of two houses on a shared system.

Reason Chosen: These new lakefront homes had received a permit to install a conventional septic tank and lateral field. The project felt that the site demanded advanced treatment and drip dispersal to prevent pollution to the lake.

Technology: Each home has a two compartment septic tank with a BioMicrobics FAST treatment unit installed in the second section. The highly treated effluent from each FAST unit flows to one shared pump tank to be time and pressure dosed up to a drip dispersal field installed in imported soil. The system is capable of treating 720 gallons per day.

Management: This site was constructed on EPA Level 5 under which the homeowners pay a monthly fee to the RME, which owns and operates the system.

Lessons Learned: Normally there is no easy way for multiple homes to share one treatment unit. By utilizing the RME EPA Level 5 management, each owner pays a monthly fee to the RME for maintenance. The result is that the property owner has the convenience similar to city sewer while having an advanced onsite wastewater treatment system (OWTS).

New homes sharing advanced OWTS

Septic, treatment and pump tanks for two homes

DD Highway Subdivision

The DD Highway Subdivision location is near Branson West, Missouri. The site is composed of ten houses on a shared system.

<u>Reason Chosen</u>: This subdivision was the classic example of a good quality decentralized wastewater treatment system installed to serve a small subdivision, but due to lack of proper management and maintenance, the system was in failure and subject to a notice of violation by the Department of Natural Resources. The system had not been maintained in years. A pump had failed allowing sewage to flow directly into the lake. The sand filter had trees and weeds growing in it and there was no fence surrounding the facility. It was unknown when the individual septic tanks had last been pumped.

<u>Technology</u>: Each home has a 1000 gallon septic tank. The effluent flows to one shared 1000 gallon effluent lift station tank. The effluent is pumped to a recirculating sand filter with the treated effluent dispersed into a lateral field. This system is capable of treating 2775 gallons per day.

<u>Management</u>: This site was remediated and changed to EPA Level 5 management under which the home owners pay a monthly fee to the RME, which owns and operates the system.

<u>Lessons Learned</u>: Normally there is no easy way for multiple homes to share one treatment unit. This subdivision had no property owner's association in place and the developer had been handling all maintenance. When the developer died, the system was no longer maintained. By utilizing the RME EPA Level 5 management, each owner pays a monthly fee to the RME for maintenance and operation. The result is that the property owner has the convenience similar to city sewer while insuring the system functions properly.

Effluent flowing to lake due to pump failure

Old lateral field used as trash dump

Old lateral field grown up in weeds

Sand filter grown over with weeds and trees

Sand filter after vegetation is cleared

Sand filter with new chain link fence

Pump tanks for treatment unit

Newly installed lateral field

Shell Knob Apartments

The Shell Knob Apartments location is near Shell Knob, Missouri. The site is composed of five units and a house for a total of 15 bedrooms with an average flow of 1800 gallons per day.

Reason Chosen: These lakefront units will have different owners. The EPA Level 5 management will solve the issues when one wastewater treatment system is shared by multiple owners. The existing house had a conventional septic tank and lateral field.

Technology: Each two units share a two compartment septic tank with a BioMicrobics FAST OWTS installed in the second compartment. The highly treated effluent from each FAST unit will flow to one shared pump tank to be time and pressure dosed up to a drip dispersal field installed in imported soil. This system is capable of treating 1800 gallons per day.

Management: This site was constructed on EPA Level 5 under which the home owners pay a monthly fee to the RME, which will own and operate the system.

Lessons Learned: This system is installed but has not had any flow as of the end of the project due to health problems with the developer preventing the units from being completed. It is anticipated that completion will happen sometime in 2008. This site is a successful use of individual treatment systems sharing a large drip dispersal field. The lake front location with steep slope and lack of adequate soil requires advanced treatment and drip dispersal in imported soil as the only option to prevent untreated effluent from entering the lake.

Two units under construction and 3 foundations

Septic tank and aeration unit between unit slabs

Shell Knob Subdivision

Shell Knob Subdivision is a retirement community located in Barry County near Shell Knob, Missouri. It's approximately 45 miles from Branson, approximately 60 miles from Springfield, Missouri, and approximately 20 miles from Berryville, Arkansas.

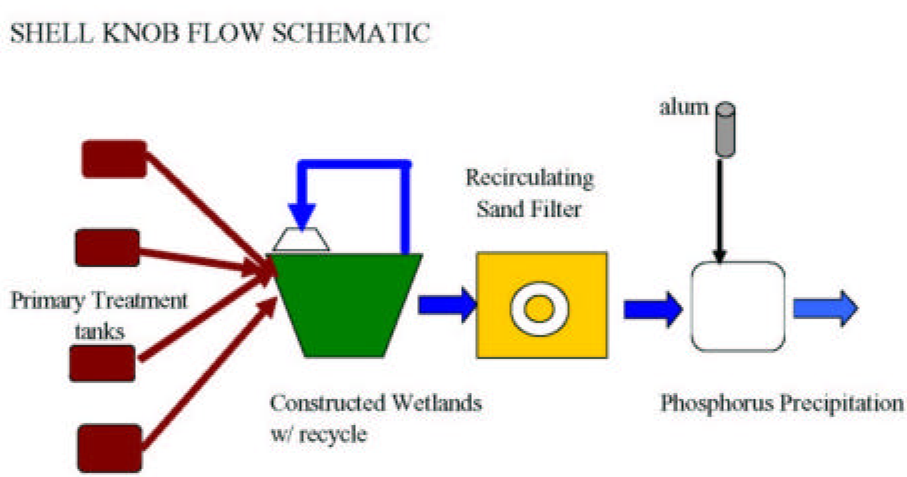
Reason Chosen: Wastewater treatment using constructed wetlands has received much interest nationwide. The project contracted with the owner of the wastewater treatment system to provide monitoring and maintenance.

Technology: The system was engineered by Michael Ogden, P.E. of Natural Systems International, LLC of Santa Fe, New Mexico. Each unit shares a septic tank with the effluent flowing down to a pump tank to be dosed to the wetland cells. The two cells have a liner with 3 feet of gravel. Plants in the gravel help with evapotranporation and nutrient removal. Wetland treated effluent then circulates through a gravel filter, undergoes phosphorus removal by chemical addition and precipitation and UV light disinfection before surface discharge. This system is capable of treating 12,000 gallons per day.

Management: This site was constructed on EPA Level 3 under which the property owner owns the equipment and is required to either contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the property owner or the property owner conducts the required operation and maintenance.

Lessons Learned: The wastewater treatment system installed on this site serves 32 apartment units plus a senior center in the first phase of development. The Neighborhood Assistance Program (NAP), a project of the Missouri Department of Economic Development, funded a portion of the construction of the senior center. This project was directly related to clean water activities and objectives of the demonstration project because it required effective onsite wastewater treatment for residents of this community. The wetlands project was approved by the Department of Natural Resources and permitted the demonstration to monitor this new technology for treating wastewater.

The treatment facilities consist of individual septic tanks, subsurface flow constructed wetlands with recycle to gravel trickling filter, UV disinfection unit, and phosphorus precipitation and removal. The average daily flow was estimated to be 12,000 gallons per day with a population equivalent of 185.




Wetland ponds under construction

The initial design called for two ponds


Newly constructed with small plants

UV & chemical feed for phosphorus removal


Effluent passes through sand filter

Visit by Interim Committee on water quality


Senior center served by wetlands

Plant growth in wetland cells

Partnership sign on site

Second year mature plant growth

The project is one of the first large operational wetland systems in the area. It is designed to provide clean water discharge, as opposed to the conventional septic tank systems that currently continue to pollute Table Rock Lake. The constructed wetlands approach is also very cost effective, at estimated 60 percent less construction cost than conventional treatment systems for a similar size development. In addition to providing an effective treatment system, this project was designed as a demonstration of vegetation treatment options. It also provides water quality data on the effectiveness of wetlands treatment.

Average of water sample data from the Shell Knob subdivision wetlands for each parameter arranged by influent, wetlands effluent. RSF (recirculating sand filter) effluent and final effluent leaving the treatment system to surface waters.

Shell Knob Subdivision Sample Results

Sample Location	**BOD mg/l**	**TSS mg/l**	**pH**	**P mg/l**	**NH_3 mg/l**	**Nitrate mg/l**
Influent	131.04	61.25	7.36	5.23	50.87	1.28
Wetlands Effluent	5.88	5.36	7.25	1.76	4.03	0.98
RSF Effluent	3.30	4.70	7.16	0.81	1.99	2.74
Final Effluent	3.27	3.11	7.37	0.28	1.58	3.49

For complete data tables see Appendix II

Galena Apartments

The Galena Apartments Resort location consists of 11 cottages of varying sizes located near Galena, Missouri. The resort is located on Table Rock Lake.

Reason Chosen: The decentralized surface discharge wastewater treatment system was a good fit for the RME EPA Level 5 maintenance. The owner plans to sell off cabins as a planned community with an association to maintain the facilities. The Department of Natural Resources and Stone County Planning and Zoning are requiring a decentralized sewage treatment system in order to sell off the cabins.

Technology: Recirculating sand filter

Size (GPD): 2640

Management: This site was constructed on EPA Level 5 under which the property owner pays a monthly fee to RME, which will own and operate the system.

Lessons Learned: The system was constructed and completed but there has been no flow to the system as of the end of this project due to no cabins being sold. The RME will own and operate when needed.

Cabins will be sold to individuals owners

OCWC will own and operate the system

Kimberling City Campground

The Kimberling City Campground is located on Table Rock Lake in Kimberling City just east of the Kimberling City, Highway 13 bridge. The shower house was in need of a more adequate and upgraded wastewater treatment systems to handle effluent from four flush toilets, two sinks and six shower stalls.

Reason Chosen: The soil is shallow and rocky and not suitable for the conventional onsite wastewater treatment system with lateral lines that was currently being utilized. The existing system consisted of a rusted metal 500 gallon septic tank and a failing lateral system that surfaced at peak shower usage and ran untreated effluent into the nearby lake. Due to the shallow soils, any system installed on this site would have to utilize advanced treatment and then spread out the treated effluent enough to allow the soil to soak up the liquids.

Technology: The treatment system consists of a 1500 gallon concrete septic tank with a 1.5 Bio-Microbics/FAST aeration unit. It also has a 1000 gal pump tank with ½ horsepower high head pump and 3,000 linear feet of drip dispersal tubing in two zone drip fields utilizing existing soil. The dispersal of effluent is time dosed through the drip lines to ensure even distribution of liquids to the drip field throughout the day, rather than at peak usage times. This system was designed to treat and disperse 1,500 gallons per day.

Management: This site was constructed on EPA Level 3 in which the property owner owns the equipment and is required to contract with an approved operator for operation and maintenance of the system for a fee to be paid by the owners. Upon installation, the owners entered into a service contract agreement with an approved operator.

Lessons Learned: When Table Rock Lake was filled in the early 1960's, public shower houses were constructed and utilized the standard wastewater treatment of the time, a metal septic tank followed by a convention lateral field. Of course, according to today's regulations, those tanks are too small and the laterals are far too short. Many of these systems are still in operation today and are polluting the lake due to failure and overuse. The Kimberling City site was a demonstration of advanced treatment and drip irrigation to solve a failing commercial wastewater system. There was sufficient existing soil on site so no imported soil was required for the drip field.

Old metal tank removed from Kimberling City Campground

Trenching in the drip irrigation dispersal lines

Sufficient existing soil was already in place

Drip dispersal field showing proximity to the lake

Signage in front of treatment and pump tank

Shell Knob Restaurant South

The Shell Knob Restaurant South location is a restaurant located near Shell Knob, Missouri.

Reason Chosen: The site had a failing experimental system using wood chips, plants and tires. The effluent then flowed to an undersized lateral field in poor soils and was surfacing. The existing system consisted of 3 septic tanks with "wetland" area and laterals.

Technology: The kitchen wastewater flows to a 1500 gallon grease trap and 1500 gallon septic before entering the 1500 gallon tank in which a commercial BioMicrobics FAST aeration unit was installed. The bathroom wastewater flows into another 1500 septic tank then into the commercial FAST unit. The treated effluent then flows to two 500 gallon pump tanks and is time and pressure dosed to a drip field installed in imported soils.

Size (GPD): 2,000

Management: This site was constructed on EPA Level 5 under which the property owner pays a monthly fee to RME, which will own and operate the system.

Lessons Learned: This restaurant had a history of wastewater problems. The experimental system installed a few years earlier was one attempt to find a solution but it was not based on proven technology or good science. The project was able to show that advanced treatment using drip dispersal in imported soil was effective for treating high strength restaurant waste. Shortly after the system was installed, the property sold. The new owner was not as cooperative as the previous owner. The new owner did not want to pay the monthly fee to the RME nor did he want to give the RME access for system repair. Only when the new owner defaulted on his sales contract and the previous owner reassumed ownership was the RME able to bring the system back into normal working condition. As this site was one of the four being heavily monitored, some of the test data results show poorer results than would have been the case if the system had been properly maintained during all of the monitoring period.

Failing wood chip system

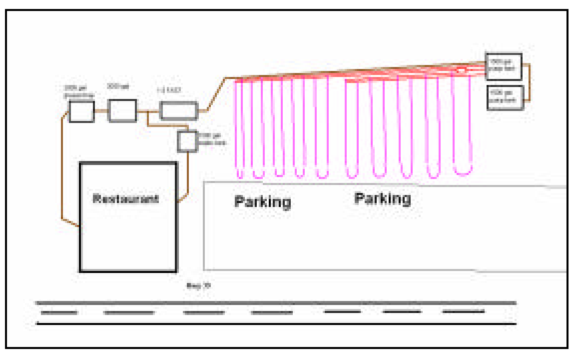


Diagram of advanced treatment system

Grease trap, 2 septic tanks and treatment

Commercial FAST in 1500 gallon tank

Treated effluent flows to 2 pump tanks

Valve doses two zones in drip field

Drip tubing placed on bed of imported soil

Tubing covered by 8” of soil

Shell Knob Restaurant North Location

The Shell Knob Restaurant North location is a restaurant located in Shell Knob, Missouri on the shore of Table Rock Lake.

Reason Chosen: This site has had a failing system for a number of years. The Department of Natural Resources had issued a Notice of Violation for a failing system. The owner decided to install a wetland identical but smaller to the Shell Knob Senior Center. The project provided maintenance and monitoring. The existing system consisted of tanks and a failed treatment system.

Technology: The system was engineered by Michael Ogden, P.E. of Natural Systems International, LLC of Santa Fe, New Mexico. Restaurant waste flows first to a grease trap then to a septic tank. The effluent flows down to the pump tank to be dosed to the wetland cells. The two cells have a liner with 3 feet of gravel. Plants in the gravel help with evapotranporation and nutrient removal. Wetland treated effluent then circulates through a gravel filter, undergoes phosphorus removal by chemical addition and precipitation and UV light disinfection before surface discharge.

Size (GPD): 3,000

Management: This site was constructed on EPA Level 3 under which the property owns the equipment and is required to either contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the property owner or the property owner conducts the required operation and maintenance.

Lessons Learned: After having various treatment systems fail over a number of years at this location with untreated effluent directly entering the lake, the project wanted to test the constructed wetlands technology. The project found that even with high strength restaurant waste, the treatment system consistently performed within the permit limits established by the Department of Natural Resources for surface discharges directly to the environment.

Two cell wetland with plants on one side

Plants help remove nutrients from effluent

Plant growth establish in both cells

V light disinfection and polishing by sand filter

Chemical feed for phosphorus removal

PVC pipes control water level in cells

Below is a table of average water sample data from the Shell Knob Restaurant (north) wetlands for each parameter arranged by influent, wetlands effluent. RSF (recirculating sand filter) effluent and final effluent leaving the treatment system to surface waters.

Shell Knob Restaurant (North) Sample Results

Sample Location	**BOD mg/l**	**TSS mg/l**	**pH**	**P mg/l**	**NH_3 mg/l**	**Nitrate mg/l**
Influent	184.62	47.86	6.96	5.51	44.73	0.26
Wetlands Effluent	3.12	1.76	7.29	2.86	1.73	1.13
RSF Effluent	2.14	2.99	7.72	2.50	0.50	1.75
Final Effluent	1.66	8.09	7.54	1.50	0.26	2.14

For complete data tables see Appendix II

Galena Resort

The Galena Resort location consists of a two bedroom house and ten single bedroom rentals located near Galena, Missouri.

Reason Chosen: Lakefront lagoon leaking directly to lake near swimming area. The original sewage treatment system consisted of a single cell lagoon. The lagoon was leaking and discharging untreated sewage directly into the lake. The Health Department had given the owner 3 years to fix the problem.

Technology: Two new 1,500 gallon septic tanks and effluent filters, three Zabel SCAT units, a 500 gallon pump tank with pump and filter and floats. A drip irrigation dispersal system utilizes existing soil below the drip tubing and imported soil above. Included were a survey of the property, soil evaluation and system engineering. This design is capable of treating 1440 gallons per day.

Management: This site was constructed on EPA Level 3 under which the property owner owns the equipment and is required to maintain the system by either contracting with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the property owner or the property owner conducting their own operation and maintenance.

Lessons Learned: The drip field on this site was originally designed to utilize the existing soil. Due to rock fragments encountered, the trencher could not be used. The drip tubing was installed on top of the existing soil with a covering of 8 inches of imported soil. It was later learned that a "plow" attachment on a skid steer loader would have successfully installed the drip tubing in the existing rocky soil. As with most of the other resort sites, the owners felt confident they could handle the maintenance needed for the treatment system. During the course of the project, the owners indeed proved skilled in being able to handle routine cleaning of filters, flushing of drip tubing and other basic required maintenance but they were not experienced in trouble shooting the cause of any problems that occurred. This underscores the need for a maintenance provider to be involved with the advanced OWTS to trouble shoot and repair them when problems do occur.

Failing lake front lagoon

Untreated sewage leaking directly into the lake

Rock fragment would not allow trenching

Drip tubing installed on top of existing soil.

A covering of 8 inches of imported soil.

The drip dispersal field with grass planted

Zabel SCAT media filters using foam cubes

Zabel SCAT units installed and plumbed

Reeds Spring Resort

The Reeds Spring Resort location consists of 17 total units from 1 to 4 bedrooms located near Reeds Spring, Missouri.

Reason Chosen: This surface discharging system was required by DNR to add phosphorus removal equipment before the treated effluent entered the lake.

Technology: Grinder pumps sending effluent to a recirculating sand filter (RSF) with UV light disinfection. This system is capable of treating 9600 gallons per day.

Management: This site was constructed on EPA Level 3 under which the property owner owns the equipment and is required to either contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the property owner or the property owner conducts the required operation and maintenance.

Lessons Learned: The project provided phosphorus removal equipment to a new existing surface discharging recirculating sand filter serving a lakefront resort thereby keeping nutrients out of the lake.

Resort cabins served by system

Recirculating sand filter

Tanks and equipment house

UV light disinfection equipment

Highway OO Resort

This lakefront resort has a capacity of 70 people and consists of 24 resort bedrooms and the owner's 3 bedroom home with an expected average flow of less than 2,800 gallons per day. The site is near State Highway OO in Stone County, Missouri, approximately 20 miles from Branson, approximately 55 miles from Springfield, Missouri, and approximately 35 miles from Berryville, Arkansas.

Reason Chosen: The existing treatment system consisted of separate septic tanks with conventional lateral fields in various stages of failure with effluent observed running directly into the lake. Six existing septic tanks and conventional lateral fields served the resort. Soil tests determined the site well suited for a drip irrigation system utilizing existing soil. This site demonstrated taking effluent from individual septic tanks to a central aeration treatment unit and then dispersing the treated effluent by pumping to a drip dispersal field installed in existing soil.

Technology: Two Bio-Microbics FAST 0.5 aeration units were installed into two dual compartment 1,500 gallon concrete tanks along with 9,350 linear feet of drip dispersal tubing. The system utilizes a four-zone drip irrigation system for dispersal of treated effluent. The system is capable of handling 2,800 gallons of effluent per day.

Management: This site was constructed on EPA Level 3 under which the property owner owns the equipment and is required to either contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the property owner or the property owner conducts the required operation and maintenance.

Lessons Learned: Many lakefront resorts were built in the 1960's and 1970's. Normally they consist of separate cabins each having their own septic tank and lateral field. At the time of construction, there were no existing regulations covering installation of onsite systems so it is common to find small metal septic tanks with just a few feet of lateral lines for each cabin. At this site there was a combination of old septic tanks that would need to be replaced along with some newer tanks that had already been replaced and were properly sized and water tight. The effluent from the septic tanks is sent by gravity or pumping to a central treatment area. After treatment, the effluent is dispersed from the pump tanks to a four zone drip field utilizing existing soil. It is noted that this was one of the very few lakefront demonstration sites that had sufficient existing soil for the lateral field. This type of system is much more cost effective to install and maintain than the alternative surface discharge system such as a recirculating sand filter that would require disinfection and phosphorous removal and an NPDS permit.

Lakefront Resort near Highway OO

Surfacing sewage entering the Lake

Septic and aeration tanks with dispersal and return lines for drip irrigation

Sewage tank and filter tank installed and individual sewer line for resort cabin

A portion of the drip irrigation field and entrenched drip dispersal lines

Lampe Resort

The Lampe Resort location consists of a three bedroom single family home and eight rental units with an expected average flow of 1560 gallons per day. The site is located just across a lake cove from Lampe, MO.

Reason Chosen: The Health Department had given the owners 18 months to replace leaking lagoon. The sewage treatment currently consists of a single cell lagoon that is partially located on Corp land and leaking.

Technology: Two new 1,500 gallon septic tanks with effluent filters. Three Zabel (Quantics) SCAT modules and a 500 & 300 gallon pump tank with pumps, filters and floats. The drip irrigation dispersal system was installed utilizing imported soil. This treatment system is capable of treating 1560 gpd.

Management: This site was constructed on EPA Level 3 under which the property owner owns the equipment and is required to contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the homeowner or for the property owner to do the required maintenance themselves.

Lessons Learned: The waste flows by gravity from the home and cabins to the septic tank and treatment system. The only suitable area for a drip system was above the resort on the hillside. A soil survey determined that there was not enough existing soil so the drip dispersal field was constructed at this location with imported soil. The property owner felt they could handle the maintenance. While the owner proved they could do an adequate job with the routine maintenance of cleaning filters and flushing lines, they were not able to cope with the problems that arose. Excess organic growth in the pump tank was causing the filters to clog repeatedly. While the owner kept cleaning the filter, a maintenance provider was needed to determine the need for chemicals to kill the organic growth.

Resort served by failing lagoon

Setting tanks required rock removal

Zabel SCAT units treat wastewater

Wastewater sprays over foam cubes

Septic tanks and two pump tanks

Effluent filter requires cleaning

Drip dispersal field in imported soil

Drip dispersal field with vegetation established

Cape Fair Resort

The Cape Fair Resort location consists of 11units from 1 to 4 bedrooms and one home located near Cape Fair, Missouri.

Reason Chosen: This resort was in close proximity to the lake. The lagoon overflow was allowing effluent to run over the surface. Existing system consisted of one 1000 gallon septic and a failing undersized lagoon.

Technology: The new system consists of septic and pump tanks, a BioMicrobics FAST system and a drip dispersal system installed in imported soil. This design is capable of treating 1920 gallons per day.

Management: This site was constructed on EPA Level 3 under which the property owner owns the equipment and is required to either contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the property owner or the property owner conducts the required operation and maintenance.

Lessons Learned: The project provided phosphorus removal equipment to a new existing surface discharging recirculating sand filter serving a lakefront resort thereby keeping nutrients out of the lake.

Old lagoon with resort in background

Imported soil drip field under construction

Hwy DD Resort

The Hwy DD Resort location consists of a three bedroom single family home and four one bedroom cabins located on Gobbler Mountain Road in Branson West, Missouri. The site is near County Highway DD in Stone County, Missouri, approximately 20 miles from Branson, approximately 50 miles from Springfield, Missouri, and approximately 40 miles from Berryville, Arkansas.

<u>Reason Chosen</u>: Failing system with untreated effluent surfacing.

<u>Current System Condition</u>: The existing system consisted of a 2,000 gallon septic tank with a non-functioning aerator and a non-functioning chlorinator tank which led to a 100 foot open discharge line.

<u>Technology</u>: Installation included a Zoeller turbine pump, time dose control panel, Zabel SCAT biofilter, a 5,000 gallon concrete storage tank with a Zoeller turbine pump and control panel with timer.

System design included installing low-flow toilets and shower heads in all units which lowered the peak design flow to 740 gpd from the calculated peak flow of 1080 gpd. Even with the lower flow rate a 7,400 square feet area and 3,700 linear feet of drip tubing would be required for drip dispersal.

Since this site had limited area available for the drip field, only 1,200 linear feet of drip tubing was installed in imported soil to handle effluent dispersal of up to 240 gpd. Usage exceeding 240 gpd up to 500 gpd would be stored in a 5,000 gallon concrete storage tank to be time dispersed during periods of lower flow. If the storage tank reached capacity, the effluent would be removed by a qualified pumper and taken to a municipal treatment facility.

<u>Size (GPD)</u>: 740

<u>Management</u>: This site was constructed on EPA Level 3 under which the Licensee owns the equipment and is required to either contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the property owner or the property owner conducts the required operation and maintenance.

<u>Lessons Learned</u>:

This site had more design flow than was land available to disperse the treated effluent. Since the property was a resort with not only seasonal usage but usage that varied from weekend to weekday, the plan utilized a 5,000 gallon drip field dosing tank that would allow for storage of the treated effluent until daily usage allowed for timed dispersal. If usage did not decrease and the tank reached capacity, a pumper would haul the effluent to a local municipal treatment plant. This site demonstrated the successful use of changing components such as tank size to overcome the lack of available land for the drip field. The property owner elected to conduct the required maintenance himself and proved capable of handling the normal maintenance tasks of filter cleaning and line flushing. He also became very interested in system operation by keeping a daily log of water flow and pump run time using the meters and counters installed for this purpose. While the owner handled normal maintenance tasks he was not trained in trouble shooting problems on the system. A siphon effect due to the lack of a weep hole being drilled caused the drip field to develop wet spots that required a trained maintenance provider to locate and repair. While the property owner can handle routine maintenance, there still needs to be a trained maintenance provider.

Concrete septic and treatment dosing tanks.

5,000 gal. drip dosing tank was poured in place.

Tubing connected to supply and return lines

Drip tubing installed ready to be covered

Flexible tubing allows for retention of trees

Treatment unit installed on the dosing tank

Reeds Spring Residence

The Reeds Spring Residence location is an existing single family residence located near Reeds Spring, MO.

Reason Chosen: Completely rusted septic tank. The rusted lid was also a safety hazard. Rusted metal septic tank with untreated effluent leaking out the bottom of tank and following ledge rock into the lake. No effluent was entering the lateral field.

Technology: A new 1,500 gallon two compartment septic tank with a BioMicrobics FAST aeration system installed in the second compartment. Treated effluent flows by gravity into the existing lateral field. This system will treat more than 500 gallons per day.

Management: This site was constructed on level 5 under which the property owner pays a monthly fee to the RME, which will own and operate the system.

Lessons Learned: The new home built on this lake front lot a few years ago was allowed to connect to the old metal septic tank and lateral system. An inspection by a licensed onsite inspector would have discovered the need for a new OWTS. The project was able to demonstrate the use of an advanced OWTS utilizing the existing conventional lateral field. If the existing lateral field could not have been used, a drip field with imported soil would have been required.

View from lake shore to house

Shoreline showing ledge rock in front of site

Pumping tank through rusted out lid

Rusted metal tank removed from ground

Effluent left tank through rusted out bottom

New septic / treatment tank delivered

Tank hole enlarged with dynamite due to rock

Tank installed and ready for backfill

Shell Knob Owls Point Residence

The Shell Knob Owls Point Residence location is a single family residence near Shell Knob, Missouri. The home is three bedrooms with a design flow of 360 gallons per day.

Reason Chosen: This site had been given approval for a convention septic tank lateral field by the local regulatory agency in spite of the steep slopes, small lot and lack of soil. This is a new home construction.

Technology: A new 1,000 gallon septic tank with effluent filter followed by a Premier Tech Peat Filter (closed bottom) treatment system. Treated effluent flows to a 500 gallon pump tank with pump, filter, and floats. Treated effluent is time and pressure dosed to drip irrigation effluent dispersal system. This system is capable of treating 360 gallons per day.

Management: This site was constructed on EPA Level 5 under which the Licensee pays a monthly fee to RME, which will own and operate the system.

Lessons Learned: This was one of the first project sites. The plan was for the drip tubing to be installed in the existing soil but when installation began, it was evident that there was not enough soil present. The installer placed the tubing on top of the existing soil covering it with imported soil. Soon after the system was placed in service, the treated effluent was found to be surfacing. On investigation by soil scientists and engineers, it was found that there was not enough existing soil under the drip tubing, not enough imported soil over the drip tubing and that the imported soil was placed with a rubber tired machine causing excessive compaction. The complete drip field was replaced at this site with imported soil. Future installations of imported soil drip fields were made with a tracked machine to minimize compaction.

Front yard before drip field installation

After installation of tanks and drip field

Blasting required to set septic tank

Single pass peat moss treatment system

Repair begins on drip field with imported soil

Drip tubing installed on imported soil

Imported soil placed over the drip tubing

Treated effluent is pumped up to drip field

Lampe Residence

The Lampe residence location is a single family lakefront residence on the southern side of Table Rock Lake. The home is 4 bedrooms with an average flow of less than 500 gallons per day. The site is near State Highway 13 in Stone County, Missouri, approximately 20 miles from Branson, approximately 55 miles from Springfield, Missouri, and approximately 25 miles from Berryville, Arkansas.

Reason Chosen: The existing system consisted of a rusted metal tank and convention lateral drain field. There did not appear to be a problem with the existing absorption field.

Technology: The site presented suitable conditions for installation of a Bio-Microbics FAST aeration unit installed in a new 1,000 gallon fiberglass septic tank. This type of system was chosen because it could effectively serve the site while utilizing the existing lateral field for dispersal of the treated effluent. This onsite wastewater treatment system was designed for use up to 480 gallons per day.

Management: This site was constructed under EPA Level 3management system in which the property owner also owns the equipment and is required to contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the homeowner.

Lessons Learned: Every day old rusted metal tanks are replaced around Table Rock Lake. In many cases the existing lateral lines are not long enough or in sufficient soil or to provide proper treatment of septic tank effluent. The demonstration project installed advanced treatment then utilized the existing laterals for dispersal of the treated effluent. Because the site did not allow the placement of a concrete tank by the boom truck, a fiberglass tank that could be set with excavating equipment was chosen.

Old rusted tank removed from the Lampe residence

Lakeside lot on steep hill with existing lateral field

New fiberglass tank with advanced treatment installed

Monitoring to evaluate system performance

Kimberling City Residence

The Kimberling City Residence location is a single family residence is located near Kimberling City, Missouri. The home is 3 bedrooms with an average flow of 360 gallons per day.

Reason Chosen: The chamber lateral field had standing and pooling effluent due to biomat build up.

Current System Condition: Conventional 1000 gal. septic tank with gravity flow to chamber leach bed.

Technology: A Bio-Microbics RetroFAST 0.375 unit installed in the property owners existing 1,000 gallon concrete septic tank. The treated effluent will be dispersed by gravity using the existing chamber lateral field. Storm water (gutters) will be diverted from lateral field area.

Size (GPD): 360

Management: This site was constructed on EPA Level 5 under which the Licensee pays a monthly fee to RME, which owns and operates the system.

Lessons Learned: This site demonstrated the successful remediation of a failing lateral field. The aerobic highly treated effluent allowed the bacteria to remove the biomat and the effluent was able to again disperse into the soil. Inspection of the chambers showed no standing or pooling effluent present after only a few months of operation. This property owner also was very excited to be a part of the EPA Level 5 management. He was elected to the Board of Directors of the RME by the other property owners at the first annual member meeting.

Septic tank and chamber lateral field

Chamber system full with septic effluent

Existing tank uncovered

Square access hole cut in tank lid

RetroFAST is easy to ship to site

RetroFAST lowered in the tank.

Plastic wings hold system in place.

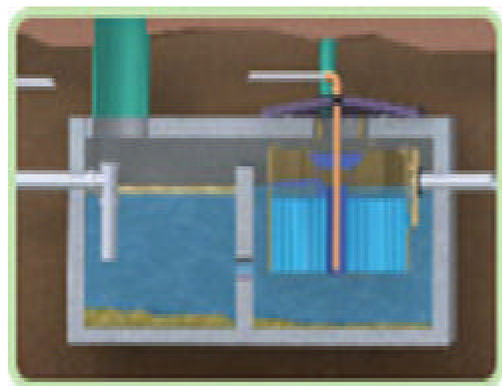


Diagram of system installed in tank.

Ozark Residence

The Ozark Residence location is a single family residence located in Ozark, Missouri near State Highway 65 in Christian County, Missouri, approximately 25 miles from Branson, approximately 20 miles from Springfield, Missouri, and approximately 75 miles from Berryville, Arkansas.

Reason Chosen: Site had surfacing effluent with a spring within 100 feet of the system. The existing system consisted of a convention septic tank with a lateral drain field. Neither the tank nor the length of the lateral lines conformed to the current Christian County standards as defined by the Christian County Health Department Report and Soil Profile.

Technology: BioMicrobics FAST System preinstalled in 1000 concrete tank with drip dispersal field installed in existing soil.

Size (GPD): 360

Management: This site was constructed on EPA Level 3 under which the Licensee owns the equipment and is required to contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the homeowner.

Lessons Learned: Advanced treatment using drip dispersal was able to overcome marginal soil conditions while protecting ground water (spring). This location was in an area that had sufficient soil so that there was no need for imported soil in the lateral field.

A spring is located in the front yard

The hole is ready for the tanks

Air pump, tank vent, control panel and riser

Supply and return line to drip field

Highway H Residence

The Highway H location is a new construction single family residence located in Lampe, Missouri. The home is 3 bedrooms with an expected average flow of less than 500 gallons per day. The site is near State Highway H in Stone County, Missouri, approximately 20 miles from Branson, approximately 55 miles from Springfield, Missouri, and approximately 25 miles from Berryville, Arkansas.

Reason Chosen: This lakefront site was small, steep and had very little soil and so challenging that installing a successful onsite system would be a major accomplishment.

Technology: A Bio-Microbics FAST 0.5 aeration unit installed in a 1,500 gallon two compartment concrete tank and utilizing drip dispersal in imported soil. The 1,000 gallon side is the septic tank and houses the FAST treatment unit and the 500 gallon compartment houses the drip pump and filter. This system was designed to handle 360 gallons per day.

Management: This site was constructed on EPA Level 3 under which the Licensee owns the equipment and is required to contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the homeowner.

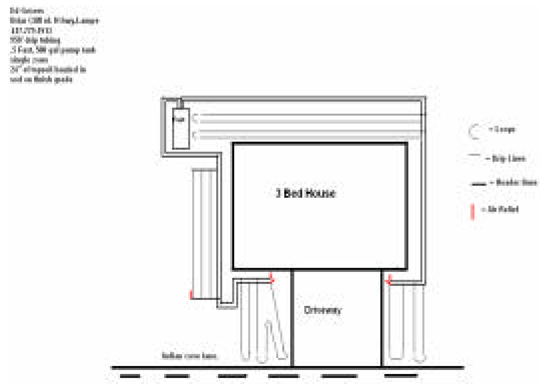
Lessons Learned: A lakefront lot is desirable when building a new home but presents many challenges in installing an onsite treatment system. This 60’ x 100’ lot was steep with solid rock and almost no soil. To gain a small yard, a large retaining wall was built. This small yard housed the tank and most of the drip field with additional drip tubing installed on both sides of the house and in the very small front yard so as to achieve the appropriate amount of square feet of lateral field. The drip field was covered in sod and provides water and nutrients for the lawn. This system is functioning well and is considered a showcase for overcoming very tough site conditions with advanced treatment and irregular shaped drip field. See layout diagram.

Retaining wall allowed level site for drip field

Components are installed in one tank to save space

Drip dispersal lines installed around the Highway H residence

Imported soil ready to be placed



Drawing of drip line placement

Pump tank filter and valves

Sod being placed over the drip field

Campbell Point Residence

The Campbell Point Residence location is a single family residence located near Campbell Point Marina in Shell Knob, Missouri. The site is near State Highway 39 in Stone County, Missouri, approximately 50 miles from Branson, approximately 60 miles from Springfield, Missouri, and approximately 25 miles from Berryville, Arkansas.

Reason Chosen: Rusted metal tank had collapsed so homeowner had dug up and cut sewer line just outside of trailer home to allow raw sewage to flow overland. Site had numerous rock outcroppings and very little existing soil. The existing system consisted of a conventional metal septic tank and lateral field.

Technology: A Bio-Microbics FAST aeration unit installed in a 1,500 gallon two compartment concrete tank, a 500 pump tank and utilizing single zone drip dispersal field in imported soil. This onsite system was designed to treat 360 gallons of effluent per day.

Management: This site was constructed on EPA Level 3 under which the property owner owns the equipment and is required to contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the homeowner.

Lessons Learned: There are thousands of old metal tanks still in use around Table Rock Lake. In this case, the tank had collapsed causing sewage to back up into the home. The old lateral field would have more than likely been placed on solid rock in the hopes that effluent would travel into the cracks in the rock and not surface. The demonstration project found that advanced treatment followed by drip dispersal in imported soil can overcome these very tough site conditions.


Raw sewage flowing from sewer pipe and flowing across yard


Old metal collapsed septic tank at the Campbell Point residence

Septic / treatment / Pump tanks and drip dispersal lines

Galena Residence

This location is an existing single family residence near Galena, Missouri. The home is 4 bedrooms with an expected average flow of less than 500 gallons per day. The site is near State Highway Y and Pioneer Point Drive in Stone County, Missouri, approximately 25 miles from Branson, approximately 50 miles from Springfield, Missouri, and approximately 50 miles from Berryville, Arkansas.

Reason Chosen: Failing conventional system with a rusted metal septic tank with holes that release septic waste directly into surrounding area.

Technology: A Bio-Microbics FAST aeration unit installed in a 1,500 gallon two compartment concrete tank. The dispersal of treated effluent was time and pressure dosed from a 500 gallon concrete dosing tank to the single zone drip field utilizing 1200 linear feet of drip dispersal tubing in imported soil.

Management: This site was constructed on EPA Level 3 under which the property owner owns the equipment and is required to contract with an approved operator for operation and maintenance of the system for a monthly fee to be paid by the homeowner.

Lessons Learned: This home was purchased by a couple relocating from St. Louis, MO. A home inspection listed the septic system as "metal tank" but there was no indication of any problems by the inspector. The buyers had been on a municipal sewer system and had no understanding of a septic system. A few years later when they decided to pump their tank, they discovered that at the time the house was built, the plumbing was hooked up to a failing and rusted metal septic tank underscoring the need for a detail septic system inspection when a home sells.

Old tank was located directly behind the house

Old rusted metal tank

Nutrients in septic effluent feed algae

This site is lake front

New concrete septic tank with treatment unit

Aeration blower and motor

Drip dispersal lines installed on imported soil bed

Imported soil placed on top to complete the field

Ridgedale, MO Residence

The Ridgedale location is a single family, lakefront residence with 3 bedrooms. The homeowner was planning to add two bedrooms to the home. The site is near State Highway 86 in Taney County, Missouri, approximately 15 miles from Branson, approximately 60 miles from Springfield, Missouri, and approximately 30 miles from Berryville, Arkansas.

Reason Chosen: This lakefront home originally built as a part-time lake home was being used fulltime by a family of five. The site had very little soil and would require a unique way to disperse the effluent in an environmentally friendly manner. Old metal tank with approximately 50 ft. lateral line was completely inadequate for the property and use. The sewage was running from the inadequate system straight into lake as seen by evidence of algae where the effluent was reaching the water.

Technology: A 1500 gallon 2 compartment concrete septic tank followed by a Bio-Microbics FAST aeration unit installed in another 1,500 gallon two compartment concrete tank. The 1,000 gallon side of the second tank holds the FAST unit and the 500 gallon compartment houses the drip pump and filter. The lateral field is drip installed in imported soil. This system was designed to treat 600 gallons per day.

Management: This site was constructed on EPA Level 5 under which the property owner grants ownership of the system to Ozarks Clean Water Company for operation and maintenance of the system in exchange for a monthly fee to be paid by the homeowner.

Lessons Learned: Many lakefront homes built for weekend use are now fulltime residences. The onsite treatment system which is normally undersized will now fail with full time use. At this site, the rusted metal tank was located beneath the wooden deck with just a few feet of pipe leading under the boulders brought in to make a level parking area. A river of untreated effluent was polluting the lake. The steep site had very little soil so the treated effluent is now dispersed using drip tubing in imported soil.

Failing septic system showing flow over the ground from inadequate lateral line

Imported soil for ready for drip dispersal field

Tubing and piping for installing drip dispersal field

Septic / treatment and pump tanks in place

Drip tubing connected to supply pipe

Drip field ready to be covered with soil

Completed drip field with established vegetation

APPENDIX-II

WATER QUALITY MONITORING DATA

Site	System Type/Sample Location	Date	Time (24:00)	Average Daily Flow (gal/day)	Rainfall (Prev. 7 days) (in)	Sample Temperature °F	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (µS/cm)	Total Phophorus (mg/L)	Total Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate and Nitrite Nitrogen (mg/L)	Total Suspended Solids (mg/L)	Fecal Coliform (col./100mL)	5 Day Biochemical Oxygen Demand (mg/L)
Cape Fair Resort	FE	8/21/06	15:15	558	---	73.0	0.21	7.69	1,056	2.53	61	>5.0	0.01	44	1,020,000	350
	STE	8/21/06	15:30	"	---	74.1	0.07	7.21	1,043	2.56	9.8	>5.0	9.76	77	1,100,000	335
	STE	9/19/06	8:30	558	---	73.6	0.09	7.37	1,164	3.76	R	>5.0	0.01	98	8,500,000	192
	FE	9/19/06	8:45	"	---	73.0	0.4	7.7	1,164	3.77	44.3	>5.0	0.01	44	2,000,000	132
	STE	10/18/06	15:35	518	---	68.4	1.74	8.30	788	2.05	15.6	>5.0	0.01	49	860,000	57
	FE	10/18/06	15:45	"	---	67.6	0.0	7.76	864	2.110	15.5	0.60	13.9	7	460	6
	DDIU-1	10/18/06	16:00	"	---	62.2	5.9	6.75	567	0.299	19.9	0.18	18.4	7	7,200	3
	DDIU-2	10/18/06	16:15	"	---	60.4	5.4	7.1	566	0.338	15.2	0.16	11.2	9	1,700	3
	FE	11/20/06	6:30	288	1.45	58.1	5.0	7.7	942	1.88	19.7	0.17	15.5	2	7,820	3
	STE	11/20/06	6:50	"	1.45	57.8	0.3	7.2	1,091	3.31	13.5	>5.0	0.03	57	7,000,000	93
	DDIU-2	11/20/06	8:10	"	1.45	37.6	9.9	6.9	1,032	0.19	76	0.02	6.76	2	72	3
	DDID-1	11/20/06	7:45	"	1.45	38.3	7.8	7.8	586	0.09	19.2	0.04	14.9	5	45	3
	DDIU-1	11/20/06	8:00	"	1.45	39.0	11.5	6.8	579	0.15	18.8	0.02	14.9	10	99	3
	STE	12/11/06	8:22	249	0.43	49.4	0.4	7.4	625	1.84	9.2	>5.0	0.01	18	22,000	25
	FE	12/11/06	8:12	"	0.43	51.5	9.2	7.9	605	1.80	9.7	0.06	7.58	4	108	3
	DDID-1	12/11/06	8:15	"	0.43	---	---	---	---	---	---	>5.0	---	---	210	---
	DDIU-1	12/11/06	8:45	"	0.43	42.5	10.7	6.6	401	0.13	72	0.02	4.26	11	5	3
	DDIU-2	12/11/06	8:50	"	0.43	38.2	11.4	6.8	855	0.14	27	0.02	1.10	10	63	3
	DDID-2	12/11/06	8:35	"	0.43	44.2	12.1	6.7	620	0.08	15.3	0.07	12.0	---	5	3
	STE	1/30/07	14:15	351	0	45.7	0.5	7.08	637	1.33	11.6	>5.0	0.11	4	48,700	45
	FE	1/30/07	14:30	"	0	47.2	9.2	7.52	544	1.28	10.7	0.02	9.57	2	210	3
	DDIU-1	1/30/07	14:45	"	0	33.8	7.8	6.47	697	0.091	27.6	0.02	15.9	11	5	3
	DDIU-2	1/30/07	15:00	"	0	31.9	12.6	7.12	556	0.082	7.61	0.02	3.96	10	5	3
	FE	2/21/07	8:15	570	0.01	46.5	10.1	7.77	546	1.28	7.49	0.02	7.34	2	36	3
	STE	2/21/07	8:30	"	0.01	43.8	0.7	7.29	588	1.32	8.35	>5.0	0.08	12	7,030	23
	DDIU-2	2/21/07	8:45	"	0.01	34.7	13.3	7.40	458	0.070	4.19	0.02	4.26	4	5	3
	DDIU-1	2/21/07	8:40	"	0.01	37.8	9.9	6.62	1,099	0.085	61.2	0.02	23.31	5	5	3
	FE	3/21/07	10:00	441	2.56	59.6	1.5	7.67	834	2.13	19.91	>5.0	2.81	18	16,300	18
	STE	3/21/07	10:15	"	2.56	58.0	0.7	7.19	737	1.98	23.46	>5.0	0.10	32	126,000	81
	DDID-1	3/21/07	9:10	"	2.56	59.0	8.0	6.37	157	---	---	>5.0	---	---	27	19
	DDID-2	3/21/07	9:15	"	2.56	54.2	8.7	6.61	403	0.16	8.35	0.02	7.11	87	81	3
	DDIU-1	3/21/07	9:25	"	2.56	55.8	8.4	6.32	225	0.35	23.08	0.04	16.25	90	171	3
	DDIU-2	3/21/07	9:30	"	2.56	56.3	9.4	7.39	377	0.12	2.01	0.02	0.46	9	72	3
	FE	4/30/07	8:45	349	0.00	65.0	2.6	7.83	772	2.13	43.30	>5.0	3.99	2	7,730	3
	STE	4/30/07	9:00	"	0.00	65.28	0.42	7.32	972	2.58	21.6	>5.0	0.01	31	138000	139
	DDIU-2	4/30/07	9:15	"	0.00	58.46	8.04	7.58	596	0.11	37.5	0.02	0.01	2	27	3
	STE	5/31/07	8:20	744	0.44	72.27	0.12	7.40	1079	4.51	49.7	>5.0	0.03	43	242000	123
	FE	5/31/07	8:45	"	0.44	72.14	0.24	7.81	1241	2.77	68.2	>5.0	0.03	41	68000	83
	DDIU-2	5/31/07	9:00	"	0.44	67.15	4.48	6.82	491	0.15	10	0.13	0.12	5	36	3
	DDID-2	5/31/07	9:20	"	0.44	64.67	3.64	6.20	123	0.70	24	0.02	0.26	---	1530	9
	STE	6/25/07	7:50	1398	0.80	76.24	0.22	7.51	1206	2.91	34.4	>5.0	0.13	51	1,240,000	165
	FE	6/25/07	8:00	"	0.80	76.32	0.43	7.93	1245	3.21	33.5	>5.0	0.09	31	580,000	81
	DDIU-2	6/25/07	8:30	"	0.80	71.04	3.07	7.05	723	0.16	10	0.02	0.10	2	126	3
	DDID-1	6/25/07	8:40	"	0.80	70.47	---	7.24	---	1.87	12.5	0.02	9.98	199	991	---
	DDID-2	6/25/07	8:55	"	0.80	69.10	0.77	6.02	142	0.46	1.33	0.02	0.18	5	63	3
	STE	7/30/07	9:00	1131	0.62	77.90	0.86	6.98	1163	2.79	40.9	>5.0	0.01	67	1,040,000	287
	FE	7/30/07	8:45	"	0.62	79.34	1.01	7.62	1034	3.06	39.4	>5.0	0.01	38	60,000	129
	DDIU-1	7/30/07	9:20	"	0.62	75.38	0.47	6.63	361	0.56	3.97	0.02	0.47	15	21,000	11
	DDID-2	7/30/07	9:30	"	0.62	73.22	1.08	5.44	95	0.71	1.79	0.02	1.27	15	766	3

Site	System Type/Sample Location	Date	Time (24:00)	Average Daily Flow (gal/day)	Rainfall (Prev. 7 days) (in)	Sample Temperature °F	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (µS/cm)	Total Phophorus (mg/L)	Total Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate and Nitrite Nitrogen (mg/L)	Total Suspended Solids (mg/L)	Fecal Coliform (col./100mL)	5 Day Biochemical Oxygen Demand (mg/L)
Shell Knob Restaurant	FE	12/13/05	11:20	"		49.5	0.50	7.83	692	14.1	15.2	4.50	0.01	40	15,600	55
	STE	12/13/05	11:45	"		49.6	0.10	7.27	549	14.3	15.6	4.90	0.01	35	344,000	125
	FE	1/12/06	12:40	"	0.35	52.5	0.04	7.64	841	11.7	36.3	>5.0	0.01	105	6,260	84
	STE	1/12/06	13:30	"	0.35	---	---	---	---	12.1	45.1	>5.0	0.05	126	17,700	845
	DDID-1	1/12/06	13:50	"	0.35	51.4	9.71	7.34	580	0.356	55.7	0.15	26.9	2	27	3
	DDID-2	1/12/06	14:00	"	0.35	49.3	10.5	7.72	651	0.327	141.1	0.09	67.1	4	---	---
	FE	2/21/06	14:30	364	1.07	46.0	1.7	7.55	683	9.07	26.7	3.74	1.49	30	559	68
	STE	2/21/06	14:00	"	1.07	---	---	---	---	16.0	53.5	3.84	0.01	110	1,100	1120
	DDID-1	2/21/06	13:45	"	1.07	45.5	3.7	6.54	611	0.002	17.2	0.07	11.2	2	45	3
	DDID-2	2/21/06	13:50	"	1.07	35.4	12.5	7.44	383	0.269	38.7	0.60	29.9	2	5	21
	FE	3/15/06	13:00	295	3.53	57.0	1.8	7.08	542	4.77	5.40	2.98	0.01	20	3,000	59
	STE	3/15/06	13:30	"	3.53	---	---	---	---	6.64	17.1	4.50	0.01	109	12,600	502
	DDID-1	3/15/06	15:50	"	3.53	53.8	2.1	6.30	439	0.05	9.64	0.48	8.69	47	5	16
	DDID-2	3/15/06	13:45	"	3.53	54.1	5.3	7.15	783	1.16	25.1	0.20	20.9	2	5	39
	FE	4/11/06	9:05	1089	2.29	61.3	0.0	7.34	846	8.27	27.0	>5.0	0.108	23	180	19
	STE	4/11/06	9:35	"	2.29	---	---	---	---	10.30	19.8	>5.0	0.106	126	40,000	763
	DDID-1	4/11/06	9:51	"	2.29	60.1	3.6	6.89	364	0.09	8.0	0.34	7.00	52	5	3
	DDID-2	4/11/06	10:00	"	2.29	61.2	5.7	7.42	838	1.10	18.6	0.59	13.3	2	114	3
	STE	5/8/06	10:00	715	---	---	---	---	---	1.06	R	>5.0	0.01	126	336,000	488
	FE	5/8/06	9:15	"	---	66.2	0.01	7.54	569	0.66	9.94	>5.0	0.01	25	5,000	23
	DDID-1	5/8/06	10:15	"	---	64.9	1.9	7.06	---	0.02	1.51	0.02	0.73	2	18	3
	DDID-2	5/8/06	10:25	"	---	63.3	2.5	7.42	744	0.20	1.15	0.03	0.65	12	5	3
	DDIU-2	5/8/06	10:45	"	---	64.0	5.5	7.75	102	0.16	1.63	0.44	0.01	122	18	7
	STE	6/12/06	8:45	132	0.61	---	---	---	---	2.72	R	>5.0	0.26	71	126,000	765
	FE	6/12/06	8:15	"	0.61	74.3	0.8	6.48	1,220	1.51	5.81	>5.0	0.12	43	246,000	350
	DDID-1	6/12/06	9:15	"	0.61	75.0	2.7	6.74	350	0.05	0.84	0.02	0.58	13	5	3
	DDID-2	6/12/06	9:30	"	0.61	75.9	4.3	7.50	986	0.70	2.35	0.02	1.41	7	5	3
	STE	7/12/06	10:35	365	---	---	---	---	---	2.48	R	>5.0	0.05	61	500,000	547
	FE	7/12/06	10:15	"	---	77.18	0.02	6.77	552	1.44	34.80	>5.0	0.01	33	196,000	123
	STE	8/21/06	8:30	365	0.39	---	---	---	---	2.41	R	3.71	0.01	64	104,000	490
	FE	8/21/06	8:15	"	0.39	79.16	0.02	5.72	942	2.13	9.51	3.85	0.01	49	200,000	125
	DDID-1	8/21/06	8:45	"	0.39	81.32	2.59	5.82	147	0.35	2.94	0.02	0.85	12	5	3
	DDID-2	8/21/06	9:00	"	0.39	83.48	0.19	6.25	428	2.33	11.1	3.47	0.01	13	2,500	18
	FE	9/19/06	9:45	"	1.01	72.68	0.13	6.74	877	3.80	67.6	>5.0	0.01	2	75,000	60
	STE	9/19/06	10:00	595	1.01	---	---	---	---	3.74	R	>5.0	0.01	20	540,000	318
	DDID-2	9/19/06	9:30	"	1.01	68.00	1.08	7.26	781	1.49	4.07	3.21	2.52	2	100	7
	FE	10/18/06	20:35	"	1.93	65.7	0.19	6.98	812	2.14	15.40	>5.0	0.01	19	50,000	29
	STE	10/18/06	20:45	"	1.93	---	---	---	---	2.68	R	>5.0	0.01	35	188,000	230
	DDID-2	10/18/06	20:55	"	1.93	63.7	3.66	7.72	674	1.09	5.99	0.11	1.95	2	3,200	4
	DDID-1	10/18/06	21:00	301	1.93	63.1	5.88	7.64	544	0.78	15.8	1.56	9.65	17	2,900	6
	FE	11/20/06	9:00	236	1.28	56.3		6.94	939	3.53	17.1	>5.0	0.01	19	47,000	28
	STE	11/20/06	9:20	"	1.28	---	---	---	---	3.54	7.57	>5.0	0.06	69	11,800	298
	DDID-1	11/20/06	10:10	"	1.28	46.0		7.27	724	0.06	4.60	0.04	12.9	2	250	3
	DDID-2	11/20/06	9:40	"	1.28	44.5		7.19	927	0.02	19.2	0.04	2.59	2	153	3
	STE	12/11/06	10:15	370	0.12	---	---	---	---	3.44	11.2	>5.0	0.01	52	220,000	165
	FE	12/11/06	10:00	"	0.12	48.5	0.57	6.90	695	2.09	13.8	>5.0	0.01	16	43,000	21
	DDID-2	12/11/06	10:20	"	0.12	46.2	7.43	7.34	667	0.63	5.15	0.62	2.95	6	36	3
	DDID-1	12/11/06	10:30	"	0.12	45.3	4.52	6.74	754	0.07	12.2	0.02	8.35	2	18	3
	DDIU-1	12/11/06	10:45	"	0.12	45.5	11.66	7.29	133	0.16	5.97	0.83	2.48	5	5	3
	STE	1/30/07	12:30	398	0	---	---	---	---	1.94	2.69	4.88	0.10	32	270,000	230
	DDIU-1	1/30/07	12:55	"	0	37.7	11.24	6.97	95	0.337	5.00	1.74	1.15	18	5	3
	DDID-1	1/30/07	12:40	"	0	39.7	4.48	6.68	576	0.019	6.35	0.02	4.23	2	54	3
	DDID-2	1/30/07	12:45	"	0	38.9	9.99	6.86	627	0.966	8.62	2.20	3.44	4	11,300	8
	FE	2/21/07	10:00	398	0	42.0	0.88	6.89	692	2.86	15.8	>5.0	0.08	22	20,000	19
	STE	2/21/07	10:20	"	0	---	---	---	---	4.80	22.0	>5.0	0.07	20	24,000	209
	DDID-2	2/21/07	10:15	"	0	41.6	4.40	7.18	587	1.91	7.74	0.56	5.75	2	991	3
	DDID-1	2/21/07	10:25	"	0	41.4	11.01	7.24	559	0.05	9.42	0.02	6.16	11	5	3
	FE	3/21/07	12:05	374	0.9	57.1	1.31	6.92	824	3.03	15.26	>5.0	0.10	40	63,300	77
	STE	3/21/07	11:50	"	0.9	54.8	1.64	6.42	776	3.37	16.86	>5.0	0.10	41	90,900	254
	DDID-1	3/21/07	11:30	"	0.9	52.9	6.92	7.01	641	0.05	7.74	0.02	7.28	5	54	3
	DDID-2	3/21/07	11:40	"	0.9	53.2	6.10	7.54	701	1.10	4.23	2.35	0.84	10	11,200	10
	FE	4/30/07	10:40	512	1.08	57.5	0.71	6.95	828	2.86	46.01	>5.0	0.01	33	56,000	47
	STE	4/30/07	10:55	"	1.08	---	---	---	---	3.14	R	>5.0	0.01	45	160,000	343
	DDID-2	4/30/07	11:10	"	1.08	60.4	3.03	7.33	785	1.91	54.38	0.82	6.55	2	45	3
	STE	5/31/07	10:15	525	0.91	---	---	---	---	4.33	37.86	>5.0	0.01	87	1,610,000	360
	FE	5/31/07	10:30	"	0.91	65.9	0.32	6.89	875	3.61	31.93	>5.0	0.01	32	156,000	85
	DDID-2	5/31/07	10:45	"	0.91	67.7	3.35	7.28	795	2.34	8.26	4.53	0.81	9	6,210	3
	FE	6/25/07	10:10	718	0.48	70.8	0.46	6.96	941	3.03	24.39	>5.0	0.08	45	65,600	53
	STE	6/25/07	10:30	"	0.48	---	---	---	---	3.65	26.76	>5.0	0.09	76	360,000	268
	DDID-1	6/25/07	10:45	"	0.48	73.9	1.50	6.95	896	0.06	0.85	0.02	0.18	2	162	3
	DDID-2	6/25/07	11:00	"	0.48	72.8	2.89	7.23	890	1.45	10.56	>5.0	1.01	13	79,000	14
	FE	7/30/07	11:00	783	0.02	74.1	0.90	6.66	603	2.82	30.95	>5.0	0.01	37	550,000	95
	DDID-2	7/30/07	11:15	"	0.02	78.6	0.82	7.14	841	2.42	11.35	>5.0	3.31	19	7,820	11

Site	System Type/Sample Location	Date	Time (24:00)	Average Daily Flow (gal/day)	Rainfall (Prev. 7 days) (in)	Sample Temperature °F	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (µS/cm)	Total Phophorus (mg/L)	Total Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate and Nitrite Nitrogen (mg/L)	Total Suspended Solids (mg/L)	Fecal Coliform (col./100mL)	5 Day Biochemical Oxygen Demand (mg/L)
Lampe Resort	ZFE	8/3/05	13:30	----	------	------	1.80	7.49	2,176	5.70	---	4.40	1.08	13	66,000	34
	STE	8/3/05	13:50	"	------	82.8	0.59	6.80	1,526	8.69	---	4.57	0.49	143	---	413
	ZFE	11/9/05	10:00	119	------	60.4	3.75	7.60	1,595	5.84	---	0.93	22.4	2	70	15
	ZFE	11/9/05	10:00	"	------	60.4	3.75	7.60	1,595	5.98	---	0.90	21.7	2	50	16
	STE	11/9/05	10:30	"	------	61.2	0.02	7.72	1,984	8.52	---	>5.0	0.00	51	2,000	31
	ZFE	12/13/05	9:20	119	------	44.6	3.46	7.40	1,195	5.72	24.0	3.07	20.9	2	5	66
	STE	12/13/05	9:45	"	------	44.2	0.18	7.30	1,216	7.77	21.5	4.96	0.01	39	41,900	273
	ZFE	1/12/06	10:30	119	0.46	43.9	8.28	7.53	1,805	6.08	40.4	0.32	19.9	2	5	12
	STE	1/12/06	10:50	"	0.46	46.8	6.71	7.95	1,345	6.4	42.3	>5.0	R	7	2,000	220
	ZFE	2/21/06	12:00	119	0.05	40.1	7.67	7.64	1,158	4.79	35.5	0.12	21.4	4	5	3
	STE	2/21/06	12:30	"	0.05	42.1	0.33	7.94	1,525	6.86	35.4	3.90	0.0	32	3,200	16
	ZFE	3/15/06	11:25	119	3.67	50.7	5.70	7.09	1,489	5.43	26.0	0.42	16.5	9	6,180	97
	STE	3/15/06	11:15	"	3.67	53.6	0.00	7.47	---	4.80	18.0	4.61	0.01	21	103,000	253
	DDID-1	3/15/06	10:30	"	3.67	50.0	4.66	7.49	1,326	3.87	15.7	0.81	14.5	16	171	87
	DDIU-1	3/15/06	10:45	"	3.67	51.1	5.36	7.43	405	0.76	14.8	0.15	13.9	16	5	38
	ZFE	4/11/06	11:40	240	2.41	61.0	5.59	7.30	1,781	3.29	15.4	2.71	9.69	2	820	7
	STE	4/11/06	11:20	"	2.41	60.1	0.06	7.41	1,786	4.05	20.9	3.50	0.74	23	1,300,000	37
	DDID-1	4/11/06	12:30	"	2.41	67.6	8.26	7.61	1,860	1.84	20.1	0.02	9.16	57	54	3
	DDIU-1	4/11/06	12:40	"	2.41	65.5	7.71	7.73	394	0.12	10.2	0.02	8.78	35	5	3
	ZFE	5/8/06	11:45	240	2.41	68.4	2.30	7.56	1,560	0.55	16.4	>5.0	5.99	12	4,200	35
	STE	5/8/06	12:15	"	2.41	66.7	0.80	7.69	1,657	0.58	18.5	>5.0	0.01	45	43,000	93
	DDID-1	6/12/06	11:10	677	0.36	75.0	3.20	7.18	1,184	0.52	13.5	0.84	10.5	64	1,310	5
	DDIU-1	6/12/06	11:15	"	0.36	72.1	4.02	7.42	277	0.23	1.36	0.02	0.63	68	5	6
	ZFE	6/12/06	10:20	"	0.36	75.9	0.68	7.11	3,367	2.00	40.5	>5.0	0.121	57	898,000	89
	STE	6/12/06	10:45	"	0.36	74.7	0.63	6.34	3,360	1.69	53.2	>5.0	0.127	71	1,700,000	300
	ZFE	7/12/06	11:30	1353	------	75.6	3.69	6.82	1,263	0.91	22.1	4.94	0.9	16	26,900	20
	STE	7/12/06	11:50	"	------	71.1	0.30	6.86	1,207	0.95	28.4	>5.0	0.0	28	500,000	49
	DDID-1	7/12/06	12:45	"	------	84.2	11.30	6.35	2,023	0.51	5.80	2.92	0.8	12	5,900	46
	ZFE	8/21/06	11:30	1027	------	81.3	1.07	5.92	2,048	2.12	R	>5.0	9.9	8	15,700	16
	STE	8/21/06	11:45	"	0.11	81.3	0.05	5.70	2,024	2.08	R	>5.0	0.0	45	369,000	45
	DDID-1-A	8/21/06	11:00	"	0.11	79.3	0.84	5.74	998	1.49	R	>5.0	11.6	2	2,800	18
	DDID-1-B	8/21/06	10:45	"	0.11	81.3	1.58	5.90	2,147	0.28	10.60	4.98	3.6	21	1,730	11
	ZFE	9/19/06	12:15	655	------	68.4	4.34	7.54	1,576	2.04	58.0	>5.0	11.6	13	6,100	8
	STE	9/19/06	12:30	"	------	70.5	0.99	7.35	1,675	2.62	38.2	>5.0	5.9	28	40,000	16
	DDID-1	9/19/06	13:45	"	------	79.7	1.73	5.81	1,934	1.13	30.2	0.52	9.7	5	200	3
	DDID-1	10/18/06	20:50	376	2.21	63.3	6.22	7.58	1,439	1.49	15.50	0.12	12.8	21	8,000	1
	DDIU-1	10/18/06	21:00	"	2.21	64.0	5.74	7.82	206	0.18	2.50	0.16	0.59	45	155	1
	ZFE	10/18/06	20:00	"	2.21	63.7	4.64	7.68	1,620	2.19	9.61	>5.0	13.00	5	5,900	6
	STE	10/18/06	20:20	"	2.21	63.3	0.74	7.47	1,691	1.95	12.60	>5.0	6.58	21	287,000	30
	STE	11/20/06	11:00	325	1.61	50.1	2.02	7.33	1,987	3.42	19.20	>5.0	5.90	13	4,800	13
	ZFE	11/20/06	11:20	"	1.61	45.4	9.51	7.56	1,929	3.07	19.56	>5.0	14.6	5	991	11
	DDIU-1	11/20/06	10:30	"	1.61	43.6	11.50	7.64	302	0.04	2.07	0.02	0.83	2	5	3
	DDID-1	11/20/06	10:45	"	1.61	45.8	11.52	7.67	1,592	1.21	14.20	0.14	13.20	2	5	3
	ZFE	12/11/06	11:30	189	0.59	43.3	11.02	7.63	1,803	2.82	15.50	>5.0	10.30	9	19,000	17
	STE	12/11/06	11:45	"	0.59	43.5	4.09	7.41	1,773	2.87	15.7	>5.0	4.74	13	53,000	14
	DDID-1	12/11/06	12:00	"	0.59	46.9	12.73	7.71	221	0.09	0.5	0.05	0.18	21	5	3
	DDIU-1	12/11/06	11:50	"	0.59	45.5	7.51	7.50	1,344	1.10	10.7	0.14	6.94	2	5	3
	ZFE	1/30/07	10:30	160	0	37.2	10.32	7.44	1,489	2.20	26.5	>5.0	11.6	8	11,000	25
	STE	1/30/07	10:45	"	0	39.5	2.09	7.35	1,553	2.17	24.1	>5.0	4.83	7	43,000	20
	DDID-1	1/30/07	10:15	"	0	37.2	11.98	7.76	1,210	0.972	16.0	1.44	10.68	9	5	3
	ZFE	2/21/07	11:45	140	0	42.5	9.63	7.42	1,484	3.20	23.2	>5.0	9.28	14	25,000	50
	STE	2/21/07	11:50	"	0	41.6	0.98	7.27	1,497	3.37	20.9	>5.0	0.58	32	114,000	35
	DDID-1	2/21/07	11:35	"	0	43.6	11.01	7.25	1,015	1.02	10.8	0.02	0.52	7	27	3
	DDIU-1	2/21/07	11:30	"	0	44.5	11.95	7.48	151	0.125	2.80	0.02	1.28	9	5	3
	ZFE	3/21/07	13:25	245	0.16	55.2	7.04	7.62	2,125	2.53	19.56	>5.0	9.36	9	2,900	11
	STE	3/21/07	13:35	"	0.16	54.0	1.79	7.52	2,103	2.86	20.68	>5.0	0.39	31	54,000	31
	DDID-1	3/21/07	13:10	"	0.16	56.5	9.70	7.58	1,916	1.23	6.50	0.17	3.58	244	5	3
	DDIU-1	3/21/07	12:55	"	0.16	57.3	9.61	7.51	180	0.19	1.47	0.13	0.37	34	18	3
	ZFE	4/30/07	12:45	280	---	64.7	6.42	7.80	1,296	2.57	63.45	>5.0	6.46	6	10,400	8
	STE	4/30/07	13:00	"	---	63.3	2.03	7.56	1,366	2.61	23.15	>5.0	0.71	33	600,000	36
	DDIU-1	4/30/07	12:25	"	---	62.2	6.94	7.59	295	0.19	37.03	1.25	0.20	19	5	3
	DDID-1	4/30/07	12:35	"	---	61.3	6.86	7.52	798	1.26	44.82	0.72	1.12	14	510	3
	ZFE	4/30/07	12:45	"	---	---	---	---	---	2.55	59.38	>5.0	6.02	13	11,700	9
	ZFE	5/31/07	12:00	400	---	69.5	5.30	7.67	1825	2.71	47.65	>5.0	17.35	4	17,900	14
	STE	5/31/07	12:15	"	---	69.1	1.67	7.55	1871	3.04	45.64	>5.0	8.49	16	330,000	26
	STE	5/31/07	12:15	"	---	---	---	---	---	3.10	41.10	>5.0	8.48	17	230,000	22
	ZFE	6/25/07	12:15	921	0.57	76.0	5.89	7.55	1778	2.61	28.75	>5.0	19.54	7	104,000	33
	STE	6/25/07	12:30	"	0.57	75.4	0.50	7.49	1850	3.24	31.03	>5.0	9.95	27	1,230,000	30
	ZFE	7/30/07	12:45	1177	0.94	81.5	1.44	7.08	1364	2.99	31.21	>5.0	12.70	25	248,000	26
	STE	7/30/07	13:00	"	0.94	78.6	0.40	7.29	1465	2.80	30.68	>5.0	0.01	69	2,160,000	73

Site	System Type/Sample Location	Date	Time (24:00)	Average Daily Flow (gal/day)	Rainfall (Prev. 7 days) (in)	Sample Temperature °F	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (µS/cm)	Total Phophorus (mg/L)	Total Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate and Nitrite Nitrogen (mg/L)	Total Suspended Solids (mg/L)	Fecal Coliform (col./100mL)	5 Day Biochemical Oxygen Demand (mg/L)
Kimberling City Residence	RFE	6/6/05	11:50	------	------	------	1.01	R	---	4.45	3.0	0.19	0.8	16	81	18
	RFE	7/7/05	12:00	------	------	------	1.05	7.98	R	2.92	15.1	4.58	3.5	148	260,000	326
	RFE	11/9/05	14:10	------	------	65.1	0.72	7.87	2,142	7.07	---	0.18	14.3	17	270	14
	RFE	12/12/05	15:30	------	------	54.7	5.49	8.23	1,541	8.07	36.4	0.96	32.9	25	3,400	76
	RFE	1/12/06	8:22	------	0.29	56.3	7.23	7.71	1,597	7.54	33.5	1.28	11.4	16	3,300	220
	RFE	2/21/06	9:30	------	0.43	52.3	8.23	7.73	1,483	5.81	46.2	1.16	22.0	21	219,000	118
	RFE	3/15/06	8:40	------	5.17	57.4	1.72	7.48	1,558	7.51	41.3	0.64	18.2	95	1,610	66
	GDP2 & GDP3	3/15/06	9:00	------	5.17	52.9	2.21	7.64	1,660	3.92	46.3	1.95	14.6	942	36	220
	RFE	4/11/06	13:30	------	0.54	59.4	13.80	7.93	1,593	3.84	18.3	0.02	9.9	24	162	15
	RFE	5/8/06	14:00	------	2.32	72.9	1.31	8.02	2,400	0.87	23.9	1.20	13.0	49	5,000	73
	GDP1 & GDP3	5/8/06	14:15	------	2.32	70.9	2.28	7.46	748	0.63	5.68	3.11	4.59	1254	45	53
	RFE	6/12/06	12:45	------	0.2	75.7	2.22	7.82	2,410	2.33	21.8	4.32	8.5	45	1,000,000	118
	RFE	7/12/06	14:00	128	---	77.0	0.94	7.50	1,628	2.46	49.2	0.30	17.0	132	16,400	21
	RFE	8/21/06	13:13	105	---	78.6	2.73	5.55	1,131	1.88	13.2	0.11	11.1	19	229	12
	RFE	9/19/06	14:45	95	0.98	74.1	0.84	7.68	2,168	3.59	47.9	0.20	13.1	106	7,600	28
	RFE	10/18/06	17:45	58	2.01	67.5	6.34	8.08	2,010	1.95	15.7	0.42	12.6	22	270,000	44
	RFE	11/20/06	13:15	22	---	54.8	9.93	8.26	2,018	2.99	14.3	0.04	11.9	2	378	3
	RFE	12/11/06	13:30	40	0.59	54.1	8.99	7.94	1,760	2.96	15.7	>5.0	9.1	11	41,000	19
	RFE	1/30/07	8:45	94	0	51.6	8.42	7.65	2,024	2.08	31.0	1.67	16.7	22	55,000	3
	RFE	2/21/07	13:15	120	0	52.4	8.71	7.72	2,696	2.92	23.7	0.31	14.9	2	7,910	3
	RFE	3/21/07	14:45	120	0.19	58.7	3.38	7.82	1,860	1.49	15.31	1.23	10.98	9	45,000	24
	RFE	3/21/07	14:45	"	1.3	58.7	3.38	7.82	1,860	2.68	12.84	1.22	10.90	9	48,000	26
	RFE	4/30/07	15:00	120	1.51	63.0	3.65	7.62	2,288	2.63	58.86	0.02	4.02	17	440	5
	RFE	5/31/07	14:00	120	0.83	70.1	0.44	7.92	2,251	2.73	20.92	0.21	12.12	16	4,300	13
	RFE	6/25/07	13:55	120	1.49	76.0	5.31	8.22	2,120	2.74	18.62	>5.0	11.80	10	79,000	13
	RFE	6/25/07	13:55	"	1.49	76.0	5.31	8.22	2,120	2.32	16.24	>5.0	11.83	16	45,000	17
	RFE	7/30/07	14:45	120	1.2	78.8	3.28	8.05	2,238	2.54	9.62	0.02	7.72	16	21,100	15

Data Table Legend

Monitoring System Type/Sample Location	
STE	Septic Tank Effluent
FE	FAST System Effluent
RFE	RetroFAST System Effluent
ZFE	Zabel SCAT Filter Effluent
DDID-(1 or 2)	Drip Dispersal Field Subsurface Monitor 1 denotes half-pipe lysimeter 2 denotes sheet lysimeter
DDIU-(1 or 2)	Control Subsurface Monitor 1 denotes half-pipe lysimeter 2 denotes sheet lysimeter
GDP	Gravity Dispersal Piezometer
---	No Data Available
R	Rejected Value

Shell Knob Restaurant N-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Aug-06	Influent	86.40	52.00	7.14	7.26	77.94	0.25	N/A	
	Wetlands Effluent	1.77	4.00	7.26	5.22	3.16	0.25		
	RSF Effluent	2.67	3.40	8.18	4.3	0.25	1.5		
	Final Effluent	1.15	4.65	8.21	1.85	0.19	2.00		78
Jul-06	Influent	194.40	96.00	6.96	6.84	56.18	0.25	N/A	
	Wetlands Effluent	4.59	1.40	7.14	3.91	4.93	0.50		
	RSF Effluent	2.22	0.60	7.72	2.18	0.47	2.00		
	Final Effluent	2.49	17.30	7.17	1.41	0.82	2.00		194
Jun-06	Influent	142.20	88.00	6.94	5.37	89.98	0.25	N/A	
	Wetlands Effluent	3.66	8.00	7.05	3.76	2.55	2.00		
	RSF Effluent	13.53	68.00	7.04	3.38	0.35	2.00		
	Final Effluent	2.67	14.50	7.65	2.01	0.53	3.00		446
May-06	Influent	66.60	124.00	7.00	10.40	47.64	0.25	N/A	
	Wetlands Effluent	3.75	0.60	7.03	4.00	0.81	0.25		
	RSF Effluent	0.81	1.20	7.57	3.76	0.15	0.50		
	Final Effluent	1.20	13.00	7.67	3.24	0.68	2.00		244
Apr-06	Influent	105.60	28.00	7.15	10.84	69.48	0.25	N/A	
	Wetlands Effluent	3.12	11.00	6.96	6.04	1.07	0.50		
	RSF Effluent	2.73	0.40	7.88	3.60	0.15	0.25		
	Final Effluent	1.74	18.10	6.89	1.86	0.16	1.00		323
Mar-06	Influent	141.00	72.00	6.94	8.60	32.04	0.25	N/A	
	Wetlands Effluent	2.58	4.00	7.28	4.47	1.25	0.25		
	RSF Effluent	1.41	1.80	7.97	3.39	0.32	1.50		
	Final Effluent	0.60	5.86	7.36	0.57	0.24	1.50		
Jan-06	Influent	178.20	52.00	7.07	7.64	50.58	0.25	N/A	
	Wetlands Effluent	1.59	1.20	7.43	3.36	1.39	2.50		
	RSF Effluent	0.87	0.60	8.06	4.23	0.14	1.25		
	Final Effluent	1.23	2.45	8.14	0.65	0.23	1.00		0
Dec-05	Influent	163.20	44.00	7.15	6.56	61.02	0.25	N/A	
	Wetlands Effluent	1.71	0.20	7.52	3.69	1.70	3.00		
	RSF Effluent	0.78	0.80	8.45	3.69	0.08	1.50		
	Final Effluent	0.67	8.20	8.42	1.55	0.01	0.50		82

Shell Knob Restaurant N-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Nov-05	Influent	55.20	32.00	7.12	6.48	50.58	0.25		
	Wetlands Effluent	1.59	1.30	7.32	3.92	1.00	0.25	N/A	
	RSF Effluent	0.99	1.40	8.17	3.78	0.10	0.50		
	Final Effluent	1.59	4.60	7.38	1.12	0.01	1.00		68
Oct-05	Influent	141.60	44.00	7.02	6.45	62.10	0.25		
	Wetlands Effluent	0.57	4.20	7.38	3.96	0.58	0.50	N/A	
	RSF Effluent	0.69	1.60	7.58	4.44	0.04	1.50		
	Final Effluent	1.90	5.00	7.80	3.75	0.06	1.50		24
Sep-05	Influent	163.80	104.00	7.06	7.08	76.90	0.25		
	Wetlands Effluent	2.22	3.15	7.19	4.32	1.52	1.50	N/A	
	RSF Effluent	3.39	1.75	8.20	3.72	0.17	1.00		
	Final Effluent	3.36	2.80	7.97	3.15	0.08	2.00		75
Aug-05	Influent	232.20	108.00	6.94	7.50	55.90	0.25		
	Wetlands Effluent	7.83	1.00	7.21	4.71	3.03	3.00	N/A	
	RSF Effluent	2.28	1.05	7.95	4.74	0.11	4.00		
	Final Effluent	0.87	2.15	7.58	4.47	0.13	5.00		526
Jul-05	Influent	232.80	38.00	6.82	4.26	37.80	0.25		
	Wetlands Effluent	3.10	5.30	6.92	4.01	2.36	1.00	N/A	
	RSF Effluent	0.15	1.50	7.73	3.94	1.18	3.00		
	Final Effluent	2.85	2.40	7.94	3.18	0.11	5.00		138
Jun-05	Influent	178.88	20.00	6.76	6.80	52.10	0.25		
	Wetlands Effluent	4.04	1.20	7.05	4.40	4.80	0.50	N/A	
	RSF Effluent	1.76	1.50	7.94	4.20	3.60	2.00		
	Final Effluent	1.55	15.20	8.03	3.90	0.11	3.00		140
May-05	Influent	202.75	50.00	6.81	4.15	56.60	0.25		
	Wetlands Effluent	1.51	3.10	7.16	3.42	1.96	1.00	N/A	
	RSF Effluent	2.28	0.70	7.98	3.20	0.26	1.00		
	Final Effluent	2.51	12.20	7.88	3.04	0.26	2.50		271
Apr-05	Influent	170.79	46.00	6.82	4.59	35.20	0.25		
	Wetlands Effluent	5.01	0.25	7.20	1.84	1.52	1.00	N/A	
	RSF Effluent	3.74	0.85	7.11	1.18	0.26	1.50		
	Final Effluent	0.66	0.55	7.15	1.52	0.09	3.00		135

Shell Knob Restaurant N-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Mar-05	Influent	295.34	38.00	6.72	4.59	48.10	0.25		
	Wetlands Effluent	4.46	0.30	7.44	0.86	0.44	1.50	N/A	
	RSF Effluent	1.56	0.30	7.18	0.73	0.02	1.50		
	Final Effluent	4.23	4.35	7.15	0.32	0.21	3.00		151
Feb-05	Influent	222.65	22.00	7.36	4.96	23.20	0.25		
	Wetlands Effluent	1.14	0.10	7.51	1.14	10.40	0.50	N/A	
	RSF Effluent	2.35	0.25	7.64	0.89	3.27	1.00		
	Final Effluent	3.03	17.20	7.34	0.40	0.19	1.00		1249
Jan-05	Influent	158.14	24.00	7.21	4.76	29.60	0.25		
	Wetlands Effluent	2.75	1.50	7.34	1.70	1.29	1.00	N/A	
	RSF Effluent	1.53	0.40	7.36	0.73	0.08	1.50		
	Final Effluent	2.59	5.25	7.49	0.65	0.16	1.50		
Dec-04	Influent	78.91	28.00	7.61	4.18	36.40	0.25		
	Wetlands Effluent	2.54	0.30	7.66	1.65	0.08	0.75	N/A	
	RSF Effluent	1.59	0.10	7.84	0.72	0.04	0.50		
	Final Effluent	0.94	0.35	7.69	0.32	0.01	0.50		
Nov-04	Influent	191.41	20.00	6.95	5.31	64.00	0.25		
	Wetlands Effluent	1.51	0.60	7.32	1.59	0.40	0.25	N/A	
	RSF Effluent	1.14	0.80	7.75	0.92	0.08	0.75		
	Final Effluent	1.17	5.25	7.48	0.36	0.02	1.00		
Oct-04	Influent	216.00	52.00	6.86	7.50	48.60	0.25		
	Wetlands Effluent	1.59	1.00	7.33	2.36	0.84	0.50	<1	
	RSF Effluent	1.51	0.70	7.78	2.70	0.13	1.00		
	Final Effluent	0.51	4.50	7.48	2.20	0.08	1.00		150
Sep-04	Influent	231.59	12.00	6.73	3.12	49.50	0.25		
	Wetlands Effluent	2.34	0.85	7.10	2.89	1.05	0.50	<1	
	RSF Effluent	0.72	0.50	7.85	3.81	1.13	1.50		
	Final Effluent	0.84	2.05	7.63	1.71	0.31	1.50		741
Aug-04	Influent	357.85	50.00	6.53	4.80	71.50	0.25		
	Wetlands Effluent	3.68	0.80	6.95	3.30	2.24	1.50	<1	
	RSF Effluent	0.74	1.20	7.77	2.94	0.40	3.00		
	Final Effluent	0.93	13.45	7.24	1.04	0.61	4.00		927

Shell Knob Restaurant N-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Jul-04	Influent	364.29	98.00	6.68	8.33	99.70	0.25		
	Wetlands Effluent	1.80	0.70	7.32	2.40	1.02	1.50	<1	
	RSF Effluent	1.24	1.00	7.90	2.80	0.66	3.00		
	Final Effluent	0.66	6.20	7.76	1.59	0.16	3.00		926
Jun-04	Influent	278.41	76.00	6.51	7.04	37.50	0.25		
	Wetlands Effluent	2.42	1.00	7.16	2.10	1.44	0.75	<1	
	RSF Effluent	1.83	1.80	7.78	1.89	0.41	1.50		
	Final Effluent	1.40	7.15	7.70	0.97	0.50	1.50		1584
May-04	Influent	188.04	40.00	6.85	2.88	17.70	0.25		
	Wetlands Effluent	7.50	0.75	7.14	1.90	1.46	1.00	<1	
	RSF Effluent	1.21	1.55	7.62	1.63	0.51	3.00		
	Final Effluent	1.14	5.60	7.72	0.96	0.37	3.00		1085
Apr-04	Influent	217.18	18.00	6.58	2.94	5.85	0.25		
	Wetlands Effluent	2.98	0.10	7.14	1.81	0.31	1.00	4	
	RSF Effluent	0.84	0.90	7.30	1.75	0.21	3.00		
	Final Effluent	1.38	7.50	7.12	0.99	0.43	3.00		2015
Mar-04	Influent	167.04	36.00	6.94	4.12	18.15	0.25		
	Wetlands Effluent	3.76	0.20	7.55	0.99	0.46	1.50	N/A	
	RSF Effluent	3.23	2.05	7.79	0.82	0.33	1.50		
	Final Effluent	0.51	9.32	7.72	0.65	0.12	1.50		660
Feb-04	Influent	93.48	20.00	7.17	1.85	4.00	0.75		
	Wetlands Effluent	3.80	0.55	7.52	1.52	1.06	2.00	N/A	
	RSF Effluent	1.35	0.45	7.55	1.25	0.35	3.00		
	Final Effluent	2.10	12.80	7.20	0.88	0.47	3.00		959
Jan-04	Influent	121.18	50.00	6.86	2.64	16.60	0.25		
	Wetlands Effluent	4.08	0.75	7.28	1.57	1.07	3.00	N/A	
	RSF Effluent	3.92	0.60	7.18	1.22	0.25	3.00		
	Final Effluent	0.93	15.20	6.91	0.42	0.17	3.00		
Dec-03	Influent	166.45	14.00	7.01	1.98	12.96	0.25		
	Wetlands Effluent	4.11	0.55	7.66	1.30	0.28	2.00	N/A	
	RSF Effluent	3.44	0.25	7.73	1.07	0.28	2.50		
	Final Effluent	4.38	27.63	7.37	0.44	0.47	2.50		

Shell Knob Restaurant N-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Nov-03	Influent	137.52	16.00	7.29	3.03	19.25	0.25		
	Wetlands Effluent	2.39	0.20	7.87	1.45	0.63	1.50	<1	
	RSF Effluent	2.81	1.70	8.06	1.37	0.21	2.00		
	Final Effluent	0.91	2.95	7.85	0.42	0.20	2.00		
Oct-03	Influent	279.32	41.00	7.08	3.40	32.64	0.25		
	Wetlands Effluent	5.01	0.87	7.73	3.00	1.35	0.25	<1	
	RSF Effluent	1.23	1.74	7.79	1.54	0.17	2.00		
	Final Effluent	1.75	5.30	7.51	0.38	0.15	2.00		
Sep-03	Influent	241.45	22.00	7.07	4.56	18.15	0.25		
	Wetlands Effluent	2.70	0.70	7.01	1.49	1.07	0.50	<1	
	RSF Effluent	2.20	1.25	6.72	1.04	1.22	1.00		
	Final Effluent	1.75	2.05	6.16	0.44	0.88	1.00		

Shell Knob Subdivision-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH_3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Aug-06	Influent	97.20	120.00	7.50	9.80	83.72	0.25	N/A	
	Wetlands Effluent	2.64	1.80	7.24	2.61	2.66	0.25		
	RSF Effluent	1.26	1.40	7.22	0.08	0.25	3.00		
	Final Effluent	0.56	7.05	7.21	0.40	0.09	4.00		
Jul-06	Influent	120.00	108.00	7.49	5.24	32.18	0.25	N/A	
	Wetlands Effluent	3.93	7.00	7.08	2.51	4.20	0.50		
	RSF Effluent	3.42	9.00	6.86	0.89	0.51	2.00		
	Final Effluent	0.99	3.60	7.29	0.42	0.65	3.00		
Jun-06	Influent	118.80	96.00	7.28	6.96	72.18	0.25	N/A	
	Wetlands Effluent	4.92	6.40	7.06	2.41	3.01	0.25		
	RSF Effluent	1.47	1.60	6.24	0.67	0.38	3.00		
	Final Effluent	1.08	1.35	7.49	0.50	0.48	5.00		
May-06	Influent	52.20	96.00	7.25	4.92	26.28	0.25	N/A	
	Wetlands Effluent	2.58	10.00	6.90	3.33	3.10	0.25		
	RSF Effluent	0.96	29.00	6.59	3.15	1.61	3.00		
	Final Effluent	1.14	14.90	7.30	0.38	1.44	2.00		
Apr-06	Influent	133.80	52.00	7.32	6.85	68.76	0.25	<1	
	Wetlands Effluent	4.50	1.00	7.06	3.27	8.04	0.50		
	RSF Effluent	2.04	15.00	5.96	0.28	3.07	5.00		
	Final Effluent	2.43	9.78	6.54	0.41	3.25	5.00		
Mar-06	Influent	243.00	132.00	6.76	8.12	62.82	0.25	N/A	
	Wetlands Effluent	10.30	16.50	7.12	4.18	10.96	0.50		
	RSF Effluent	6.27	6.50	6.59	0.65	9.57	3.00		
	Final Effluent	5.12	2.60	6.85	0.39	9.57	4.00		
Feb-06	Influent	169.80	26.00	7.14	6.18	56.18	0.25	N/A	
	Wetlands Effluent								
	RSF Effluent								
	Final Effluent								
Jan-06	Influent	142.20	44.00	6.90	7.95	61.02	0.30	N/A	
	Wetlands Effluent	7.92	2.40	7.08	2.92	8.28	1.00		
	RSF Effluent	6.57	15.80	6.77	0.76	1.02	3.00		
	Final Effluent	1.16	9.50	6.92	0.46	1.34	3.00		

Shell Knob Subdivision-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH_3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Dec-05	Influent	135.00	52.00	7.31	6.65	53.46	0.25	N/A	
	Wetlands Effluent	5.97	1.10	7.07	2.82	8.25	0.75		
	RSF Effluent	3.36	0.80	6.94	0.14	1.24	3.00		
	Final Effluent	1.35	2.20	7.18	0.22	1.14	3.00		
Nov-05	Influent	102.00	48.00	7.43	6.95	62.10	0.25	N/A	
	Wetlands Effluent	2.28	1.80	7.04	2.17	4.43	0.25		
	RSF Effluent	0.99	3.60	6.81	0.13	0.32	3.00		
	Final Effluent	1.79	5.85	7.11	0.28	0.46	5.00		
Oct-05	Influent	107.40	52.00	7.36	5.18	57.41	0.25	<1	
	Wetlands Effluent	6.99	21.40	7.31	3.69	4.90	0.25		
	RSF Effluent	3.99	6.90	7.07	0.38	0.73	1.50		
	Final Effluent	1.02	5.80	7.32	0.42	0.68	5.00		
Sep-05	Influent	112.20	32.00	7.25	4.80	67.14	0.25	30	
	Wetlands Effluent	9.87	15.30	7.14	0.68	4.81	1.00		
	RSF Effluent	1.35	2.45	7.20	0.26	0.23	3.00		
	Final Effluent	0.70	3.75	7.40	0.14	0.29	3.00		
Aug-05	Influent	72.11	144.00	7.15	4.24	44.64	0.25	94	
	Wetlands Effluent	3.65	8.10	7.01	1.80	2.51	0.25		
	RSF Effluent	5.78	10.10	7.14	1.37	0.31	0.50		
	Final Effluent	3.57	3.10	7.38	0.43	0.30	1.50		
Jul-05	Influent	169.80	26.00	7.14	6.18	56.18	0.25	<1	
	Wetlands Effluent	3.05	6.70	6.94	2.19	5.14	0.25		
	RSF Effluent	0.29	3.90	7.02	1.46	3.27	1.50		
	Final Effluent	0.82	4.90	7.38	0.36	2.19	3.00		
Jun-05	Influent	141.90	94.00	7.18	4.25	72.72	0.25	99	
	Wetlands Effluent	6.12	4.90	6.90	2.94	6.56	0.25		
	RSF Effluent	3.33	3.90	7.07	2.37	3.45	1.00		
	Final Effluent	7.68	4.00	7.32	0.31	2.51	2.00		
May-05	Influent	122.70	72.00	7.05	3.76	44.19	0.25	4	
	Wetlands Effluent	9.39	14.50	7.04	1.18	5.18	1.50		
	RSF Effluent	6.70	4.20	7.12	0.76	4.96	3.00		
	Final Effluent	6.93	2.70	7.46	0.41	2.18	4.00		

Shell Knob Subdivision-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH_3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Apr-05	Influent	144.00	88.00	7.10	6.18	41.46	0.25	<1	
	Wetlands Effluent	5.28	5.40	7.04	3.56	1.41	0.25		
	RSF Effluent	3.16	1.30	7.06	3.26	5.30	1.50		
	Final Effluent	6.27	1.40	7.34	0.36	3.65	2.00		
Mar-05	Influent	147.40	44.00	7.20	4.96	24.18	0.25	N/A	
	Wetlands Effluent	9.58	7.80	7.29	2.67	12.40	1.00		
	RSF Effluent	3.71	1.80	7.29	1.51	6.19	3.00		
	Final Effluent	3.10	1.00	7.54	0.46	4.38	3.00		
Feb-05	Influent	151.50	106.00	7.28	5.12	43.12	0.25	N/A	
	Wetlands Effluent	11.38	9.65	7.37	0.82	5.19	1.00		
	RSF Effluent	2.25	7.50	7.01	0.56	3.18	4.00		
	Final Effluent	3.62	3.60	7.48	0.31	3.13	6.00		
Jan-05	Influent	79.20	120.00	7.30	6.14	38.17	0.25	N/A	
	Wetlands Effluent	7.13	2.00	7.53	0.86	2.91	0.25		
	RSF Effluent	5.01	11.90	7.45	0.53	2.61	1.00		
	Final Effluent	0.87	2.75	7.38	0.47	1.41	1.50		
Dec-04	Influent	144.00	134.00	7.32	4.28	45.18	0.25	N/A	
	Wetlands Effluent	7.41	8.70	7.29	0.96	3.19	0.25		
	RSF Effluent	4.98	1.80	7.33	0.41	1.79	1.50		
	Final Effluent	9.35	0.70	7.50	0.43	1.31	2.50		
Nov-04	Influent	133.85	34.00	7.16	5.44	13.32	0.50	N/A	
	Wetlands Effluent	4.22	5.20	7.25	2.65	4.92	0.50		
	RSF Effluent	2.82	3.75	7.28	1.60	2.37	1.50		
	Final Effluent	8.74	3.30	7.46	0.43	2.11	2.50		
Oct-04	Influent	128.95	28.00	7.08	4.80	68.32	0.25	<1	
	Wetlands Effluent	3.79	4.00	7.41	2.56	4.65	0.25		
	RSF Effluent	3.55	1.20	7.38	1.03	1.40	1.00		
	Final Effluent	2.67	0.70	7.77	0.38	0.84	2.00		
Sep-04	Influent	121.27	114.00	7.11	4.50	72.16	0.25	21	
	Wetlands Effluent	2.82	9.53	6.99	1.81	3.24	0.25		
	RSF Effluent	2.05	2.50	7.13	0.83	0.71	1.50		
	Final Effluent	2.95	2.95	7.28	0.44	0.33	1.50		982

Shell Knob Subdivision-Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH_3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Jul-04	Influent	84.48	92.00	7.31	4.35	69.93	0.25		
	Wetlands Effluent	6.66	2.66	7.23	2.04	3.65	0.50		
	RSF Effluent	5.22	6.80	7.07	0.60	1.19	2.00		
	Final Effluent	3.30	5.25	7.20	0.30	0.57	3.00		1444
Jun-04	Influent	143.20	26.00	7.29	4.15	67.50	0.25		
	Wetlands Effluent	13.34	5.70	7.13	2.07	4.04	0.25	270	
	RSF Effluent	4.61	1.70	7.35	0.96	0.76	1.50		
	Final Effluent	4.77	6.50	7.59	0.47	0.57	3.00		1019
May-04	Influent	181.23	84.00	7.28	4.84	71.68	0.25		
	Wetlands Effluent	5.20	5.70	6.99	1.79	3.52	0.50	<1	
	RSF Effluent	4.80	4.20	7.16	1.05	1.77	3.00		
	Final Effluent	5.82	0.10	7.27	0.37	0.74	5.00		907
Apr-04	Influent	212.68	62.00	7.17	5.30	48.96	0.25		
	Wetlands Effluent	9.90	21.40	7.22	2.84	3.18	2.00	<1	
	RSF Effluent	4.54	5.60	7.26	1.83	2.64	3.00		
	Final Effluent	1.40	2.65	7.35	0.36	2.58	5.00		1898
Mar-04	Influent	203.26	56.00	7.34	4.30	48.96	0.25		
	Wetlands Effluent	11.81	2.00	7.29	2.88	7.95	1.50	N/A	
	RSF Effluent	5.28	3.10	7.28	2.05	6.24	4.00		
	Final Effluent	7.55	3.30	7.32	0.37	3.24	5.00		2703
Feb-04	Influent	140.20	18.00	7.52	5.08	41.86	0.25		
	Wetlands Effluent	16.05	1.40	7.52	2.94	10.35	1.00	N/A	
	RSF Effluent	6.12	1.90	7.48	2.41	8.20	3.00		
	Final Effluent	5.59	2.36	7.52	0.41	7.50	3.00		781
Jan-04	Influent	126.67	46.00	7.46	4.38	38.88	0.50		
	Wetlands Effluent	8.20	1.10	7.41	2.28	9.48	0.50	N/A	
	RSF Effluent	4.23	1.50	7.39	1.27	6.35	3.00		
	Final Effluent	12.70	1.00	7.40	0.42	6.21	4.00		2470
Dec-03	Influent	168.16	22.00	7.57	4.80	45.92	0.25		
	Wetlands Effluent	7.92	2.00	7.36	1.92	5.46	1.50	N/A	
	RSF Effluent	5.37	1.35	7.30	1.28	4.16	3.00		
	Final Effluent	8.20	1.05	7.27	0.41	2.64	5.00		2091

Shell Knob Subdivision-Wetlands Monitoring Data provided by White River Valley Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH_3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
Nov-03	Influent	132.91	43.00	7.49	3.92	40.64	0.25		
	Wetlands Effluent	2.55	3.10	7.34	0.92	2.22	0.75	<1	
	RSF Effluent	1.47	3.60	7.29	0.16	0.12	3.00		
	Final Effluent	0.54	2.15	7.35	0.17	0.13	3.00		1704
Oct-03	Influent	164.36	28.00	7.58	3.72	44.64	0.25		
	Wetlands Effluent	13.01	2.30	7.37	0.41	1.69	0.25	<1	
	RSF Effluent	3.83	3.65	7.56	0.15	0.28	1.50		
	Final Effluent	2.38	0.25	7.47	0.14	0.05	2.00		810
Sep-03	Influent	176.79	48.00	7.82	4.96	59.84	0.25		
	Wetlands Effluent	1.45	1.00	7.47	0.30	0.60	0.25	1	
	RSF Effluent	2.21	0.15	7.73	0.25	0.20	1.50		
	Final Effluent	3.03	0.75	7.70	0.16	0.25	1.50		871
Aug-03	Influent	151.50	122.00	7.50	5.64	50.24	1.10		
	Wetlands Effluent	2.36	3.10	7.49	0.39	0.72	1.54	<1	
	RSF Effluent	3.24	2.70	7.57	0.11	0.23	6.60		
	Final Effluent	2.40	0.70	7.62	0.22	0.22	6.60		258
Jul-03	Influent	195.22	50.00	7.56	6.48	56.23	1.10		
	Wetlands Effluent	3.94	1.80	7.24	0.39	0.72	1.54	<1	
	RSF Effluent	4.36	2.75	7.20	0.05	0.13	4.40		
	Final Effluent	1.55	3.26	7.21	0.06	0.11	6.60		
Jun-03	Influent	57.32	37.60	7.62	5.84	61.28	1.10		564
	Wetlands Effluent	2.66	0.35	7.35	0.37	0.92	1.32	23	
	RSF Effluent	2.00	7.40	7.15	0.13	0.28	3.30		
	Final Effluent	0.74	5.90	7.10	0.11	0.23	3.30		
Jun-03	Influent	131.68	24.20	7.75	6.04	62.24	1.10		564
	Wetlands Effluent	3.01	1.45	7.38	0.37	0.53	1.32		
	RSF Effluent	2.12	1.00	7.44	0.02	0.23	6.60		
	Final Effluent	2.34	0.25	7.46	0.03	0.19	6.60		
May-03	Influent	90.11	13.00	7.57	6.00	59.20	1.10		
	Wetlands Effluent	3.45	2.20	7.43	0.24	0.53	4.40	4	
	RSF Effluent	2.05	1.80	7.35	0.01	0.25	3.30		
	Final Effluent	1.64	1.80	7.66	0.04	0.32	3.30		731

Shell Knob Subdivision Wetlands Monitoring Data provided by White River Environmental Services

Month	Sample Location	BOD mg/l	TSS mg/l	pH	P mg/l	NH_3 mg/l	Nitrate mg/l	Fecal Coliform cols/100 ml	Effluent Flow gpd
May-03	Influent	112.98	26.50	7.64	4.89	60.14	1.10		
	Wetlands Effluent	1.63	0.75	7.48	0.53	1.59	2.20		
	RSF Effluent	2.12	1.10	7.28	0.01	0.04	6.60		
	Final Effluent	1.53	1.05	7.34	0.04	0.07	6.60		731
Apr-03	Influent	177.16	26.50	7.49	4.89	43.30	1.10		
	Wetlands Effluent	2.45	0.55	7.81	0.05	0.03	4.40	<1	
	RSF Effluent	0.87	2.20	7.75	0.02	0.04	2.20		
	Final Effluent	1.39	0.10	8.15	0.01	0.07	2.20		287
Apr-03	Influent	74.50	62.00	7.77	6.10	50.71	1.10		
	Wetlands Effluent	1.92	5.50	7.42	0.09	0.15	3.52		
	RSF Effluent	1.51	8.10	7.29	0.02	0.01	3.52		
	Final Effluent	1.14	6.05	7.56	0.06	0.04	3.08		287
Mar-03	Influent	57.75	6.10	7.72	0.02	0.03	17.60		
	Wetlands Effluent	4.39	0.10	7.42	0.05	0.02	1.10	N/A	
	RSF Effluent	2.76	0.15	7.27	0.01	0.02	1.10		
	Final Effluent	1.53	0.05	7.46	0.01	0.01	1.10		
Mar-03	Influent	24.20	1.40	7.78	0.04	0.01	22.00		
	Wetlands Effluent	1.18	0.35	7.36	0.07	0.01	1.10		
	RSF Effluent	0.96	0.30	7.21	0.01	0.02	1.10		
	Final Effluent	1.38	0.20	7.38	0.02	0.02	1.10		
Feb-03	Influent								
	Wetlands Effluent							N/A	
	RSF Effluent								
	Final Effluent	3.21	0.50		0.04				
Jan-03	Influent								
	Wetlands Effluent							N/A	
	RSF Effluent								
	Final Effluent	2.39	0.25		0.02				

APPENDIX-III

MAPS

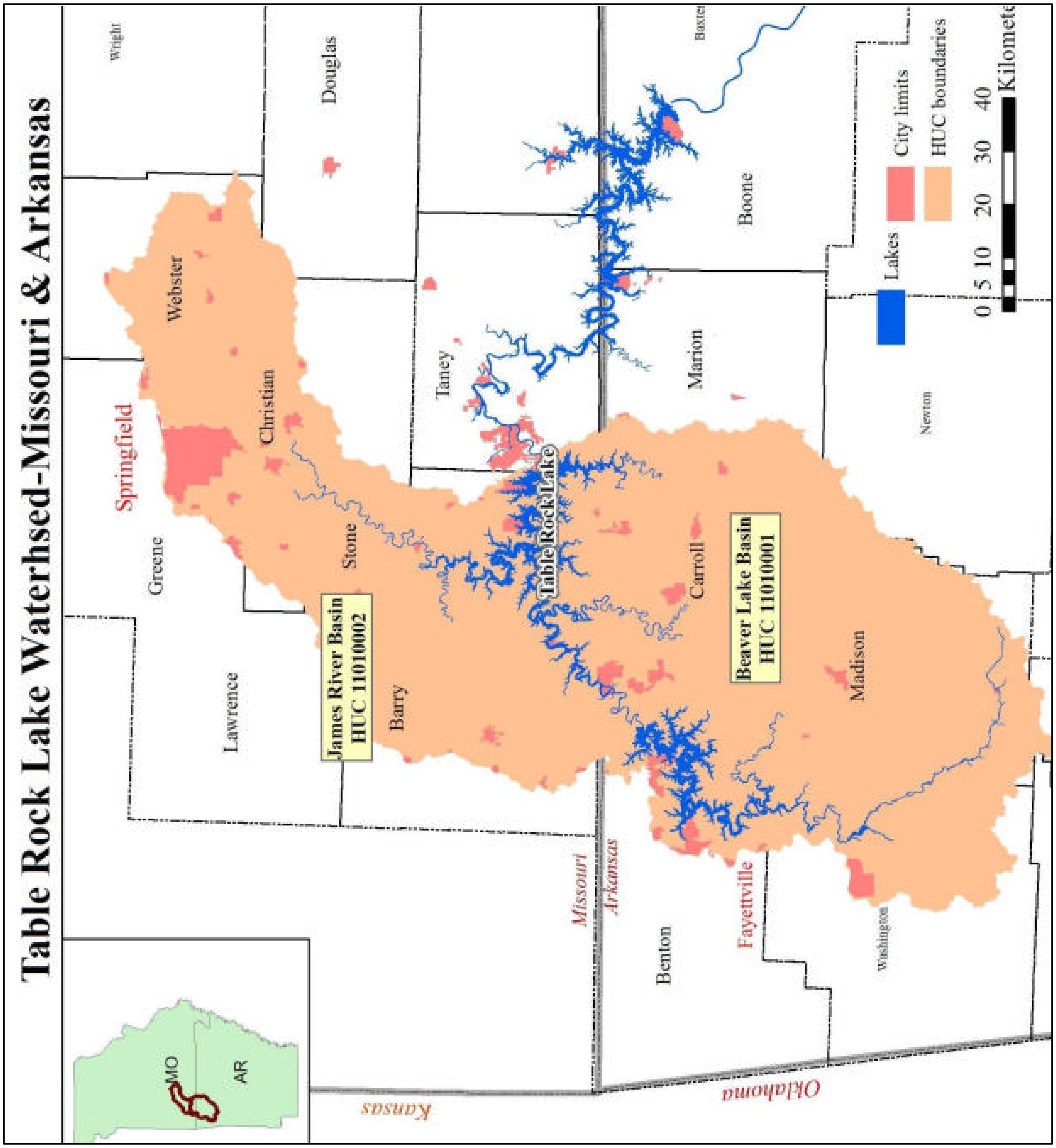
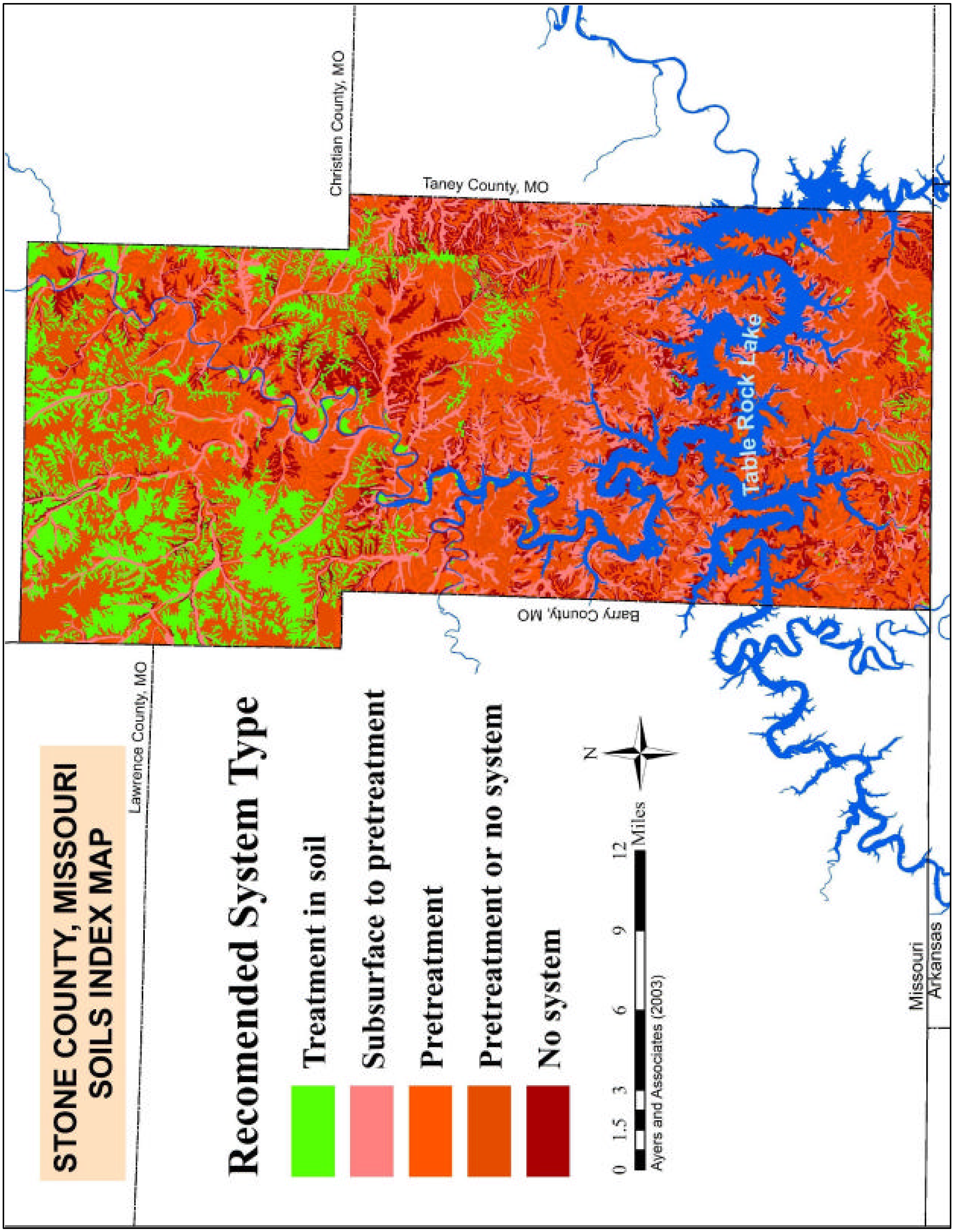
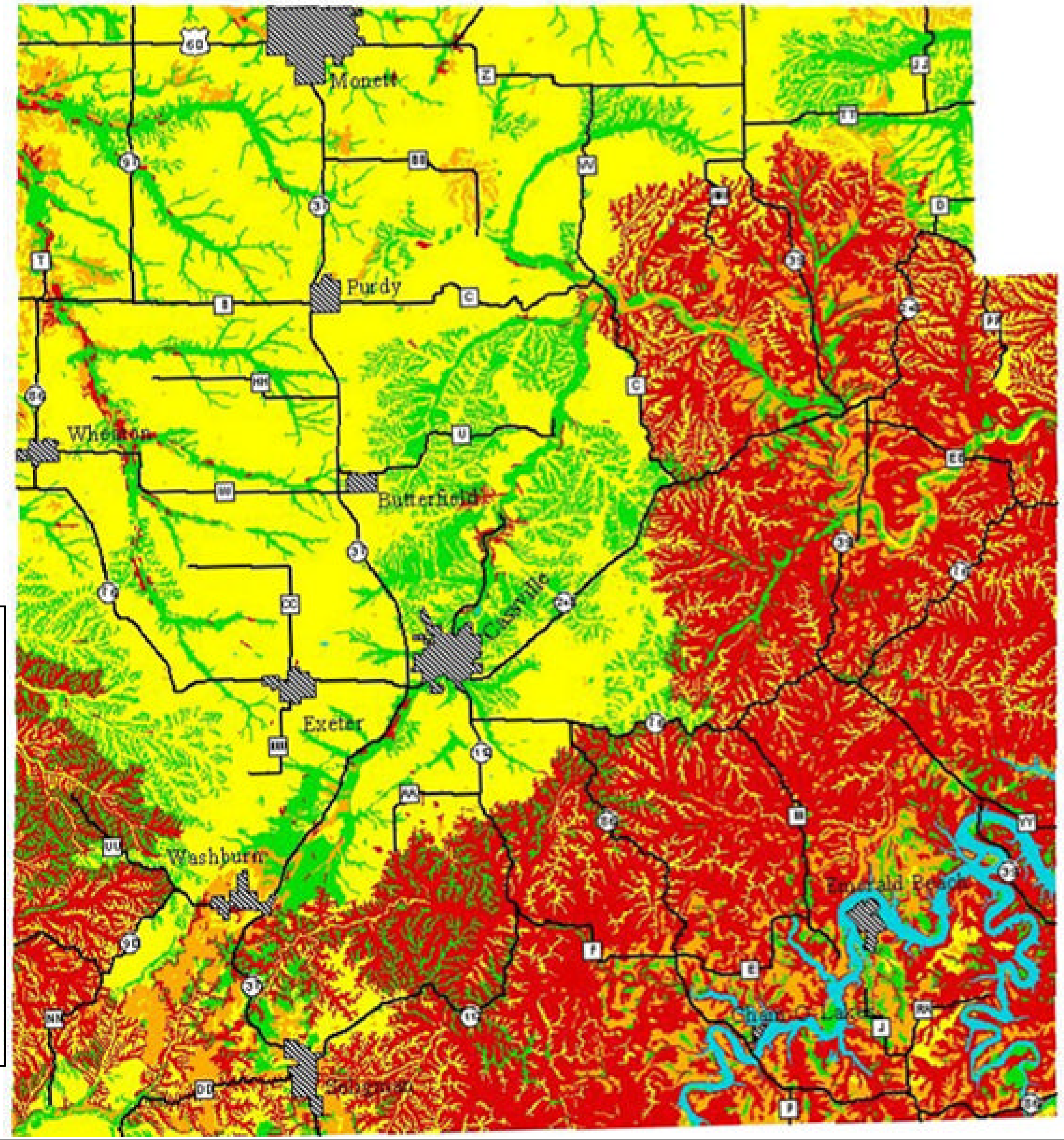


Table Rock Lake Waterhsed-Missouri & Arkansas
Wright
Douglas
Webster
Springfield
Christian
Greene
Stone
Taney
Lawrence
Barry
James River Basin
HUC 11010002
Table Rock Lake
Beaver Lake Basin
HUC 11010001
Carroll
Madison
Boone
Marion
Newton
Baxter
Benton
Fayettville
Washington
Missouri
Arkansas
Kansas
Oklahoma
MO
AR
Lakes
City limits
HUC boundaries
0 5 10 20 30 40
Kilometers


STONE COUNTY, MISSOURI
SOILS INDEX MAP
Recomended System Type
Treatment in soil
Subsurface to pretreatment
Pretreatment
Pretreatment or no system
No system
N
0 1.5 3 6 9 12 Miles
Ayers and Associates (2003)
Lawrence County, MO
Christian County, MO
Taney County, MO
Barry County, MO
Table Rock Lake
Missouri
Arkansas

Barry County, Missouri

Soil potentials for standard septic systems



Legend
Soil Potential Index Range

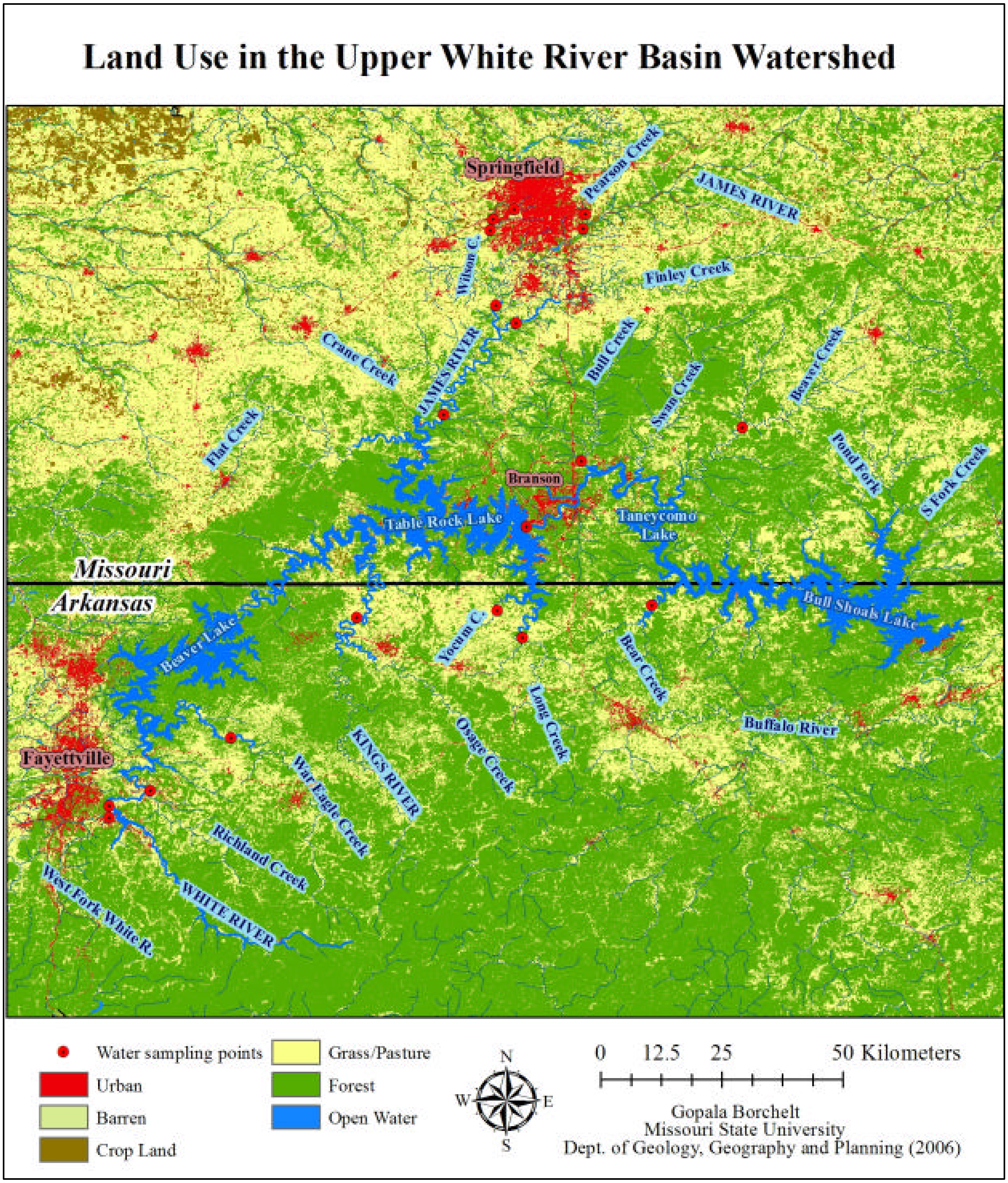
76-100 High Potential for standard septic system with few soil limitations

51-75 Medium Potential for standard septic system with moderate degree of soil limitations

26-50 Low Potential for standard septic system with greater degree of soil limitations

0-25 Very Low Potential for standard septic system with greatest degree of soil limitations

Water/Area Lakes


Land Use in the Upper White River Basin Watershed
Springfield
Pearson Creek
JAMES RIVER
Wilson C.
Finley Creek
Crane Creek
JAMES RIVER
Bull Creek
Swan Creek
Beaver Creek
Flat Creek
Pond Fork
S Fork Creek
Branson
Table Rock Lake
Taneycomo Lake
Missouri
Arkansas
Bull Shoals Lake
Beaver Lake
Yocum C.
Bear Creek
Long Creek
Osage Creek
KINGS RIVER
Buffalo River
Fayettville
War Eagle Creek
Richland Creek
West Fork White R.
WHITE RIVER
Water sampling points
Urban
Barren
Crop Land
Grass/Pasture
Forest
Open Water
N
W
E
S
0 12.5 25 50 Kilometers
Gopala Borchelt
Missouri State University
Dept. of Geology, Geography and Planning (2006)

Geology in the Upper White River Basin Watershed