Evaluation of Sediment Impacts on Hydrologic and Nutrient Loadings from Groundwater Seepage to Lake Jesup

Final Report

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SECTION 1

INTRODUCTION

1.1 Background

Lake Jesup is a 10,660-acre shallow, hypereutrophic lake located in northern-central Seminole County. A general location map for Lake Jesup is given on Figure 1-1. The lake is currently included on the Verified List, developed by the Florida Department of Environmental Protection (FDEP), as impaired for nutrients and unionized ammonia. Lake Jesup (WBID 2981) is also a priority waterbody as part of the State of Florida's Surface Water Improvement and Management (SWIM) Program. The mouth of Lake Jesup (WBID 2981A) is hydraulically connected to the St. Johns River at the northern end by a narrow channel near the SR 46 bridge and causeway. The SR 417 bridge, completed in 1993, crosses the lake near the western end. A small island, commonly referred to as Bird Island, is located near the center of Lake Jesup.

Lake Jesup is an extremely shallow waterbody with a mean depth ranging from approximately 3-4 ft, depending upon water elevation. The average water stage in Lake Jesup is approximately 1.8-2.0 ft (NGVD). In general, net water movement occurs from Lake Jesup into the St. Johns River, although flow reversal is observed periodically during periods of differential rainfall in adjacent sub-basin areas.

The drainage basin for Lake Jesup covers an area of approximately 87,331 acres (FDEP, 2006). An overview of the Lake Jesup watershed and sub-basin areas is given on Figure 1-2. The vast majority of the watershed is located within Seminole County, with a small portion of the southwest end extending into Orange County. The watershed area includes 11 separate municipalities, including Sanford, Lake Mary, Oviedo, Winter Springs, Longwood, Casselberry, Altamonte Springs, Maitland, Winter Park, Eatonville, and Orlando. Large portions of the watershed are highly urbanized, consisting of a combination of residential, commercial, and transportation land uses. The mean hydraulic residence time for Lake Jesup has been estimated from 82-99 days, depending upon the source.

A final TMDL report for Lake Jesup was issued by FDEP on April 14, 2006 which establishes total maximum daily loads (TMDLs) for nutrients and unionized ammonia in Lake Jesup. The TMDL report provides estimates of annual total phosphorus loadings from various sources into Lake Jesup, calibrated for the period from 1995-2002, which include surface runoff, baseflow, septic tanks, artesian input, atmospheric deposition, and inflow from the St. Johns River. Nutrient loadings from septic tanks are included based upon the number of septic tanks within 200 meters of any waterbody connected to Lake Jesup. The input referred to as "artesian inputs" reflects contributions from upwelling of the Floridan Aquifer from two springs (Clifton Springs and Lake Jesup Springs) which is separate from shallow groundwater seepage.

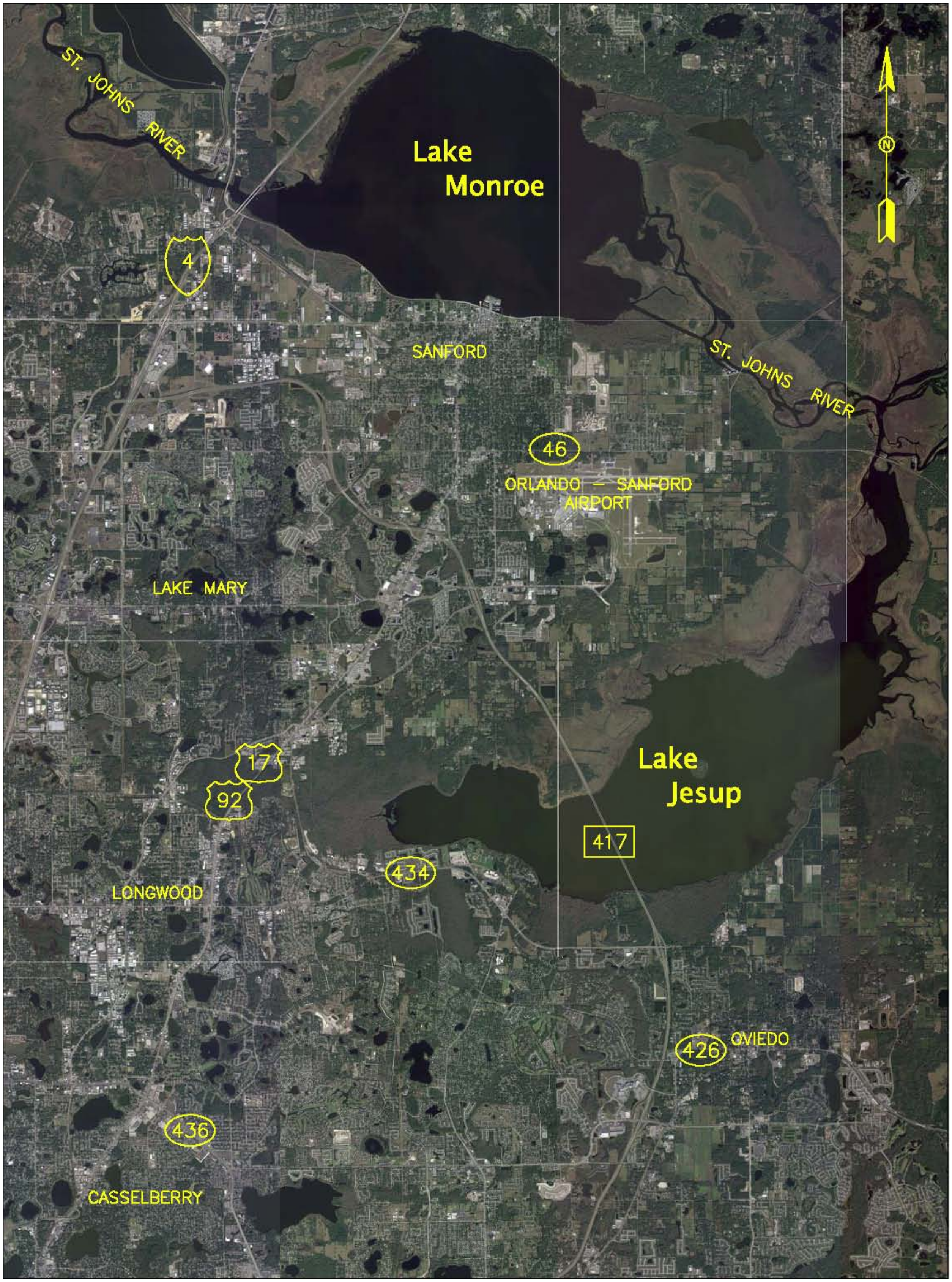


Figure 1-1. Location Map for Lake Jesup.

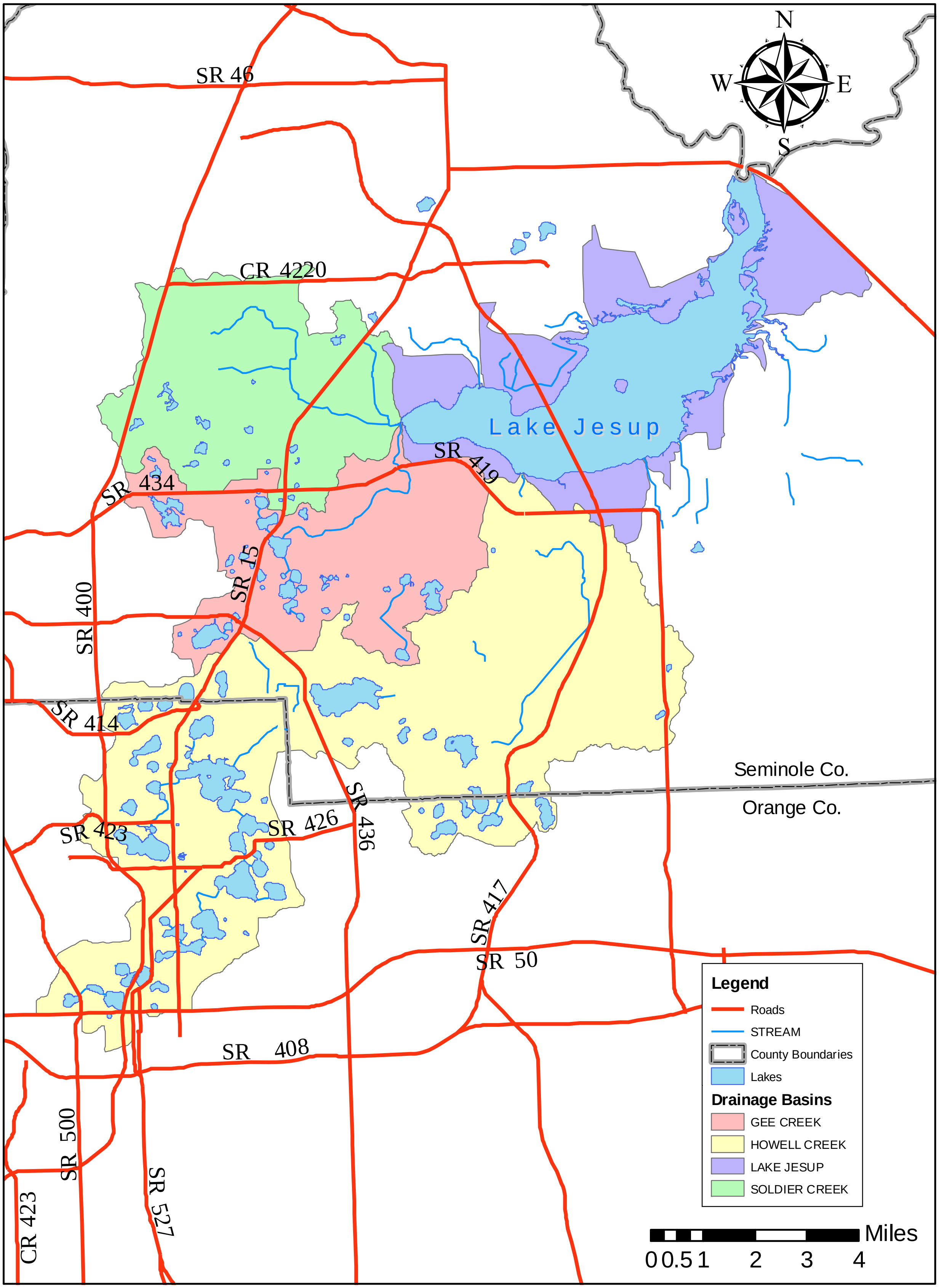


Figure 1-2. Lake Jesup Watershed and Sub-basin Areas.
(SOURCE: Final FDEP TMDL Report, 2006)

According to FDEP, estimates of hydrologic and nutrient loadings from shallow groundwater into Lake Jesup are partially included in the TMDL report. The percentage of the total stream flow that was baseflow, estimated using a hydrograph separation technique based on the measured flow in gauged streams, is also applied to the ungauged areas that are immediately adjacent to the lake, representing the shallow groundwater entering directly into the lake primarily around the perimeter of the lake. Additional nutrient loadings were added to the baseflow by FDEP to reflect loadings from septic tanks within 200 meters of the lake or a tributary. The baseflow loadings calculated using this method include the sum of tributary dry weather flow and seepage around the perimeter of the lake plus septic loadings. According to the TMDL report, the baseflow component contributed an annual average of 17,513 ac-ft/yr of water, 10,400 kg/yr of total nitrogen, and 3,300 kg/yr of total phosphorus to Lake Jesup during the period from 1995-2002.

An independent evaluation of the hydrologic and nutrient loadings from groundwater seepage to Lake Jesup was conducted by ERD from 2009-2010. Groundwater seepage meters were installed at 40 locations within Lake Jesup, and 9 separate monitoring events were conducted at each site over a 14-month field monitoring program from June 2009-August 2010. During each monitoring event, field measurements of seepage volume were conducted at each site, and a filtered water sample was collected for laboratory analysis. The mean measured seepage inflow into Lake Jesup during the field monitoring program was 1.18 liters/m^2-day, equivalent to approximately 22,994 ac-ft/yr. This value is substantially greater than the TMDL estimate of the overall annual baseflow inputs to Lake Jesup of 17,513 ac-ft/yr. Groundwater seepage entering Lake Jesup was characterized by elevated levels of both total nitrogen and total phosphorus, with an estimated annual nitrogen influx of 89,183 kg/yr and an estimated annual phosphorus influx of 9,484 kg/yr. Each of these values is also substantially greater than the baseflow loading estimates provided in the TMDL report which includes both the lake and the entire watershed. Questions arose at the time as to the source of the nutrient loadings and whether the elevated nutrient concentrations reflect seepage reaching the lake or if the seepage is impacted by migration through the existing muck sediments.

The previous groundwater seepage study conducted by ERD was designed to determine the significance of groundwater seepage entering Lake Jesup in comparison with the estimated hydrologic and nutrient budgets provided in the TMDL report. However, the ERD study did not address the ultimate source of nutrient loadings entering Lake Jesup through groundwater seepage or the significance of existing sediments in regulating seepage characteristics.

A supplemental evaluation was conducted by ERD from January 2012-March 2013 to further evaluate the impacts of the existing sediments on seepage characteristics entering the lake. The potential impact of sediments on groundwater seepage were evaluated by conducting side-by-side comparisons of seepage meters installed in areas with and without existing sediments. Pairs of seepage meters with and without existing sediments were installed at 6 separate locations throughout Lake Jesup. The results of this study form the basis of this current report. This evaluation provides important information on sediment impacts on groundwater seepage which assists in the general understanding of nutrient dynamics within the lake and provides additional information to evaluate potential impacts of dredging projects within the lake.

1.2 Work Efforts Conducted by ERD

Field monitoring was conducted by ERD over a 15-month period from January 2012-March 2013 to evaluate the impacts of existing sediments on the hydrologic and water quality characteristics of shallow groundwater seepage inflows to Lake Jesup. Side-by-side groundwater seepage meters were installed at 6 locations within Lake Jesup, with one seepage meter in each pair exposed to the existing sediments and one meter installed on the firm lake bottom. Six separate monitoring events were conducted at each monitoring site over the 15-month field monitoring program. During each monitoring event, field measurements of seepage volume were conducted, and a filtered seepage sample was collected for laboratory analyses.

This report has been divided into four separate sections for presentation of the work efforts conducted by ERD. Section 1 contains an introduction to the report, background information on Lake Jesup and phosphorus loadings, and a general overview of the work efforts performed by ERD. A discussion of field and laboratory activities is given in Section 2. Section 3 contains a discussion of the results of the field and laboratory activities. A summary is presented in Section 4. Appendices are also attached which contain technical data and analyses used to support the information contained within the report.

SECTION 2

FIELD AND LABORATORY ACTIVITIES

2.1 Introduction

A schematic of a typical hydrologic cycle illustrating groundwater seepage to surface waters is given on Figure 2-1. Shallow groundwater seepage originates as precipitation which infiltrates into the ground. Water which is not evaporated or transpired by vegetation continues to infiltrate vertically through the ground until reaching the saturated water table zone. At this point, the groundwater begins to move laterally, down-gradient, until reaching the nearest waterbody.

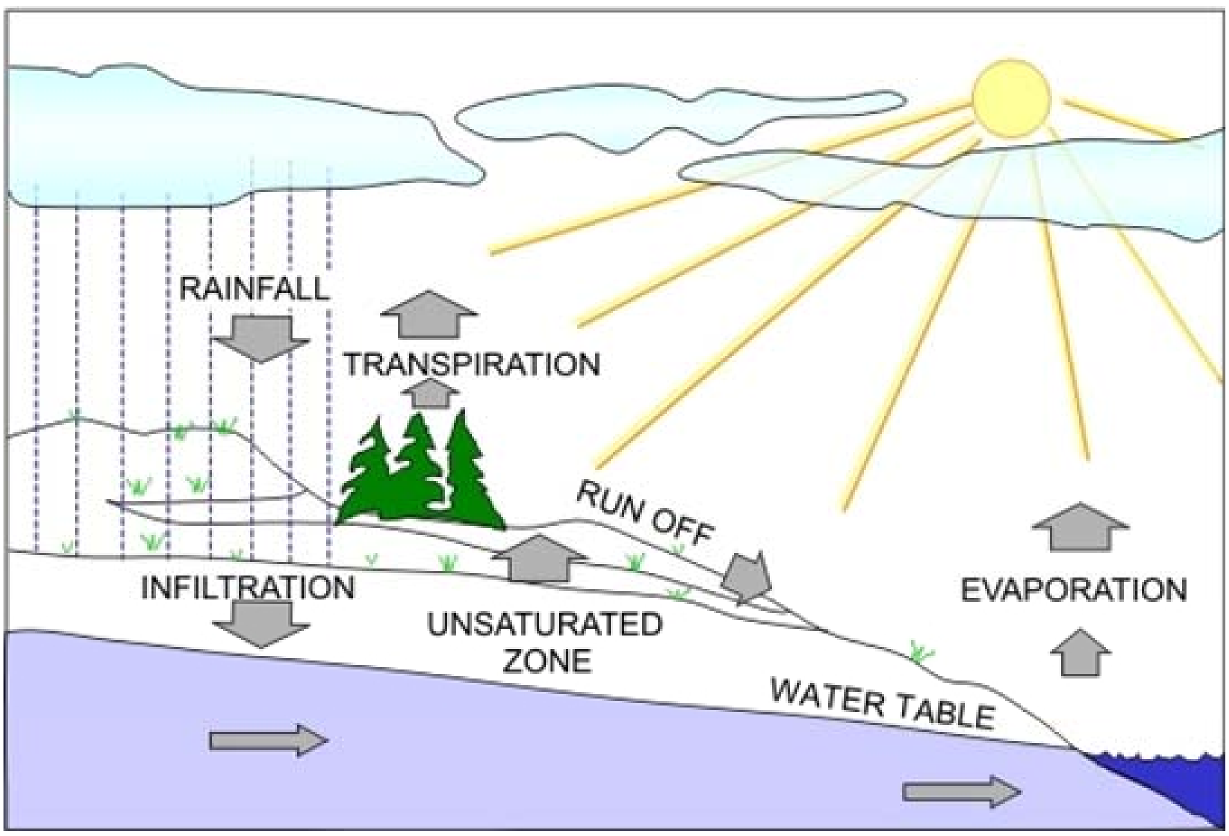


Figure 2-1. Hydrologic Cycle Illustrating Groundwater Seepage to Surface Waters.

The chemical characteristics of the groundwater seepage are impacted by a variety of factors, including: land cover; soil characteristics; travel distance through the soil; and other groundwater inputs from septic tanks, fertilizers, agricultural activities, wastewater disposal, and industrial activities. Many hydrologic models and TMDL evaluations incorrectly assume that groundwater seepage originates exclusively as a result of inputs from septic tanks which are adjacent to the receiving waterbody, and groundwater inputs are routinely under-estimated in terms of both volume and nutrient loadings.

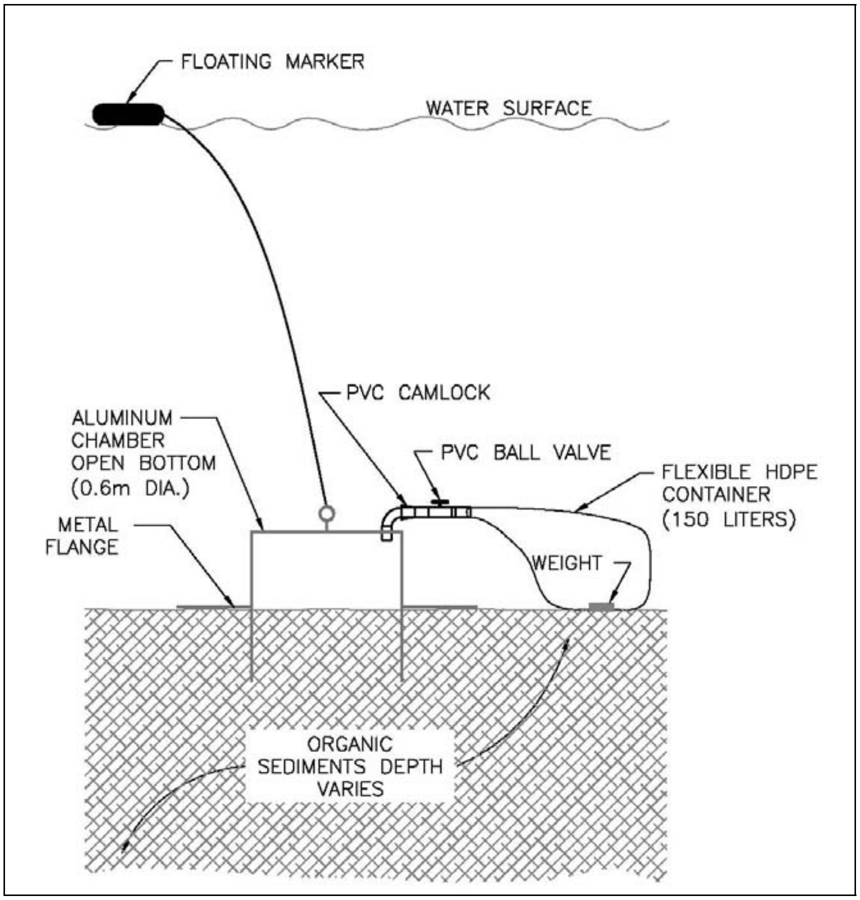
Field investigations were performed by ERD to evaluate the impacts of existing sediments on the quantity and quality of shallow groundwater seepage entering Lake Jesup. Seepage inflow into the lake in areas with and without existing sediments was quantified using pairs of underwater seepage meters installed at 6 locations throughout the lake. Seepage meters provide a mechanism for direct measurement of groundwater inflow into a lake by isolating a portion of the lake bottom so that groundwater seeping up through the bottom sediments into the lake can be collected and characterized. Use of the direct seepage meter measurement technique avoids errors, assumptions, and extensive input data required when indirect techniques are used, such as the Gross Water Budget or Subtraction Method, as well as computer modeling and flow net analyses.

With installation of adequate numbers and proper placement, seepage meters can be a very effective tool to estimate groundwater-surface water interactions. Seepage inflow is generally greatest along the perimeter of a waterbody, and the majority of seepage meters are typically placed in shallow shoreline areas. Seepage inflow generally decreases with distance from the shoreline, and fewer seepage meters are placed in central portions of a lake. Placement of seepage meters should also consider variability in upland land uses, topography, and sewage disposal techniques to properly characterize groundwater inflows to a lake. The seepage meter technique has been recommended by the U.S. Environmental Protection Agency (EPA) and has been established as an accurate and reliable technique in field and tank test studies (Lee, 1977; Erickson, 1981; Cherkauer and McBride, 1988; Belanger and Montgomery, 1992). One distinct advantage of seepage meters is that seepage meters can provide estimates of both water quantity and quality entering a waterbody, whereas estimated or modeling-based methods can only provide information on water quantity. ERD has conducted seepage monitoring in over 40 lakes within the State of Florida.

2.2 Field Activities

2.2.1 Seepage Meter Construction and Installation

Schematics of typical seepage meter installations used in Lake Jesup to evaluate sediment impacts on seepage are given on Figure 2-2. Seepage meters were constructed from a 2-ft diameter aluminum cylinder with a closed top and open bottom and a height of 36 inches. Each seepage meter isolated a sediment area of approximately 3.14 ft^2. The seepage meters used in Lake Jesup were also equipped with a 4-ft diameter flange which was welded to the outside of the aluminum cylinder to help stabilize the meters in areas of unconsolidated sediments, particularly in central portions of Lake Jesup, and to minimize settling of the meters over time. A photograph of a typical seepage meter used in Lake Jesup is given in Figure 2-3. The seepage meters were inserted into the lake sediments to the metal flange, resulting in a sediment penetration of approximately 18-24 inches, with approximately 8-12 inches of water trapped inside the seepage meter above the sediments. A large concrete weight (~75 lbs) was placed on top of each seepage meter.



a.
Seepage Meter
Installed on Top of
Existing Sediments

b.
Seepage Meter
Installed in Area
with Muck
Sediment Removed

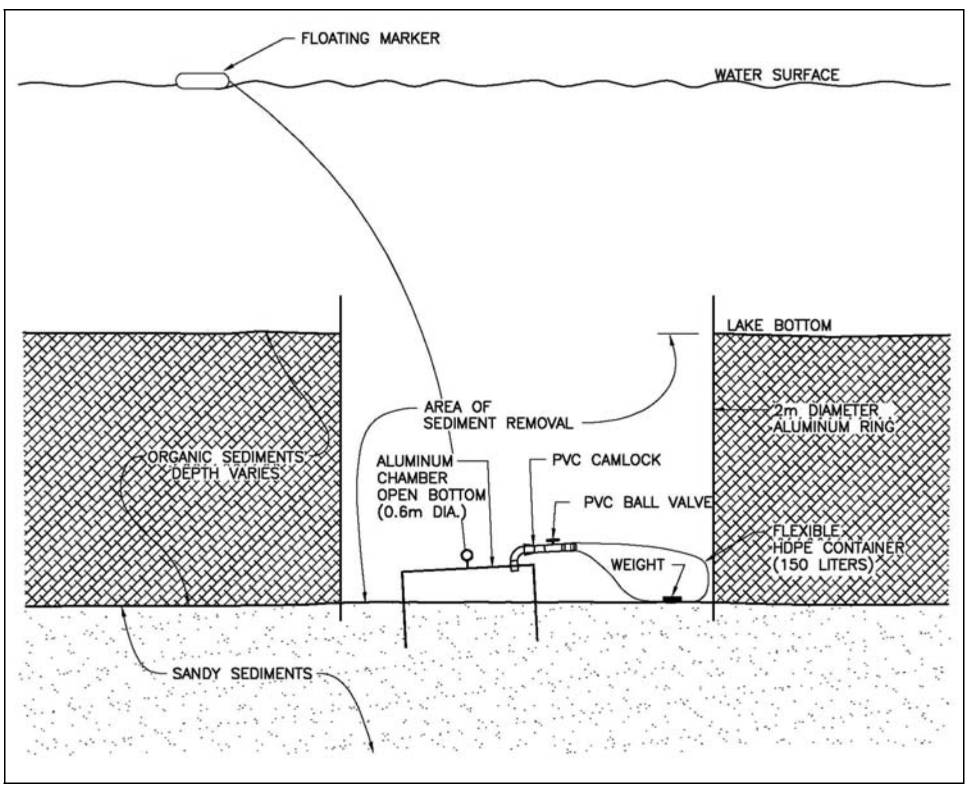


Figure 2-2. Typical Seepage Meter Installation.

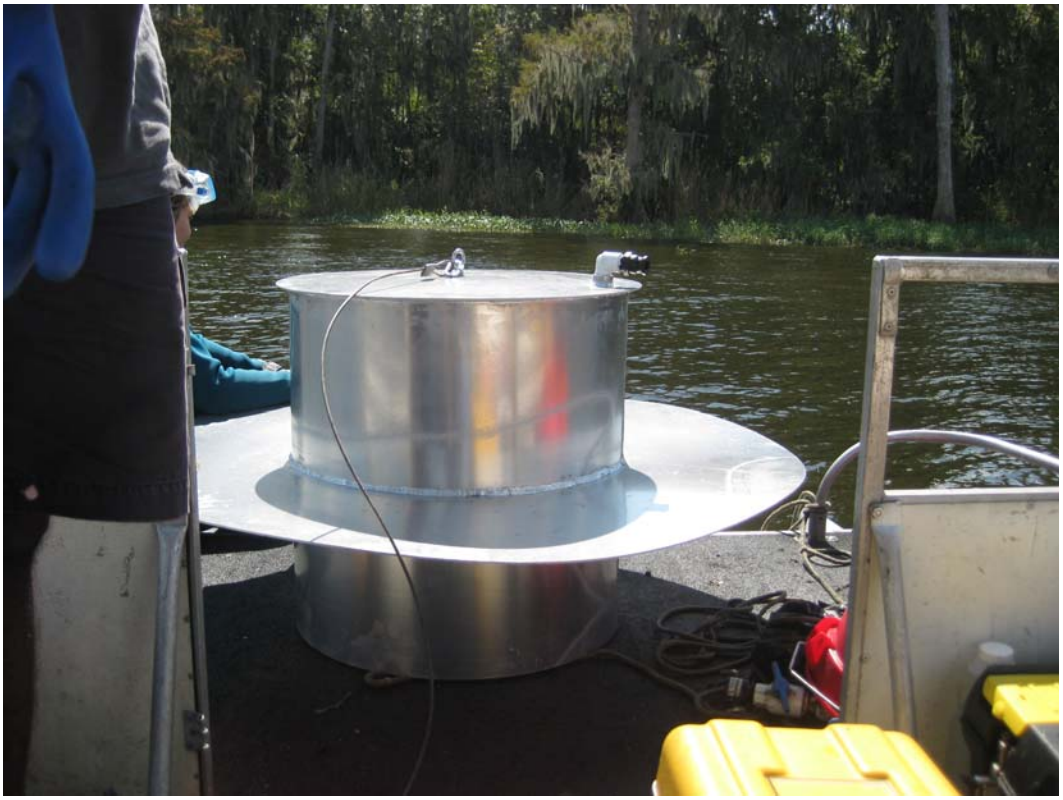
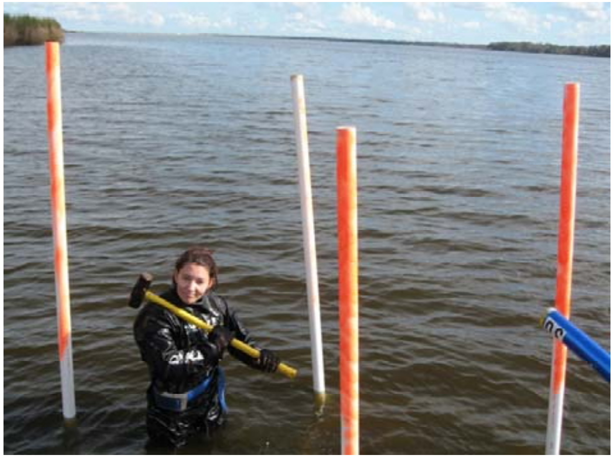


Figure 2-3. Typical Seepage Meter Used in Lake Jesup.

Pairs of seepage meters were installed at 6 locations in Lake Jesup. One of the seepage meters was installed on top of the existing sediments, as illustrated on Figure 2-2a, with the second seepage meter installed adjacent to the first seepage meter in an area where the existing organic sediments had been removed, as illustrated on Figure 2-2b. A 2-meter diameter and 1-meter tall aluminum ring was inserted through the sediments and into the firm sandy bottom of the lake. The organic sediments were pumped from the interior of the cylinder down to the firm sandy sediments using a 3-inch Mudhog-type pump. The seepage meter was then installed inside the chamber on the firm sandy sediments which form the original bottom of Lake Jesup. This protocol allowed a side-by-side comparison of the seepage characteristics collected in areas with and without the existing sediment accumulations.

The parent sediment material in Lake Jesup was primarily sand mixed with organic material. In many areas, the sand was cemented and dense, making it difficult to insert the seepage meter. Areas of blue clay mixed with sand were also observed.

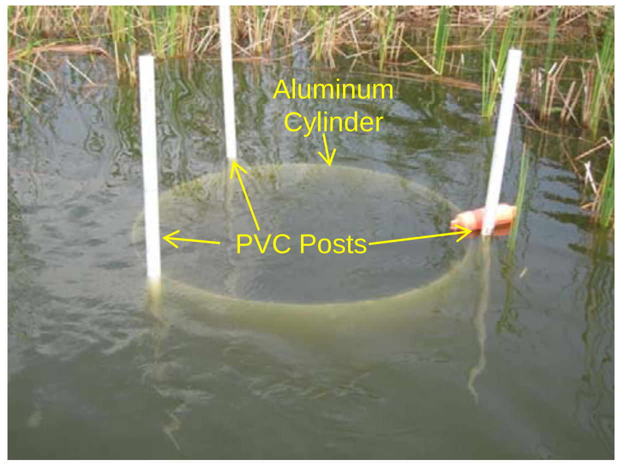
Photographs of the installation process for the aluminum cylinders, including sediment removal, are given on Figure 2-4. The aluminum cylinder was inserted through the existing organic sediments to the firm sand bottom using a sledge hammer. The muck was then pumped from inside the chamber to expose the firm sand bottom of the lake. The organic material which was pumped from the cylinder consisted primarily of very fine flocculent particles which required a considerable amount of time to settle from the water column back into the sediment layer. When the installation was completed, each of the aluminum cylinders was marked using three to four 2-inch PVC posts to warn boaters of the potential hazard and to assist in locating the sites for collection of groundwater samples.



Cylinder inserted into sediments using sledge hammer

Muck is pumped from cylinder to firm bottom

Muck impacts on lake water



Completed installed chamber

Figure 2-4. Photographs of Installation of the Aluminum Cylinders and Sediment Removal.

In general, seepage meter pairs were installed primarily around the perimeter of the lake since seepage is most significant in shoreline areas. The seepage meters installed on the existing muck sediments were inserted through the unconsolidated sediment layer into the consolidated sediments. The seepage meters were inserted by repeatedly pounding around the perimeter of the meter using a 20-pound hammer weight until the seepage meter met significant resistance from the sediment material, and no additional movement of the meter was observed. Seepage meters installed in these areas were extremely stable, and additional settling of the seepage meters during the monitoring program is unlikely.

In central portions of the lake where the muck accumulations were deeper, the seepage meters were inserted through the surficial unconsolidated sediments into the layer of consolidated sediments. If possible, the flange was extended to the top of the consolidated sediment layer to achieve maximum stability for the seepage meter. The seepage meter installed on muck sediments in central portions of the lake was less stable than the shoreline meters since the parent bottom material could not be reached. The meter penetrated into the consolidated sediment layer, which provided a relatively stable platform since the outer flange was resting on top of the consolidated layer. However, further limited settling of this meter over time cannot be ruled out.

A 0.75-inch PVC fitting was threaded into the top of each seepage cylinder. The 0.75-inch PVC fitting was attached to a female quick-disconnect PVC camlock fitting. A flexible polyethylene bag, with an approximate useable volume of 40 gallons (150 liters), was attached to the seepage meters using a quick-disconnect PVC male camlock fitting with a terminal ball valve. Each of the collection bags was constructed of 3-mil black polyethylene to prevent light penetration into the bag which could potentially stimulate photosynthetic activity within the sample prior to collection and result in an alteration of the chemical characteristics of the sample.

Prior to attachment to the seepage meter, all air was removed from inside the polyethylene collection bag, and the PVC ball valve was closed so that lake water would not enter the collection bag prior to attachment to the seepage meter. A diver then connected the collection bag to the seepage meter using the PVC camlock fitting. After attaching the collection bag to the seepage meter, the PVC ball valve was then opened, allowing seepage to enter the bag. Groundwater influx into the open bottom of the seepage meter is collected inside the flexible polyethylene bag. Photographs of the seepage sample collection process are given on Figure 2-5.

Diver preparing to retrieve collection bag; sediment easily disturbed

Diver returning with collection bag during seepage monitoring event

Figure 2-5. Photographs of the Seepage Sample Collection Process.

Each seepage meter was installed with a slight tilt toward the outlet point so that any gases which may be generated inside the seepage meter would exit into the collection bag, preventing buoyant conditions from developing inside the meter. Two 10-ounce plastic-coated fishing weights were placed inside each of the collection bags to prevent the bags from floating up towards the water surface as a result of trapped gases. The location of each pair of seepage meters was indicated by 2-inch PVC poles inserted around the perimeter of the aluminum cylinder.

Six pairs of seepage meters (12 seepage meters total) were installed in Lake Jesup on January 25 and 31, 2012. Locations for the seepage meters are indicated on Figure 2-6. The majority of the seepage meters were installed around the perimeter of the lake at a water depth of approximately 3 ft. A pair of seepage meters was also installed in a more central portion of the lake.

An expanded location map for seepage monitoring Site 1 is given on Figure 2-7. Site 1 is located on the northern shore of the western lobe of the lake where the inflow from Soldiers Creek enters Lake Jesup. Land use adjacent to seepage monitoring Site 1 includes a combination of wetland and upland forests.

An expanded location map for seepage monitoring Site 2 is given on Figure 2-8. Site 2 is located on the southern side of the western lobe adjacent to a residential community and the mouth of Howell Creek, and is the only seepage monitoring site with significant urbanized activity adjacent to the site. This site also exhibited some of the deepest and most flocculent sediments observed within the lake. The photographs included in Figure 2-5 were taken at this site.

An expanded location map for seepage monitoring Site 3 is given on Figure 2-9. Site 3 is located on the southern side of Lake Jesup slightly west of the inflow for Solary Creek. Watershed areas adjacent to Site 3 consist primarily of wetland and upland forested areas.

An expanded location map for seepage monitoring Site 4 is given on Figure 2-10. Site 4 is located in the northern-central portion of Lake Jesup adjacent to wetland marshes and upland areas used primarily for cattle grazing activities.

An expanded location map for seepage monitoring Site 5 is given on Figure 2-11. Site 5 is located adjacent to an expansive wetland area with upland land use consisting primarily of agricultural activities.

An expanded location map for seepage monitoring Site 6 is given on Figure 2-12. Site 6 is located in the northeastern portion of Lake Jesup adjacent to the inflows from Black Creek and Salt Creek. This site was located near the center portion of the lake to evaluate sediment impacts in areas other than the monitored shoreline areas.

2.2.2 <u>Seepage Meter Monitoring</u>

Polyethylene collection bags were attached to each of the 12 seepage meters at the time of installation. The initial seepage monitoring event was conducted during March 2012, approximately 6 weeks following installation. During this event, the volume of seepage collected at each site was measured and recorded. However, the collected sample was discarded since the initial sample represents a combination of seepage and lake water trapped inside the seepage meter at the time of installation. Beginning with the second monitoring event, samples were retained for laboratory analyses. Each of the 12 seepage meters was monitored on approximately a bi-monthly basis from January 2011-March 2012, with shorter event intervals during wet season conditions and longer event intervals during dry season conditions. Seepage monitoring events were conducted during the months of March, July, August, November, January and March. Five separate seepage monitoring events were conducted for evaluation of quantity and quality at each of the monitoring sites. The seepage meters were removed at the end of the monitoring program.

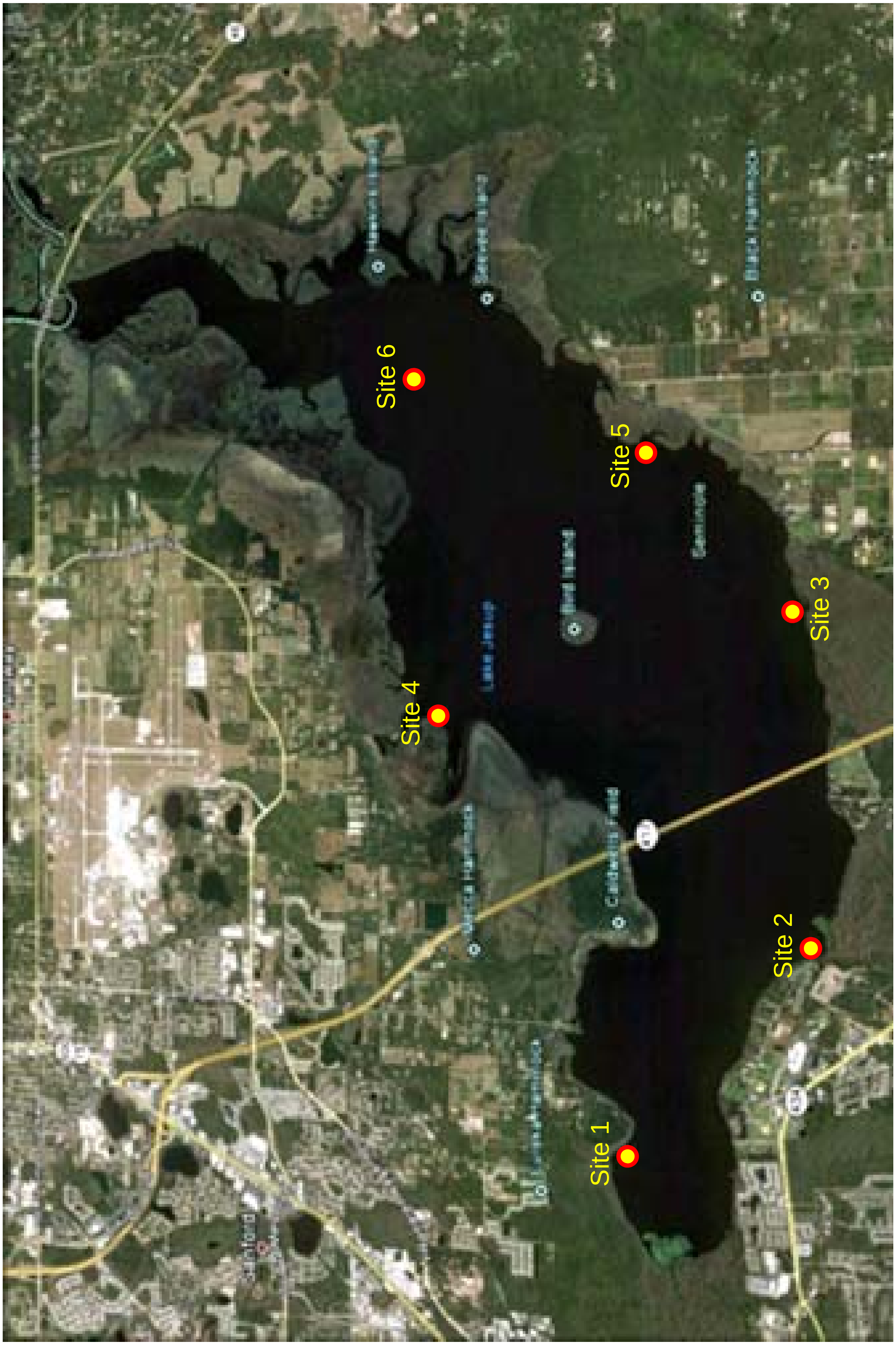


Figure 2-6. Locations for Seepage Meter Pairs Installed in Lake Jesup.

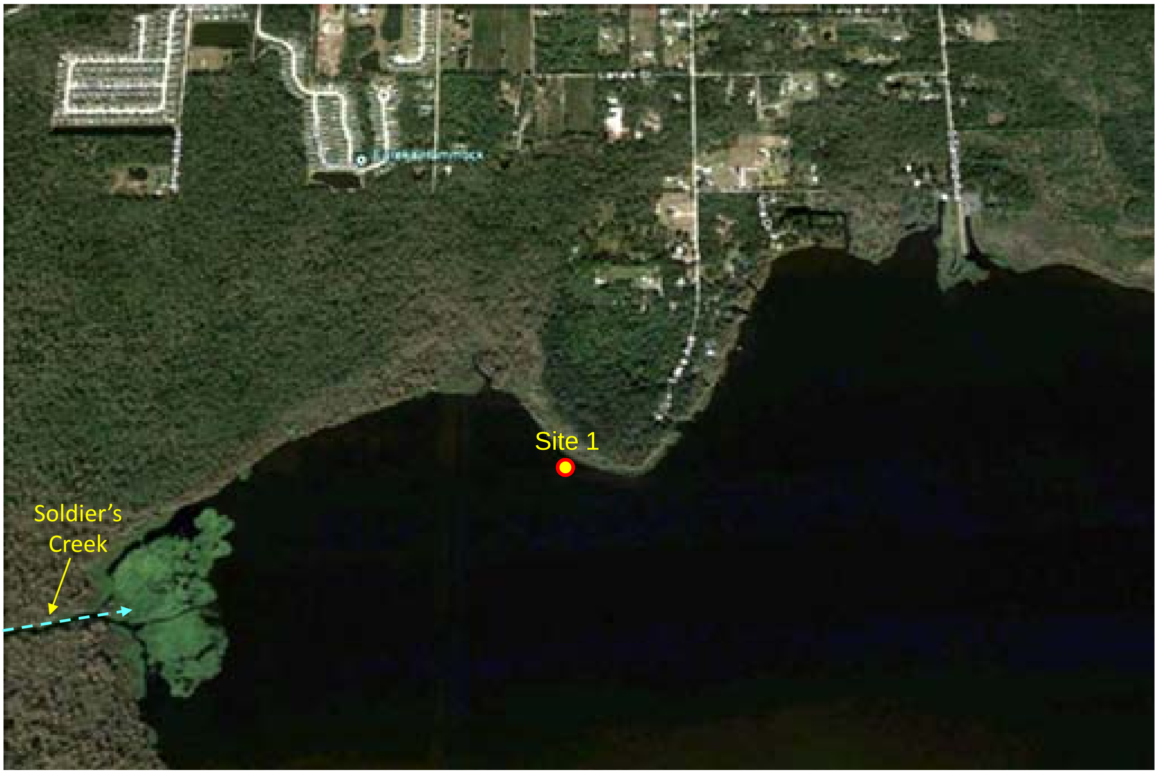


Figure 2-7. Expanded Location Map for Seepage Monitoring Site 1.

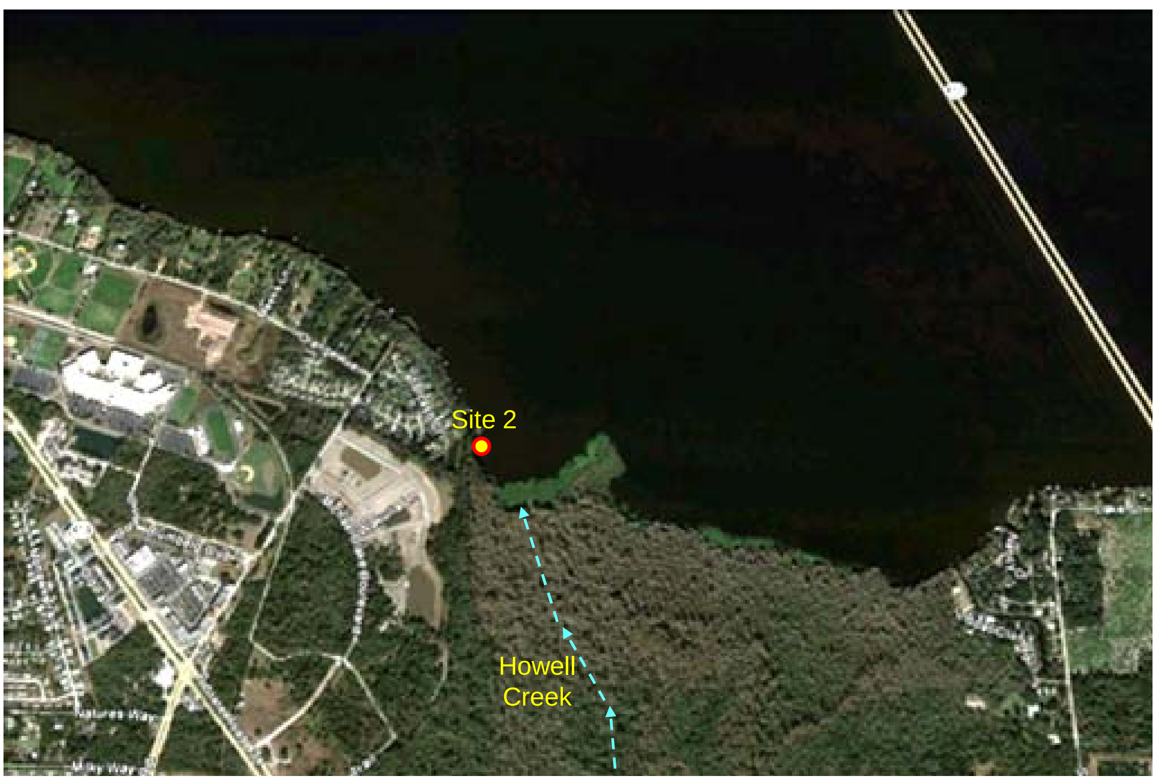


Figure 2-8. Expanded Location Map for Seepage Monitoring Site 2.

Figure 2-9.   Expanded Location Map for Seepage Monitoring Site 3.

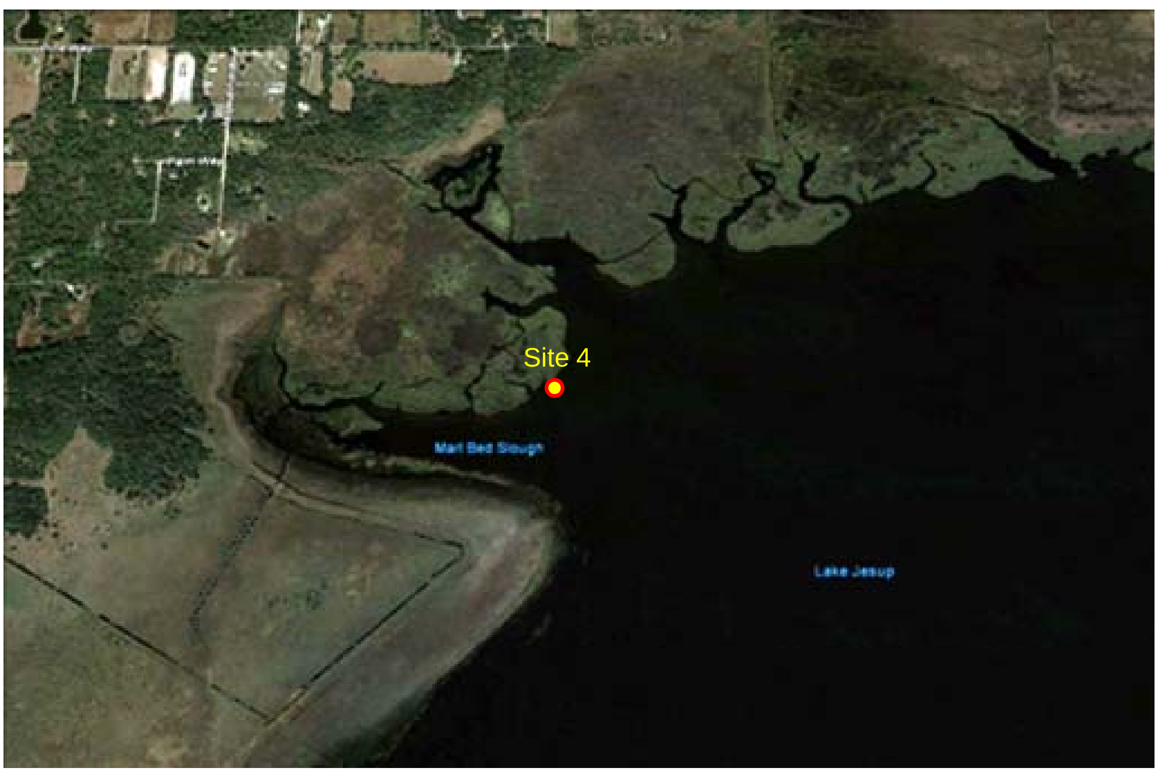


Figure 2-10.   Expanded Location Map for Seepage Monitoring Site 4.

Figure 2-11. Expanded Location Map for Seepage Monitoring Site 5.

Figure 2-12. Expanded Location Map for Seepage Monitoring Site 6.

During the collection process, a diver was used to close the PVC ball valve and remove the collection bag from the seepage meter using the quick-disconnect camlock fitting. The collection bag was placed onto the boat and the contents were emptied into a polyethylene container. The volume of seepage collected in the container was measured using either a 4-liter graduated cylinder or a 20-liter graduated polyethylene bucket, depending on the collected volume.

During some of the initial monitoring events, seepage meter samples were found to contain turbidity or particles originating from the sediments isolated within the seepage meter. Since these suspended contaminants are not part of the seepage flow, all seepage meter samples collected for chemical analyses were field-filtered using a 0.45 micron disposable glass fiber filter typically used for filtration of groundwater samples. A new filter was used for each seepage sample. Seepage samples were filtered immediately following collection using a battery operated peristaltic pump at a flow rate of approximately 0.25 liter/minute. The filtered seepage sample was placed in ice for return to the ERD laboratory for further chemical analyses.

During collection of the seepage samples, information was recorded on the time of sample collection, the total volume of seepage collected at each site, and general observations regarding the condition of the seepage collection bags and replacement/repair details. The seepage flow rate at each location is calculated by dividing the total collected seepage volume (liters) by the area of the seepage meter and the time (days) over which the seepage sample was collected.

2.3 Laboratory Analyses

Each of the collected seepage samples was evaluated in the ERD Laboratory for general parameters and nutrients. A summary of laboratory methods and MDLs for analyses conducted on water samples collected during this project is given in Table 2-1. The ERD Laboratory is NELAC-certified (No. 1031026). Additional details on field operations, laboratory procedures, and quality assurance methodologies are provided in the ERD Comprehensive Quality Assurance Plan.

TABLE 2-1

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES

MEASUREMENT PARAMETER		METHOD	METHOD DETECTION LIMITS (MDLs)[1]
General Parameters	Hydrogen Ion (pH)	SM-21, Sec. 4500-H^+ B[2]	NA
	Specific Conductivity	SM-21, Sec. 2510 B	0.2 µmho/cm
	Alkalinity	SM-21, Sec. 2320 B	0.5 mg/l
Nutrients	Ammonia-N (NH_3-N)	SM-21, Sec. 4500-NH_3 G	0.005 mg/l
	Nitrate + Nitrite (NO_x-N)	SM-21, Sec. 4500-NO_3 F	0.005 mg/l
	Total Nitrogen	SM-21, Sec. 4500-N C	0.01mg/l
	Orthophosphorus (SRP)	SM-21, Sec. 4500-P F	0.001 mg/l
	Total Phosphorus	SM-21, Sec. 4500-P B.5	0.001 mg/l

1. MDLs are calculated based on the EPA method of determining detection limits
2. Standard Methods for the Examination of Water and Wastewater, 21st Ed., 2005.

SECTION 3

RESULTS

A discussion of field and laboratory activities conducted by ERD to evaluate the impacts of the existing muck sediments on the quantity and quality of shallow groundwater seepage entering Lake Jesup is given in the following sections. These sections include a discussion of rainfall, quantity of data collected, seepage inflow rates, and chemical characteristics of groundwater seepage with and without sediment contact.

3.1 Rainfall Characteristics

Shallow groundwater seepage originates primarily as rainfall which infiltrates into shallow soils and migrates down gradient within a watershed until reaching a surface waterbody, channel, river, or stream. As a result, rainfall has a significant impact on the quantity of shallow groundwater seepage entering the lake.

A review of available rainfall recording stations in the vicinity of Lake Jesup was conducted to identify potential sources for estimation of historical rainfall characteristics in the general area of Lake Jesup as well as measured rainfall during the field monitoring program from January 2012-March 2013. Two separate rainfall recording stations were identified in the general vicinity of Lake Jesup. One site is identified as "Sanford Experimental Station" (NCDC Station No. 87982) which is located south of Lake Monroe, and west of downtown Sanford, approximately 6 miles northwest of Lake Jesup. Rainfall data at this site are available from June 1956-present. A second rainfall recording station, maintained by SJRWMD and identified as Citrus Road (Site No. 09992839), is located approximately 3.2 miles southwest of Lake Jesup and appears to be the closest recording rainfall site to the lake. However, meteorological data at this station are available only from 1995-present.

The purpose of the long-term historical rainfall station is to provide estimates of "normal" monthly rainfall in the vicinity of Lake Jesup. The Sanford Experimental Station is selected as the source of these data so that a longer historical period of record could be included. Monthly rainfall records were obtained for this site over the period from 1971-2000, and these data are used to reflect "normal" rainfall in the general vicinity of Lake Jesup. The location of the Sanford Experimental Station site is indicated on Figure 3-1.

Rainfall characteristics during the field monitoring program from January 2012-March 2013 were obtained from the SJRWMD Citrus Road (Site No. 09992839) recording site due to the closer proximity to Lake Jesup. Daily rainfall records are available at this site over the entire period of the field monitoring program for the seepage evaluation project. Therefore, rainfall recorded at the Citrus Road site is used to reflect actual rainfall in the vicinity of Lake Jesup during the field monitoring program. The location of the Citrus Road site is also given on Figure 3-1.

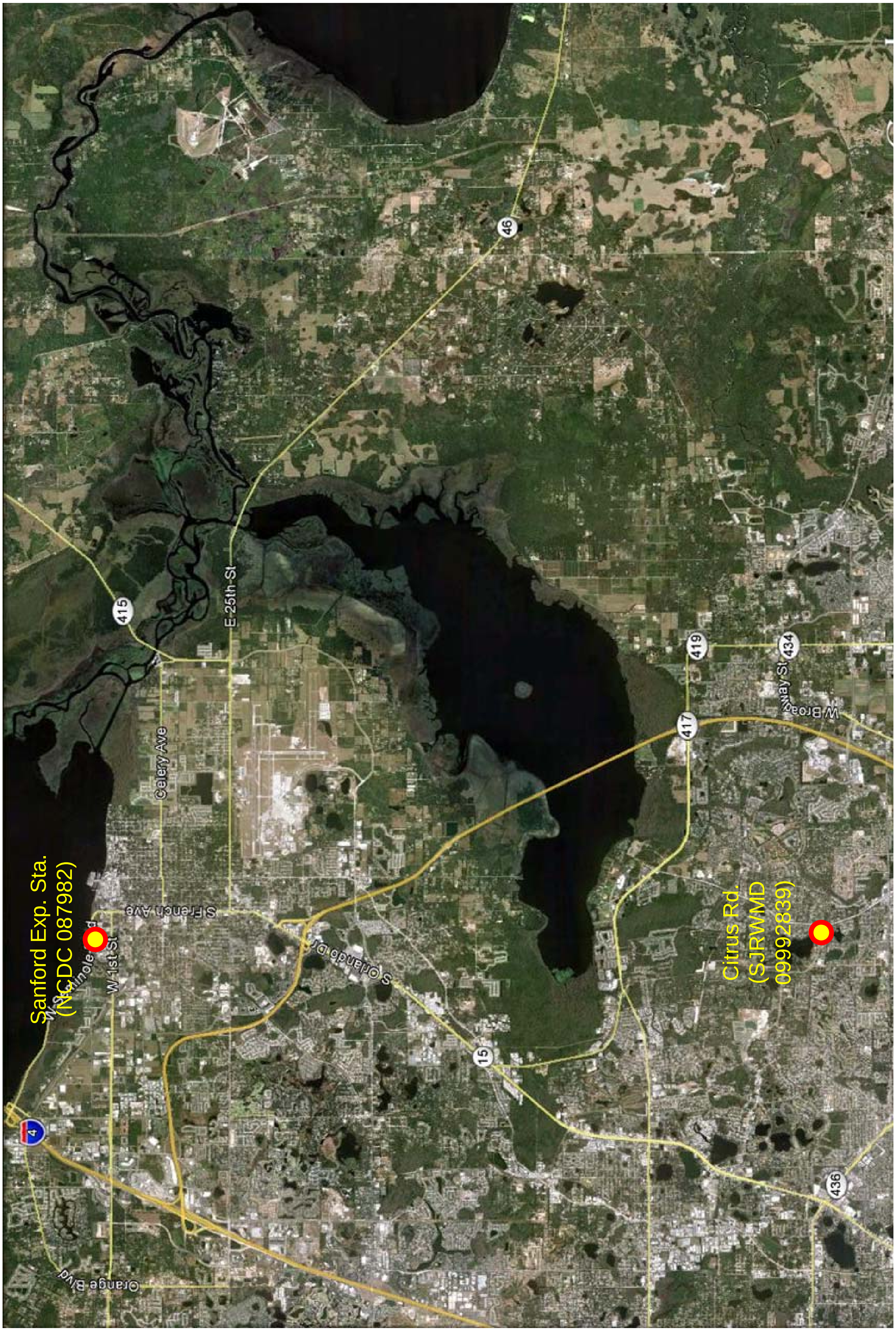


Figure 3-1. Locations of Identified Rainfall Recording Stations in the Vicinity of Lake Jesup.

A comparison of long-term "normal" rainfall in the vicinity of Lake Jesup (based upon the historical data at the Sanford Experimental Station site) and "actual" rainfall during the field monitoring program from January 2012-March 2013 (based upon rainfall records collected at the Citrus Road site) is given in Table 3-1. During the 15-month monitoring program, a total of approximately 59.90 inches of rainfall fell in the general vicinity of Lake Jesup. The long-term historical (normal) rainfall during the 15-month monitoring program is approximately 60.67 inches. The measured rainfall of 59.90 inches during the field monitoring program is approximately 1% less than the long-term annual mean of 60.67 inches.

TABLE 3-1

SUMMARY OF MEASURED AND HISTORICAL RAINFALL IN THE VICINITY OF LAKE JESUP

MONTH		RAINFALL AT THE CITRUS ROAD SITE (January 2012-March 2013) (inches)	MEAN RAINFALL AT THE SANFORD EXPERIMENTAL STATION (87982 NCDC) (1971-2000) (inches)
2012	January	0.11	2.73
	February	1.88	2.93
	March	1.15	3.87
	April	1.29	2.32
	May	3.88	3.28
	June	14.08	6.95
	July	4.61	6.86
	August	10.92	7.75
	September	7.61	6.16
	October	7.09	3.71
	November	0.28	2.23
	December	2.09	2.35
2013	January	1.19	2.73
	February	1.84	2.93
	March	1.88	3.87
	TOTALS:	**59.90**	**60.67**

A graphical comparison of measured and historical rainfall in the vicinity of Lake Jesup is given on Figure 3-2. Rainfall measured in the vicinity of Lake Jesup at the Citrus Road site during February, May, and December 2012 appears to be approximately normal compared with long-term rainfall characteristics. Substantially lower than normal rainfall occurred in the vicinity of Lake Jesup during January, March-April, July, and November 2012, and January-March 2013. Substantially higher than normal rainfall was observed during June, August, September, and October 2012.

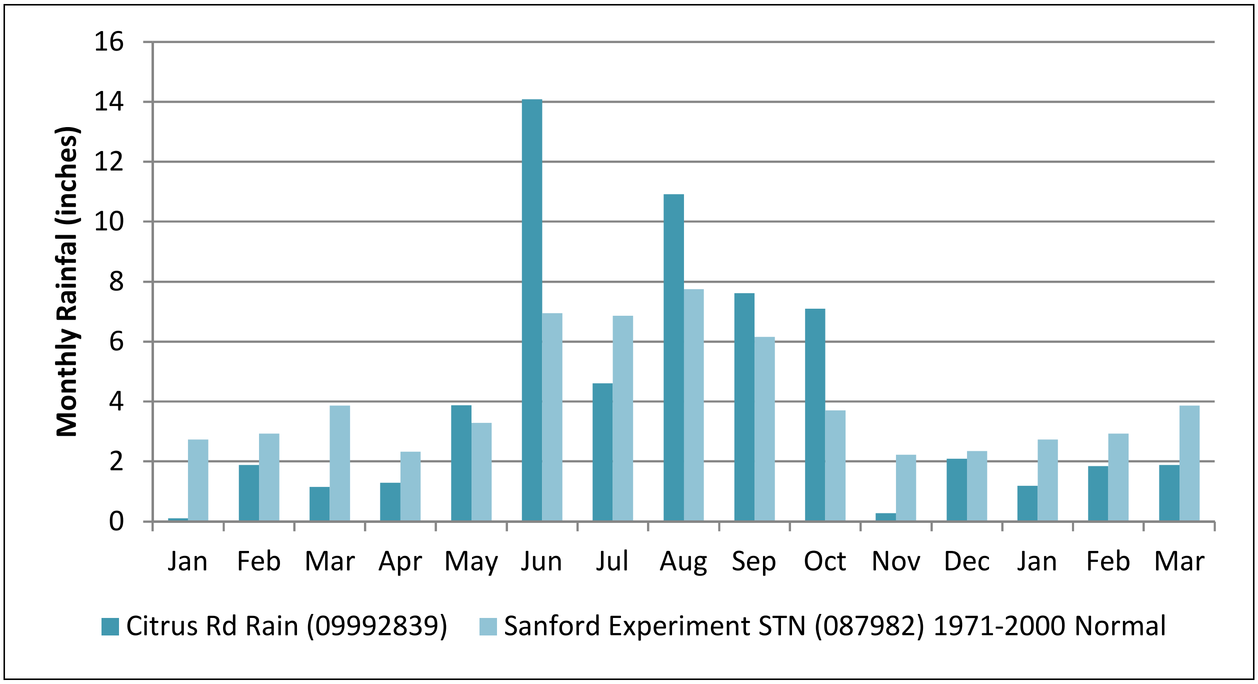


Figure 3-2. Comparison of Measured and Historical Rainfall in the Vicinity of Lake Jesup.

3.2 Hydrologic Inputs

3.2.1 Data Collection

Seepage influx into Lake Jesup was monitored over a 415-day period from January 25, 2012-March 15, 2013. Six separate seepage monitoring events were conducted to evaluate the quantity of shallow seepage entering Lake Jesup, with and without sediment contact, with laboratory analysis of the seepage samples conducted during 5 of the 6 monitoring events.

During the field monitoring program, 65 seepage samples were collected to measure volumetric inflow rates at the 12 monitoring sites. This value represents approximately 90% of the 72 potential seepage samples which would have been generated by conducting 6 monitoring events at each of the 12 sites. A graphical illustration of the number of samples collected at each of the seepage monitoring sites in Lake Jesup is given on Figure 3-3. Nine of the 12 seepage sites had useable inflow data during all 6 of the potential events. Two of the seepage monitoring sites produced useable inflow data during 5 of the 6 monitoring dates, with 1 site (Site 6), located in central portions of the lake where the equipment was most visible, producing useable inflow data during only 1 monitoring event.

Figure 3-3. Number of Useable Groundwater Seepage Inflow Samples Collected at the 6 Monitoring Sites.

The principle causes for the low percentage of useable seepage samples at Site 6 are vandalism of the seepage meters along with damage caused by wildlife. The external seepage meter at this site (with sediment contact) was uprooted from the sediments on multiple occasions, with resulting damage to the seepage meter fittings and collection bags. On most dates, the meter was either repaired or, if the damage was too severe, replaced with a new seepage meter. As a result, only 1 of the 6 potential samples was collected at this site.

The surficial sediments in Lake Jesup are extremely unconsolidated and easily disturbed. The process of retrieving the collected seepage samples using a diver stirred up plumes of flocculent sediment material which created a large area of elevated turbidity near the sampling location. A photograph of sediment resuspension during collection of seepage samples is given in Figure 3-4. These resuspended sediments had no impact on the seepage samples and is mentioned only to illustrate conditions within the lake.

Figure 3-4. Resuspended Sediments During Collection of Seepage Samples.

3.2.2 <u>Seepage Inflow</u>

A complete listing of individual seepage measurements conducted at each of the 12 monitoring sites during each of the monitoring events is given in Appendix A. Information is provided on the date and time of installation for each of the seepage meters, date and times for each of the field monitoring events, volume of seepage collected during each event, and the calculated seepage time and seepage rate. General comments and observations concerning the condition of the seepage meter and sample collection system are also provided.

A summary of measured seepage inflows to Lake Jesup from January 2012-March 2013 at each of the 6 pairs of monitoring sites is given in Table 3-2. Information is provided for the mean seepage inflow measured at each site, the measured minimum and maximum inflow rates, and the number of samples collected at each site. The majority of seepage inflow rates range from approximately 0.2-1.5 liters/m^2-day. The mean seepage inflow rates listed on Table 3-2 and in Appendix A reflect weighted inflow rates rather than the mean of the individual measured inflow rates since the monitoring events are not evenly spaced. The mean inflow rate for each site is calculated according to the following equation:

$$\textit{Mean Inflow Rate} = \frac{\textit{Total Seepage Volume Collected}}{\textit{Number of Days Included in Collected Samples}}$$

TABLE 3-2

SUMMARY OF MEASURED SEEPAGE INFLOWS TO LAKE JESUP FROM JANUARY 2012-MARCH 2013

SITE	WITHOUT SEDIMENTS				WITH SEDIMENTS			
	Number of Samples	Seepage Rate (liters/m^2-day)			Number of Samples	Seepage Rate (liters/m^2-day)		
		Minimum Value	Maximum Value	Mean		Minimum Value	Maximum Value	Mean
1	6	0.36	0.84	0.55	6	0.51	1.08	0.82
2	5	0.34	3.82	2.11	6	0.35	1.38	0.75
3	6	0.34	0.96	0.56	6	0.66	1.10	0.84
4	6	0.01	0.77	0.26	6	0.26	1.19	0.50
5	6	0.20	0.55	0.33	6	0.24	0.97	0.50
6	5	0.11	0.51	0.27	2	0.46	0.55	0.51

A summary of mean seepage inflows at the Lake Jesup monitoring sites, with and without sediment contact, is given in Table 3-3. Mean inflow rates for the seepage meters with sediment contact were higher in value at 5 of the 6 monitoring sites, while only 1 site (Site 2) exhibited higher inflow rates in the seepage meter without sediment contact. The lower seepage inflow rates observed in the seepage meters installed inside the aluminum cylinders with the sediments removed can be at least partially explained by the type and consistency of the parent soil material which lies underneath the accumulated muck layers. As discussed in Section 2, the parent sandy bottom of Lake Jesup consists of a cemented mixture of sand and fine organic matter. It was extremely difficult to insert the seepage meters into this material to obtain a watertight seal. As a result, the lower measured seepage rates inside the aluminum cylinders are likely related to the inability to form a tight seal between the seepage meter and the parent lake bottom material.

TABLE 3-3

SUMMARY OF MEAN SEEPAGE INFLOWS AT THE LAKE JESUP MONITORING SITES

SITE	MEAN SEEPAGE INFLOW ($liters/m^2$-day)	
	Without Sediments	With Sediments
1	0.55	0.82
2	2.11	0.75
3	0.56	0.84
4	0.26	0.50
5	0.33	0.50
6	0.27	0.51
Mean	**0.68**	**0.65**
Geometric Mean	**0.50**	**0.64**

Arithmetic mean and geometric mean values are provided at the bottom of Table 3-3 to reflect the overall mean seepage inflow rates for seepage meters with and without sediment contact. The arithmetic mean values are very similar, with a mean of 0.68 liters/m^2-day for seepage meters without sediment contact compared with 0.65 liters/m^2-day for seepage meters with sediment contact. The geometric mean value is also calculated for the seepage data since virtually all environmental data exhibit log-normal distributions, and a geometric mean may be a more accurate reflection of central tendency than a simple arithmetic mean. The geometric mean for seepage inflow without sediment contact is 0.50 liters/m^2-day compared with 0.64 liters/m^2-day for seepage collected in areas with sediment contact.

A statistical summary of measured seepage inflow rates at the 6 monitoring sites is given in Figure 3-5. A graphical summary of the monitoring data is presented in the form of Tukey box plots, also often called "box and whisker plots". The bottom of the box portion of each plot represents the lower quartile, with 25% of the data points falling below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data falling above this value. The horizontal line within the box represents the median value, with 50% of the data falling both above and below this value. The vertical lines, also known as "whiskers", represent the 5 and 95 percentiles for the data sets. Individual values which fall outside of the 5-95 percentile range are indicated as **red dots**.

As indicated on Figure 3-5, median values (indicated by the blue horizontal lines in each of the box plots) are higher for Sites 1-5 for seepage meters placed with existing sediments compared with seepage meters installed without sediments. No conclusions can be made regarding relative seepage inflow rates at Site 6 since only one measurement was recorded in the seepage meter installed with sediment contact. A discussion of potential causes for the observed differences in measured seepage inflow rates is given in Section 3.2.4.

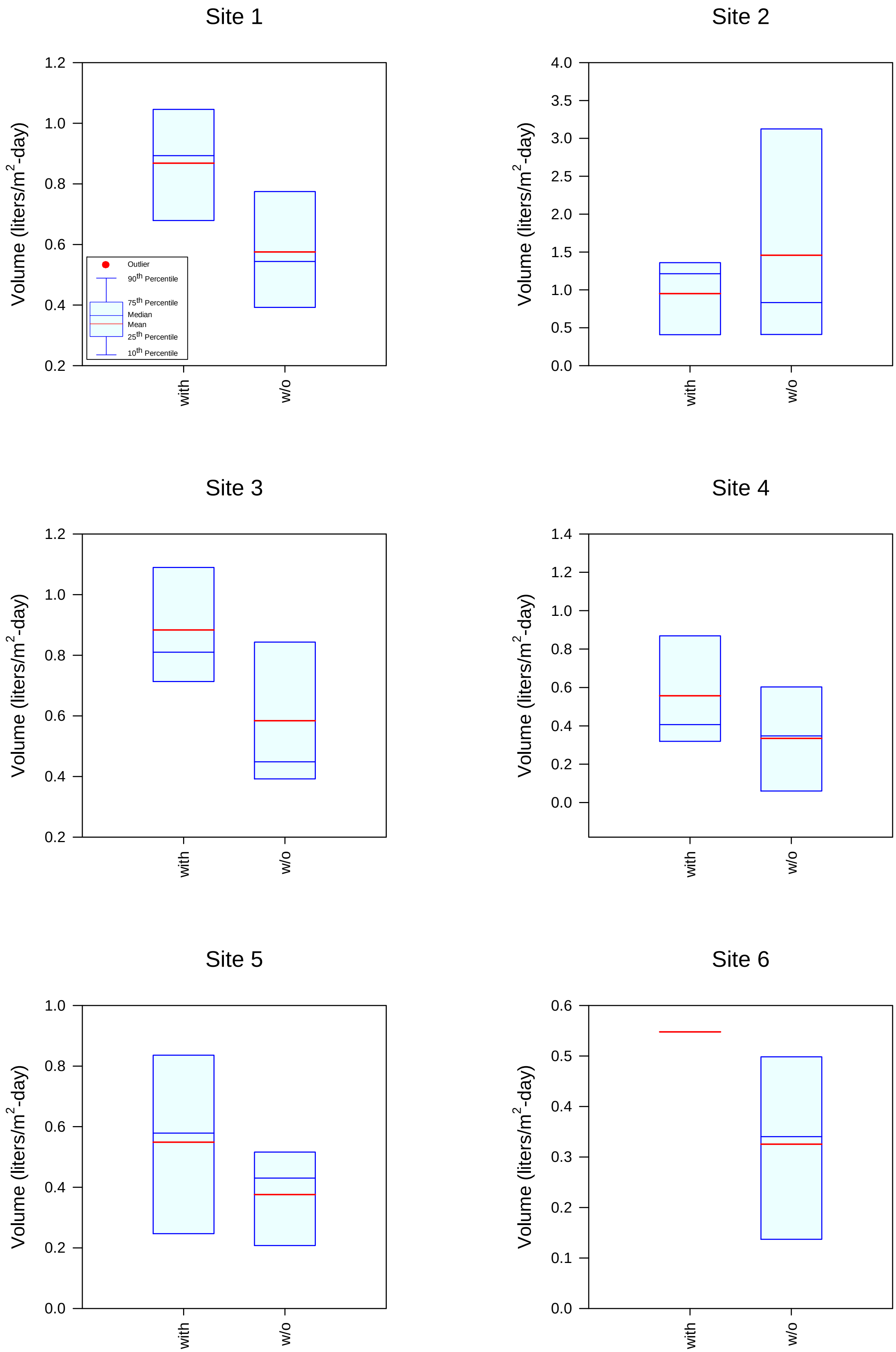


Figure 3-5.

Statistical Comparison of Measured Seepage Inflow Rates at the 6 Monitoring Sites With and Without Sediment Contact.

An analysis was conducted to determine if statistically significant differences exist between seepage inflow rates measured in seepage meters with and without sediment contact. A summary of an analysis of variance (ANOVA) comparison of seepage inflow rates in seepage meters installed in areas with and without sediments is given in Table 3-4. ANOVA comparisons were conducted using the PROC GLM procedure of SAS. The data sets were evaluated for normality and equality of variances prior to testing. The calculated model significance level is provided, with values of 0.05 or less indicating statistically significant differences at the 0.05 level of significance or better, and values in excess of 0.05 indicating a lack of statistical significance. Mean values are provided for seepage meters with and without sediment contact. The results of a Tukey grouping analysis are also provided which identify statistically similar treatment types. Seepage inflow rates are listed from highest to lowest for each treatment type.

TABLE 3-4

ANOVA COMPARISON OF SEEPAGE INFLOW RATES IN LAKE JESUP WITH AND WITHOUT SEDIMENT CONTACT

DATA TREATMENT	MODEL SIGNIFICANCE LEVEL	CONDITION	MEAN VALUE (liters/m^2-day)	TUKEY GROUPING
Normal Data	0.2743	Without With	0.68 0.65	A A
Log-Transformed Data	0.0245	With Without	0.64 0.50	A B

As indicated on Table 3-4, no statistically significant difference was detected between seepage inflow rates in Lake Jesup measured in areas with and without sediment contact using the collected data. However, when a log transformation was applied to the inflow data, the inflow rates observed in the chambers with sediment contact were statistically higher in value than inflow rates measured in seepage meters without sediment contact.

3.2.3 Seasonal Variability in Seepage Rates

As discussed in Section 3.1, rainfall in the vicinity of Lake Jesup was approximately normal during the field monitoring program. Since seepage originates from rainfall, seepage inflow to Lake Jesup should be higher during periods of frequent rainfall or following significant rain events.

A summary of mean seepage inflows to Lake Jesup for each of the 6 collection dates is given on Table 3-5. The mean values summarized in this table reflect the log-normal mean value for all seepage inflow data collected on each collection date. The values summarized in Table 3-4 appear to exhibit a slight seasonal pattern, with more elevated seepage inflow rates during wet season conditions and reductions in seepage inflow observed during dry season conditions.

TABLE 3-5

MEAN SEEPAGE INFLOWS TO LAKE JESUP BY COLLECTION DATE

DATE	MEAN SEEPAGE INFLOW (liters/m²-day)	
	Without Sediments	With Sediments
3/9/12	0.80	0.83
7/13/12	0.87	0.41
8/24/12	0.72	1.06
11/30/12	0.26	0.58
1/25/13	0.62	0.80
3/15/13	0.42	0.89

A graphical comparison of mean event seepage inflow rates to Lake Jesup during the field monitoring program in areas with and without sediment contact is given on Figure 3-6. Measured event rainfall depths from the Citrus Road site are also included for comparison purposes. In general, seepage inflow appears to be loosely correlated with rainfall in the watershed, with stable or increasing seepage values during periods of high rainfall, and decreasing seepage rates during periods of low rainfall.

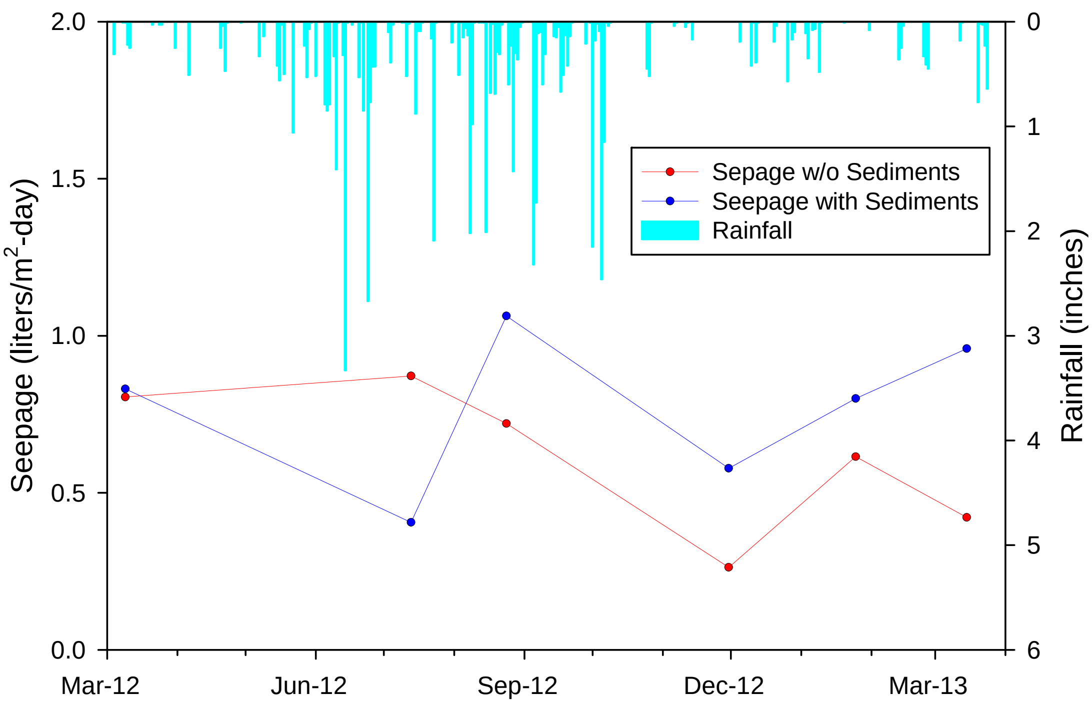


Figure 3-6. Temporal Variability in Mean Seepage Inflow Rates to Lake Jesup During the Field Monitoring Program.

3.2.4 Error Evaluation

Volumetric measurements of seepage inflow using the seepage meter method are subject to several potential sources of error. First, a loss of seepage could occur as a result of an incomplete seal between the perimeter of the seepage meter and the bottom sediments. If this seal is not intact, seepage inflow may escape from the seepage meter into the lake without being collected in the sample bag. This type of error is generally limited to areas with firm sandy sediments, such as those which occurred inside the aluminum cylinders. Consolidated muck sediments, such as those found throughout Lake Jesup, provide an excellent seal with the seepage apparatus. As discussed previously, loss of seepage may have occurred in the seepage meters installed on the sandy bottom.

A second potential for error exists if additional settling of the seepage meters occurs during the field monitoring program. As the seepage meter settles, the displaced water volume is forced into the seepage bag and is included in the seepage field measurements. This phenomenon was highly unlikely in the meters installed on the cemented sand bottom. In muck type sediments, this type of error is generally minimized by inserting the seepage meters until the thick consolidated organic material is reached. This was possible for many of the shoreline seepage meters installed in Lake Jesup, and error from additional settling of the seepage meters is not a significant concern in these portions of the lake. All of the shoreline seepage meters were installed at least into the consolidated sediment layer and were pounded into the sediments until no additional movement of the seepage meter occurred. Although additional settling of the seepage meters cannot be ruled out in these areas, any additional movement should be very minimal. No visual changes in seepage meter profiles were observed by the field crew at any of the monitoring sites.

However, the seepage meter installed in a more central portion of the lake (Site 6) was located in an area with deeper muck accumulations, and it was not possible to insert the seepage meter into the firm organic sediments. The enlarged flange welded onto the seepage meters (Figure 2-3) is intended to both stabilize the seepage meter and minimize settling in unconsolidated sediments. However, errors in seepage measurements created by settling at Site 6 are still possible, but thought to be relatively minimal.

3.3 Chemical Characteristics of Seepage Samples

Seepage samples collected during the final 5 of 6 seepage monitoring events in Lake Jesup were submitted for laboratory analyses. The initial samples were discarded since they reflected a combination of seepage and residual lake water from the seepage meter installation. A complete listing of laboratory measurements conducted on individual seepage samples collected at each of the 12 monitoring sites is given in Appendix B. A total of 54 seepage samples was collected during the field monitoring program for laboratory analyses. This value reflects approximately 90% of the number of potential samples for laboratory analyses which would have been generated by conducting 5 monitoring events at each of the 12 monitoring sites (60 potential seepage samples).

A summary of mean chemical characteristics of seepage samples collected in Lake Jesup from January 2012-March 2013 is given in Table 3-6. The data summarized in this table reflect the volume-weighted mean characteristics for each of the evaluated parameters at each monitoring site.

TABLE 3-6

MEAN CHARACTERISTICS OF GROUNDWATER SEEPAGE COLLECTED AT THE LAKE JESUP SEEPAGE MONITORING SITES FROM JANUARY 2012-MARCH 2013

SITE	SAMPLE DESCRIPTION	NUMBER OF SAMPLES COLLECTED	pH (s.u.)	ALK. (mg/l)	SPEC. COND. (μmho/cm)	NH_3-N (μg/l)	NO_x-N (μg/l)	TOTAL N (μg/l)	SRP (μg/l)	TOTAL P (μg/l)
1	Without	5	7.43	90.0	764	378	2,167	3,761	143	160
	With	5	7.37	89.4	745	894	1,114	3,449	135	159
2	Without	4	7.65	129	361	632	19	766	118	141
	With	5	7.63	126	465	1,330	361	2,022	205	237
3	Without	5	7.55	137	976	1,424	2,209	5,192	416	452
	With	5	7.41	104	899	1,521	249	3,462	177	219
4	Without	5	7.64	163	1,044	991	4,004	6,558	741	790
	With	5	7.47	132	985	1,834	2,360	5,664	582	623
5	Without	5	7.52	152	1,388	3,015	1,211	5,604	303	369
	With	5	7.36	98.1	961	1,231	502	3,103	34	120
6	Without	4	7.47	234	2,081	4,453	2,122	7,934	1,298	1,565
	With	1	7.21	134	1,042	3,038	63	4,649	30	34

In general, groundwater seepage entering Lake Jesup was found to be approximately neutral to slightly alkaline in pH, with measured values ranging from 7.43-7.65 in seepage collected without sediment contact, and values ranging from 7.21-7.63 in samples collected with sediment contact. Seepage entering Lake Jesup was also moderately to well buffered, with the majority of measured alkalinity values in excess of 100 mg/l. Alkalinity values in seepage collected without sediment contact ranged from 90-234 mg/l, while alkalinity values in samples collected with sediment contact ranged from 89.4-134 mg/l. In general, samples collected without sediment contact appear to exhibit somewhat higher alkalinity values than samples collected with sediment contact, suggesting that the sediments may consume alkalinity from the seepage during migration through the sediment layers.

Seepage samples collected in Lake Jesup were also characterized by moderate to elevated levels of specific conductivity. Mean conductivity values in sediments collected without sediment contact ranged from 361-2,081 μmho/cm, while conductivity values in samples collected with sediment contact ranged from 465-1,042 μmho/cm. The data suggests that the sediments may also be consuming dissolved ions from the seepage during migration through the sediments, resulting in lower conductivity values after sediment contact.

Measured concentrations of ammonia in groundwater seepage were highly variable throughout Lake Jesup in samples collected both with and without sediment contact. Mean ammonia concentrations in samples collected without sediment contact ranged from 378-4,453 μg/l, while samples collected with sediment contact ranged from 894-3,038 μg/l. Although the data are highly variable, the sediments do not appear to either add or remove ammonia inputs from groundwater seepage.

Measured concentrations of NO_x were also highly variable in seepage samples collected throughout Lake Jesup. Mean NO_x concentrations in seepage samples collected with sediment contact ranged from 19-4,004 µg/l, while NO_x concentrations in seepage collected with sediment contact ranged from 63-2,360 µg/l. In contrast to ammonia, NO_x concentrations appear to be somewhat different in samples collected with and without sediment contact. In general, seepage samples collected without sediment contact exhibited substantially higher concentrations of NO_x compared with samples collected with sediment contact. These data suggest that denitrification processes may be responsible for removing NO_x during migration through the sediments. Measured concentrations of total nitrogen in groundwater seepage entering Lake Jesup were also highly variable in value.

Measured total nitrogen concentrations in seepage samples collected without sediment contact ranged from 766-7,934 µg/l, while total nitrogen concentrations in seepage samples collected with sediment contact ranged from 2,022-5,664 µg/l. Overall, total nitrogen concentrations were higher in seepage collected without sediment contact than in samples collected with sediment contact, further suggesting that denitrification processes may be responsible for removing nitrogen in seepage during migration through the organic sediment layers.

Measured concentrations of SRP were both highly variable and high in value in seepage samples collected from Lake Jesup. Mean SRP concentrations in samples collected without sediment contact ranged from 118-1,298 µg/l, while mean SRP concentrations in seepage samples collected with sediment contact ranged from 30-582 µg/l. Overall, phosphorus concentrations in seepage collected without sediment contact were substantially greater in value than samples collected with sediment contact, suggesting that SRP removal may occur during migration of the seepage through the organic sediment layers.

A similar trend is also apparent for total phosphorus, with mean total phosphorus concentrations in seepage samples collected without sediment contact ranging from 141-1,565 µg/l, and total phosphorus concentrations in samples with sediment contact ranging from 34-623 µg/l. Overall, the mean total phosphorus concentration in samples collected without sediment contact appears to be much greater in value than total phosphorus concentrations collected in seepage with sediment contact.

As indicated on Figure 3-3, the seepage monitoring sites are numbered in order from west to east, with Site 1 located on the west end of the lake and Site 6 on the east end. As indicated on Table 3-6, a distinct concentration gradient is present in seepage characteristics across Lake Jesup, with increasing concentrations of alkalinity, ammonia, total nitrogen, SRP, and total phosphorus from west to east. This gradient is highly apparent for seepage collected on the sand bottom, which reflects the characteristics of seepage reaching the lake bottom, and is much less apparent for seepage which has migrated through the sediment layer. These data suggest that the sediments may be modifying the characteristics of seepage which results in more uniform seepage characteristics which actually discharge into Lake Jesup.

A statistical comparison of measured seepage pH values in samples collected with and without sediment contact is given on Figure 3-7. Mean seepage pH values appear to be relative similar in samples collected with and without sediment contact at Sites 1, 3, and 4, with slightly more elevated pH measurements observed in samples collected without sediment contact at Sites 2 and 5. No comparison can be made for pH values at Site 6 since only one sample is available which was collected with sediment contact. In general, measured sediment pH values without sediment contact appear to exhibit a higher degree of variability than samples collected with sediment contact for Sites 1, 3, 4, and 5.

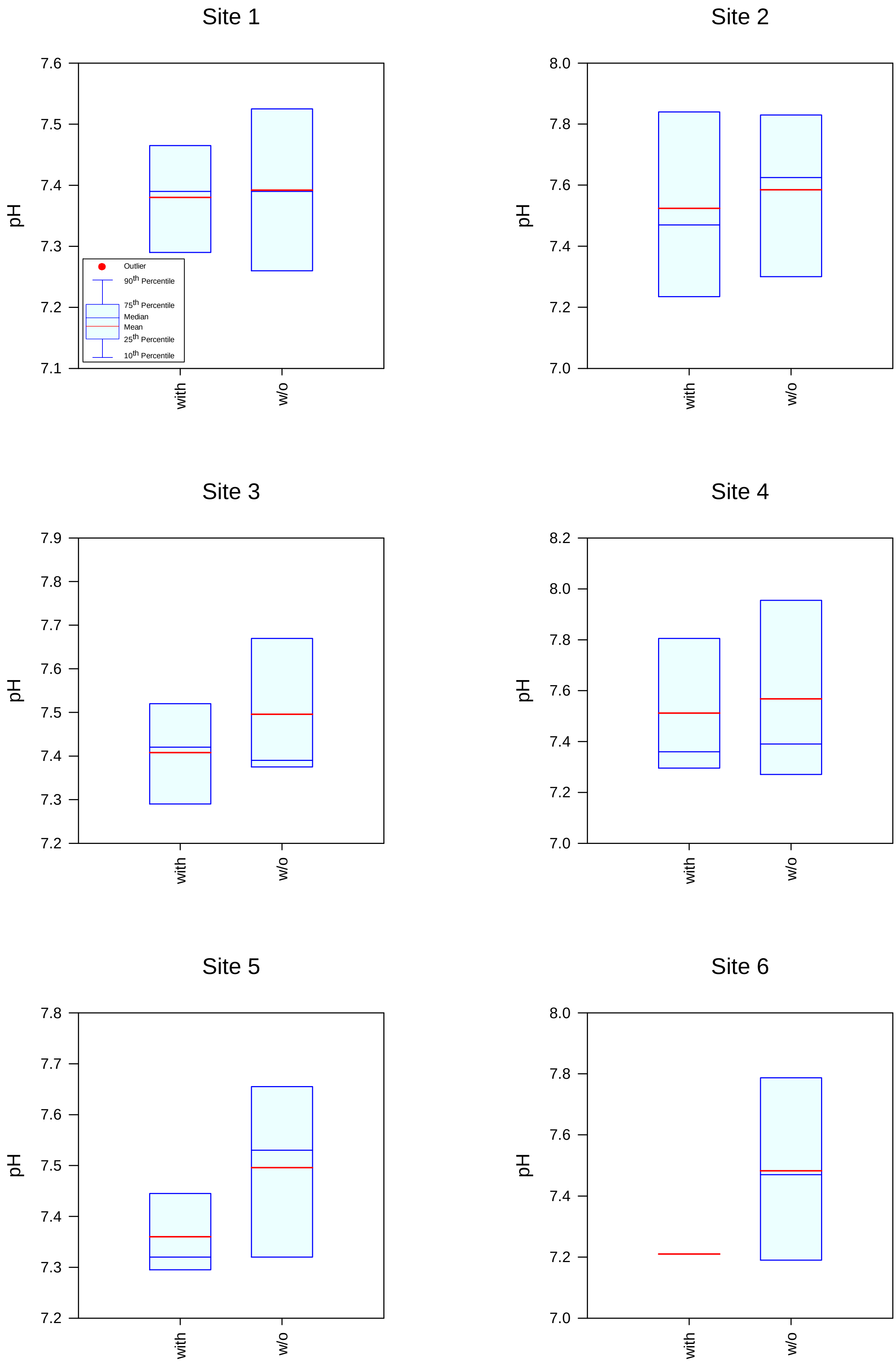


Figure 3-7.

Statistical Comparison of pH Values in Seepage Samples Collected With and Without Sediment Contact.

A statistical comparison of measured seepage alkalinity values in samples collected with and without sediment contact is given on Figure 3-8. Measured alkalinity values exhibited a relatively wide range of variability in concentrations at several of the monitoring sites. In general, more elevated levels of alkalinity were observed in samples collected without sediment contact for Sites 2, 3, and 5, with relatively similar values between samples collected with and without sediments at Site 1 and a more elevated median value observed for samples with sediment contact at Site 4. Measured alkalinity values were also highly variable within the lake, with a general trend of increasing alkalinity from west to east across Lake Jesup.

A statistical comparison of measured conductivity values in seepage samples collected with and without sediment contact is given on Figure 3-9. Median conductivity values at Sites 1 and 3 are relatively similar in samples collected with and without sediment contact. However, measured conductivity values at Sites 4 and 5 appear to be greater in samples collected without sediment contact, suggesting that migration through the sediments may reduce available ions entering the lake through groundwater seepage. The opposite pattern was observed at Site 2 where a higher level of conductivity was observed in samples collected with sediment contact compared to samples collected without sediment contact. Measured conductivity values were also highly variable throughout the lake, with a general trend of increasing conductivity from west to east within Lake Jesup.

A statistical comparison of measured ammonia concentrations in seepage samples collected with and without sediment contact is given on Figure 3-10. Median ammonia concentrations were higher in samples collected with sediment contact at Sites 1, 2, 3, and 4, with relatively similar median values observed at Site 5. Overall, the data suggests that ammonia may be released from the sediments into groundwater seepage although the pattern does not appear to be uniform throughout the lake.

A statistical comparison of measured NO_x concentrations in seepage samples collected with and without sediment contact is given on Figure 3-11. At Sites 1 and 3, samples collected without sediment contact exhibited a much higher median concentration for NO_x. Relatively similar NO_x concentrations were observed between samples collected with and without sediment contact at Sites 4 and 5, with substantially higher NO_x concentrations observed in samples collected with sediment contact at Site 2. These data also suggest that sediments may be impacting NO_x concentrations, although the trend is variable throughout the lake.

A statistical comparison of concentrations of total nitrogen in seepage samples collected with and without sediment contact is given on Figure 3-12. Seepage concentrations of total nitrogen were relatively similar at Site 1 between samples collected with and without sediment contact. Samples with sediment contact exhibited higher median concentrations of total nitrogen at Sites 2 and 4, while the highest total nitrogen concentrations at Sites 3 and 5 occurred in seepage meters without sediment contact. Similar to trends previously observed for NO_x, sediment impacts on seepage characteristics appear to be highly variable throughout Lake Jesup, with sediments in some areas resulting in increases in total nitrogen and sediments in other areas resulting in decreases in total nitrogen.

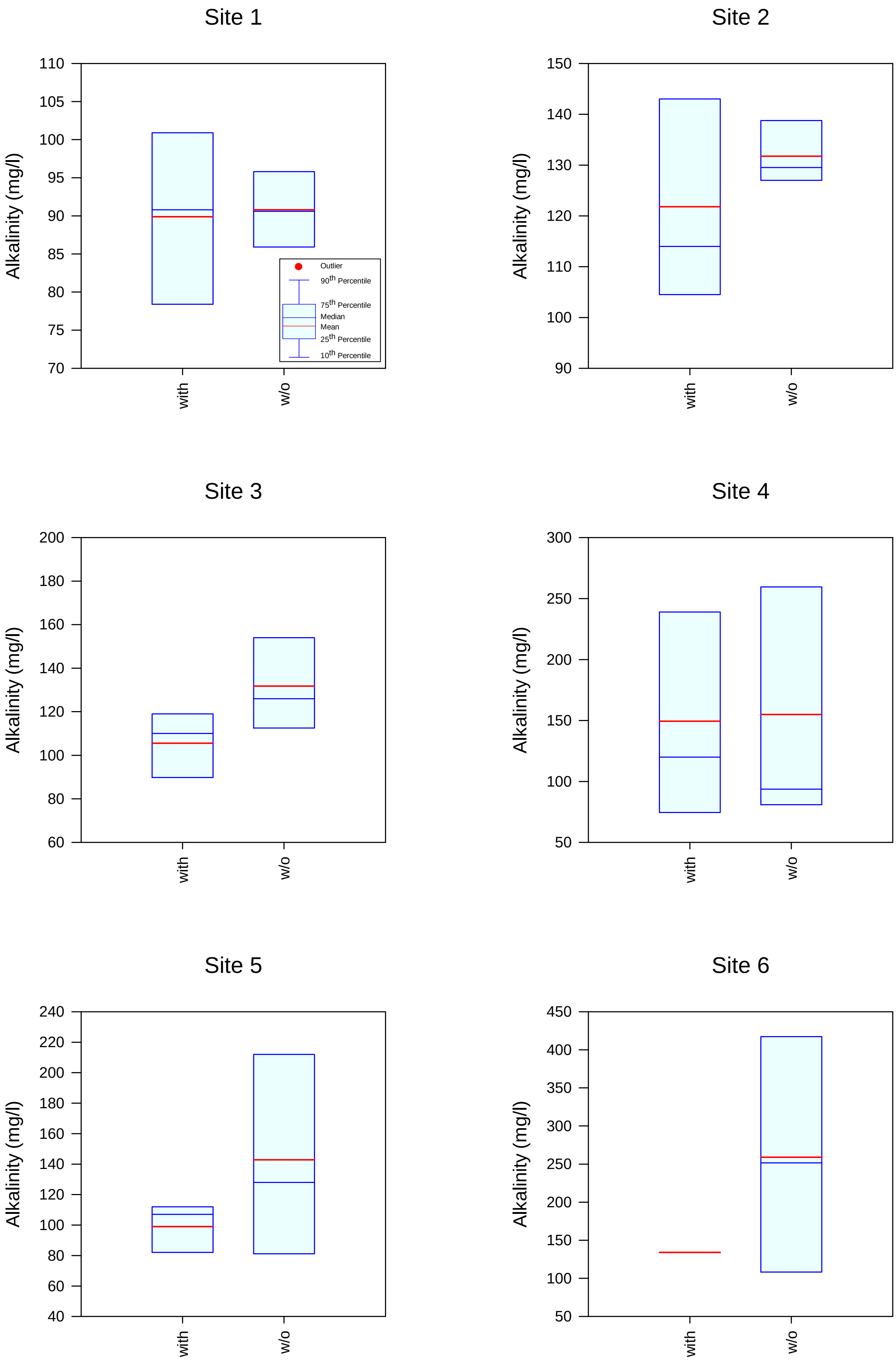


Figure 3-8.

Statistical Comparison of Alkalinity Values in Seepage Samples Collected With and Without Sediment Contact.

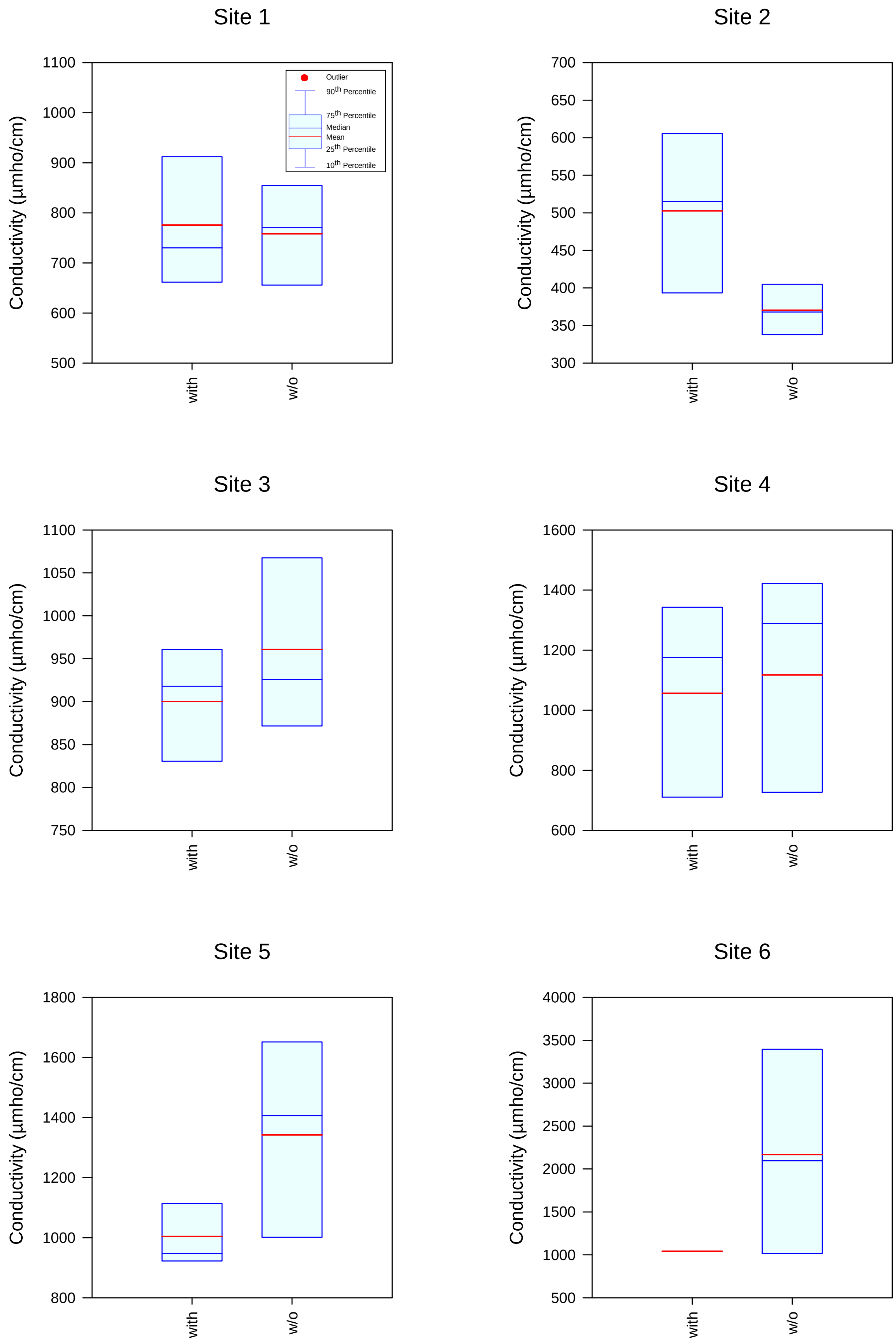


Figure 3-9.

Statistical Comparison of Conductivity Values in Seepage Samples Collected With and Without Sediment Contact.

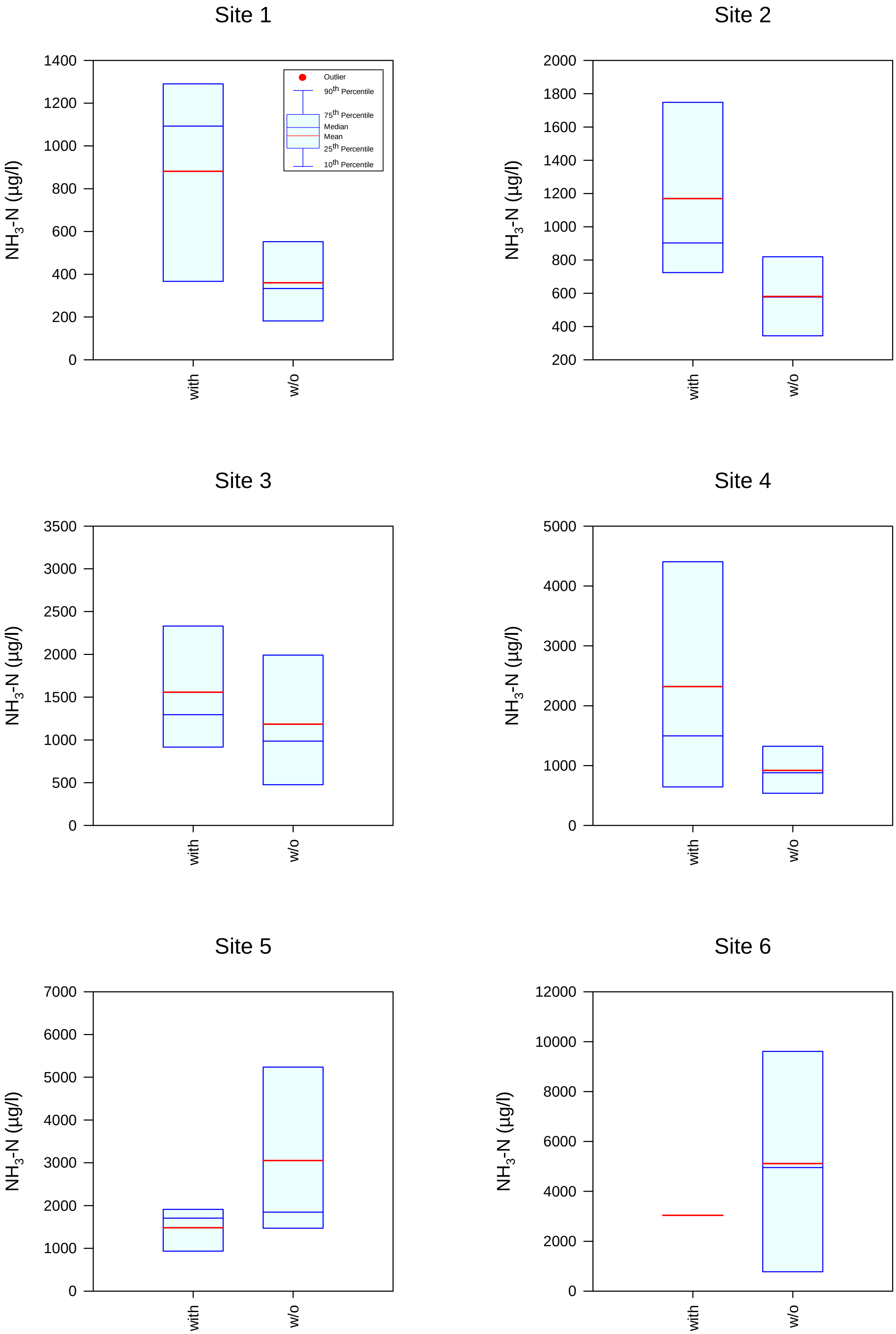


Figure 3-10.

Statistical Comparison of Ammonia Concentrations in Seepage Samples Collected With and Without Sediment Contact.

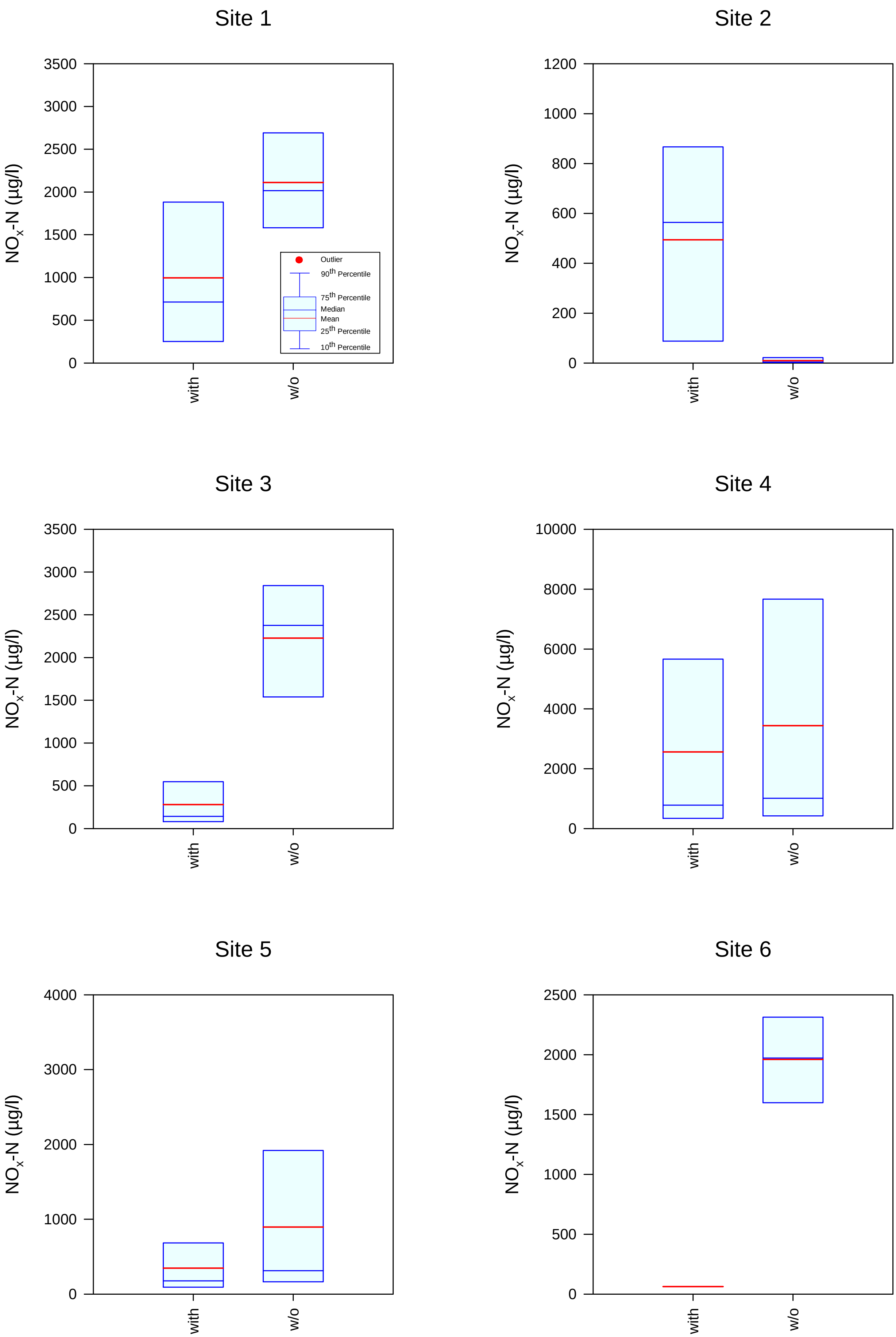


Figure 3-11.

Statistical Comparison of NO_x Concentrations in Seepage Samples Collected With and Without Sediment Contact.

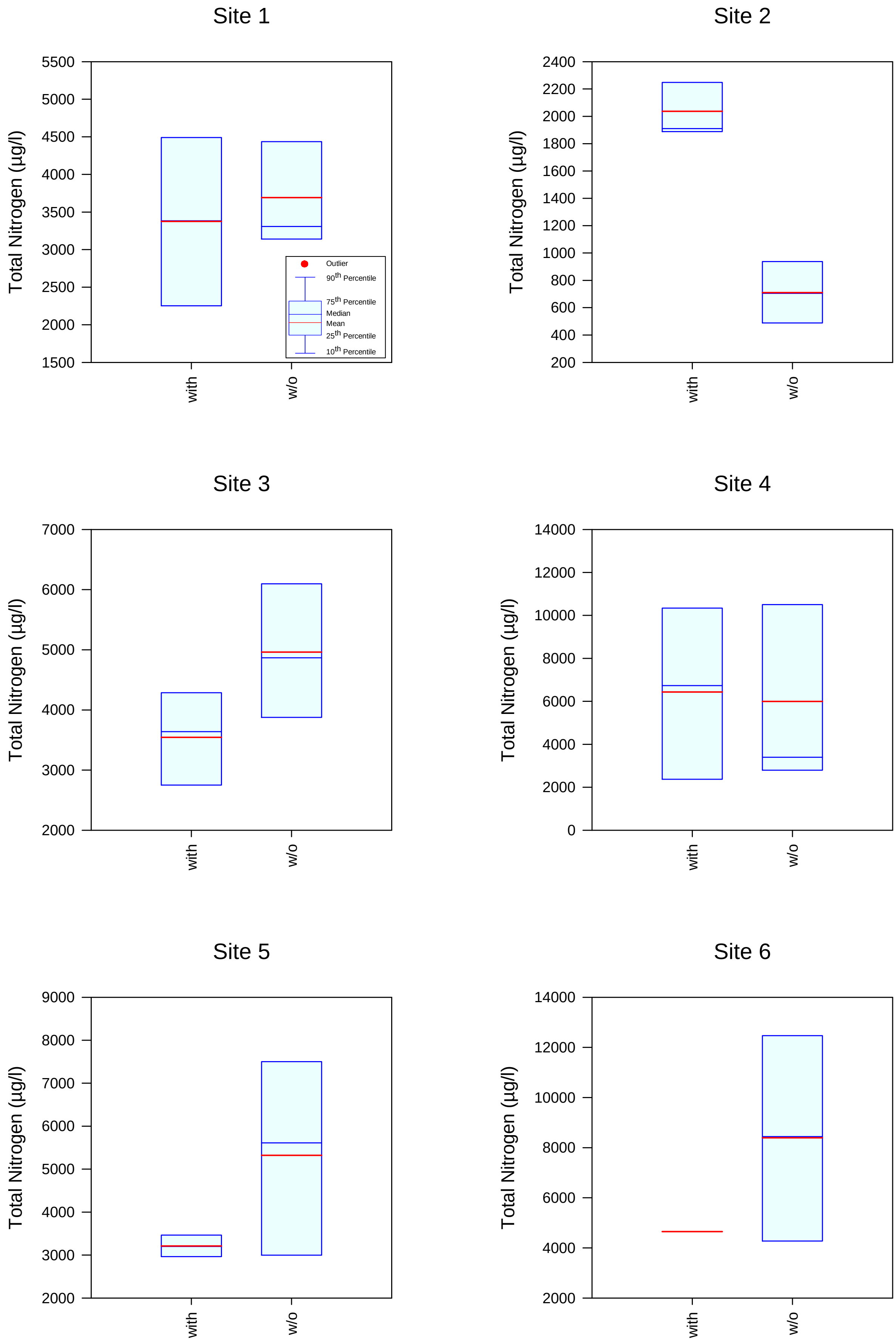


Figure 3-12.

Statistical Comparison of Total Nitrogen Concentrations in Seepage Samples Collected With and Without Sediment Contact.

A statistical comparison of measured SRP concentrations in seepage samples collected with and without sediment contact in Lake Jesup is given on Figure 3-13. Measured SRP concentrations were higher in value in seepage collected without sediment contact at Sites 1, 3, and 5, with higher SRP concentrations observed in chambers with sediment contact at Sites 2 and 4. Similar to the trend observed previously for total nitrogen, impacts to SRP concentrations appear to vary throughout Lake Jesup.

A statistical comparison of measured seepage concentrations of total phosphorus in samples collected with and without sediment contact is given on Figure 3-14. More elevated total phosphorus concentrations were observed in samples collected without sediment contact at Sites 1, 3, and 5, with higher total phosphorus concentrations observed with sediment contact at Sites 2 and 4. Impacts of sediments on seepage characteristics also appears to be variable throughout Lake Jesup.

An ANOVA comparison of seepage characteristics in Lake Jesup with and without existing sediments is given in Table 3-7. This analysis was conducted using a combined data set formed from all of the collected measured seepage characteristics, and the chemical characteristics measured in seepage meters with sediment contact were compared with the characteristics of the combined samples collected without sediment contact. No statistically significant differences were observed in seepage characteristics collected in Lake Jesup with or without existing sediments. However, it is interesting to note that the highest mean concentrations for each of the parameters listed in Table 3-7 occurred in samples collected without sediment contact. Although not statistically significant at the 0.05 level of significance, statistically significant differences would have been recognized for alkalinity, NO_x, and SRP if the analysis had been conducted at a 0.10 level of significance.

An ANOVA comparison of seepage characteristics in Lake Jesup with and without existing sediments, using a log-normal transformation of the data, is given on Table 3-8. A log-normal transformation was conducted to the data since environmental data normally exhibit log-normal distributions. Based upon this analysis, statistically significant differences were observed only for SRP and total phosphorus, with significantly higher concentrations observed in samples collected without sediments than in samples collected with sediments. No statistically significant differences were observed at the 0.05 level of significance for any of the other remaining parameters, although the differences in measured alkalinity concentrations would have been significant at the 0.10 level of significance. Similar to the trend observed for the non-transformed data set summarized in Table 3-7, the highest values for each of the measured parameters were obtained in samples collected without sediment contact, although the differences were only statistically significant for SRP and total phosphorus.

An additional ANOVA comparison was conducted to evaluate seepage characteristics in Lake Jesup with and without existing sediments by individual monitoring site. This analysis was conducted using data collected at a given site for seepage samples with sediment contact which is compared with seepage characteristics collected without sediment contact. A summary of statistically significant differences in seepage characteristics for each of the individual monitoring sites, using the non-transformed data sets, is given in Table 3-9. Parameters which did not have statistically significant differences (0.05 level) are not included in Table 3-9.

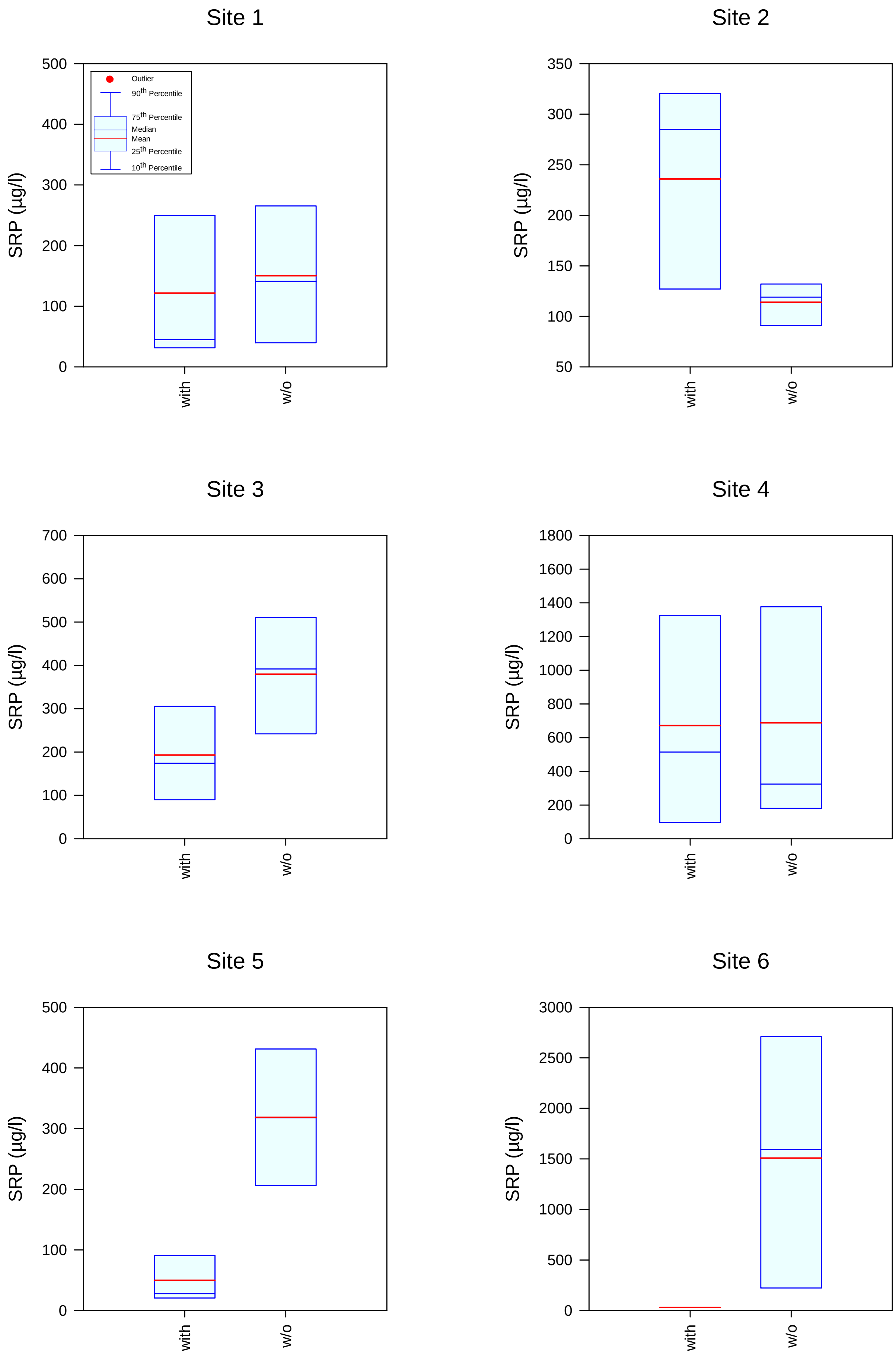


Figure 3-13.

Statistical Comparison of SRP Concentrations in Seepage Samples Collected With and Without Sediment Contact.

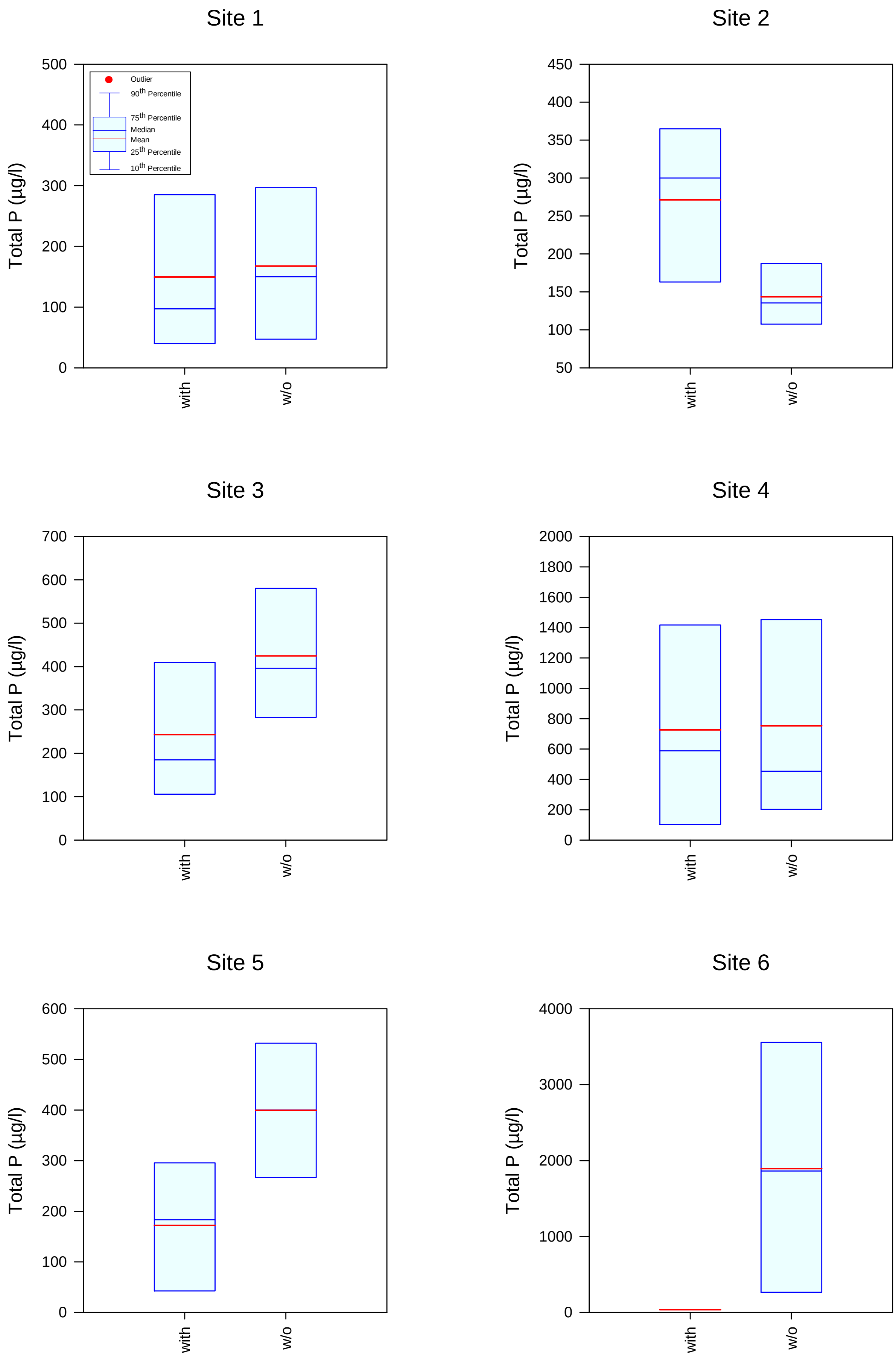


Figure 3-14.

Statistical Comparison of Total Phosphorus Concentrations in Seepage Samples Collected With and Without Sediment Contact.

TABLE 3-7

ANOVA COMPARISON OF NON-TRANSFORMED SEEPAGE CHARACTERISTICS IN LAKE JESUP WITH AND WITHOUT EXISTING SEDIMENTS

PARAMETER	UNITS	MODEL SIGNIFICANCE LEVEL	CONDITION	MEAN CONCENTRATION	TUKEY GROUPING
pH	s.u.	0.2347	without	7.50	A
			with	7.43	A
Alkalinity	mg/l	0.0759	without	149	A
			with	114	A
Conductivity	µmho/cm	0.94	without	1,109	A
			with	855	A
Ammonia	µg/l	0.6343	without	1,798	A
			with	1,541	A
NO_x	µg/l	0.0749	without	1,830	A
			with	901	A
Total N	µg/l	0.1635	without	4,867	A
			with	3,754	A
SRP	µg/l	0.0951	without	506	A
			with	246	A
Total P	µg/l	0.1083	without	603	A
			with	302	A

TABLE 3-8

ANOVA COMPARISON OF LOG-TRANSFORMED SEEPAGE CHARACTERISTICS IN LAKE JESUP WITH AND WITHOUT EXISTING SEDIMENTS

PARAMETER	UNITS	MODEL SIGNIFICANCE LEVEL	CONDITION	MEAN CONCENTRATION	TUKEY GROUPING
pH	s.u.	0.2360	without	7.50	A
			with	7.43	A
Alkalinity	mg/l	0.0846	without	131	A
			with	104	A
Conductivity	µmho/cm	0.2346	without	948	A
			with	814	A
Ammonia	µg/l	0.5567	without	1,139	A
			with	970	A
NO_x	µg/l	0.3414	without	567	A
			with	339	A
Total N	µg/l	0.5516	without	3,703	A
			with	3,311	A
SRP	µg/l	0.0095	without	275	A
			with	117	B
Total P	µg/l	0.0324	without	329	A
			with	171	B

TABLE 3-9

SUMMARY OF SIGNIFICANT DIFFERENCES IN SEEPAGE CHARACTERISTICS (NON-TRANSFORMED) WITH AND WITHOUT SEDIMENT CONTACT BY MONITORING SITE

SITE	PARAMETER	UNITS	MODEL SIGNIFICANCE LEVEL	CONDITION	MEAN CONCENTRATION	TUKEY GROUPING
1	None	--	--	--	--	--
2	Total N	μg/l	0.0001	With Without	2,037 710	A B
3	NO_x	μg/l	0.0003	Without With	2,227 280	A B
4	None	--	--	--	--	--
5	SRP	μg/l	0.0036	Without With	318 50	A B
	Total P	μg/l	0.0357	Without With	399 172	A B
6	NO_x	μg/l	0.0203	Without With	1,961 63	A B

No statistically significant differences were observed for any of the evaluated parameters at monitoring Sites 1 and 4. However, a statistically significant difference in total nitrogen concentrations was observed at Site 2, with higher total nitrogen concentrations observed in samples collected with sediment contact compared with samples collected without sediment contact. The more elevated concentrations of total nitrogen observed in seepage with sediment contact at Site 2 is contrary to the lake-wide trend of higher seepage concentrations without sediment contact. At this site, it appears that migration of seepage through the existing sediments results in an increase in total nitrogen concentrations compared with concentrations entering the lake through the sand bottom layer.

Statistically significant differences were observed at Site 3 for NO_x, at Site 5 for SRP and total phosphorus, and at Site 6 for NO_x between samples collected with and without sediment contact. However, in contrast to the trend observed at Site 2, the statistically significant differences observed at Sites 3, 5, and 6 all indicate more elevated concentrations for each of the significant parameters without sediment contact and lower concentrations with sediment contact. Data collected at these three sites suggest that the sediments act as a sink for various forms of nitrogen and phosphorus which enters Lake Jesup through the bottom sediment layers.

A summary of significant differences in seepage characteristics for samples collected with and without sediment contact using the log-transformed data set is given in Table 3-10. No statistically significant differences were observed between samples collected with and without sediment contact for any of the measured parameters at Site 4. Statistically significant differences were observed for NO_x at Sites 1, 3, and 6 as well as SRP at Site 5, with higher concentrations observed for the indicated parameters in samples collected without sediment contact compared with samples collected with sediment contact, suggesting that the sediments provide uptake for various forms of nitrogen and phosphorus during migration from the parent sandy layer through the existing organic muck sediments.

TABLE 3-10

SUMMARY OF SIGNIFICANT DIFFERENCES IN SEEPAGE CHARACTERISTICS (LOG-TRANSFORMED) WITH AND WITHOUT SEDIMENT CONTACT BY MONITORING SITE

SITE	PARAMETER	UNITS	MODEL SIGNIFICANCE LEVEL	CONDITION	MEAN CONCENTRATION	TUKEY GROUPING
1	NO_x	µg/l	0.0457	Without With	2,051 659	A B
2	NO_x	µg/l	0.0048	With Without	259 5	A B
	Total N	µg/l	0.0002	With Without	2,028 679	A B
	SRP	µg/l	0.0449	With Without	216 112	A B
3	NO_x	µg/l	0.0010	Without With	2,143 189	A B
4	None	--	--	--	--	--
5	SRP	µg/l	0.0025	Without With	381 37	A B
6	NO_x	µg/l	0.0006	Without With	1,933 65	A B

However, similar to the trend observed for the non-transformed data set, the statistically significant differences observed at Site 2 all indicate higher concentrations of parameters with sediment contact compared with concentrations measured without sediment contact. These data suggest that sediment and seepage characteristics at Site 2 are somehow different than characteristics measured in other parts of the lake since the sediments appear to be a source of nutrients at Site 2 rather than a sink, as observed at each of the remaining sites.

The statistical analyses discussed previously indicate that in most areas of the lake the existing sediments do not significantly enhance concentrations of groundwater seepage entering Lake Jesup. It appears that the existing sediments may result in reductions in concentrations for many parameters as the seepage migrates from the sand bottom through the thick layers of accumulated muck. For parameters such as SRP and total phosphorus, phosphorus concentrations are approximately double in samples collected without sediment contact compared with samples collected with sediment contact. Lesser differences are observed for each of the remaining parameters, although in all cases (with the exception of Site 2), samples collected with sediment contact are lower in value than samples collected without sediment contact.

The field and laboratory data suggest that, in most areas of Lake Jesup, the existing sediments do not currently have a negative impact on water quality characteristics of seepage inputs entering Lake Jesup. The sediments appear to be a sink for virtually all of the measured seepage parameters by removing alkalinity, nitrogen, and phosphorus which enters the lake from groundwater seepage. The field and laboratory data suggest that removal of the existing sediments may increase loadings to Lake Jesup from groundwater seepage, although the magnitude of this additional loading should be compared with the load reduction achieved by removing the nutrient-rich sediments and the associated internal recycling.

Over the past 20 years, ERD has conducted monitoring of groundwater seepage in over 40 lakes within the State of Florida, and ERD maintains a database of measured seepage concentrations for each monitored lake. A statistical comparison of seepage nutrient concentrations in Lake Jesup with and without sediment contact and seepage concentrations measured by ERD in other Central Florida lakes is given on Figure 3-15. The Lake Jesup data reflect all samples collected during the field monitoring program with and without sediment contact. In general, measured concentrations of both total nitrogen and total phosphorus in seepage entering Lake Jesup are greater than median concentrations for groundwater seepage measured by ERD in other Central Florida lakes. Measured concentrations of total nitrogen and total phosphorus in Lake Jesup seepage samples collected without sediment contact are greater in value than median concentrations measured with sediment contact.

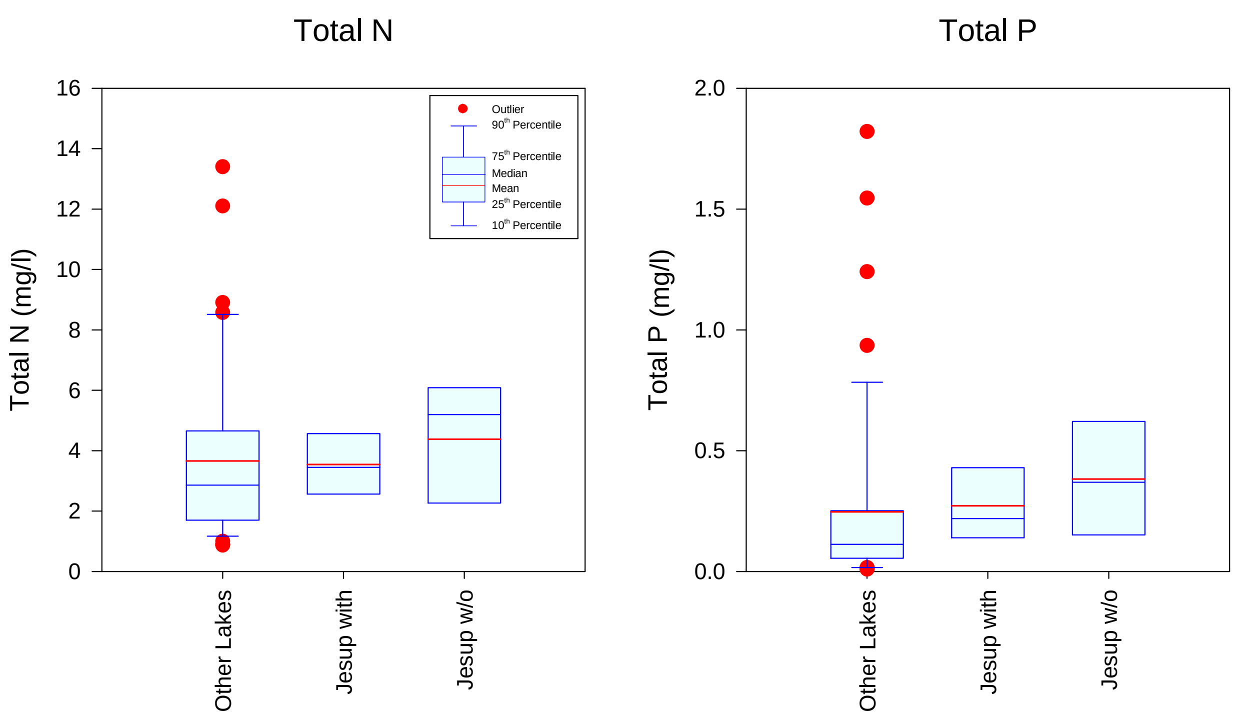


Figure 3-15. Comparison of Seepage Nutrient Concentrations in Lake Jesup With and Without Sediments and Seepage Concentrations Measured in Other Central Florida Lakes.

3.4 Horizontal Variability in Seepage Characteristics

A graphical comparison of flow-weighted mean concentrations of alkalinity in Lake Jesup seepage samples collected with and without sediment contacts is given on Figure 3-16. The mean concentration for samples collected with sediment contact reflects the first number in parentheses underneath each of the site designations, with the mean concentration without sediment contact given as the second value. In general, measured seepage concentrations were relatively similar in samples collected with and without sediment contact in the extreme western portions of Lake Jesup. However, a trend of increasing alkalinity values is apparent in eastern portions of the lake as well as a larger difference between alkalinity measurements conducted in samples collected with and without sediment contact.

Figure 3-16. Flow-Weighted Mean Concentrations of Alkalinity in Lake Jesup Seepage Samples With and Without Sediment Contact.

A graphical summary of flow-weighted mean concentrations of ammonia in Lake Jesup seepage samples collected with and without sediment contact is given on Figure 3-17. In general, ammonia concentrations in groundwater seepage appear to be lowest in western portions of the lake, with ammonia concentrations in samples collected with sediment contact approximately twice as high as samples collected without sediment contact. A general trend of increasing ammonia seepage concentrations is apparent in eastern portions of the lake, particularly at Sites 5 and 6.

A graphical comparison of flow-weighted mean concentrations of total nitrogen in seepage samples collected in Lake Jesup with and without sediment contact is given on Figure 3-18. Similar to the trends observed for ammonia, the lowest seepage concentrations of total nitrogen appear to occur in western portions of the lake. Seepage concentrations of total nitrogen increase substantially in areas west of SR 417 to values which are approximately 2-3 times greater than concentrations measured west of SR 417. The most elevated seepage total nitrogen concentrations were observed at Sites 4, 5, and 6. At Sites 4 and 5, total nitrogen concentrations with sediments were somewhat lower than concentrations measured without sediments.

Figure 3-17. Flow-Weighted Mean Concentrations of Ammonia in Lake Jesup Seepage Samples With and Without Sediment Contact.

Figure 3-18. Flow-Weighted Mean Concentrations of Total Nitrogen in Lake Jesup Seepage Samples With and Without Sediment Contact.

A graphical comparison of flow-weighted mean concentrations of SRP in seepage samples collected from Lake Jesup with and without sediment contact is given on Figure 3-19. In general, seepage concentrations of SRP were lowest in value in areas west of SR 417, with higher values measured in areas east of SR 417, particularly for samples collected without sediments. Substantially elevated levels of SRP were observed in seepage collected at Sites 3, 4, 5, and particularly at Site 6 in areas where sediments had been removed. The flow-weighted mean SRP concentration at Site 6 of 1,298 μg/l reflects seepage characteristics as it enters Lake Jesup prior to migrating through the organic sediment layer. This value reflects an extremely elevated phosphorus concentration which is input into the lake on a continuous basis.

Figure 3-19. Flow-Weighted Mean Concentrations of SRP in Lake Jesup Seepage Samples With and Without Sediment Contact.

A graphical summary of flow-weighted mean concentrations of total phosphorus in seepage samples collected from Lake Jesup with and without sediment contact is given on Figure 3-20. In general, concentrations of total phosphorus exhibit a pattern similar to that discussed previously for SRP. The lowest concentrations of total phosphorus in groundwater seepage generally occur west of SR 417, with substantially higher concentrations observed in areas east of SR 417. Substantially elevated seepage concentrations of total phosphorus were observed at Sites 3, 4, 5, and 6, particularly in samples collected without sediment contact. Phosphorus concentrations entering Lake Jesup in these areas appear to be mitigated to some extent during migration through the sediments. However, extremely elevated levels of total phosphorus appear to be entering Lake Jesup from groundwater seepage, particularly in western portions of the lake.

Figure 3-20. Flow-Weighted Mean Concentrations of Total Phosphorus in Lake Jesup Seepage Samples With and Without Sediment Contact.

3.5 Comparison with Previous Studies

As referenced in Section 1, an evaluation of the hydrologic and nutrient loadings from groundwater seepage to Lake Jesup was conducted by ERD from 2009-2010, with a Final Report issued in February 2011. Groundwater seepage meters were installed at 40 locations within Lake Jesup, and nine separate monitoring events were conducted at each site over a 14-month field monitoring program.

A comparison of mean seepage characteristics measured during the 2011 and 2013 seepage evaluations was conducted to evaluate seepage characteristics in similar areas of Lake Jesup measured during the two separate studies. Each of the six monitoring sites used during the 2013 study have a corresponding monitoring site from the 2011 study in relatively close proximity. Since the 2011 study only included seepage meters with sediment contact, only the 2013 seepage samples collected with sediment contact are used for comparison. Monitoring Sites 1-4 from the 2013 study have closely located seepage monitoring sites available from the 2011 study which contained sufficient data for comparison of chemical characteristics. Monitoring Sites 5 and 6 also contain closely located monitoring sites from the 2011 study, but the 2011 monitoring site closest to Site 5 contains only a limited number of data points, while the monitoring Site 6 from the current study contains no useable data for the seepage meters installed with sediment contact. Therefore, comparable monitoring sites are only available for the current monitoring sites designated as Sites 1-4.

A tabular comparison of mean measured seepage characteristics at similar monitoring sites during the 2011 and current 2013 seepage study is given on Table 3-11. Measured seepage pH values are relatively similar in value at each of the four comparable monitoring sites during both the 2011 and 2013 evaluations. Measured alkalinity values also appear to be in relatively close agreement, with the exception of Site 3 which exhibits a somewhat lower alkalinity value during the current study than observed during 2011. Measured conductivity values between the two studies are very similar at each of the four comparable sites.

TABLE 3-11

COMPARISON OF MEAN MEASURED SEEPAGE CHARACTERISTICS AT SIMILAR MONITORING SITES DURING THE 2011 AND CURRENT SEEPAGE STUDY

SITE NUMBER	STUDY REFERENCE	pH (s.u.)	ALKALINITY (mg/l)	CONDUCTIVITY (μmho/cm)	TOTAL N (μg/l)	TOTAL P (μg/l)
1	2013[1]	7.37	89.1	745	3,449	159
37	2011[2]	7.41	118	673	3,802	386
2	2013[1]	7.63	126	465	2,022	237
32	2011[2]	7.33	102	564	4,256	600
3	2013[1]	7.41	104	899	3,462	219
28	2011[2]	7.91	226	996	9,946	1,248
4	2013[1]	7.47	132	985	5,664	623
22	2011[2]	7.66	151	968	5,557	598

1. Harper, H.H. (April 2013). "Evaluation of Sediment Impacts on Hydrologic and Nutrient Loadings from Groundwater Seepage to Lake Jesup." Draft Final Report.

2. Harper, H.H. (February 2011). "Evaluation of Hydrologic and Nutrient Loadings from Groundwater Seepage to Lake Jesup." Final Report.

Measured concentrations of total nitrogen at Sites 1, 2, and 4 are relatively similar to values measured during the previous 2011 study. However, a relatively large difference was observed in measured nitrogen concentrations at Site 3 between the 2011 and 2013 studies. A similar pattern was also observed for seepage concentrations of total phosphorus, with relatively similar concentrations observed at Sites 1, 2, and 4 and a relatively large difference in measured total phosphorus concentrations at Site 3. Overall, with the exception of Site 3, seepage characteristics are relatively similar between the two monitoring sites at similarly located monitoring sites.

SECTION 4

SUMMARY AND CONCLUSIONS

4.1 Summary

An initial evaluation of the hydrologic and nutrient loadings from groundwater seepage to Lake Jesup was conducted by ERD from 2009-2010, with a Final Report issued in February 2011. Groundwater seepage meters were installed in 40 locations within Lake Jesup, and 9 separate monitoring events were conducted at each site over a 14-month field monitoring program from June 2009-August 2011. Groundwater seepage entering Lake Jesup was characterized by elevated levels of both total nitrogen and total phosphorus in this initial seepage study, and the calculated annual seepage mass loadings were substantially greater than baseflow loading estimates provided in the TMDL report for Lake Jesup. Questions then arose at the time as to the source of the nutrient loadings and whether the elevated seepage nutrient concentrations are impacted by migration through the existing muck sediments.

A supplemental evaluation was conducted by ERD from January 2010-March 2013 to further evaluate the impacts of the existing sediments on seepage characteristics entering the lake. Side-by-side comparisons of seepage meters installed in areas with and without existing sediments were used to evaluate potential impacts of the sediments on seepage inputs. Pairs of seepage meters with and without existing sediments were installed at 6 separate locations throughout Lake Jesup, and field monitoring was conducted by ERD over a 415-day period from January 2012-March 2013 to evaluate the impacts of existing sediments on the hydrologic and water quality characteristics of shallow groundwater seepage inflows to Lake Jesup. Rainfall during the seepage field monitoring program was approximately normal, with an estimated 59.90 inches of rainfall occurring in the vicinity of Lake Jesup during the period from January 2012-March 2013 compared with a long-term "normal" rainfall of 60.67 inches.

Six separate monitoring events were conducted to evaluate the quantity of shallow seepage entering Lake Jesup, with and without sediment contact, with laboratory analyses of the seepage samples conducted during 5 of the 6 monitoring events. Seepage inflow rates into Lake Jesup were relatively similar in meters installed with and without sediment contact, with an arithmetic mean of 0.68 liters/m^2-day for seepage meters incubated without sediment contact compared with 0.65 liters/m^2-day for meters with sediment contact. Geometric mean values were slightly different, with an overall mean seepage inflow of 0.50 liters/m^2-day without sediment contact compared with 0.64 liters/m^2-day with sediment contact. Analysis of variance (ANOVA) comparisons were conducted to evaluate whether statistically significant differences exist in measured seepage rates with and without sediment contact. No statistically significant difference was detected using the normal field measured data, although the seepage meters incubated with sediment contact were found to have a statistically higher inflow rate when a log transformation was conducted on the data set.

The slightly lower seepage inflow rate measured in seepage meters inserted on the sand bottom of the lake is thought to be due to the inability to form a tight seal between the seepage meter and the cemented sand bottom, which allowed some of the incoming seepage to bypass the seepage meter collection system. Overall, there appears to be no significant difference in seepage inflow rates in areas with and without sediment contact.

Groundwater seepage entering Lake Jesup was found to be approximately neutral to slightly alkaline in pH, moderately to well buffered, with low to elevated levels of conductivity, depending on location within the lake. Measured nutrient concentrations were highly variable in seepage samples, with a general trend of lower nutrient concentrations in western portions of the lake and higher nutrient concentrations in eastern portions of the lake for seepage samples collected without sediment contact. An ANOVA comparison was conducted to identify statistically significant differences between seepage characteristics collected in Lake Jesup with and without existing sediments. When the combined raw data sets were compared, no statistically significant differences were detected between seepage collected with and without existing sediments, although each of the evaluated parameters exhibited higher values in seepage collected without existing sediments than in seepage collected with existing sediments. When a log transformation was conducted to the data sets, statistically significant differences in seepage characteristics were detected for both SRP and total phosphorus, with higher concentrations for each parameter observed in seepage samples collected without sediment contact compared with seepage samples collected with sediment contact.

A supplemental ANOVA comparison was conducted to identify statistically significant differences between seepage characteristics with and without existing sediments for each of the individual monitoring sites. The comparison conducted using the non-transformed data set indicated statistically significant differences in seepage characteristics for NO_x at Sites 3 and 6, and SRP and total phosphorus at Site 5. Each of these analyses indicated higher concentrations for these parameters in samples collected without sediment contact compared with samples collected with sediment contact. These data suggest that the sediments act as a sink for nutrient loadings entering Lake Jesup through the parent sandy sediment material. However, a statistically significant difference for total nitrogen was observed at Site 2 which indicated higher concentrations with sediment contact than without, suggesting that the sediments may be a source of nutrients to the seepage inflow in the area of Site 2, located near the mouth of Howell Creek.

The ANOVA comparison conducted on the log-transformed data set indicated statistically significant differences for NO_x at Sites 1, 3, and 6, and a statistically significant difference for SRP at Site 5. Each of these differences reflect higher concentrations in seepage without sediment contact than in seepage collected with sediment contact, suggesting that the sediments may remove certain forms of nitrogen and phosphorus which enter Lake Jesup through the parent sandy bottom material. However, similar to the trend observed for the non-transformed data set, statistically significant differences were observed at Site 2 for NO_x, total nitrogen, and SRP, all of which indicate higher concentrations with sediment contact than without, suggesting that the sediments are a source of nutrients to groundwater inflow in the vicinity of Site 2.

The field and laboratory data collected at 5 of the 6 sites suggest that the existing sediments do not currently exert a negative impact on water quality characteristics of seepage inputs entering Lake Jesup. The sediments in Lake Jesup are highly active on a microbial level, as evidenced by the nearly permanent anoxic conditions which exist within the sediments. Therefore, the microbial community appears to be utilizing nutrients and alkalinity from the seepage, resulting in lower concentrations of seepage actually reaching the water column of Lake Jesup compared with seepage which originates from the lake bottom. In contrast, data collected at one of the 6 sites suggest that the sediments may be contributing nutrients to seepage flow.

Based upon the analyses conducted during this study, the primary source of the elevated seepage characteristics appears to be watershed areas adjacent to Lake Jesup. The existing sediments appear to have minimal impact on seepage characteristics in most areas of Lake Jesup, and may, in fact, be reducing seepage concentrations of nutrients and alkalinity to some extent. Further studies are recommended to evaluate why data collected at Site 2 appear to be contrary to data collected in other parts of Lake Jesup.

4.2 Conclusions

Both the 2011 and 2013 seepage studies conducted by ERD confirm that shallow groundwater seepage represents a significant hydraulic and nutrient loading to Lake Jesup which is largely unaccounted for in the TMDL for the lake. The measured seepage inflows to Lake Jesup represent 12% of the total annual hydrologic inputs summarized in the TMDL report, along with 33% of the annual nitrogen loadings and 36% of the annual phosphorus loadings. These additional seepage loadings reduce the significance of runoff as a loading source and impact the water quality benefits which can be achieved through stormwater management projects.

Lake Jesup exhibits a strong horizontal gradient in seepage characteristics from west to east across the lake, the magnitude of which is unprecedented in previous seepage monitoring conducted by ERD. Migration of the seepage through the muck sediments reduces much of the observed variability in raw seepage characteristics which enter the lake through the sand bottom. In some areas, the sediments appear to be providing uptake for some of the seepage constituents, while in other areas the sediments appear to contribute loadings to the seepage inflow.

The role of sediments in regulating seepage characteristics is largely unrelated to the independent role of the sediments in contributing nutrient loadings to the lake through internal recycling. The sediments in Lake Jesup are highly anoxic, regardless of dissolved oxygen concentrations measured in the water column, and although the rate of nutrient recycling has not been fully quantified, the sediments are almost certainly a significant additional source of nutrient loadings to the lake which has also not been included in the TMDL evaluation. There is no question that the seepage loadings to Lake Jesup estimated in the 2011 ERD study include a portion of the internal loading as well, particularly in more central portions of the lake, but separation of these inputs cannot be achieved based on the collected seepage data. Further studies are recommended to quantify nutrient loadings from internal recycling.

APPENDICES

APPENDIX A

FIELD MEASUREMENTS OF SEEPAGE INFLOW VOLUMES IN LAKE JESUP FROM JANUARY 2012 – MARCH 2013

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 1 - Without Sediments**

Date Installed: 1/25/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/25/12	11:05	-----	-----	-----	-----	-----	Bags Installed
3/9/12	10:15	7.25	1/25/12	11:05	44.0	0.61	Measured volume, no sample collected
7/13/12	10:42	18.5	3/9/12	10:15	126.0	0.54	Sample collected, bag in good condition
8/24/12	10:12	9.5	7/13/12	10:42	42.0	0.84	Sample collected, bag in good condition
11/30/12	11:18	11.25	8/24/12	10:12	98.0	0.42	Sample collected, bag in good condition
1/25/13	11:24	10.75	11/30/12	11:18	56.0	0.71	Sample collected, bag in good condition
3/15/13	10:25	4.75	1/25/13	11:24	49.0	0.36	Sample collected, bag in good condition
					Mean Seepage:	**0.55**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 1 - With Sediments**

Date Installed: 1/25/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/25/12	11:14	-----	-----	-----	-----	-----	Bags Installed
3/9/12	10:18	10.5	1/25/12	11:14	44.0	0.88	Measured volume, no sample collected
7/13/12	10:47	17.25	3/9/12	10:18	126.0	0.51	Sample collected, bag in good condition
8/24/12	10:17	12.25	7/13/12	10:47	42.0	1.08	Sample collected, bag in good condition
11/30/12	11:25	26.75	8/24/12	10:17	98.0	1.01	Sample collected, bag in good condition
1/25/13	11:20	13.5	11/30/12	11:25	56.0	0.89	Sample collected, bag in good condition
3/15/13	10:22	11.25	1/25/13	11:20	49.0	0.85	Sample collected, bag in good condition
					Mean Seepage:	**0.82**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 2 - Without Sediments**

Date Installed: 1/31/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/31/12	14:14	-----	-----	-----	-----	-----	Bags Installed
3/9/12	10:30	21.5	1/31/12	14:14	37.8	2.10	Measured volume, no sample collected
7/13/12	10:26	130	3/9/12	10:30	126.0	3.82	Sample collected, bag in good condition
8/24/12	10:00	11.75	7/13/12	10:26	42.0	1.04	Sample collected, bag in good condition
11/30/12	10:55	-----	8/24/12	10:00	-----	-----	No sample collected, meter flipped, meter reinstalled
1/25/13	11:05	9.5	11/30/12	10:55	56.0	0.63	Sample collected, bag in good condition
3/15/13	11:00	4.5	1/25/13	11:05	49.0	0.34	Sample collected, bag in good condition
					Mean Seepage:	**2.11**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 2 - With Sediments**

Date Installed: 1/31/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/31/12	14:26	-----	-----	-----	-----	-----	Bags Installed
3/9/12	10:32	6.25	1/31/12	14:26	37.8	0.61	Measured volume, no sample collected
7/13/12	10:33	11.75	3/9/12	10:32	126.0	0.35	Sample collected, bag in good condition
8/24/12	10:03	13.75	7/13/12	10:33	42.0	1.21	Sample collected, bag replaced
11/30/12	11:00	12.5	8/24/12	10:03	98.0	0.47	Sample collected, bag in good condition
1/25/13	11:09	20.25	11/30/12	11:00	56.0	1.34	Sample collected, bag in good condition
3/15/13	11:08	18.25	1/25/13	11:09	49.0	1.38	Sample collected, bag replaced
					Mean Seepage:	**0.75**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 3 - Without Sediments**

Date Installed: 1/31/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/31/12	13:55	-----	-----	-----	-----	-----	Bags Installed
3/9/12	10:44	7.5	1/31/12	13:55	37.9	0.73	Measured volume, no sample collected
7/13/12	10:10	15.25	3/9/12	10:44	126.0	0.45	Sample collected, bag replaced
8/24/12	9:44	8.25	7/13/12	10:10	42.0	0.73	Sample collected, bag in good condition
11/30/12	10:42	11.75	8/24/12	9:44	98.0	0.44	Sample collected, bag in good condition
1/25/13	10:42	14.5	11/30/12	10:42	56.0	0.96	Sample collected, bag in good condition
3/15/13	11:45	4.5	1/25/13	10:42	49.0	0.34	Sample collected, bag in good condition
					Mean Seepage:	**0.56**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 3 - With Sediments**

Date Installed: 1/31/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/31/12	13:40	-----	-----	-----	-----	-----	Bags Installed
3/9/12	10:46	11.25	1/31/12	13:40	37.9	1.10	Measured volume, no sample collected
7/13/12	10:14	22.5	3/9/12	10:46	126.0	0.66	Sample collected, bag in good condition
8/24/12	9:48	12.5	7/13/12	10:14	42.0	1.10	Sample collected, bag in good condition
11/30/12	10:46	20.25	8/24/12	9:48	98.0	0.76	Sample collected, bag replaced
1/25/13	10:46	12.25	11/30/12	10:46	56.0	0.81	Sample collected, bag in good condition
3/15/13	11:50	14.25	1/25/13	10:46	49.0	1.08	Sample collected, bag in good condition
					Mean Seepage:	**0.84**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 4 - Without Sediments**

Date Installed: 1/31/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/31/12	13:34	-----	-----	-----	-----	-----	Bags Installed
3/9/12	11:02	5.5	1/31/12	13:34	37.9	0.54	Measured volume, no sample collected
7/13/12	9:26	3.75	3/9/12	11:02	125.9	0.11	Sample collected, bag in good condition
8/24/12	9:00	8.75	7/13/12	9:26	42.0	0.77	Sample collected, bag in good condition
11/30/12	9:35	0.25	8/24/12	9:00	98.0	0.01	Sample collected, bag replaced
1/25/13	10:10	5.25	11/30/12	9:35	56.0	0.35	Sample collected, bag in good condition
3/15/13	13:05	5.75	1/25/13	10:10	49.1	0.43	Sample collected, bag in good condition
					Mean Seepage:	**0.26**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 4 - With Sediments**

Date Installed: 1/31/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/31/12	13:42	-----	-----	-----	-----	-----	Bags Installed
3/9/12	11:04	9.75	1/31/12	13:42	37.9	0.95	Measured volume, no sample collected
7/13/12	9:20	8.75	3/9/12	11:04	125.9	0.26	Sample collected, bag in good condition
8/24/12	9:05	13.5	7/13/12	9:20	42.0	1.19	Sample collected, bag in good condition
11/30/12	9:30	10.75	8/24/12	9:05	98.0	0.41	Sample collected, bag replaced
1/25/13	10:14	5.75	11/30/12	9:30	56.0	0.38	Sample collected, bag in good condition
3/15/13	13:10	7.25	1/25/13	10:14	49.1	0.55	Sample collected, bag replaced
					Mean Seepage:	**0.50**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 5 - Without Sediments**

Date Installed: 1/25/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/25/12	12:40	-----	-----	-----	-----	-----	Bags Installed
3/9/12	11:18	5.25	1/25/12	12:40	43.9	0.44	Measured volume, no sample collected
7/13/12	9:58	6.75	3/9/12	11:18	125.9	0.20	Sample collected, bag in good condition
8/24/12	9:32	5.5	7/13/12	9:58	42.0	0.49	Sample collected, bag in good condition
11/30/12	10:30	5.75	8/24/12	9:32	98.0	0.22	Sample collected, bag in good condition
1/25/13	10:27	6.5	11/30/12	10:30	56.0	0.43	Sample collected, bag in good condition
3/15/13	12:15	7.25	1/25/13	10:27	49.1	0.55	Sample collected, bag in good condition
					Mean Seepage:	**0.33**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 5 - With Sediments**

Date Installed: 1/25/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/25/12	12:52	-----	-----	-----	-----	-----	Bags Installed
3/9/12	11:21	11.5	1/25/12	12:52	43.9	0.97	Measured volume, no sample collected
7/13/12	10:03	8.75	3/9/12	11:21	125.9	0.26	Sample collected, bag in good condition
8/24/12	9:36	8.25	7/13/12	10:03	42.0	0.73	Sample collected, bag in good condition
11/30/12	10:25	6.25	8/24/12	9:36	98.0	0.24	Sample collected, bag in good condition
1/25/13	10:31	8.75	11/30/12	10:25	56.0	0.58	Sample collected, bag in good condition
3/15/13	12:20	12.5	1/25/13	10:31	49.1	0.94	Sample collected, bag replaced
					Mean Seepage:	**0.50**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 6 - Without Sediments**

Date Installed: 1/25/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/25/12	14:05	-----	-----	-----	-----	-----	Bags Installed
3/9/12	11:34	4.75	1/25/12	14:05	43.9	0.40	Measured volume, no sample collected
7/13/12	9:42	3.75	3/9/12	11:34	125.9	0.11	Sample collected, bag in good condition
8/24/12	9:18	5.25	7/13/12	9:42	42.0	0.46	Sample collected, bag in good condition
11/30/12	10:00	5.75	8/24/12	9:18	98.0	0.22	Sample collected, bag in good condition
1/25/13	11:45	-----	11/30/12	10:00	-----	-----	No sample collected, bag missing, bag replaced
3/15/13	12:40	6.75	1/25/13	11:45	49.0	0.51	Sample collected, bag in good condition
					Mean Seepage:	**0.27**	

Seepage Meter Field Measurements

Location: Lake Jesup **Site: 6 - With Sediments**

Date Installed: 1/25/12 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
1/25/12	14:19	-----	-----	-----	-----	-----	Bags Installed
3/9/12	11:37	5.5	1/25/12	14:19	43.9	0.46	Measured volume, no sample collected
7/13/12	9:40	-----	3/9/12	11:37	-----	-----	No sample collected, bag missing, bag replaced
8/24/12	9:22	-----	7/13/12	9:40	-----	-----	No sample collected, meter flipped, meter reinstalled
11/30/12	10:10	-----	8/24/12	9:22	-----	-----	No sample collected, bag missing, bag replaced
1/25/13	11:50	-----	11/30/12	10:10	-----	-----	No sample collected, bag missing, bag replaced
3/15/13	12:45	7.25	1/25/13	11:50	49.0		Sample collected, bag in good condition
					Mean Seepage:	**0.51**	

APPENDIX B

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE SAMPLES COLLECTED IN LAKE JESUP FROM JANUARY 2012 – MARCH 2013

Characteristics of Groundwater Seepage Collected in Lake Jesup from January 2012 - March 2013

Sample Description	Date Collected	pH (s.u.)	Alkalinity (mg/L)	Spec. Cond. (µmho/cm)	NH_3-N (µg/L)	NO_X-N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Seepage (liters/m^2-day)
SP 1C	7/13/12	7.39	84.4	922	248	2,015	3,307	224	284	0.54
SP 1C	8/24/12	7.51	87.4	787	333	2,871	4,540	141	150	0.84
SP 1C	11/30/12	7.31	101	604	529	2,512	4,331	307	309	0.42
SP 1C	1/25/13	7.54	90.6	707	575	1,501	3,189	37	44	0.71
SP 1C	3/15/13	7.21	90.6	770	115	1,663	3,091	43	50	0.36
Min. Value		**7.21**	**84.4**	**604**	**115**	**1,501**	**3,091**	**37**	**44**	**0.36**
Max. Value		**7.54**	**101**	**922**	**575**	**2,871**	**4,540**	**307**	**309**	**0.84**
Flow-weighted Mean		**7.43**	**90.0**	**764**	**378**	**2,167**	**3,761**	**143**	**160**	**0.55**
SP 1L	7/13/12	7.50	90.8	1,021	1,093	311	3,383	45	119	0.51
SP 1L	8/24/12	7.43	73.8	605	1,254	1,106	3,746	63	97	1.08
SP 1L	11/30/12	7.34	104	730	1,326	2,656	5,236	437	451	1.01
SP 1L	1/25/13	7.39	83.0	718	211	714	2,116	18	24	0.89
SP 1L	3/15/13	7.24	97.8	803	523	191	2,390	45	56	0.85
Min. Value		**7.24**	**73.8**	**605**	**211**	**191**	**2,116**	**18**	**24**	**0.51**
Max. Value		**7.50**	**104**	**1,021**	**1,326**	**2,656**	**5,236**	**437**	**451**	**1.08**
Flow-weighted Mean		**7.37**	**89.4**	**745**	**894**	**1,114**	**3,449**	**135**	**159**	**0.82**
SP 2C	7/13/12	7.74	127	349	717	28	855	123	147	3.82
SP 2C	8/24/12	7.23	132	411	438	3	555	115	124	1.04
SP 2C	1/25/13	7.86	141	334	313	3	465	83	102	0.63
SP 2C	3/15/13	7.51	127	387	854	3	965	135	201	0.34
Min. Value		**7.23**	**127**	**334**	**313**	**3**	**465**	**83**	**102**	**0.34**
Max. Value		**7.86**	**141**	**411**	**854**	**28**	**965**	**135**	**201**	**3.82**
Flow-weighted Mean		**7.65**	**129**	**361**	**632**	**19**	**766**	**118**	**141**	**2.11**

Characteristics of Groundwater Seepage Collected in Lake Jesup from January 2012 - March 2013

Sample Description	Date Collected	pH (s.u.)	Alkalinity (mg/L)	Spec. Cond. (µmho/cm)	NH_3-N (µg/L)	NO_X-N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Seepage (liters/m^2-day)
SP 2L	7/13/12	7.39	114	663	902	564	1,911	323	396	0.35
SP 2L	8/24/12	7.77	100	548	775	632	1,906	114	118	1.21
SP 2L	11/30/12	7.08	109	515	674	1,101	2,272	318	334	0.47
SP 2L	1/25/13	7.91	147	362	1,866	156	2,223	285	300	1.34
SP 2L	3/15/13	7.47	139	425	1,629	19	1,871	140	208	1.38
Min. Value		**7.08**	**100**	**362**	**674**	**19**	**1,871**	**114**	**118**	**0.35**
Max. Value		**7.91**	**147**	**663**	**1,866**	**1,101**	**2,272**	**323**	**396**	**1.38**
Flow-weighted Mean		**7.63**	**126**	**465**	**1,330**	**361**	**2,022**	**205**	**237**	**0.75**
SP 3C	7/13/12	7.47	126	1,084	444	3,066	5,485	430	555	0.45
SP 3C	8/24/12	7.37	101	926	511	1,511	3,788	298	315	0.73
SP 3C	11/30/12	7.39	131	860	985	2,617	4,865	392	396	0.44
SP 3C	1/25/13	7.87	177	1,051	2,901	2,376	6,709	592	606	0.96
SP 3C	3/15/13	7.38	124	883	1,082	1,567	3,960	186	251	0.34
Min. Value		**7.37**	**101**	**860**	**444**	**1,511**	**3,788**	**186**	**251**	**0.34**
Max. Value		**7.87**	**177**	**1,084**	**2,901**	**3,066**	**6,709**	**592**	**606**	**0.96**
Flow-weighted Mean		**7.55**	**137**	**976**	**1,424**	**2,209**	**5,192**	**416**	**452**	**0.56**
SP 3L	7/13/12	7.42	97.0	988	1,178	504	3,638	227	382	0.66
SP 3L	8/24/12	7.33	82.6	877	1,833	53	3,729	112	135	1.10
SP 3L	11/30/12	7.25	116	784	2,828	143	4,843	384	437	0.76
SP 3L	1/25/13	7.57	122	918	1,295	594	3,225	174	185	0.81
SP 3L	3/15/13	7.47	110	934	654	107	2,277	68	76	1.08
Min. Value		**7.25**	**82.6**	**784**	**654**	**53**	**2,277**	**68**	**76**	**0.66**
Max. Value		**7.57**	**122**	**988**	**2,828**	**594**	**4,843**	**384**	**437**	**1.10**
Flow-weighted Mean		**7.41**	**104**	**899**	**1,521**	**249**	**3,462**	**177**	**219**	**0.84**

Characteristics of Groundwater Seepage Collected in Lake Jesup from January 2012 - March 2013

Sample Description	Date Collected	pH (s.u.)	Alkalinity (mg/L)	Spec. Cond. (µmho/cm)	NH_3-N (µg/L)	NO_X-N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Seepage (liters/m^2-day)
SP 4C	7/13/12	7.31	93.6	1,526	878	19	2,493	324	454	0.11
SP 4C	8/24/12	7.39	75.2	716	652	825	3,092	152	160	0.77
SP 4C	11/30/12	7.23	86.4	738	423	1,011	3,396	208	244	0.01
SP 4C	1/25/13	8.02	244	1,289	1,066	6,926	9,599	1,262	1,330	0.35
SP 4C	3/15/13	7.89	275	1,317	1,575	8,403	11,399	1,491	1,576	0.43
Min. Value		**7.23**	**75**	**716**	**423**	**19**	**2,493**	**152**	**160**	**0.01**
Max. Value		**8.02**	**275**	**1,526**	**1,575**	**8,403**	**11,399**	**1,491**	**1,576**	**0.77**
Flow-weighted Mean		**7.64**	**163**	**1,044**	**991**	**4,004**	**6,558**	**741**	**790**	**0.26**
SP 4L	7/13/12	7.36	120	1,175	4,444	382	6,730	514	588	0.26
SP 4L	8/24/12	7.32	70.0	752	1,222	298	2,794	147	149	1.19
SP 4L	11/30/12	7.27	79.0	669	65	781	1,944	48	56	0.41
SP 4L	1/25/13	7.88	241	1,181	4,362	2,375	8,399	948	1,018	0.38
SP 4L	3/15/13	7.73	237	1,504	1,496	8,945	12,276	1,703	1,817	0.55
Min. Value		**7.27**	**70.0**	**669**	**65**	**298**	**1,944**	**48**	**56**	**0.26**
Max. Value		**7.88**	**241**	**1,504**	**4,444**	**8,945**	**12,276**	**1,703**	**1,817**	**1.19**
Flow-weighted Mean		**7.47**	**132**	**985**	**1,834**	**2,360**	**5,664**	**582**	**623**	**0.50**
SP 5C	7/13/12	7.25	94.4	1,406	3,989	254	5,609	317	569	0.20
SP 5C	8/24/12	7.39	67.8	1,052	1,845	312	3,319	95	181	0.49
SP 5C	11/30/12	7.53	128	950	1,282	74	2,678	398	400	0.22
SP 5C	1/25/13	7.73	225	1,683	6,488	381	8,450	464	495	0.43
SP 5C	3/15/13	7.58	199	1,620	1,659	3,459	6,554	318	352	0.55
Min. Value		**7.25**	**67.8**	**950**	**1,282**	**74**	**2,678**	**95**	**181**	**0.20**
Max. Value		**7.73**	**225**	**1,683**	**6,488**	**3,459**	**8,450**	**464**	**569**	**0.55**
Flow-weighted Mean		**7.52**	**152**	**1,388**	**3,015**	**1,211**	**5,604**	**303**	**369**	**0.33**

Characteristics of Groundwater Seepage Collected in Lake Jesup from January 2012 - March 2013

Sample Description	Date Collected	pH (s.u.)	Alkalinity (mg/L)	Spec. Cond. (µmho/cm)	NH_3-N (µg/L)	NO_X-N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Seepage (liters/m^2-day)
SP 5L	7/13/12	7.35	89.6	1,213	1,708	22	3,198	47	183	0.26
SP 5L	8/24/12	7.32	74.4	944	1,584	160	3,200	28	67	0.73
SP 5L	11/30/12	7.27	113	1,015	2,044	194	3,569	134	365	0.24
SP 5L	1/25/13	7.54	111	947	1,781	177	3,361	27	226	0.58
SP 5L	3/15/13	7.32	107	901	288	1,172	2,727	14	18	0.94
Min. Value		**7.27**	**74.4**	**901**	**288**	**22**	**2,727**	**14**	**18**	**0.24**
Max. Value		**7.54**	**113**	**1,213**	**2,044**	**1,172**	**3,569**	**134**	**365**	**0.94**
Flow-weighted Mean		**7.36**	**98.1**	**961**	**1,231**	**502**	**3,103**	**34**	**120**	**0.50**
SP 6C	7/13/12	7.54	428	3,047	9,835	1,549	12,486	2,740	3,726	0.11
SP 6C	8/24/12	7.87	385	3,509	8,923	2,351	12,415	2,608	3,050	0.46
SP 6C	11/30/12	7.40	118	1,148	976	1,746	4,210	578	676	0.22
SP 6C	3/15/13	7.12	105	972	710	2,197	4,466	104	128	0.51
Min. Value		**7.12**	**105**	**972**	**710**	**1,549**	**4,210**	**104**	**128**	**0.11**
Max. Value		**7.87**	**428**	**3,509**	**9,835**	**2,351**	**12,486**	**2,740**	**3,726**	**0.51**
Flow-weighted Mean		**7.47**	**234**	**2,081**	**4,453**	**2,122**	**7,934**	**1,298**	**1,565**	**0.50**
SP 6L	3/15/13	7.21	134	1,042	3,038	63	4,649	30	34	0.55
Min. Value		**7.21**	**134**	**1,042**	**3,038**	**63**	**4,649**	**30**	**34**	**0.55**
Max. Value		**7.21**	**134**	**1,042**	**3,038**	**63**	**4,649**	**30**	**34**	**0.55**
Flow-weighted Mean		**7.21**	**134**	**1,042**	**3,038**	**63**	**4,649**	**30**	**34**	**0.51**