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PATHOGEN SIMULATION USING SOIL AND WATER TOOL (SWAT) MODEL AND BACTEROIDES SOURCE TRACKING TECHNIQUE

By

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ABSTRACT OF THE DISSERTATION

Pathogen Simulation Using Soil and Water Assessment Tool (SWAT)

Model and *Bacteroides* Source Tracking Technique

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The Upper Salem River Watershed (USRW), located in southern New Jersey, is listed as impaired for pathogens by The New Jersey Department of Environmental Protection (NJDEP) (NJDEP 2011). A 2003 Total Maximum Daily Load (TMDL) for the watershed recommended the use of pathogen source tracking to identify pathogen sources and develop a quantitative model to simulate pathogen pollution in the watershed (NJDEP 2003). This research comprises three parts:

a) Fecal coliform and *E. coli* simulation using the Soil and Water Assessment Tool (SWAT) model in the USRW; this is the first study to conduct sensitivity analysis, calibration and validation of the SWAT model for two widely used pathogen indicators for multiple sampling stations in one watershed. The results of the sensitivity analysis indicate that pathogen input is the most sensitive parameter in the simulation of both indicators. Fecal coliform and *E. coli* simulation at five of six sampling stations generally showed good calibration and validation based on Nash-Sutcliffe efficiency values (0.04 to 0.71).

b) Investigation of temperature effects on the persistence of bovine-*Bacteroides*; the primary goal of this part of the research was to identify the decay rate of bovine-

Bacteroides in stream water at 4°C, 20°C and 30°C. The decay constant of bovine-*Bacteroides* was calculated between 0.01 h^{-1} in the mesocosm incubated at 4°C to 0.05 h^{-1} in the mesocosm at 30°C. Comparison of this study with other similar studies indicates that as temperature increased, a greater discrepancy in compared constant values was observed.

c) Pathogen source tracking was done using a multiple linear regression analysis in the USRW. The primary goals of this research phase were to use a bovine-*Bactreroides* source tracking technique to investigate if bovine feces are a contributing pathogen source to the river system and to identify the spatial distribution of bovine pathogen discharge to the USRW. The results of the simulated model showed agreement with the potential bovine distribution sources (i.e., animal feeding facilities). A probability of occurrence map of bovine derived pathogens was also developed to spatially identify which sub-watersheds have greater likelihood of pathogen contributions from bovine sources.

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1. Introduction

Pathogens are a small subset of microorganisms that are harmful to humans. In case of entrance to the human body they can cause sickness or even death. Categories of waterborne pathogens include:

a) Bacteria; feces derived from warm-blooded animals are a source for many types of bacteria (i.e., *Streptococcus*, *Lactobacillus* and *Staphylococcus*) that can be found in water resources (USEPA, 1991).

b) Viruses; this group is inactive when outside of a living host cell. Waterborne viruses have protein coats that provide protection from environmental hazardous. Two examples of this group are hepatitis A and rotaviruses (USEPA 1993).

c) Protozoans; this group is much larger than bacteria and viruses. Two protozoans of major concern are *Giardia lamblia* causing giardiasis and *Cryptosporidium* causing cryptosporidiosis (USEPA 1993).

Illnesses from waterborne pathogens have proved a substantial public health issue, with the World Health Organization (WHO) estimating that 3.3 million people per year die from waterborne pathogens (WHO 2001). The presence of pathogens in drinking water can also cause a serious disease outbreak. In 1993, a huge outbreak of cryptosporidiosis occurred in Milwaukee, Wisconsin. The outbreak was caused by *Cryptosporidium* in the municipally treated drinking water, implying the seriousness of the threat of pathogens in public water supplies. The incident was recorded as the largest waterborne disease outbreak in U.S. history (Craun et al., 1997). There were 110 deaths from the outbreak; most of the deaths were people with weakened immune systems.

Other impacts of this outbreak were 725,000 lost work/school days, and an estimated cost of $166 million in medical charges and lost work time (USEPA, 2005).

Identification of pathogenic organisms in polluted waters is complicated because they are few and highly varied. Thus, health officials generally prefer to monitor nonpathogenic bacteria that are usually associated with pathogens transmitted by fecal contamination but are more easily sampled and measured (USEPA, 2005). These associated bacteria are called indicator organisms. In this respect, if there is a large fecal coliform population in water, it is assumed that there is a greater likelihood that pathogens are present (McMurry et al., 1998).

The most commonly used indicators are coliform bacteria and fecal streptococci. Coliform bacteria include total coliform, fecal coliform (nominally a subset of total coliform) and *E. coli* (a specific organism that is usually a fecal coliform). USEPA conducted comprehensive research studies to examine the relationship between swimming-associated illness and the microbiological quality of the waters used by recreational bathers (USEPA, 1986). This research recommended using *E. coli* rather than fecal coliform as an indicator organism. The recommended steady state geometric mean values are 126 *E. coli* colony forming units (CFU) per 100 mL and 200 fecal coliform CFU per 100 mL (USEPA 1986).

Pathogens are one of many types of pollutants introduced from point or non-point sources and then transported via run off, groundwater, pipe, direct input or other mechanism to waterbodies (Moore et al., 1989).

The United States Environmental Protection Agency (USEPA) Clean Water Act regulates standards for water quality parameters according to the designated use of the

water system. Section 303(d) of these regulations indicates, if a waterway does not fulfill the surface water quality standard, a Total Maximum Daily Load (TMDL) must be developed that will calculate the necessary pollutant reductions so that the water quality standard will be attained (USEPA, 2005). In order to successfully achieve the TMDL goals for surface waters impaired by pathogens, many scientists have suggested two areas of research requiring further exploration. These areas are:

1.1. Source identification using pathogen indicators

The usefulness of testing methods that can indicate specific sources of pathogen contamination is currently of great interest to water quality managers. Pathogen source tracking refers to the concept of applying microbiological, genotypic, phenotypic, and chemical methods to identify the origin of fecal pollution (Scott *et al.*, 2002). *Bacteroides* is a group of bacteria that has recently been used by many researchers as a host-specific indicator to track pathogen sources in different watersheds. Two original parts of this research focused on a) temperature effects on persistence of bovine-*Bacteroides* and b) pathogen source tracking using multiple linear regression analysis.

1.2. Pathogen fate and transport

Pathogen fate and transport has been simulated via several watershed-scale models. According to Jamieson *et al.* (2004), a complete watershed quality model would include components (both input and output) that (1) characterize and track pathogen sources, (2) model the survival and transport of microorganisms within/on the landscape, and (3) model the survival and transport of microorganisms in streams and lakes. No model has all of the mentioned components, but the Soil and Water Assessment Tool

(SWAT) model is the most comprehensive watershed model in use by many researchers. SWAT is also supported by USEPA (Coffey et al., 2007). The third original part of this study focused on c) a SWAT model application for both fecal coliform and *E. coli* simulation in the agricultural USRW located in southern New Jersey.

Pathogen simulation with SWAT in the USRW helped to investigate fate and transport of two pathogen indicators, fecal coliform and *E. coli*. The results of this phase can address pathogen monitoring by simulating the effect of best management practices on pathogen concentrations throughout the watershed. One of the limitations of using fecal coliform and *E. coli* as indicators in pathogen management is their inability to identify pathogen sources; therefore a recently applied indicator, *Bacteroides,* was chosen to investigate if it can be utilized to track potential sources. However, little is known about the survival and persistence of *Bacteroides* (Scott et al., 2002). Therefore, a study was undertaken here to investigate the survival and persistence of a host specific (bovine) *Bacteroides.* Bovine *Bacteroides* was chosen because a) the most dominant land use in USRW is agriculture, specifically dairy operations, at 68%, and b) the bovine primer well established. The survival and persistence study yielded results on detection limit, Arrhenius constant and decay rates, and helped to shape and develop the third phase of the research by applying multiple linear regression which determined the probability of occurrence of bovine *Bacteroides* throughout the watershed. The results of this section will help to estimate bovine pathogen contribution from each sub-basin.

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2. *E. coli* and Fecal Coliform Simulation with SWAT Model in the Upper Salem River Watershed

2.1. Background

Pathogen pollution is a serious concern for water resources managers because pathogens can harm human health through contaminated fish and shellfish, skin contact or ingestion of water. One third of the length of all impaired streams and rivers in the U.S. are classified as such due to pathogen contamination (USEPA 2011). The USRW in New Jersey is among those rivers impaired by pathogens. In order to implement state water quality standards, a Total Maximum Daily Load (TMDL) was promulgated that requires an 84% reduction of pathogen loads in the USRW (NJDEP 2003).

At present, there are two methods for tracking pathogen pollution in a river system and assessing the effectiveness of the TMDL process in improving water quality of the pathogen impaired reaches: field monitoring and mathematical modeling (Shirmohammadi et al., 2006). Field monitoring is the more suitable method to assess TMDL development, but its use is limited because of higher costs and extreme spatial and temporal river variability (Pachepsky et al., 2006). As an alternative to field monitoring, mathematical models can save time and minimize costs. Furthermore, mathematical models can forecast future conditions of the river under different management scenarios (Shirmohammadi et al., 2006).

Coffey et al. (2007) reviewed 13 quantitative simulation models that could potentially be used for simulating pathogen pollutants in agricultural watersheds. The models were assessed in four main categories: model type, inputs, outputs and

functionality. Among the 13 models, the Soil and Water Assessment Tool (SWAT) was ranked first.

The SWAT model has the capability to simulate fate and transport of pathogens as two different populations: less-persistent pathogens (e.g., fecal coliforms) and persistent pathogens (e.g., *E. coli*). The persistent pathogens are characterized by lesser die-off rates whereas the less persistent pathogens have greater die-off rates in the natural environment (Jamieson et al., 2004). This discrepancy in die-off rates leads to the observation of a higher quantity of persistent pathogens in the natural environment compared to pathogens of less persistence (Sadeghi and Arnold, 2002). Researchers have simulated either fecal coliform or *E. coli* as pathogen indicators with the SWAT model in several watersheds in the U.S., France and Ireland (Buffet et al., 2010), but no study has been attempted to simulate both indicators and compare them at the watershed scale (Table 2-1).

Table 2-1 Type of pathogen indicators simulated in SWAT model in different studies (Buffet et al., 2010)

	USA (Missouri)	USA (Kansas)	USA (Georgia)	France	Ireland
Area (km^2)	644	3,600	75	17	68
Bacteria indicator	*E. coli*	Fecal coliforms	Fecal coliforms	*E. coli*	*E. coli*

The primary objective of this study was to apply the SWAT model to simulate simultaneously fecal coliform and *E. coli* fate and transport in the USRW. The outcome of this study can be used to predict impacts of applying different best management

practices on water quality and how to achieve the TMDL goal of pathogen reduction for the USRW.

2.2. Materials

SWAT is a watershed-scale, distributed, continuous time scale model that simulates at daily or hourly time steps. It was developed to predict the effects of water use, sediment, and agricultural chemical yields. The model has nine major components: weather, hydrology, soil characteristics, sediments, plant growth, nutrients, pesticides, pathogens, and land management. The model divides a watershed into several sub-basins, which are then further subdivided into hydrologic response units (HRUs) that consist of homogenous land use, soil and slope characteristics. The SWAT model utilizes an ArcGIS interface for the definition of watershed hydrologic features, which is overlaid by the organization and management of the related spatial and tabular data.

In the SWAT model, hydrology has a major role in fate and transport of any pollutants including pathogens. Surface runoff, evapotranspiration, recharge, and stream flow form several components of SWAT hydrology. Arnold et al. (1993) have developed a link between surface and subsurface flow models to interrelate surface and subsurface water flow. Surface runoff volume and infiltration are computed with the curve number equations or the Green and Ampt method. To calculate the watershed time of concentration and channel flow, SWAT uses Manning's equation (Arnold et al., 1993). Lateral subsurface flow can occur in the soil profile from 0-2 m, the groundwater flow contribution to total stream flow is generated by simulating shallow aquifer storage, and flow from the aquifer to the stream is lagged via a recession constant derived from daily streamflow records (Green and Van Griensven 2007).

2.3. Study area

The USRW is located in Salem County in southern New Jersey (Figure 2-1). The study area covers 37 square kilometers and is drained by the Salem River. According to New Jersey Department of Environmental Protection (NJDEP) 2002 aerial orthophotography, agricultural land uses (pasture, orchard and other agriculture) dominate this drainage area, comprising 68% of land use in the watershed, followed by forest and wetland each with 11% (Table 2-2).

Table 2-2 Areas of land uses in the USRW

Land use type	Area (ha)	Percent of the watershed
Agriculture	2,525	68%
Forest	401	11%
Wetlands	394	11%
Urban	332	9%
Water	53	1%
Barren Land	3.4	~0%
Total	3,708	100%

The highest elevation within the watershed is 45 m above sea level. The elevation difference from upstream to downstream is estimated as 16 m. Throughout the Salem River Watershed, the soils are smoothly sloping and their complexity spans silt loam, sandy loam and loam. The watershed soils are moderately permeable. They have moderate water-holding capacity and organic-matter content, and natural fertility ranges from low to moderate (USDA 1969).

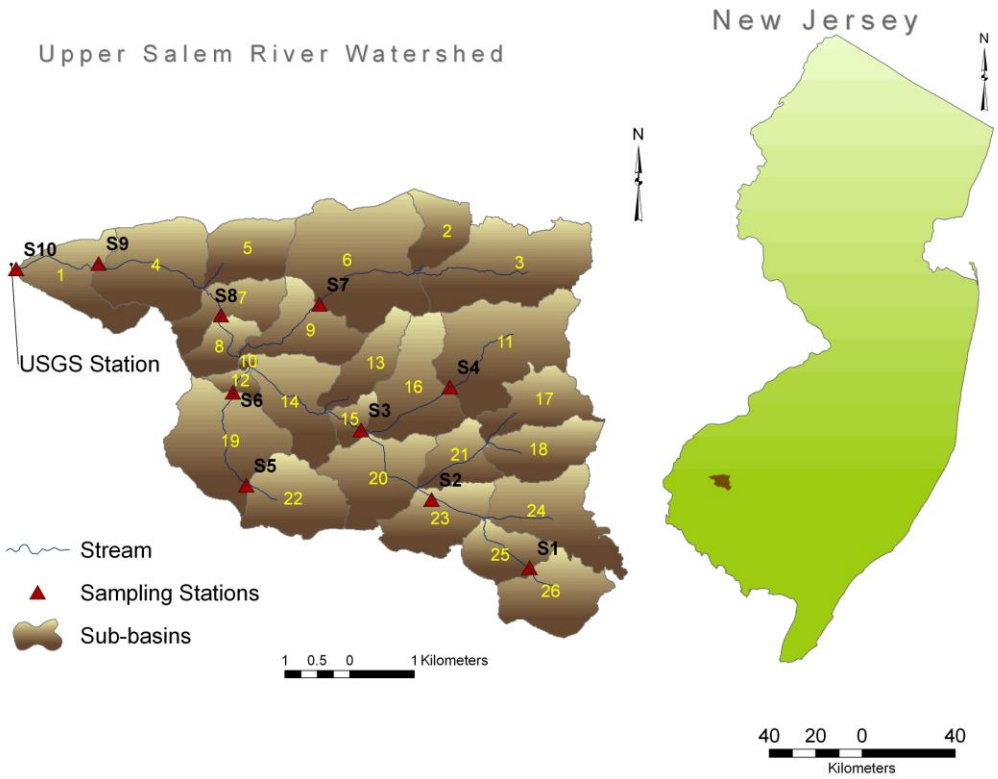


Figure 2-1. Location of sampling stations and sub-basins at the USRW

2.4. Model setup

ArcSWAT (version 2.3.4) was used to develop water quantity and quality simulation. Input GIS layers and data for ArcSWAT were acquired mainly from the Bureau of Geographic Information Systems, NJDEP's online website (http://www.state.nj.us/dep/gis/). The input layers included the Digital Elevation Model (DEM), watershed boundary, stream, and land use. Through importing the 10-meter DEM raster layer and stream layer, the SWAT model delineated the direction of flow, the extent of the watershed and 26 sub-basins, ten of which were located at sampling stations (Fig. 1). The soil layer was obtained from the State Soil Geographic (STATSGO) website (http://soils.usda.gov/survey/geography/statsgo/). The soil layer for the USRW contains soil types and associated characteristics which were found in four map unit IDs: NJ025, NJ026, NJ029 and NJ039 (Table. 2-3).

Table 2-3 Soil characteristics of each map unit located in the USRW

Map Unit ID	Sand (%)	Silt (%)	Clay (%)
NJ025	23	62	15
NJ026	59	31	10
NJ029	61	29	10
NJ039	65	26	9

After importing soil and land use layers to the SWAT model, HRUs were defined based on a threshold of 5% for land use, (i.e. land uses that cover less than 5% of the sub-basin area are dissolved to the adjacent land use, and the HRU will be based on land uses that cover greater than 5% of the sub-basin area), 0% for soil and 1% for slope. Each

HRU represents an individual sub-watershed consisting of unique land use, soil type and slope characteristics. A total of 446 HRUs were defined by the SWAT model (Appendix A). The resulting SWAT-modeled watershed contained land use percentages of 58% farm land, 7% pasture, 2% vegetated land/orchards, 12% forest, 11% wetlands, and 10% residential. The soil distribution in the model was 52% NJ025, 13% NJ029, 14% NJ039, and 20% NJ026.

Daily observed data for precipitation and maximum/minimum temperature for three years (2006-2009) from the Upper Deerfield and Clayton weather stations (each within 26 km of the watershed boundary) was obtained from the South Jersey Resource Conservation and Development Council (SJRC&D) weather system network (http://www.sjrcd.org/rise). The data was used in the preparation of weather input files for model simulation.

2.5. Sampling method

A single grab sample was collected bi-weekly at ten sampling points from June 2007 through June 2009. Surface water quality sample collection, as well as in situ measurements of pH, temperature, dissolved oxygen, stream depth, stream width, and stream velocity was conducted. Samples were analyzed for fecal coliforms, *E. coli*, ammonia-nitrogen, nitrate-nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved orthophosphate phosphorus, and total suspended solids by NJDEP Certified Laboratory # PA166, QC Laboratories. All samples were placed immediately into an ice cooler and transferred to the laboratory within 2-4 hours.

Daily flow data from USGS gauge 01482500 at the watershed outlet, station S10, was used for flow calibration and validation. For the nine upstream sampling locations,

velocities were measured bi-weekly at stream cross-sections using a Marsh-McBirney, Inc., Flo-Mate Model 2000 Flow-meter, and flow was calculated for each station during each event sampled according to the procedure described in the flow-meter instruction manual (Marsh-McBirney, Inc., 1990).

2.6. Pathogen source characterization for SWAT model

Three potential pathogen sources were identified in the USRW: livestock, human and wildlife.

2.6.1. Livestock

Feeding operations, manure spreading from grazing on pasture land, and animal feeding facilities were major livestock-derived pathogen sources in this study. The total number of livestock both at feedlots and pastures was estimated at 900 animal units (AUs), where an AU equals 455 kg, for the USRW (M. Bonham, USDA/NRDC Salem County, 2009, personal communication).

Livestock grazing management at the USRW is conduced in two separate periods: a grazing season which was estimated to be 150 days in pastures, and a non-grazing season of 215 days, in which livestock are kept in feedlot. According to ASAE Standard (2003, 2005), for each dairy animal manure production which is estimated at 86 kg day^{-1} AU^{-1} and the excreted fecal coliform bacteria load was estimated at 1.3×10^{11} cfu day^{-1} AU^{-1}. Considering the mean weight manure moisture content of 85% (ASAE Standards 2005), the bacteria load was converted into model-input units of cfu per gram of dry-weight manure.

2.6.2. Human

Septic system failure is the main source of human-oriented pathogens in the USRW. There are several possible causes of septic system failure: poor soil conditions, soil clogging, high water table, tree roots and heavy weights over any part of the system (Kaplan 1987).

Since there is no direct method to input septic systems in the SWAT model, estimated septic discharge was assumed as a fertilizer input in management of the model (Parajuli et al., 2009).

Using a land use map of the watershed, the location of each house was identified. Each rural house was assumed to use one septic system, adding up to 512 septic systems in the watershed. Assuming a 20% failure rate system (USEPA 2002), 102 systems were estimated as malfunctioning. Each septic tank was assumed to be used by three individuals in the household who discharge about 0.32 m^3 of sewage effluent every day (USEPA, 2001). Each failing septic system was assumed as a fertilizer with load of 4.7 kg ha^{-1} day^{-1} to each residential HRUs with assumption of pathogen concentration of 6.3 $\times 10^6$ cfu $(100\ mL)^{-1}$ (Parajuli et al., 2009).

2.6.3. Wildlife

The literature does not offer an inclusive wildlife population estimate report for the USRW; however, based on direct observations and available reports from the Division of Fish and Wildlife, NJDEP, the types and spatial distribution of wildlife were identified. Memorial Lake, East Lake, Avis Millpond, Slabtown Lake, Daretown Lake, and Salem River Reservoir as well as scattered forests that are located alongside the Upper Salem River, were considered as primary habitats for wildlife. These water bodies

and surrounding forests were suitable habitats for a range of mammals such as: opossum, raccoon, squirrel, fox, white-tailed deer, rabbit, and skunk, and birds such as: green-winged teal, turkey, northern shoveler, mallard duck, heron, osprey, bald eagle, hawk, swan and goose.

Based on direct observations and greater animal weight, deer were considered the greatest pathogen contributor among mammals in the study area. According to The Quality Deer Management Association, http://www.i-maps.com population density of this mammal in the USRW was estimated are between 6 and 12 head per km^2, therefore 420 deer (84 AUs) were considered in the area. The fecal coliform accumulation rate for deer was calculated by converting the number of deer per km^2 to the number of deer per acre and multiplying by fecal coliform output per deer per day (Halls, 1984). This resulted in 3.26×10^8 cfu/ac/day.

The number of waterfowl was estimated based on direct observation in the water bodies throughout the watershed. Wintering waterfowl such as ducks, teal and geese were the most abundant birds observed in the watershed, therefore these birds were considered as main pathogen contributors. Ducks and teal were estimated to winter in four large flocks of 150 birds each from November to March on four lakes and Canada geese were assumed to comprise two large flocks of 220 birds each residing in pastures. For those sub-basins with the aforementioned habitats, the pathogen accumulation rates were calculated by multiplying the pathogen generation rate (counts/animal/day) by the number of birds, resulting in a total generated per day (counts/day). The pathogen rate originating from birds ranges between 24.7×10^8 to 28.6×10^8 cfu/a/day.

Given that over 10% of the land use in the USRW offers habitat for waterfowl, wildlife was assumed as a point source of pathogen input to the river system.

2.7. Pathogen model

The SWAT model pathogen simulation component in surface water at the watershed scale was developed by Sadeghi and Arnold (2002). This component has the capability of simulating pathogens for two different populations: non-persistent microorganisms such as fecal coliform and persistent microorganisms such as *E. coli*. In the SWAT model, the only difference between these two populations is the die-off rate with the less-persistent population characterized by the more rapid die-off rate. However, the initial quantity of the less-persistent population is usually considered greater than the persistent population (Coffey et. al. 2010).

In the SWAT model, pathogen simulation is governed by fate and transport equations. Pathogen transport occurs among the following pathways: deposition of manure from animals or spreading manure fertilizers, adsorption to soil, infiltration, incorporation through tillage, extraction by run-off and transport in-stream (see Buffete et al., 2010 for equations). Pathogen fate is governed by the Chick's law first-order decay equation [Eq. 2-1]:

$$C_t = C_0 \, e^{-ktA(T-20)} \qquad \text{[Eq. 2-1]}$$

where C_t = concentration at time t, C_0 = initial concentration, K = decay rate (d^{-1}), t = time (days), A = temperature adjustment factor, and T = temperature (° C).

The number of pathogens in each transport pathway is calculated based on a system of mass balance equations.

2.8. Statistical methods

The statistical method used to evaluate measured versus predicted water flow and water quality is the Nash-Sutcliffe Efficiency coefficient *(E)*. This method is one of the most widely used comparison statistics in watershed scale hydrologic modeling and it is also recommended for use by the American Society of Civil Engineers (Moriasi et. al. 2007). The coefficient, *E*, is calculated as one minus the sum of the absolute squared difference between the predicted (P_i) and observed (O_i) values normalized by the variance of the observed values (Eq. 2-2; Krause et al., 2005):

$$E = 1 - \frac{\sum_{i=1}^{n} (Oi - Pi)^2}{\sum_{i=1}^{n} (Oi - \overline{O})^2} \qquad \text{[Eq. 2-2]}$$

where, $\bar{O}$ = mean of observed values.

The efficiency coefficient ranges between -∞ to 1, with values closer to 1 indicating greater fit between model prediction and observed values. An *E* value of zero indicates that the mean of the observations is sufficient for modeling and as good a predictor as the model, while negative values of *E* indicate that the mean of the observation data is a better predictor. According to Moriasi et al. (2007), model efficiencies were classified as excellent ($E \geq 0.9$), very good (E = 0.75-0.89), good (E = 0.5-0.74), fair (E = 0.25-0.49), poor (E = 0-0.24) and unsatisfactory ($E < 0$). For the evaluation of model efficiency in this study, pathogen data was calculated using a $\log_{10}$ transformation of simulated and measured values, comparable to other pathogen simulation studies that have a range of several orders of magnitude (Uchrin et al., 1981; Benham et al., 2006; Parajuli et al., 2009).

2.9. Results and discussion

2.9.1. Sensitivity Analysis

Calibration is complicated by the numerous model parameters that affect flow, fecal coliform and *E. coli* simulation. A sensitivity analysis can be performed to identify the relative response of the model to changes in values of specific model parameters. A sensitivity analysis can thus determine the most important parameters that control system processes.

To perform sensitivity analyses of flow simulation, the SWAT model is configured to apply combination of the Latin hypercube (LH) technique, and the one-factor-at-a-time sampling method to ensure that changes in model output correspond to the parameter changed. The technique is robust and has been widely used in modeling, but it generally requires lengthy computation times. The LH technique utilizes a stratified sampling approach that allows efficient estimation of output statistics. LH is used to subdivide the probability distribution of each parameter into N non-overlapping strata, each with an equal probability of occurrence of $1/N$. Each segment is sampled only once, thus generating N random values for each parameter (Van Griensven et al., 2002).

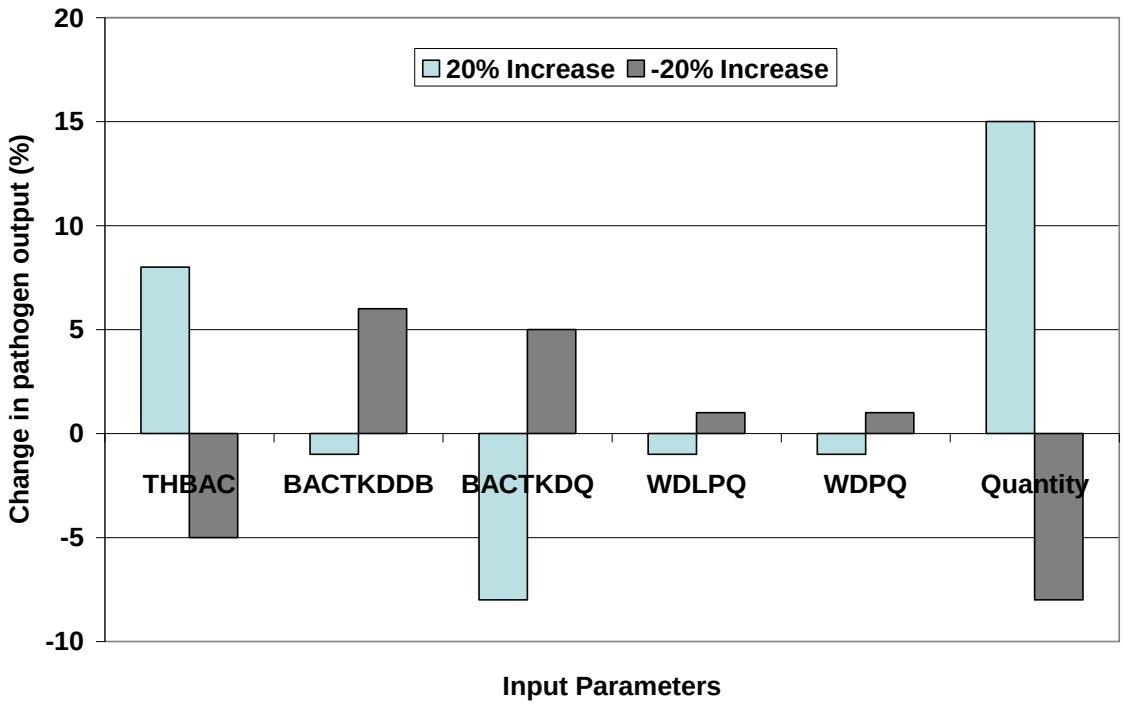
The flow sensitivity analysis was performed for 6 sampling stations including the outlet (S10) of the USRW. The results of the parameter ranking are shown in Table 2-4. The table indicates that the base-flow alpha factor and curve number have the highest degree of sensitivity in predicting surface water flow.

Table 2-4 Sensitivity analysis for flow parameters at six sampling stations

Sampling stations	Rank 1	Rank 2	Rank 3	Rank 4
S3	Alpha-BF (base-flow alpha factor)	GW_RVAP (groundwater revap coefficient)	ESCO (soil evaporation compensation)	CN2 (SCS runoff curve)
S4	Alpha-BF (base-flow alpha factor)	GW_delay (groundwater delay)	ESCO (soil evaporation compensation)	CN2 (SCS runoff curve)
S5	GW_RVAP (groundwater revap coefficient)	CN2 (SCS runoff curve)	Alpha-BF (base-flow alpha factor)	SOL_AWC (soil availability capacity)
S7	CN2 (SCS runoff curve)	Alpha-BF (base-flow alpha factor)	GW_delay (groundwater delay)	SOL_AWC(soil availability capacity)
S8	CN2 (SCS runoff curve)	GWQMN (threshold depth of water)	SOL_AWC(soil availability capacity)	ESCO (soil evaporation compensation)
S10	Alpha-BF (base-flow alpha factor)	CN2 (SCS runoff curve)	ESCO (soil evaporation compensation)	GW_delay (groundwater delay)

In the SWAT model, there are 27 pathogen associated parameters that are used in the pathogen fate and transport equations. Of the 27 parameters, 9 are specified for less persistent pathogens, 9 for persistent pathogens, and the remaining 9 parameters are common to both pathogen populations. The LH technique was not supplied to perform sensitivity analysis for pathogens in the SWAT model. Therefore, a graphical method using ±20% changes of pathogen input parameters was performed to investigate output

fluctuation. Sensitivity analysis results for the six most sensitive pathogen parameters at the watershed outlet (S10) are shown in Figure 2-2.



THBAC: temperature adjustment factor
BACTKDDB: bacteria partition coefficient in manure
BACTKDQ: bacteria partition coefficient in surface runoff
WDPQ: die-off factor for persistent pathogens in soil solution
WDLPQ: die-off factor for less persistent pathogens in soil solution
Quantity: quantity of manure applied to land and direct input to stream

Figure 2-2. Sensitivity analysis for pathogen simulation

2.9.2. Flow calibration and validation

To ensure that the flow model accurately describes the balance between baseflow and surface runoff, a comparison between simulated and measured ratios of baseflow to

total flow was performed on multiple year-long datasets. There are several techniques to separate baseflow from surface runoff in streamflow data. The USGS hydrograph separation (HYSEP) method (Sloto and Crouse, 1996) was used to separate measured baseflow from total flow. A yearly flow calibration was performed to compare baseflow with total flow at the watershed outlet (S10) over a 3 year period from June 2005 to June 2008 (Table 2-5). The results indicate superb agreement between the actual and predicted fractions of baseflow and runoff.

Table 2-5 Comparison of yearly measured and predicted ratios of base flow to total flow

Year		Total water yield (mm)	Base flow (mm)	Surface flow (mm)	Ratio of base flow to total flow
2006	Actual	672	255	417	0.38
	SWAT	645	244	401	0.40
2007	Actual	541	233	308	0.43
	SWAT	502	205	297	0.41
2008	Actual	528	211	317	0.40
	SWAT	497	219	278	0.44

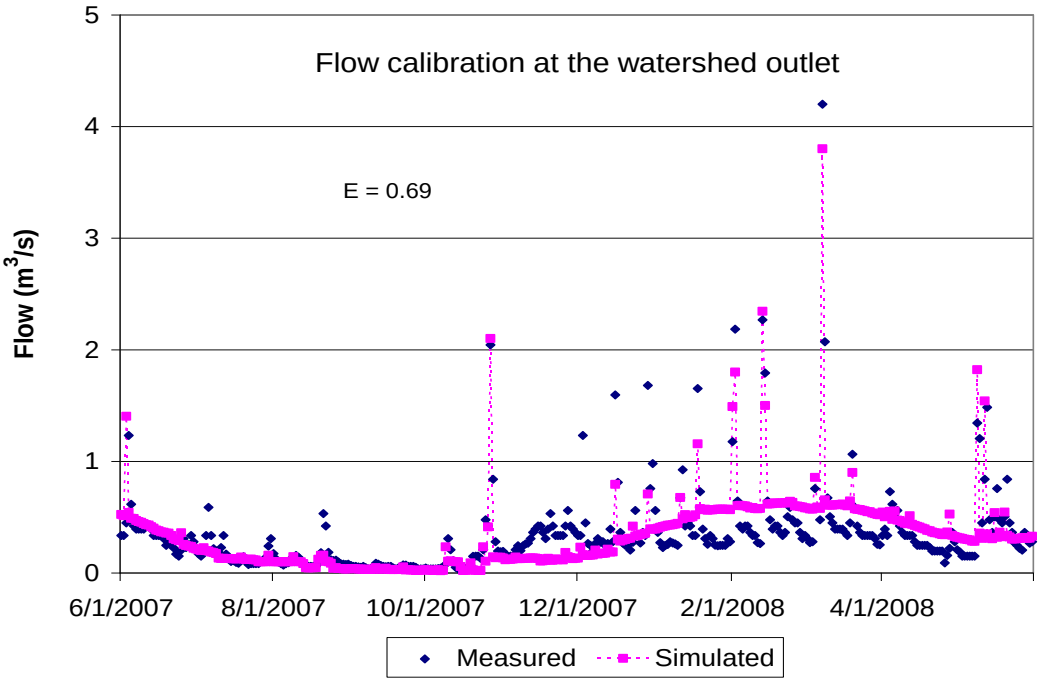
The model was manually calibrated for daily flow simulation from June 2007 to June 2008, and validated for daily flow simulation from July 2008 to July 2009 at six sampling points. For the entire calibration and validation periods, daily model output at the watershed outlet (S10) was compared against daily observed data recorded from USGS gauge station 01482500 (Figure 2-1). For the five upstream sampling points (S3, S4, S5, S7, and S8), a daily flow model calibration and validation were carried out for 33 and 25 days, respectively (Appendix B). Applied and default values for selected parameters in all sub-basins are shown in Table 2-6.

The SWAT model default parameter values yielded a fair Nash-Sutcliffe model efficiency (E = 0.32) at the watershed outlet (S10) for daily flow simulation when initially applied in the USRW. The calibration process led to an improved flow model efficiency (E = 0.69) (Figure 2-3). The same parameter values from model calibration were applied to the July 2008 to July 2009 period in order to validate the model. Nash-Sutcliffe efficiency values for model calibration and validation at all sampling stations are shown in Table 2-7. The efficiency values for flow model calibration and validation at all sampling stations range between 0.20 and 0.71, which shows poor to good model fit. However, at the station with the most samples (S10), the model efficiency results for both calibration and validation are good (E= 0.69 and E=0.53, respectively). The plots of flow calibration at S3 and flow validation at S8 are shown in Figure 2-4.

Table 2-6. Selected and default values for highly sensitive flow parameters

Parameters	Default value	Test range value	Final value bound
CN forest pasture	 70 74	 30 - 83 39 – 89	 50-75 52-78
ALPHA_BF	0.048 day	0.01 – 0.3	0.03 – 0.2
ESCO	0.95	0.01 – 1.0	0.4 – 0.9
GWQMN	1 mm H_2O	0 – 5000	89 - 442
SOL_AWC	-0.1 – 0.1 (mm H_2O/mmsoil)	0 – 1	0.1 – 0.15

CN = curve number
ALPHA_BF = base-flow alpha factor
ESCO = soil evaporation compensation factor
GWQMN = threshold depth of water in shallow aquifer
SOL_AWC = soil availability capacity



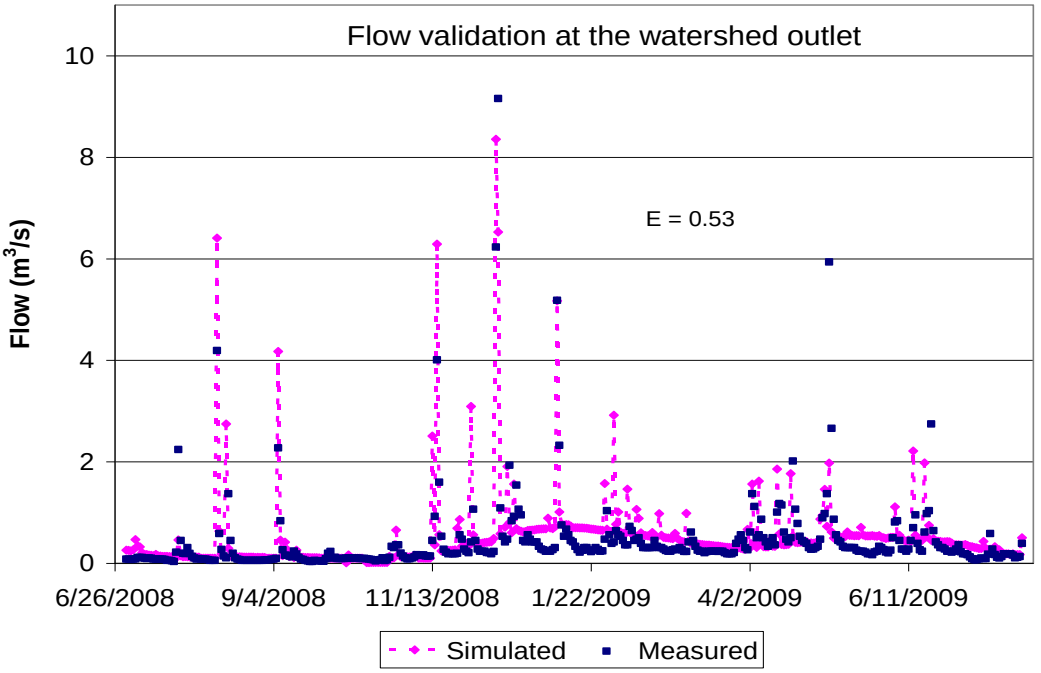


Figure 2-3. Flow calibration and validation at watershed outlet

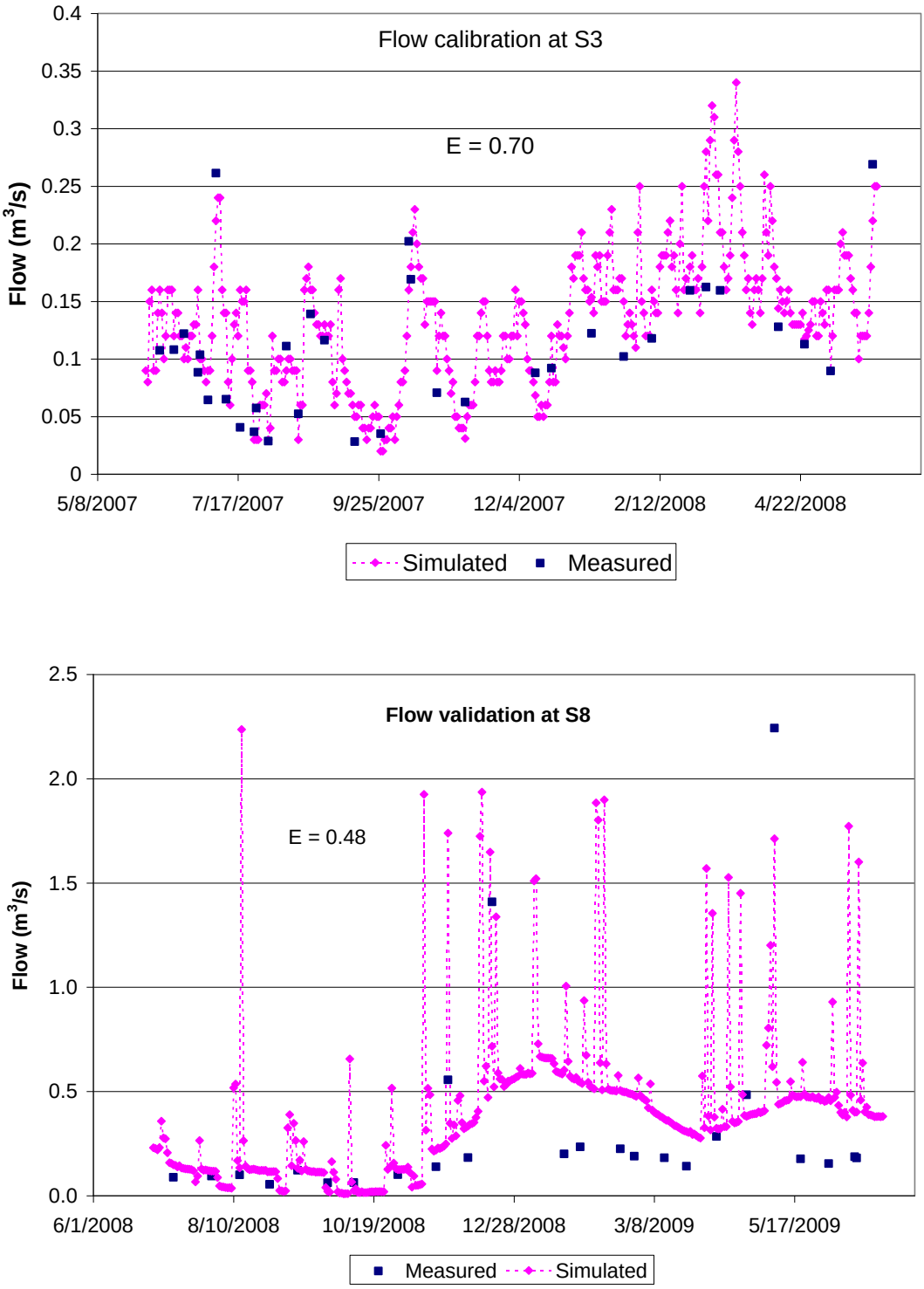


Figure 2-4. Flow calibration at S3 and validation at S8

Table 2-7. Nash-Sutcliffe efficiency values for calibration and validation for six sampling stations

Sampling points	Nash-Sutcliffe Efficiency, Model Calibration	Nash-Sutcliffe Efficiency, Model Validation
S3	0.70	0.71
S4	0.50	0.48
S5	0.45	0.40
S7	0.36	0.20
S8	0.58	0.48
S10	0.69	0.53

2.9.3. Pathogen calibration and validation

The SWAT model for USRW was calibrated for fecal coliform and *E. coli* from June 2007 to June 2008 and validated from July 2008 to July 2009 on monthly basis. In addition to the existing pathogen parameters in the SWAT model, the direct input load from wildlife was assumed as an additional calibration parameter for fecal coliform and *E. coli* simulation. Fecal coliform and *E. coli* direct loads to the USRW are shown in Table 8. Default and calibrated values for the most sensitive parameters of fecal coliform and *E. coli* are demonstrated in Table 2-9. The geometric mean of measured values for each month was compared to monthly simulated values for fecal coliform and *E. coli* (Figure 2-5). All values were then transformed on a $\log_{10}$ basis.

The Nash-Sutcliffe efficiency results for fecal coliform and *E. coli* at all sampling points, except the validation result at S8, show positive agreement between measured and simulated values (Tables 2-10 and 2-11).

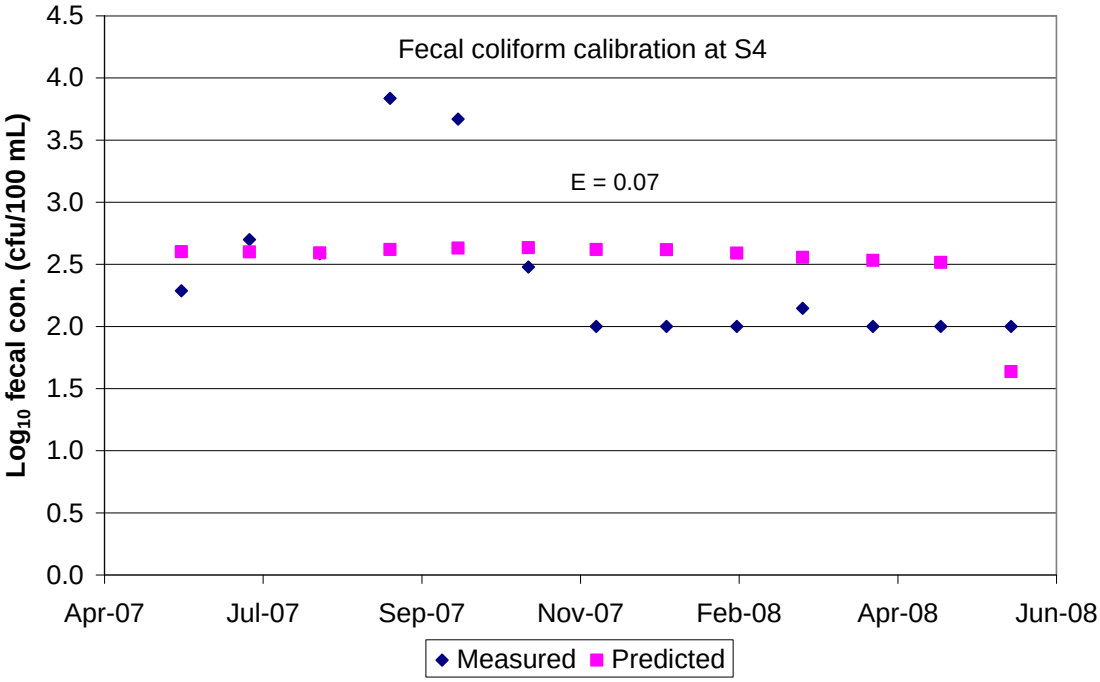
Table 2-8. Calibrated fecal coliform and *E. coli* load

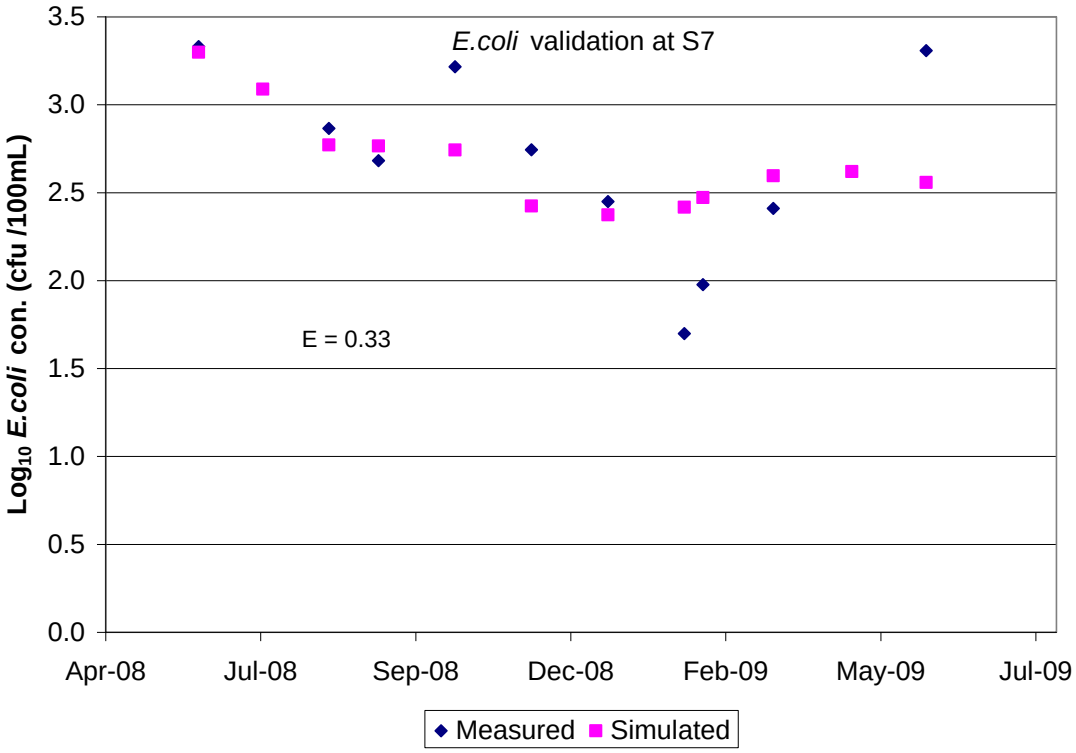
Sub-basin	Direct input, cfu ha^{-1} d^{-1}	
	Fecal	*E.coli*
1	8.1×10^{8}	5×10^{8}
6	4×10^{11}	4×10^{11}
8	7×10^{8}	2×10^{8}
11	10^{6}	10^{6}
21	8×10^{8}	8×10^{8}
23	3.8×10^{8}	5×10^{8}

Table 2-9. Calibrated and default values for fecal coliform and *E. coli*

Parameter	Default value	Fecal value bound	*E. coli* value bound
THBAC	1.07	1.07	1.07
BACTKDDB	0	0.2-0.5	0.2-0.5
BACTKDQ	175	195	195
WDPQ	0	-	0.3-0.5
WDLPQ	0	0.3-0.5	-

THBAC = temperature adjustment factor
BACTKDDB = bacteria partition coefficient in manure
BACTKDQ = bacteria partition coefficient in surface runoff
WDPQ = die-off factor for persistent organism in soil solution
WDLPQ = die-off factor for less persistent organism in soil solution


Fecal coliform calibration at S4
E = 0.07
Log10 fecal con. (cfu/100 mL)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Apr-07
Jul-07
Sep-07
Nov-07
Feb-08
Apr-08
Jun-08
Measured
Predicted


E.coli validation at S7
E = 0.33
Log10 E.coli con. (cfu /100mL)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Apr-08
Jul-08
Sep-08
Dec-08
Feb-09
May-09
Jul-09
Measured
Simulated

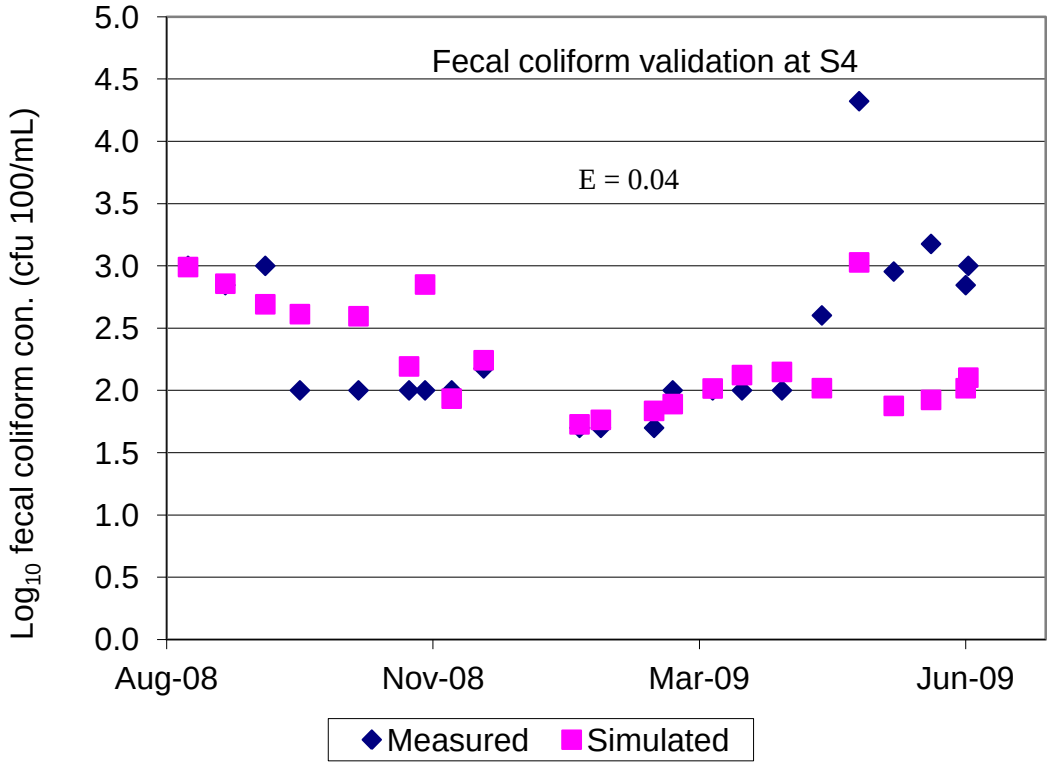


Figure 2-5. Pathogen calibration and validation at different sampling points

Table 2-10. Nash-Sutcliffe efficiency values for fecal coliform at sampling stations

Sampling points	Calibration	Validation
S3	0.23	0.11
S4	0.07	0.04
S5	0.47	0.29
S7	0.36	0.33
S8	0.13	-0.94
S10	0.12	0.11

Table 2-11. Nash-Sutcliffe efficiency values for *E. coli* at sampling stations

Sampling points	Calibration	Validation
S3	0.39	0.19
S4	0.03	0.24
S5	0.36	0.31
S7	0.33	0.31
S8	0.25	-0.81
S10	0.24	0.20

SWAT output for fecal coliform and *E. coli* are concentration based, therefore their predictions tend to be high during low flow conditions and low for high flow conditions. The SWAT predictions for pathogens are more accurate for moderate flow conditions. Comparing simulated and measured values at all sampling stations showed that the model in some months over-predicts and other months under-predicts; this fluctuation indicates that there are many factors contributing to uncertainty for pathogen simulation with the SWAT model.

2.10. Conclusions

This was the first successful attempt to simulate simultaneously fecal coliform and *E. coli* with SWAT model. Successful application of the SWAT model in the USRW showed that this model can be applied in small watersheds as well. Model calibration and validation for daily flow displayed a good Nash-Sutcliffe efficiency in most sub-basins. Fecal coliform and *E. coli* simulation at six sampling stations were performed.

Pathogen simulations produced Nash-Sutcliffe efficiencies that showed the model performed better than the observed mean; monthly predictions followed a similar trend of measured values. At S8, two unacceptable values for validation of fecal coliform and *E. coli* were observed.

A sensitivity analysis of pathogen indicator simulation showed that the quantity of indicator input and temperature adjustment factor for die-off (THBACT) are the most sensitive parameters for pathogen calibration.

Further research needs to be done in certain areas of the SWAT model associated with pathogen indicator simulation: 1) loading from damaged septic system 2) pathogen loading from wildlife 3) die-off rate in soil 4) input to water column due to sediment re-suspension and 5) fate and transport on surface land.

Although Nash-Sutcliffe values for each sampling point in this study are not overwhelming, they contribute to new knowledge in pathogen modeling and will help further understanding of the uncertainty that exists in pathogen modeling.

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3. Temperature effects on persistence of bovine-*Bacteroides* 16S rRNA genes

3.1. Background

Pathogens are the leading cause of surface water impairment in the U.S. (USEPA 2006). Depending upon the type of land use in a watershed, the potential sources of pathogens are diverse and can be classified as point sources (e.g., animal feeding operation (AFO) and wastewater treatment plant effluents) and non-point sources (e.g., livestock and land application of manures).

The most commonly used method for measuring pathogens in surface waters is to count fecal indicator pathogens, such as fecal coliform, fecal enterococci and *E. coli*. Using these methods has several limitations including lengthy culturing time of at least 18-24 hours, and the fact that major pathogen populations of the human gut are not *E. coli* or fecal coliforms, but are obligate anaerobes that are not easily cultivated (Hold et al., 2002; Lee et al., 2010).

In order to overcome the aforementioned impediments, researchers have developed rapid and more reliable methods such as using members of the genera *Bacteriodes* as alternative fecal-indicator organisms. These genera are anaerobes, more specific to host animals, have limited potential for growth, persist in the natural environment, and are restricted to warm-blooded animals (Kreader 1998).

Polymerase chain reaction (PCR) primers targeting the *Bacteriodes* 16S rRNA genes have been developed to detect human- and ruminant- associated *Bacteriodes* (Layton et al. 2006). More recently a real-time PCR assay for simultaneous detection and quantification for total, human, bovine, and swine-specific *Bacteriodes* 16S rRNA genes were developed as an alternative fecal indicator (Okabe et al. 2007b).

A number of researchers reported persistence of *Bacteriodes* 16S rRNA genes between 1 day to 3 weeks in surface waters using cultural methods and presence/absence PCR detection (Fiksdal et al., 1985, Kreader 1998). More recently, Okabe et al., (2007a) applied qPCR and reported *Bacteriodes* 16S rRNA genes persistence and decay rates for 4 different hosts (total, human-, bovine-, and swine-specific) at different incubation temperatures and salinities in environmental waters. They found that *Bacteriodes* 16S rRNA genes persisted longer at lower temperatures and higher salinities. However, in their study the decay rate was determined from the beginning of incubation to day 7 while in other reported studies the decay rate was determined for more than a week.

Bell et al., (2009) examined persistence and decay rates of *Bacteriodes* 16S rRNA genes derived from equine fecal samples in stream water using qPCR to measure gene concentration over time with treatments planned to compare filtered vs. unfiltered stream water, fecal aggregate size, initial fecal concentrations, and water temperatures. They found that first-order exponential decay functions were fitted to the data from each experiment using unfiltered stream water and the decay rate is more highly correlated to temperature than the initial *Bacteriodes* 16S rRNA genes concentration.

The objectives of this study were to investigate the persistence of bovine-specific *Bacteriodes* 16S rRNA generic markers in stream water at different temperatures and to identify their decay rate constant. The results of this study can be used for pathogen simulation in widely used watershed-scale models such as the Soil and Water Assessment Tool (SWAT). In these models, current governing equations for decay rate of pathogens are based on conventional fecal indicators (fecal coliform and *E. coli*), therefore it is essential to supplement decay rate equations of *Bacteriodes* 16S rRNA genes with the

conventional ones if data on *Bacteriodes* 16S rRNA genes are desirable to use for the models.

3.2. Materials and methods

The stream water sample was collected from the Upper Salem River, New Jersey. To hold the limnological status of the water close to natural conditions the collected water was not filtered. A fresh bovine fecal sample (still warm from bovine) was collected from a single healthy cow at G. H. Cook Campus Animal Farm, Rutgers University and immediately weighed out to make a slurry consisting of 5 mg feces (wet weight) in 95 mL of water collected from the Salem River (NJ).

This slurry was used to inoculate three flasks containing 3 liters each of Salem River water. Each flask, mesocosm, received 15 mL of slurry for a total loading of 0.26 mg/L of feces. The flasks were incubated at 4°C, 20°C or 30°C with agitation for 45 days. Mesocosms were covered with foil to reduce evaporation of water. Triplicate 25 mL samples were taken from each mesocosm and filtered through 0.45 µm pore size nitrocellulose filters. All filters were extracted and assayed for bovine markers.

3.3. Detection and quantification of *Bacteriodes* 16S rRNA genes

DNA was extracted from total filtered biomass using a DNeasy® tissue kit (Qiagen). All DNA were quantified by spectroscopy and diluted in sterile water to a concentration of 1 µg/ml. A TaqMan® based assay was performed using Applied Biosystems reagents and standard conditions on an Applied Biosystems 7300 Real-Time PCR system. The method used primers and probes developed by Layton *et al.* (2006) for

the detection of bovine- *Bacteriodes* 16S rRNA genes. The copy number was calculated by comparison to a standard curve made with plasmids containing bovine-sourced target 16S RNA genes amplified with the primers Bac 32f and Bac 708r (Bernhard and Field, 2000).

3.4. Data and statistical analysis

All *Bacteroides* 16S rRNA genes/mL were log-transformed for statistical analysis to allow comparison of data spanning two to three orders of magnitude. Decay rates (k) for the measured log concentration of *Bacteroides* 16S rRNA genes in each temperature were calculated using Microsoft Excel 2007. For each temperature treatment, decay rate measurements were calculated from day zero to the time that *Bacteroides* 16S rRNA genes concentration in the experimental mesocosm was below the detection limit. To calculate decay rate for *Bacteroides* 16S rRNA genes the following first-order decay equation was used (Eq. 3-1; Bell et al., 2009; Kay et al., 2008):

$$C(t) = C_0 \times e^{-kt} \qquad \text{[Eq. 3-1]}$$

where C is the log concentration of *Bacteroides* 16S rRNA genes/mL at time *t* (day), C_0 is the initial log concentration of *Bacteroides* 16S rRNA genes/mL, and k is the decay rate associated with the decay of the log *Bacteroides* 16S rRNA genes/mL. Time values were altered to hours from day.

3.5. Results and discussion

The detection limits of bovine- *Bacteroides* were measured to be 1.0×10^4 copies per 100 ml. Mesocosms containing fecal slurries were incubated for 45 days at 4, 20, and 30°C. Temperature had an effect on the decay of bovine- *Bacteroides* 16S rRNA genes. As shown in Table 3-1, *Bacteroides* 16S rRNA gene concentrations in stream water mesocosms incubated at lower temperatures decayed more slowly than those incubated at higher temperatures. The variations in decay of the *Bacteroides* 16S rRNA gene concentrations were reflected in two and five times increase of k values (0.01 [± 0.013] h^{-1}, 0.02 h^{-1} [± 0.005] and 0.05 h^{-1} [± 0.005]) at temperatures of 4, 20 and 30°C, respectively. The calculated initial concentrations of the *Bacteroides* 16S rRNA gene concentrations (8.9 to 9.5 copy of *Bacteroides* /100mL) was in the range of measured initial concentrations (8.75 to 9.5 copy of *Bacteroides* /100mL).

The concentration dropped about 2-3 orders of magnitude from day 1 to day 3 at 20 and 30°C, and after 14 days at 4°C (Figure 3-1). The copy numbers in each temperature treatment reached its quantification limit within the length of the experiment.

The decay constant and corresponding temperature values were input to the Arrhenius equation. An Arrhenius constant of $\Theta = 1.06$ with $R^2 = 0.95$ was found. This value can be applied in any watershed scale fate and transport model that could apply bovine *Bacteroides*as a pathogen indicator.

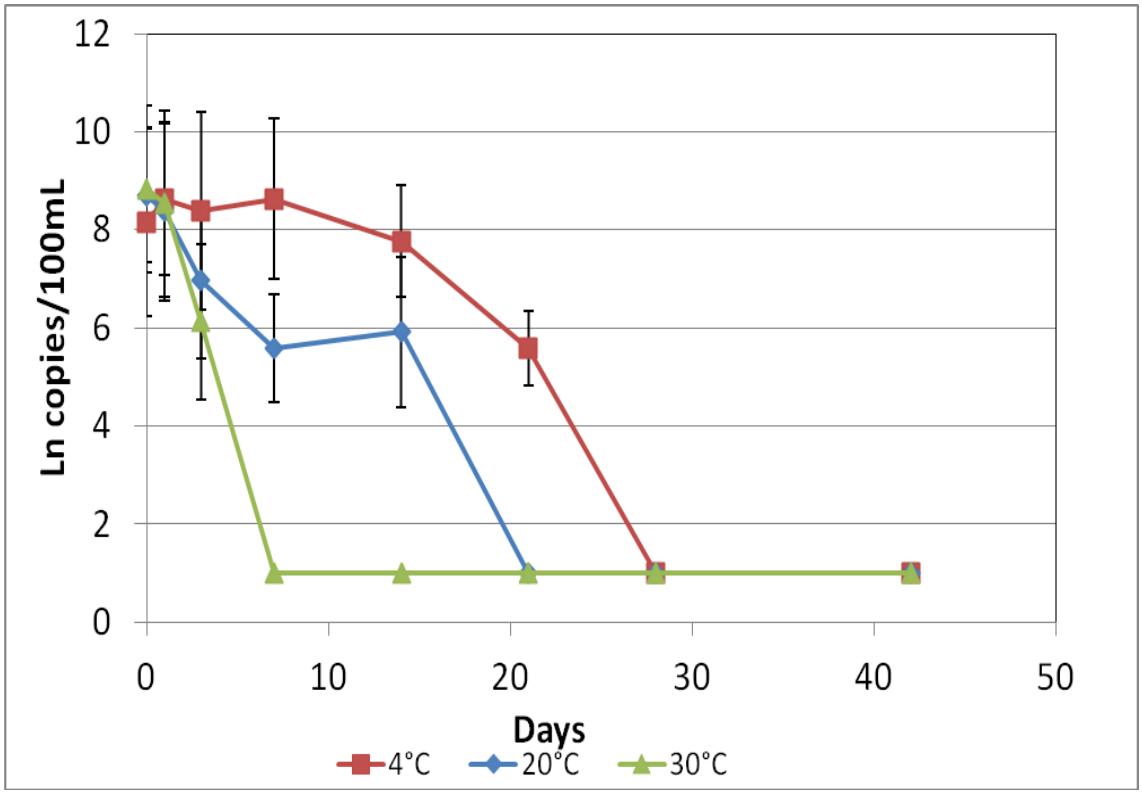

Figure 3-1. Persistence of feces-derived bovine-*Bacteroides* 16S rRNA gene in stream water incubated at 4, 20 and 30°

Table 3-1 *Bacteroides* decay rate determined from mesocosm experiments using stream water

Temperature	r^2*	Calculated C_0 **	K***
4° C	0.76	9.4 (± 0.73)	0.01 (± 0.013)
20° C	0.98	8.9 (± 0.22)	0.02 (± 0.005)
30° C	0.98	9.5 (± 0.22)	0.05 (± 0.005)

* r^2 = goodness of fit to a linear equation, ($C = C_0 + kt$), where C = natural log *Bacteroides* 16S rRNA genes/mL, and t = time

** calculated C_0 = natural log initial concentration of *Bacteroides* 16S rRNA genes/mL. The *P* value for all calculated C_0 was <0.05 at all temperatures

K*** = decay rate (per hour). The P value for K was <0.05 at all temperatures

3.6. Conclusions

In this research we investigated the persistence of bovine-*Bacteroides* 16S rRNA genes exposed to different temperatures, which could indicate a significant source of AFO and pasture runoff in many agricultural dominated watersheds of North America. The detection limit of bovine-*Bacteroides* 16S rRNA gene was measured at about 1.0×10^4 copies per 100 ml. This detection limit is in the ranges reported for different host specific *Bacteroides* 16S rRNA gene (4.2×10^2 to 1.2×10^4 copies per 100 ml) (Okabe et al., 2007a).

The decay rates measured in this research increased with higher temperature and fit a first order decay pattern. Comparison of the decay rate constant of *Bacteroides* 16S rRNA genes between this work and existing literature values shows similarity at lower temperatures and a discrepancy at higher temperatures. Bell et al., (2009) reported the decay rates for *Bacteroides* 16S rRNA genes 0.007 h^{-1} for 5°C, 0.02 h^{-1} for 15°C and 0.029 h^{-1} for 30°C whereas Okabe et al., (2007a) claimed 0.0025 h^{-1} for 4°C, 0.01 h^{-1} for 20°C and 0.029 h^{-1} for 30°C. These data strengthen the assumption that at lower temperature predators are inactive to degrade the *Bacteroides* 16S rRNA genes while at higher temperature grazing can be the main cause of *Bacteroides* 16S rRNA genes declination (Rose et al., 2007; Sherr et al., 1988; Bell et al., 2009).

Using the decay rate constants obtained from the three incubated temperatures, the Arrhenius constant was calculated as $\Theta = 1.06$ which allows simulation of decay in any possible range of water temperatures. This value falls within the range of other typical Arrhenius constant values (Chapra 1997).

Thus far, the only governing equations for simulation of pathogens in watershed-scale models are based on temperature variation, therefore temperature was considered as the only variable to measure decay rate for *Bacteroides* 16S rRNA genes. In this context, more study is needed to investigate the relationship between *Bacteroides* 16S rRNA genes and other biotic variables such as type of predators and abiotic variables such as sediment concentration.

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4. Pathogen source tracking using multiple regression analysis in Upper Salem River Watershed

4.1. Background

Early approaches to identify fecal coliform sources within surface water included analyzing for a fecal coliform to fecal streptococci (FC-FS) ratio, the output of which would assign the contamination as human, non-human, or both (USEPA, 2005). A ratio of greater than 4.0 would show human pollution, and a ratio of less than or equal to 0.7 would indicate non-human (Chapra, 1997). More recently pathogen source tracking methods have been used to assist in recognizing potential sources responsible for the fecal pollution of water bodies at the watershed scale. Some of these methods are library-dependent such as those that rely on fingerprint databases of cultured microorganisms and some are library-independent such as nucleic acid amplification techniques that do not require cultivation of microorganisms (Stewart et al., 2003; Stoeckel et al., 2004; USEPA, 2005).

Bacteroides assays are the most widely used cultivation and library independent pathogen assays for pathogen source tracking (USEPA, 2005). *Bacteroides* is a genus of obligatory anaerobic, gram-negative bacteria that are found in all mammals and birds. *Bacteroides* comprises up to 40% of the amount of bacteria in feces and 10% of the fecal mass. Because of the large quantity in the feces, they are an ideal target organism for identifying fecal contamination (Layton et al., 2006).

Furthermore, *Bacteroides* have been recognized as having wide geographical stability and distribution in target host animals and are a promising microbial species for differentiating fecal sources (USEPA 2005). Some *Bacteroides* are bovine-specific so that they can be used for tracking bovine fecal pollution in the environment. Layton et al. (2006) demonstrated the use of real-time polymerase chain reaction (PCR) assays to target *Bacteroides* species 16S rRNA to a host animal. The assays successfully targeted total *Bacteroides* in a water sample, as well as human- and bovine-related *Bacteroides.*

The Total Maximum Daily Load (TMDL) promulgated for the USRW, located in southern New Jersey, stipulates an 84% reduction in the load of fecal coliforms to the river (NJDEP 2003). One recommendation of the TMDL is to better identify the bacteria sources through a pathogen source tracking study. Due to lack of pathogen point source, i.e., waste water treatment plants, in this watershed it can be a very difficult task to pinpoint what are the main pathogen sources and where exactly pathogens discharge to the river. In this context, the primary goal of this research is to use a *Bacteroides* source tracking technique to address the following concerns: 1) to investigate if bovine feces are a contributing pathogen source to the water system and 2) to identify the spatial distribution of bovine pathogen discharge to the USRW. The results of this research can help to make better decisions to select the most appropriate best management practices in order to achieve the TMDL goal.

4.2. Study area

The USRW encompasses 36 km^2 and is drained by the Salem River. At the downstream end of this watershed is a United States Geological Survey (USGS) water quantity and quality station on the Salem River at Woodstown (01482500). Based on

2002 aerial imagery, land use (Table 4-1) in the USRW is predominately agriculture (68%) and also has a large percent of forest and wetland land use (22%) with low density residential areas (9%) (Figure 4-1). The 2002 United States Department of Agriculture (USDA) National Agricultural Statistics Services (NASS), http://www.nass.usda.gov, reported that 25% of the farms inventoried in Salem County raise cattle and calves.

Table 4-1. Areas of land uses in the USRW

Land use type	Area (ha)	Percent of the watershed
Agriculture	2,525	68%
Wetlands	394	11%
Forest	401	11%
Urban	332	9%
Water	53	1%
Barren Land	3.4	~0%
Total	3,708	100%

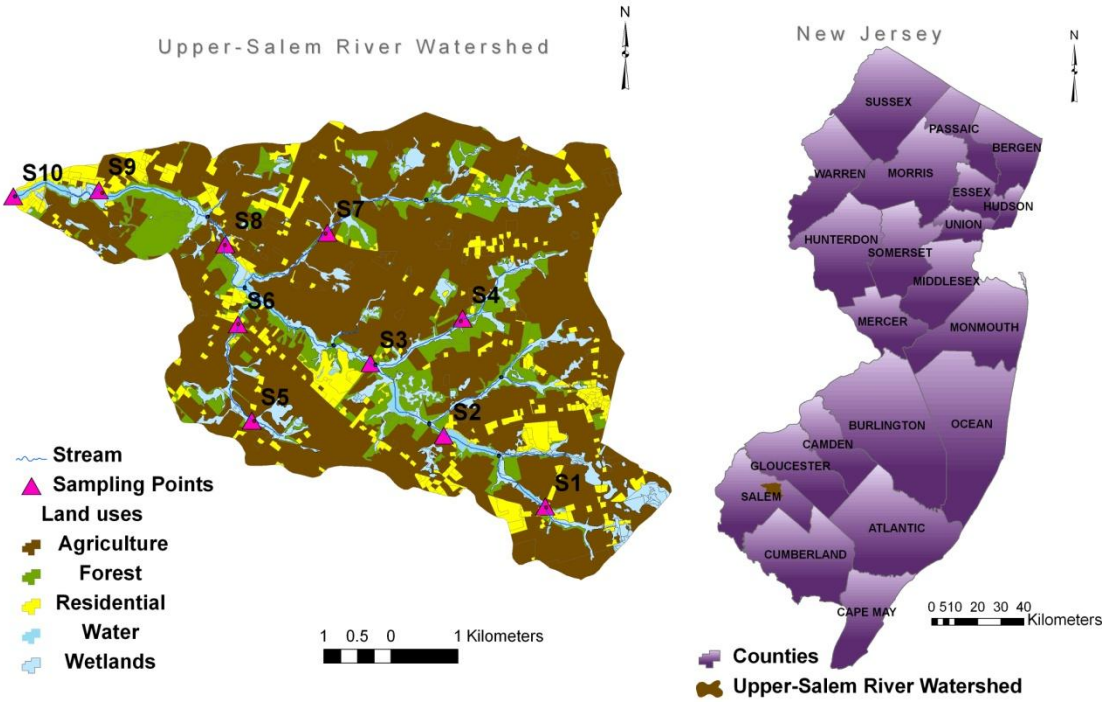

Figure 4-1. Land use map of the USRW

4.3. Methods

4.3.1. GIS pre-processing

ArcGIS (version 9.3) was used to develop a land use and pathogen spatial distribution map. Input GIS layers and data for ArcGIS were acquired from the Bureau of Geographic Information Systems, NJDEP's online website (http://www.state.nj.us/dep/gis/). These layers comprised watershed boundary, stream, and land use.

The stream layer and sampling station coordinates were pre-processed in a GIS to ensure that sites were positioned on the correct stream segment. There are many reasons why it is rare for GIS sampling points collected within a stream to fall directly on a line segment representing a point on the stream. Though points collected using global positioning systems are differentially corrected, some stretches of river (e.g., meanders) can move slightly from their mapped position while being overlaid with sampling stations. Streams are often represented by lines, so samples collected on the banks of a large river may not fall directly on a line segment. Digital streams' datasets may contain mapping errors and generalizations, such as the absence of small tributaries and the homogenization of form, which are found when streams are represented at coarser scales (Peterson et al., 2006). As a result of these data problems, 12 of 22 sites were discarded because the survey stream could not be identified.

The ArcSWAT model automatic delineation system was applied to divide the USRW into 26 sub-watersheds, ten of which had outlets located at sampling stations.

4.3.2. Field sampling program

Ten sampling stations were selected throughout the watershed to collect water quality and quantity (Figure 4-1). Of the ten sampling stations, six of them (S1, S2, S3, S8, S9, and S10) are located on the main stream and the other four (S5, S6, S4 and S7) are based in tributaries.

A single grab sample was collected bi-weekly at ten sampling points from June 2007 through June 2009. Surface water quality sample collection was collected and in situ measurements of pH, temperature, dissolved oxygen, stream depth, stream width, and stream velocity were recorded. Samples were analyzed for fecal coliform, *E. coli*, ammonia nitrogen, nitrate-nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved orthophosphate phosphorus, and total suspended solids by NJDEP Certified Laboratory # PA166, QC Laboratories. All samples were placed immediately into an ice cooler and transferred to the laboratory within 2-4 hours.

Daily flow data from USGS gauge 01482500 at the watershed outlet, S10, was used for flow calibration. For the other nine upstream sampling locations, velocities were measured bi-weekly at stream cross-sections using a Marsh-McBirney, Inc., Flo-Mate Model 2000 Flow-meter, and flow was calculated for each station during each event sampled per the protocol described in the flow-meter instruction manual (Marsh-McBirney, Inc., 1990).

The data collection program spanned 54 sampling events for 12 water parameters at each of the 10 sampling stations (Appendix C). In 11 of the 54 sampling events, a water sample was collected at each of the 10 stations for *Bacteroides* source tracking measurement. For the Bacteroides samples, a 100 mL grab sample of surface water was

filtered through a 0.45 µm membrane filter to collect the total biomass. The cells retained by the filters were then extracted directly from the filter with a DNeasy Tissue kit (Qiagen) using a modified DNeasy protocol. Then quantitative real-time PCR was carried out on the resulting DNA using the assay method described by Layton et al., (2006). The DNA was diluted to provide a standard concentration of template for each reaction and then amplified using TaqMan Universal PCR Master Mix (Applied Biosystem) on an ABI 7300 Real Time PCR System (Applied Biosystem). Each sample was analyzed for a BoBac primer set and compared to a standard curve for absolute quantitation. The standard was developed from the clone library of *Bacteroides* sequences amplified from bovine feces.

The detection limit for bovine *Bacteroides* was identified as 10^4 copies. The limit of detection is the minimum concentration or copy number of a control DNA target that routinely yields a PCR product.

4.4. Statistical method

Multiple linear regression (MLR) was used to develop a model between 10 water quality and quantity variables (x_1, $x_2,\ldots,x_{10}$) and Bovine *Bacteroides* as a response variable (y_1). In MLR, one approach to simplifying multiple regression equations is the stepwise procedures (Bailey et al., 1995). These include forward selection, backwards elimination, and stepwise regression. They add or remove variables one-at-a-time until some stopping rule is satisfied. In this research, backward elimination was used which started with all the predictors, 10 variables, in the model. The variable that is least significant, the one with the greatest p value, was removed and the model was refitted.

Each subsequent step removes the least significant variable in the model until all remaining variables had individual *p* values less than 0.05.

4.5. Results and discussion

The results of the applied MLR model between $\log_{10}$ transformed bovine *Bacteroides* and water parameters (flow, total phosphorus, total nitrogen, total suspended solids, fecal coliform, *E. coli*, temperature, dissolved oxygen and pH) are shown in Table 4-2. Water parameters of total suspended solids, *E. coli*, temperature, and pH were eliminated by using backward elimination approach.

Table 4-2. Summary of MLR model

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	6.342	0.436	14.537	8.46E-27	5.476	7.207
Q	0.070	0.024	2.839	0.00542	0.021	0.119
DO	-0.189	0.033	-5.591	1.83E-07	-0.257	-0.122
TN	0.157	0.032	4.921	3.23E-06	0.094	0.221
TP	2.502	0.814	3.073	0.002699	0.888	4.117
Log fecal	-0.303	0.114	-2.647	0.009362	-0.531	-0.076

Q = flow, DO = dissolved oxygen, TN = total nitrogen, TP = total phosphorus and log fecal = transformed $\log_{10}$ of fecal coliform

The model, based on n = 110, had an R^2 value of 0.48, and a standard error of 0.76. The final equation is [Eq. 4-1]:

$$\text{Log}_{10}\ \text{BoBac} = 6.3 + 0.07Q - 0.19DO + 2.5TP - 0.3\ \text{Log}_{10}\text{Fecal} + 0.16TN \quad \text{[Eq. 4-1]}$$

The above equation [Eq. 4-1] proposes that the concentration of bovine *Bacteroides* is a function of flow, dissolved oxygen, total phosphorus, total nitrogen and fecal coliform. The positive dependence of bovine *Bacteroides* concentration on flow expected due to wash off loading of bovine *Bacteroides* from overland to the stream during storm events and resultant increased stream flow. The positive dependence of bovine *Bacteroides* concentration on total phosphorus and total nitrogen concentrations is also expected since bovine manure contains both phosphorus and nitrogen nutrients, and any manure deposition to the stream would boost the concentrations of all three parameters. The negative dependence of bovine *Bacteroides* on fecal coliform is not clear but it could be due to differences in originating sources. Fecal coliform has several sources, e.g., human and wildlife, whereas the only bovine *Bacteroides* source is bovine. Therefore an increase in fecal coliform that has been originated from non-bovine sources will not be reflected in elevated bovine *Bacteroides.*

With applying this model to each sampling station in addition to the 11 measured data points, 43 modeled data were added to the data set. A plot of measured versus simulated concentration of bovine *Bacteroides* at S9 shows a good fit with R^2 of 0.75 (Figure 4-2 and 4-3). The obtained model set was used to evaluate if each sub-watershed was impacted by bovine *Bacteroides*. Table 3 shows a summary of bovine *Bacteroides* data at all 10 sampling stations. The detection limit of 10^4 copies is assumed to be the minimum limit for tracking bovine pathogens. Therefore if any sampling event had a *Bacteroides* concentration over the detection limit, it implies that bovine pathogens were derived from the subwatersheds associated with the sampling station.

Table 4-3. Summary of bovine *Bacteroides* data set at ten sampling stations

Sampling stations	Average simulated Log(BoBac)*	Standard deviation	Min-Max Log(BoBac)	Over detection limit %
S1	4.34	0.30	3.75 - 5.09	89
S2	4.35	0.48	3.37 - 5.23	80
S3	4.37	0.53	3.57 - 5.98	81
S4	4.14	0.40	3.42 - 5.05	41
S5	5.46	0.83	3.89-7.74	95
S6	3.92	0.28	3.25 - 4.68	51
S7	3.74	0.40	3.20 - 4.48	29
S8	5.61	0.86	4.28 -10.81	100
S9	6.11	1.43	5.00 - 15.04	100
S10	5.97	1.62	4.39 - 16.49	100

* logBoBac = Log_{10} bovine *Bacteroides*

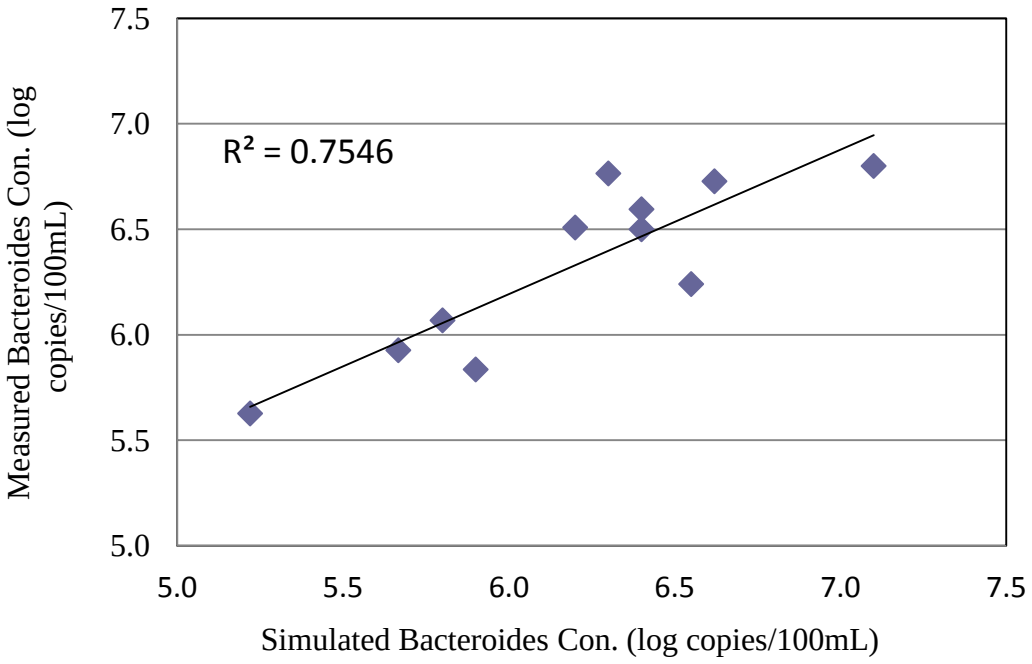

Figure 4-2. Measured versus simulated con. of bovine *Bacteroides* at S9 for 11 event

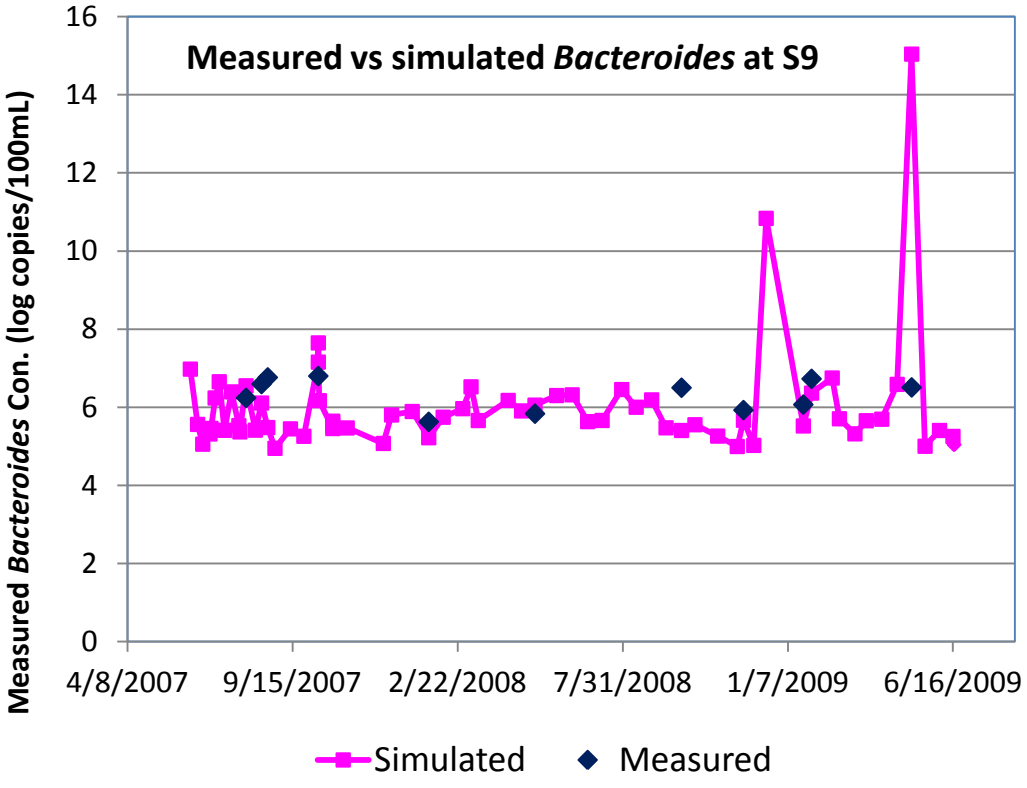

Figure 4-3. Measured versus simulated con. of bovine *Bacteroides* at S9 for 54 event

Based on the frequency of bovine-specific *Bacteroides* detected in water samples from each sampling station, a map of probability occurrence was developed (Figure 4-3). The greatest frequency of bovine *Bacteroides* detected was 100% of water quality samples in the downstream watershed sampling stations (S8, S9 and S10). This would indicate that bovine *Bacteroides* are transported by flow from upstream to downstream and accumulated behind Memorial Lake and East Lake adjacent to the sampling stations. The second greatest frequency of bovine *Bacteroides* detected in water samples was at stations S5 and S1 with 89 – 95%. Stations S5 and S1 are in the headwaters of the watershed, and are at the respective outlets of sub-basins 22 and 26. These sub-basins contain dairy farms and other animal feeding operations, therefore, a high detection frequency was expected at these two sampling stations. The third greatest frequency of bovine *Bacteroides* detection was at stations S2, S3 and S4 where manure applications in farm land and dairy farms located in the corresponding sub-basins are assumed to be the source of bovine *Bacteroides.* The fourth greatest frequency of bovine *Bacteroides* occurred at the sub-basin corresponding to station S6 where dairy farm activities and bovine *Bacteroides* transported from upstream would be the sources of bovine *Bacteroides.* The minimum frequency of bovine *Bacteroides* occurred at S7 with less than 29% detection in water samples, where only manure application and grazing activities are potential sources of bovine *Bacteroides.*

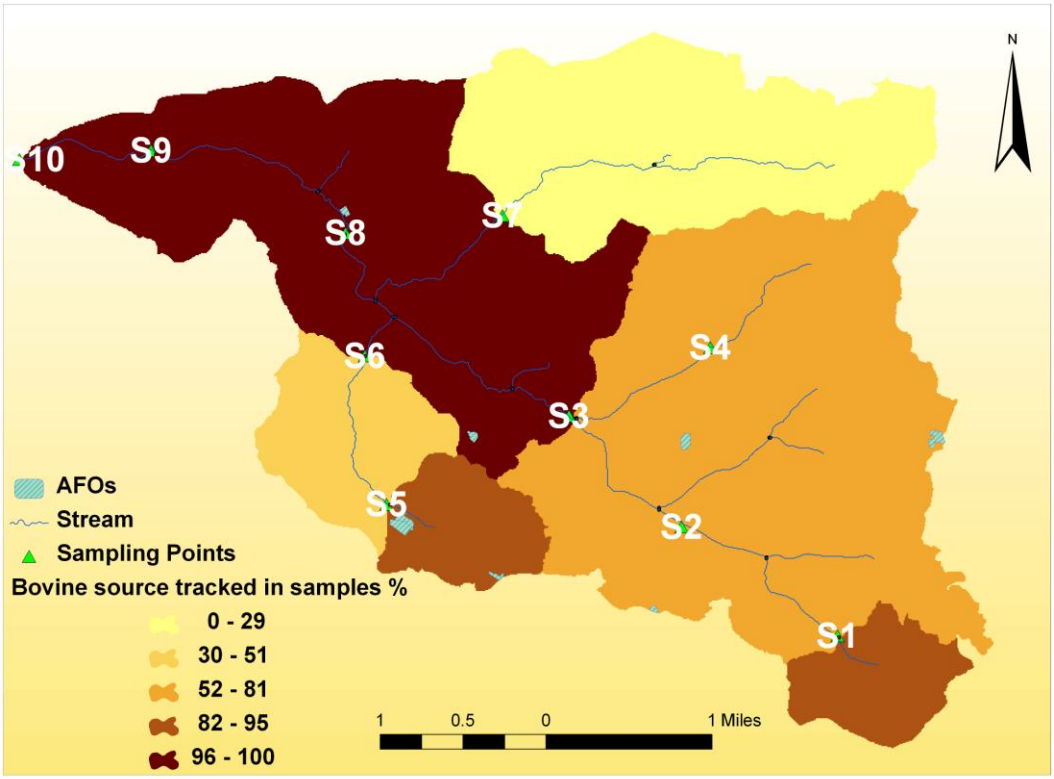

Figure 4-4. Probability occurrence of bovine *Bacteroides* in USRW

4.6. Conclusions

Bovine *Bacteroides* was predicted in the USRW using an MLR model. The result of the simulated model agrees with the potential bovine distribution source. Conducting human *Bacteroides* source tracking in the USRW will help to identify other potential pathogen sources. It also can verify the results attained from the current research.

Bovine *Bacteroides* was considered as an indicator for pathogen source tracking. Compared with other pathogen indicators, using *Bacteroides* has considerable advantages such as being less time consuming, host-specific, and culture-independent. More research needs to be conducted on 1) fate and transport processes of *Bacteroides* in land

surface, water, manure, sediment and soil, and 2) determining a standard threshold of *Bacteroides* correlated to the risk of illness in designated water uses (i.e., recreational use and drinking supply).

The bovine *Bacteroides* tracking method described here should be applied in similar watersheds to assess its applicability for wider use.

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5. Summary

This research implemented the recommendations outlined in the TMDL for the USRW. In this respect, fate and transport of conventional pathogen indicators (fecal coliform and *E. coli*) were simulated simultaneously for the first time using the SWAT model in order to use the model as an alternative for pathogen field monitoring. The conventional indicators were not capable of source tracking, therefore bovine *Bacteroides* was used as a pathogen indicator to identify sources of bovine *Bacteroides* throughout the watershed. To gain more knowledge on bovine *Bacteroides*, a laboratory test was conducted to identify Bovine *Bacteroides* persistence while exposed to different temperatures.

Fate and transport of fecal coliform and *E. coli*, two commonly used pathogen indicators, were simulated through application of the SWAT model at six sampling stations. The two indicators were successfully simulated at five of six sampling stations.

Bovine *Bacteroides* was used as a pathogen source tracking indicator in the Upper Salem River Watershed. This indicator helped to investigate if bovine feces are a contributing pathogen source to the river system and to identify the spatial distribution of bovine pathogen discharge to the USRW.

With respect to using *Bacteroides* as a pathogen tracking tool, it was found that this indicator was a very useful tool to pinpoint bovine driven pathogen sources. Therefore, the combination of using the two groups of pathogen indicators, conventional and *Bacteroides*, can be a very helpful approach to address the TMDL recommendations for the pathogen impaired USRW.

With regard to the SWAT model performance at sampling station S8, the unsatisfactory Nash-Sutcliffe efficiency value could be due to pathogen sources that were not incorporated in the model. Another possibility is the routing of pathogens through the soil profile and through the rapid pathways to groundwater and shallow aquifer which must be inserted to achieve better results, both in peak and low flows.

In the SWAT model, calibration and validation of the flow model is aided by a built-in automated sensitivity analysis technique, which facilitates optimal selection of parameter values. However, the water quality model does not have the same automated feature for sensitivity analysis, therefore a graphical method was applied which might not lead to the absolute best water quality model parameter set.

Most of all, it is apparent that the SWAT model predictions could be improved with more reliable watershed input information. Accurate data input with respect to spatial distribution of onsite dairy activities, manure application (exact location, loading, timing and frequency), failing on-site septic tanks, direct pathogen deposition to streams by livestock, wildlife distribution and population in the watershed, and grazing patterns for existing livestock would enhance model predication performance.

The pathogen model calibration and validation periods were one year each in this study, so as to enhance model reliability which increases with length of calibration and validation periods. With a longer calibration and validation period, the probability of having wet and dry seasons are higher therefore the model would be more suitable for any flow conditions.

The persistence of the bovine-*Bacteroides* 16S rRNA gene was exposed to different temperatures. The result of this experiment is useful for two purposes: a)

identifying the holding time threshold for grab samples which functions as the maximum period that samples can be kept before the start of filtering this period is important because *Bacteroides* will die off if the holding time exceeds the threshold; b) identifying the decay rate for incorporation in fate and transport equations of *Bacteroides* simulation at the watershed scale.

MLR was used to estimate probability occurrence of bovine *Bacteroides* in USRW. The final equation showed that the concentration of bovine *Bacteroides* is a function of flow, dissolved oxygen, total phosphorus, total nitrogen and fecal coliform. The greatest frequency of bovine *Bacteroides* detected was 100% of water quality samples in the downstream watershed sampling stations (S8, S9 and S10). This would indicate that bovine *Bacteroides* are transported by flow from upstream to downstream and accumulated behind Memorial Lake and East Lake adjacent to the sampling stations

6. Future research

One avenue for future research could be to quantify each of the factors influencing pathogen decay rate. There are nine factors (sunlight, temperature, salinity, predation, nutrient deficiencies, toxic substances, re-suspension of particulates with associated sorbed organisms, organism reproduction in water) influencing pathogen die-off. Of the nine factors only temperature has been used separately in watershed scale modeling, therefore, this is a highly prioritized area to investigate further to reduce amount of uncertainty.

Another direction for future research would be to conduct comprehensive research on pathogen source tracking indicators to determine which method is the most reliable to identify sources at the watershed scale, whether livestock, human or wildlife. Furthermore, quantification of pathogen source tracking can also calculate the relative contribution of each pathogen. Finally, a risk assessment of pathogen source tracking indicators could identify a suitable water quality standard for each indicator.

Finally, the SWAT pathogen model could be improved in: a) coupling groundwater to the surface water for water quality; b) incorporating surface run-off fate and transport equations for pathogens in SWAT model; c) inserting re-suspension and settling equations in the SWAT model and linking them to pathogen related equations in the water column.

APPENDIX A: HRU Reports in the SWAT Model

Upper Salem River Watershed HRU Reports Obtained from the SWAT Model						
Entire Watershed			Area[ha]	Area[acres]		
			3624.73	8956.90		
			Area[ha]	Area[acres]	%Wat.Area	
LANDUSE:						
	Wetlands-Mixed	WETL	373.80	923.67	10.31	
	Water	WATR	52.24	129.10	1.44	
	Residential-Low	URLD	350.98	867.30	9.68	
	Forest-Mixed	FRST	466.27	1152.18	12.86	
	Pasture	PAST	2293.91	5668.36	63.28	
	Corn	CORN	53.47	132.13	1.48	
	Agricultural	AGRC	3.52	8.69	0.1	
	Orchard	ORCD	30.55	75.48	0.84	
SOILS:						
	NJ025		1894.41	4681.19	52.26	
	NJ029		492.02	1215.80	13.57	
	NJ039		494.82	1222.72	13.65	
	NJ026		743.49	1837.20	20.51	
SLOPE:						
	1-3		1075.35	2657.26	29.67	
	0-1		2486.79	6144.98	68.61	
	3-5		53.92	133.24	1.49	
	>5		8.67	21.42	0.24	
	Area		Area[ha]	Area[acres]	%Wat.Area	%Sub.Area

SUBBASIN	#	1	135.23	334.16	3.73	
LANDUSE:						
	Wetlands-Mixed	WETL	14.93	36.89	0.41	11.04
	Water	WATR	10.12	25.00	0.28	7.48
	Residential-Low	URLD	33.07	81.71	0.91	24.45
	Forest-Mixed	FRST	14.55	35.96	0.4	10.76
	Pasture	PAST	62.57	154.61	1.73	46.27
SOILS:						
	NJ025		70.90	175.20	1.96	52.43
	NJ029		64.33	158.97	1.77	47.57
SLOPE:						
	1-3		23.08	57.02	0.64	17.06
	0-1		109.17	269.78	3.01	80.73
	3-5		2.98	7.37	0.08	2.2
HRUs						
1	Wetlands-Mixed	WETL/NJ025/1-3	0.19	0.48	0.01	0.14
2	Wetlands-Mixed	WETL/NJ025/0-1	5.46	13.48	0.15	4.03
3	Wetlands-Mixed	WETL/NJ029/0-1	7.45	18.41	0.21	5.51
4	Wetlands-Mixed	WETL/NJ029/1-3	1.83	4.52	0.05	1.35
5	Water	WATR/NJ029/0-1	8.03	19.83	0.22	5.93
6	Water	WATR/NJ029/3-5	0.36	0.88	0.01	0.26
7	Water	WATR/NJ029/1-3	1.73	4.28	0.05	1.28
8	Residential-Low	URLD/NJ025/0-1	7.24	17.89	0.2	5.35
9	Residential-Low	URLD/NJ025/1-3	0.53	1.31	0.01	0.39
10	Residential-Low	URLD/NJ029/0-1	19.51	48.20	0.54	14.43
11	Residential-Low	URLD/NJ029/1-3	5.79	14.31	0.16	4.28
12	Forest-Mixed	FRST/NJ025/0-1	4.96	12.26	0.14	3.67

13	Forest-Mixed	FRST/NJ025/1-3	5.57	13.75	0.15	4.12
14	Forest-Mixed	FRST/NJ025/3-5	1.34	3.31	0.04	0.99
15	Forest-Mixed	FRST/NJ029/0-1	1.16	2.87	0.03	0.86
16	Forest-Mixed	FRST/NJ029/1-3	1.28	3.17	0.04	0.95
17	Forest-Mixed	FRST/NJ029/3-5	0.23	0.58	0.01	0.17
18	Pasture	PAST/NJ025/0-1	41.61	102.83	1.15	30.77
19	Pasture	PAST/NJ025/1-3	4.00	9.88	0.11	2.96
20	Pasture	PAST/NJ029/1-3	2.15	5.31	0.06	1.59
21	Pasture	PAST/NJ029/3-5	1.05	2.59	0.03	0.78
22	Pasture	PAST/NJ029/0-1	13.76	34.00	0.38	10.17
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	2	82.20	203.11	2.27	
LANDUSE:						
	Wetlands-Mixed	WETL	9.77	24.15	0.27	11.89
	Forest-Mixed	FRST	15.09	37.29	0.42	18.36
	Pasture	PAST	57.33	141.67	1.58	69.75
SOILS:						
	NJ039		82.20	203.11	2.27	100
SLOPE:						
	0-1		71.51	176.71	1.97	87
	1-3		10.68	26.40	0.29	13
HRUs						
23	Wetlands-Mixed	WETL/NJ039/0-1	8.13	20.09	0.22	9.89
24	Wetlands-Mixed	WETL/NJ039/1-3	1.64	4.06	0.05	2

25	Forest-Mixed	FRST/NJ039/0-1	13.11	32.40	0.36	15.95
26	Forest-Mixed	FRST/NJ039/1-3	1.98	4.89	0.05	2.41
27	Pasture	PAST/NJ039/1-3	7.06	17.45	0.19	8.59
28	Pasture	PAST/NJ039/0-1	50.27	124.22	1.39	61.16
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	3	264.94	654.68	7.31	
LANDUSE:						
	Wetlands-Mixed	WETL	30.32	74.92	0.84	11.44
	Residential-Low	URLD	8.20	20.27	0.23	3.1
	Forest-Mixed	FRST	49.97	123.47	1.38	18.86
	Pasture	PAST	168.39	416.10	4.65	63.56
	Corn	CORN	8.06	19.92	0.22	3.04
SOILS:						
	NJ025		64.17	158.57	1.77	24.22
	NJ039		200.77	496.11	5.54	75.78
SLOPE:						
	0-1		223.62	552.58	6.17	84.4
	1-3		40.93	101.13	1.13	15.45
	3-5		0.39	0.97	0.01	0.15
HRUs						
29	Wetlands-Mixed	WETL/NJ025/0-1	3.68	9.09	0.1	1.39
30	Wetlands-Mixed	WETL/NJ025/1-3	0.31	0.77	0.01	0.12
31	Wetlands-Mixed	WETL/NJ039/1-3	4.34	10.73	0.12	1.64
32	Wetlands-Mixed	WETL/NJ039/0-1	21.98	54.32	0.61	8.3

33	Residential-Low	URLD/NJ039/0-1	6.55	16.20	0.18	2.47
34	Residential-Low	URLD/NJ039/1-3	1.65	4.07	0.05	0.62
35	Forest-Mixed	FRST/NJ025/0-1	1.95	4.82	0.05	0.74
36	Forest-Mixed	FRST/NJ039/1-3	14.63	36.16	0.4	5.52
37	Forest-Mixed	FRST/NJ039/0-1	33.39	82.50	0.92	12.6
38	Pasture	PAST/NJ025/0-1	48.16	119.02	1.33	18.18
39	Pasture	PAST/NJ025/1-3	4.72	11.67	0.13	1.78
40	Pasture	PAST/NJ039/0-1	101.12	249.88	2.79	38.17
41	Pasture	PAST/NJ039/1-3	14.38	35.53	0.4	5.43
42	Corn	CORN/NJ025/0-1	4.06	10.04	0.11	1.53
43	Corn	CORN/NJ025/1-3	0.89	2.19	0.02	0.33
44	Corn	CORN/NJ025/3-5	0.39	0.97	0.01	0.15
45	Corn	CORN/NJ039/0-1	2.72	6.72	0.07	1.03
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	4	208.64	515.56	5.76	
LANDUSE:						
	Wetlands-Mixed	WETL	14.46	35.73	0.4	6.93
	Water	WATR	8.95	22.13	0.25	4.29
	Residential-Low	URLD	33.40	82.54	0.92	16.01
	Forest-Mixed	FRST	62.13	153.52	1.71	29.78
	Pasture	PAST	89.70	221.65	2.47	42.99
SOILS:						
	NJ025		21.41	52.91	0.59	10.26
	NJ029		180.58	446.22	4.98	86.55
	NJ026		6.65	16.44	0.18	3.19

SLOPE:						
	0-1		121.24	299.58	3.34	58.11
	1-3		71.56	176.83	1.97	34.3
	>5		3.06	7.55	0.08	1.47
	3-5		12.79	31.59	0.35	6.13
HRUs						
46	Wetlands-Mixed	WETL/NJ025/0-1	2.06	5.08	0.06	0.98
47	Wetlands-Mixed	WETL/NJ025/1-3	0.48	1.19	0.01	0.23
48	Wetlands-Mixed	ETL/NJ029/5-999	0.54	1.34	0.01	0.26
49	Wetlands-Mixed	WETL/NJ029/3-5	0.57	1.42	0.02	0.27
50	Wetlands-Mixed	WETL/NJ029/1-3	4.45	11.00	0.12	2.13
51	Wetlands-Mixed	WETL/NJ029/0-1	6.36	15.70	0.18	3.05
52	Water	WATR/NJ029/3-5	0.70	1.72	0.02	0.33
53	Water	WATR/NJ029/1-3	2.23	5.50	0.06	1.07
54	Water	WATR/NJ029/0-1	6.03	14.90	0.17	2.89
55	Residential-Low	URLD/NJ025/0-1	0.26	0.64	0.01	0.12
56	Residential-Low	URLD/NJ025/1-3	0.53	1.31	0.01	0.25
57	Residential-Low	URLD/NJ025/3-5	0.21	0.51	0.01	0.1
58	Residential-Low	URLD/NJ029/1-3	2.08	5.15	0.06	1
59	Residential-Low	URLD/NJ029/0-1	30.32	74.93	0.84	14.53
60	Forest-Mixed	FRST/NJ025/3-5	0.47	1.17	0.01	0.23
61	Forest-Mixed	FRST/NJ025/1-3	1.74	4.31	0.05	0.84
62	Forest-Mixed	FRST/NJ025/0-1	0.29	0.71	0.01	0.14
63	Forest-Mixed	RST/NJ025/5-999	0.28	0.68	0.01	0.13
64	Forest-Mixed	RST/NJ029/5-999	2.24	5.53	0.06	1.07
65	Forest-Mixed	FRST/NJ029/3-5	9.39	23.20	0.26	4.5
66	Forest-Mixed	FRST/NJ029/0-1	11.56	28.55	0.32	5.54
67	Forest-Mixed	FRST/NJ029/1-3	36.16	89.36	1	17.33
68	Pasture	PAST/NJ025/1-3	6.14	15.18	0.17	2.95

69	Pasture	PAST/NJ025/0-1	8.36	20.67	0.23	4.01
70	Pasture	PAST/NJ025/3-5	0.59	1.45	0.02	0.28
71	Pasture	PAST/NJ026/0-1	3.25	8.04	0.09	1.56
72	Pasture	PAST/NJ026/1-3	2.54	6.27	0.07	1.22
73	Pasture	PAST/NJ026/3-5	0.86	2.12	0.02	0.41
74	Pasture	PAST/NJ029/0-1	52.75	130.36	1.46	25.28
75	Pasture	PAST/NJ029/1-3	15.20	37.55	0.42	7.28
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	5	118.09	291.81	3.26	
LANDUSE:						
	Wetlands-Mixed	WETL	9.03	22.31	0.25	7.64
	Residential-Low	URLD	19.62	48.49	0.54	16.62
	Forest-Mixed	FRST	11.88	29.35	0.33	10.06
	Pasture	PAST	77.56	191.66	2.14	65.68
SOILS:						
	NJ026		97.99	242.13	2.7	82.98
	NJ029		19.04	47.04	0.53	16.12
	NJ039		1.07	2.64	0.03	0.9
SLOPE:						
	1-3		48.28	119.30	1.33	40.88
	0-1		67.80	167.53	1.87	57.41
	3-5		1.83	4.52	0.05	1.55
	>5		0.18	0.45	0.01	0.16
HRUs						

76	Wetlands-Mixed	WETL/NJ026/1-3	2.62	6.47	0.07	2.22
77	Wetlands-Mixed	WETL/NJ026/0-1	4.65	11.49	0.13	3.94
78	Wetlands-Mixed	WETL/NJ029/3-5	0.25	0.63	0.01	0.22
79	Wetlands-Mixed	WETL/NJ029/0-1	0.52	1.28	0.01	0.44
80	Wetlands-Mixed	WETL/NJ029/1-3	0.99	2.44	0.03	0.84
81	Residential-Low	URLD/NJ026/3-5	0.44	1.08	0.01	0.37
82	Residential-Low	URLD/NJ026/1-3	10.72	26.48	0.3	9.08
83	Residential-Low	URLD/NJ026/0-1	2.82	6.97	0.08	2.39
84	Residential-Low	URLD/NJ029/3-5	0.37	0.91	0.01	0.31
85	Residential-Low	RLD/NJ029/5-999	0.18	0.45	0.01	0.16
86	Residential-Low	URLD/NJ029/0-1	3.51	8.68	0.1	2.97
87	Residential-Low	URLD/NJ029/1-3	0.52	1.28	0.01	0.44
88	Residential-Low	URLD/NJ039/0-1	1.07	2.64	0.03	0.9
89	Forest-Mixed	FRST/NJ026/3-5	0.77	1.91	0.02	0.65
90	Forest-Mixed	FRST/NJ026/0-1	3.05	7.54	0.08	2.59
91	Forest-Mixed	FRST/NJ026/1-3	8.05	19.90	0.22	6.82
92	Pasture	PAST/NJ026/1-3	24.26	59.94	0.67	20.54
93	Pasture	PAST/NJ026/0-1	40.61	100.35	1.12	34.39
94	Pasture	PAST/NJ029/1-3	1.13	2.78	0.03	0.95
95	Pasture	PAST/NJ029/0-1	11.57	28.59	0.32	9.8
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	6	327.62	809.57	9.04	
LANDUSE:						
	Wetlands-Mixed	WETL	28.92	71.45	0.8	8.83
	Residential-Low	URLD	10.34	25.56	0.29	3.16
	Forest-Mixed	FRST	35.06	86.63	0.97	10.7

	Pasture	PAST	253.30	625.93	6.99	77.32
SOILS:						
	NJ025		61.26	151.37	1.69	18.7
	NJ026		55.58	137.35	1.53	16.97
	NJ039		210.78	520.86	5.82	64.34
SLOPE:						
	1-3		142.59	352.34	3.93	43.52
	0-1		183.63	453.77	5.07	56.05
	3-5		1.40	3.47	0.04	0.43
HRUs						
96	Wetlands-Mixed	WETL/NJ025/1-3	1.08	2.67	0.03	0.33
97	Wetlands-Mixed	WETL/NJ025/0-1	1.83	4.53	0.05	0.56
98	Wetlands-Mixed	WETL/NJ026/1-3	2.30	5.68	0.06	0.7
99	Wetlands-Mixed	WETL/NJ026/0-1	2.66	6.57	0.07	0.81
100	Wetlands-Mixed	WETL/NJ039/1-3	6.73	16.64	0.19	2.06
101	Wetlands-Mixed	WETL/NJ039/0-1	14.31	35.37	0.39	4.37
102	Residential-Low	URLD/NJ025/1-3	0.87	2.15	0.02	0.27
103	Residential-Low	URLD/NJ025/0-1	0.18	0.45	0.01	0.06
104	Residential-Low	URLD/NJ026/1-3	3.48	8.59	0.1	1.06
105	Residential-Low	URLD/NJ026/0-1	2.58	6.36	0.07	0.79
106	Residential-Low	URLD/NJ039/1-3	0.47	1.16	0.01	0.14
107	Residential-Low	URLD/NJ039/0-1	2.77	6.84	0.08	0.85
108	Forest-Mixed	FRST/NJ025/1-3	5.21	12.87	0.14	1.59
109	Forest-Mixed	FRST/NJ025/0-1	5.12	12.64	0.14	1.56
110	Forest-Mixed	FRST/NJ026/0-1	0.64	1.58	0.02	0.2
111	Forest-Mixed	FRST/NJ026/1-3	4.64	11.47	0.13	1.42
112	Forest-Mixed	FRST/NJ039/3-5	1.40	3.47	0.04	0.43
113	Forest-Mixed	FRST/NJ039/0-1	7.40	18.28	0.2	2.26

114	Forest-Mixed	FRST/NJ039/1-3	10.65	26.31	0.29	3.25
115	Pasture	PAST/NJ025/1-3	29.87	73.81	0.82	9.12
116	Pasture	PAST/NJ025/0-1	17.10	42.24	0.47	5.22
117	Pasture	PAST/NJ026/1-3	14.53	35.90	0.4	4.43
118	Pasture	PAST/NJ026/0-1	24.76	61.19	0.68	7.56
119	Pasture	PAST/NJ039/1-3	62.76	155.08	1.73	19.16
120	Pasture	PAST/NJ039/0-1	104.29	257.70	2.88	31.83
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	7	100.90	249.33	2.78	
LANDUSE:						
	Wetlands-Mixed	WETL	7.42	18.33	0.2	7.35
	Residential-Low	URLD	7.61	18.81	0.21	7.54
	Forest-Mixed	FRST	4.82	11.92	0.13	4.78
	Pasture	PAST	67.73	167.37	1.87	67.13
	Corn	CORN	13.32	32.91	0.37	13.2
SOILS:						
	NJ026		19.04	47.04	0.53	18.87
	NJ029		78.86	194.87	2.18	78.16
	NJ025		3.00	7.42	0.08	2.97
SLOPE:						
	1-3		41.31	102.08	1.14	40.94
	0-1		54.83	135.50	1.51	54.35
	3-5		4.75	11.74	0.13	4.71
HRUs						

121	Wetlands-Mixed	WETL/NJ026/1-3	0.16	0.40	0	0.16
122	Wetlands-Mixed	WETL/NJ026/0-1	0.03	0.08	0	0.03
123	Wetlands-Mixed	WETL/NJ029/1-3	2.54	6.29	0.07	2.52
124	Wetlands-Mixed	WETL/NJ029/3-5	0.22	0.55	0.01	0.22
125	Wetlands-Mixed	WETL/NJ029/0-1	4.46	11.01	0.12	4.42
126	Residential-Low	URLD/NJ026/1-3	3.76	9.28	0.1	3.72
127	Residential-Low	URLD/NJ026/0-1	0.82	2.03	0.02	0.81
128	Residential-Low	URLD/NJ029/3-5	0.09	0.23	0	0.09
129	Residential-Low	URLD/NJ029/1-3	1.03	2.54	0.03	1.02
130	Residential-Low	URLD/NJ029/0-1	1.91	4.73	0.05	1.9
131	Forest-Mixed	FRST/NJ026/1-3	1.77	4.38	0.05	1.76
132	Forest-Mixed	FRST/NJ026/3-5	0.53	1.30	0.01	0.52
133	Forest-Mixed	FRST/NJ029/1-3	1.08	2.67	0.03	1.07
134	Forest-Mixed	FRST/NJ029/0-1	1.44	3.57	0.04	1.43
135	Pasture	PAST/NJ025/0-1	1.87	4.63	0.05	1.86
136	Pasture	PAST/NJ025/3-5	0.14	0.35	0	0.14
137	Pasture	PAST/NJ025/1-3	0.99	2.44	0.03	0.98
138	Pasture	PAST/NJ026/1-3	1.86	4.60	0.05	1.85
139	Pasture	PAST/NJ026/0-1	1.84	4.55	0.05	1.83
140	Pasture	PAST/NJ029/0-1	37.53	92.73	1.04	37.19
141	Pasture	PAST/NJ029/1-3	20.63	50.98	0.57	20.45
142	Pasture	PAST/NJ029/3-5	2.87	7.09	0.08	2.84
143	Corn	CORN/NJ026/3-5	0.57	1.41	0.02	0.57
144	Corn	CORN/NJ026/1-3	6.22	15.37	0.17	6.17
145	Corn	CORN/NJ026/0-1	1.47	3.63	0.04	1.46
146	Corn	CORN/NJ029/1-3	1.27	3.14	0.04	1.26
147	Corn	CORN/NJ029/3-5	0.33	0.81	0.01	0.32
148	Corn	CORN/NJ029/0-1	3.46	8.55	0.1	3.43

			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#		8.00	65.98	163.0519	1.82
LANDUSE:						
	Wetlands-Mixed	WETL	7.42	18.32	0.2	11.24
	Water	WATR	1.47	3.63	0.04	2.23
	Residential-Low	URLD	10.63	26.26	0.29	16.11
	Forest-Mixed	FRST	12.95	32.00	0.36	19.62
	Pasture	PAST	30.59	75.59	0.84	46.36
	Corn	CORN	2.93	7.25	0.08	4.44
SOILS:						
	NJ029		56.95	140.72	1.57	86.31
	NJ025		9.04	22.33	0.25	13.69
SLOPE:						
	0-1		24.47	60.46	0.67	37.08
	1-3		35.66	88.13	0.98	54.05
	3-5		4.99	12.34	0.14	7.57
	>5		0.86	2.13	0.02	1.3
HRUs						
149	Wetlands-Mixed	WETL/NJ029/0-1	5.82	14.37	0.16	8.81
150	Wetlands-Mixed	WETL/NJ029/1-3	1.60	3.95	0.04	2.42
151	Water	WATR/NJ029/3-5	0.14	0.35	0	0.21
152	Water	WATR/NJ029/1-3	0.52	1.29	0.01	0.79
153	Water	WATR/NJ029/0-1	0.81	2.00	0.02	1.23
154	Residential-Low	URLD/NJ029/3-5	0.64	1.58	0.02	0.97
155	Residential-Low	URLD/NJ029/1-3	7.30	18.03	0.2	11.06
156	Residential-Low	URLD/NJ029/0-1	2.69	6.65	0.07	4.08

157	Forest-Mixed	RST/NJ029/5-999	0.86	2.13	0.02	1.3
158	Forest-Mixed	FRST/NJ029/0-1	0.39	0.96	0.01	0.59
159	Forest-Mixed	FRST/NJ029/1-3	8.42	20.80	0.23	12.75
160	Forest-Mixed	FRST/NJ029/3-5	3.28	8.11	0.09	4.97
161	Pasture	PAST/NJ025/0-1	4.74	11.72	0.13	7.19
162	Pasture	PAST/NJ025/1-3	4.06	10.04	0.11	6.16
163	Pasture	PAST/NJ029/0-1	8.42	20.80	0.23	12.75
164	Pasture	PAST/NJ029/1-3	12.69	31.35	0.35	19.23
165	Pasture	PAST/NJ029/3-5	0.68	1.68	0.02	1.03
166	Corn	CORN/NJ025/0-1	0.23	0.57	0.01	0.35
167	Corn	CORN/NJ029/1-3	1.08	2.67	0.03	1.63
168	Corn	CORN/NJ029/0-1	1.37	3.39	0.04	2.08
169	Corn	CORN/NJ029/3-5	0.25	0.62	0.01	0.38
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	9	130.32	322.02	3.6	
LANDUSE:						
	Wetlands-Mixed	WETL	15.00	37.06	0.41	11.51
	Residential-Low	URLD	3.72	9.20	0.1	2.86
	Pasture	PAST	108.44	267.96	2.99	83.21
	Corn	CORN	3.16	7.80	0.09	2.42
SOILS:						
	NJ026		100.52	248.40	2.77	77.14
	NJ029		29.70	73.40	0.82	22.79
	NJ025		0.09	0.23	0	0.07

SLOPE:						
	1-3		61.30	151.47	1.69	47.04
	0-1		66.80	165.07	1.84	51.26
	>5		1.05	2.59	0.03	0.8
	3-5		1.17	2.90	0.03	0.9
HRUs						
170	Wetlands-Mixed	WETL/NJ026/1-3	3.94	9.73	0.11	3.02
171	Wetlands-Mixed	WETL/NJ026/0-1	6.31	15.59	0.17	4.84
172	Wetlands-Mixed	WETL/NJ029/0-1	2.81	6.95	0.08	2.16
173	Wetlands-Mixed	WETL/NJ029/1-3	1.94	4.79	0.05	1.49
174	Residential-Low	URLD/NJ026/0-1	0.87	2.16	0.02	0.67
175	Residential-Low	URLD/NJ026/1-3	1.10	2.72	0.03	0.84
176	Residential-Low	URLD/NJ029/1-3	0.75	1.86	0.02	0.58
177	Residential-Low	URLD/NJ029/0-1	1.00	2.46	0.03	0.76
178	Pasture	PAST/NJ026/1-3	43.28	106.94	1.19	33.21
179	Pasture	PAST/NJ026/0-1	42.81	105.80	1.18	32.85
180	Pasture	AST/NJ029/5-999	1.05	2.59	0.03	0.8
181	Pasture	PAST/NJ029/0-1	11.17	27.61	0.31	8.57
182	Pasture	PAST/NJ029/3-5	1.17	2.90	0.03	0.9
183	Pasture	PAST/NJ029/1-3	8.96	22.13	0.25	6.87
184	Corn	CORN/NJ025/0-1	0.09	0.23	0	0.07
185	Corn	CORN/NJ026/1-3	1.18	2.93	0.03	0.91
186	Corn	CORN/NJ026/0-1	1.03	2.54	0.03	0.79
187	Corn	CORN/NJ029/1-3	0.15	0.38	0	0.12
188	Corn	CORN/NJ029/0-1	0.70	1.73	0.02	0.54
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	10	5.59	13.82	0.15	

LANDUSE:						
	Water	WATR	3.14	7.76	0.09	56.17
	Residential-Low	URLD	0.68	1.68	0.02	12.16
	Forest-Mixed	FRST	0.20	0.49	0.01	3.58
	Pasture	PAST	1.57	3.88	0.04	28.09
SOILS:						
	NJ029		5.59	13.82	0.15	100
SLOPE:						
	0-1		2.68	6.62	0.07	47.89
	3-5		0.95	2.35	0.03	17.01
	>5		0.32	0.79	0.01	5.72
	1-3		1.64	4.06	0.05	29.37
HRUs						
189	Water	WATR/NJ029/0-1	2.37	5.86	0.07	42.4
190	Water	WATR/NJ029/3-5	0.32	0.79	0.01	5.72
191	Water	ATR/NJ029/5-99	0.11	0.27	0	1.97
192	Water	WATR/NJ029/1-3	0.34	0.84	0.01	6.08
193	Residential-Low	RLD/NJ029/5-99	0.08	0.20	0	1.43
194	Residential-Low	URLD/NJ029/0-1	0.03	0.07	0	0.54
195	Residential-Low	URLD/NJ029/1-3	0.43	1.06	0.01	7.69
196	Residential-Low	URLD/NJ029/3-5	0.14	0.35	0	2.5
197	Forest-Mixed	RST/NJ029/5-999	0.13	0.32	0	2.33
198	Forest-Mixed	FRST/NJ029/1-3	0.01	0.02	0	0.18
199	Forest-Mixed	FRST/NJ029/3-5	0.06	0.15	0	1.07
200	Pasture	PAST/NJ029/3-5	0.43	1.07	0.01	7.71
201	Pasture	PAST/NJ029/0-1	0.28	0.69	0.01	4.96
202	Pasture	PAST/NJ029/1-3	0.86	2.13	0.02	15.42

			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	11	271.65	671.27	7.49	
LANDUSE:						
	Wetlands-Mixed	WETL	24.43	60.36	0.67	8.99
	Residential-Low	URLD	18.95	46.84	0.52	6.98
	Forest-Mixed	FRST	42.56	105.17	1.17	15.67
	Pasture	PAST	178.87	442.01	4.93	65.85
	Corn	CORN	6.84	16.90	0.19	2.52
SOILS:						
	NJ025		271.65	671.27	7.49	100
SLOPE:						
	0-1		225.76	557.86	6.23	83.1
	1-3		45.90	113.41	1.27	16.9
HRUs						
203	Wetlands-Mixed	WETL/NJ025/0-1	17.05	42.14	0.47	6.28
204	Wetlands-Mixed	WETL/NJ025/1-3	7.37	18.22	0.2	2.71
205	Residential-Low	URLD/NJ025/0-1	16.25	40.16	0.45	5.98
206	Residential-Low	URLD/NJ025/1-3	2.70	6.68	0.07	1
207	Forest-Mixed	FRST/NJ025/0-1	27.89	68.91	0.77	10.27
208	Forest-Mixed	FRST/NJ025/1-3	14.68	36.26	0.4	5.4
209	Pasture	PAST/NJ025/1-3	20.41	50.42	0.56	7.51
210	Pasture	PAST/NJ025/0-1	158.47	391.59	4.37	58.33
211	Corn	CORN/NJ025/1-3	0.74	1.82	0.02	0.27
212	Corn	CORN/NJ025/0-1	6.10	15.07	0.17	2.25

			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	12	24.84	61.37	0.69	
LANDUSE:						
	Wetlands-Mixed	WETL	1.65	4.07	0.05	6.63
	Residential-Low	URLD	6.63	16.37	0.18	26.68
	Forest-Mixed	FRST	4.53	11.21	0.13	18.26
	Pasture	PAST	12.03	29.73	0.33	48.44
SOILS:						
	NJ029		17.52	43.29	0.48	70.53
	NJ025		7.32	18.09	0.2	29.47
SLOPE:						
	0-1		5.39	13.32	0.15	21.7
	1-3		18.08	44.67	0.5	72.79
	3-5		1.02	2.51	0.03	4.1
	>5		0.35	0.87	0.01	1.42
HRUs						
213	Wetlands-Mixed	WETL/NJ029/0-1	0.82	2.03	0.02	3.31
214	Wetlands-Mixed	WETL/NJ029/1-3	0.69	1.69	0.02	2.76
215	Wetlands-Mixed	WETL/NJ029/3-5	0.14	0.34	0	0.55
216	Residential-Low	URLD/NJ025/0-1	0.47	1.16	0.01	1.89
217	Residential-Low	URLD/NJ025/1-3	3.01	7.43	0.08	12.11
218	Residential-Low	URLD/NJ029/3-5	0.12	0.31	0	0.5
219	Residential-Low	URLD/NJ029/0-1	0.95	2.35	0.03	3.83
220	Residential-Low	URLD/NJ029/1-3	2.07	5.12	0.06	8.34

221	Forest-Mixed	FRST/NJ025/1-3	0.41	1.02	0.01	1.67
222	Forest-Mixed	FRST/NJ025/0-1	0.13	0.33	0	0.54
223	Forest-Mixed	FRST/NJ029/1-3	2.45	6.06	0.07	9.88
224	Forest-Mixed	FRST/NJ029/0-1	0.85	2.10	0.02	3.42
225	Forest-Mixed	FRST/NJ029/3-5	0.33	0.82	0.01	1.33
226	Forest-Mixed	RST/NJ029/5-999	0.35	0.87	0.01	1.42
227	Pasture	PAST/NJ025/1-3	2.64	6.53	0.07	10.65
228	Pasture	PAST/NJ025/0-1	0.65	1.60	0.02	2.61
229	Pasture	PAST/NJ029/0-1	1.51	3.74	0.04	6.09
230	Pasture	PAST/NJ029/1-3	6.80	16.81	0.19	27.39
231	Pasture	PAST/NJ029/3-5	0.42	1.05	0.01	1.71
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	13	92.68	229.02	2.56	
LANDUSE:						
	Wetlands-Mixed	WETL	5.54	13.69	0.15	5.98
	Forest-Mixed	FRST	3.34	8.25	0.09	3.6
	Pasture	PAST	79.58	196.66	2.2	85.87
	Corn	CORN	4.22	10.42	0.12	4.55
SOILS:						
	NJ026		55.43	136.98	1.53	59.81
	NJ025		37.25	92.04	1.03	40.19
SLOPE:						
	1-3		33.68	83.23	0.93	36.34
	3-5		0.27	0.66	0.01	0.29

	0-1		58.74	145.14	1.62	63.37
HRUs						
232	Wetlands-Mixed	WETL/NJ026/1-3	2.49	6.16	0.07	2.69
233	Wetlands-Mixed	WETL/NJ026/3-5	0.27	0.66	0.01	0.29
234	Wetlands-Mixed	WETL/NJ026/0-1	2.78	6.87	0.08	3
235	Forest-Mixed	FRST/NJ026/1-3	1.40	3.47	0.04	1.51
236	Forest-Mixed	FRST/NJ026/0-1	1.94	4.79	0.05	2.09
237	Pasture	PAST/NJ025/1-3	7.94	19.62	0.22	8.57
238	Pasture	PAST/NJ025/0-1	25.09	62.00	0.69	27.07
239	Pasture	PAST/NJ026/1-3	21.54	53.23	0.59	23.24
240	Pasture	PAST/NJ026/0-1	25.01	61.81	0.69	26.99
241	Corn	CORN/NJ025/1-3	0.30	0.75	0.01	0.33
242	Corn	CORN/NJ025/0-1	3.91	9.67	0.11	4.22
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	14	152.87	377.76	4.22	
LANDUSE:						
	Wetlands-Mixed	WETL	11.54	28.51	0.32	7.55
	Water	WATR	6.17	15.24	0.17	4.03
	Residential-Low	URLD	26.18	64.69	0.72	17.12
	Forest-Mixed	FRST	22.04	54.46	0.61	14.42
	Pasture	PAST	86.95	214.87	2.4	56.88
SOILS:						
	NJ026		96.63	238.77	2.67	63.21
	NJ029		39.45	97.47	1.09	25.8
	NJ025		16.80	41.52	0.46	10.99

SLOPE:						
	1-3		60.79	150.20	1.68	39.76
	0-1		81.72	201.93	2.25	53.45
	>5		0.67	1.65	0.02	0.44
	3-5		9.71	23.98	0.27	6.35
HRUs						
243	Wetlands-Mixed	WETL/NJ026/1-3	4.87	12.04	0.13	3.19
244	Wetlands-Mixed	WETL/NJ026/0-1	5.76	14.23	0.16	3.77
245	Wetlands-Mixed	ETL/NJ029/5-99	0.10	0.25	0	0.07
246	Wetlands-Mixed	WETL/NJ029/3-5	0.34	0.84	0.01	0.22
247	Wetlands-Mixed	WETL/NJ029/1-3	0.17	0.43	0	0.11
248	Wetlands-Mixed	WETL/NJ029/0-1	0.29	0.71	0.01	0.19
249	Water	WATR/NJ026/1-3	0.77	1.90	0.02	0.5
250	Water	WATR/NJ026/0-1	0.68	1.67	0.02	0.44
251	Water	WATR/NJ029/3-5	0.72	1.77	0.02	0.47
252	Water	ATR/NJ029/5-99	0.23	0.56	0.01	0.15
253	Water	WATR/NJ029/1-3	1.19	2.94	0.03	0.78
254	Water	WATR/NJ029/0-1	2.59	6.41	0.07	1.7
255	Residential-Low	URLD/NJ025/0-1	1.70	4.20	0.05	1.11
256	Residential-Low	URLD/NJ025/1-3	0.56	1.39	0.02	0.37
257	Residential-Low	URLD/NJ026/3-5	1.38	3.42	0.04	0.9
258	Residential-Low	URLD/NJ026/0-1	8.78	21.70	0.24	5.74
259	Residential-Low	URLD/NJ026/1-3	12.73	31.44	0.35	8.32
260	Residential-Low	URLD/NJ029/0-1	0.14	0.35	0	0.09
261	Residential-Low	RLD/NJ029/5-99	0.07	0.18	0	0.05
262	Residential-Low	URLD/NJ029/3-5	0.14	0.35	0	0.09
263	Residential-Low	URLD/NJ029/1-3	0.67	1.65	0.02	0.44
264	Forest-Mixed	FRST/NJ025/1-3	0.46	1.14	0.01	0.3
265	Forest-Mixed	FRST/NJ025/3-5	0.17	0.43	0	0.11

266	Forest-Mixed	FRST/NJ026/3-5	3.83	9.45	0.11	2.5
267	Forest-Mixed	FRST/NJ026/0-1	2.75	6.78	0.08	1.8
268	Forest-Mixed	FRST/NJ026/1-3	10.19	25.18	0.28	6.67
269	Forest-Mixed	FRST/NJ029/1-3	1.69	4.18	0.05	1.11
270	Forest-Mixed	RST/NJ029/5-999	0.27	0.66	0.01	0.17
271	Forest-Mixed	FRST/NJ029/3-5	2.68	6.63	0.07	1.76
272	Pasture	PAST/NJ025/1-3	4.59	11.34	0.13	3
273	Pasture	PAST/NJ025/0-1	8.87	21.92	0.24	5.8
274	Pasture	PAST/NJ025/3-5	0.44	1.09	0.01	0.29
275	Pasture	PAST/NJ026/1-3	15.52	38.35	0.43	10.15
276	Pasture	PAST/NJ026/0-1	29.37	72.59	0.81	19.21
277	Pasture	PAST/NJ029/1-3	7.37	18.22	0.2	4.82
278	Pasture	PAST/NJ029/0-1	20.78	51.36	0.57	13.6
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	15	37.36	92.31	1.03	
LANDUSE:						
	Wetlands-Mixed	WETL	6.32	15.63	0.17	16.93
	Residential-Low	URLD	6.73	16.64	0.19	18.03
	Forest-Mixed	FRST	7.18	17.75	0.2	19.23
	Pasture	PAST	17.11	42.28	0.47	45.81
SOILS:						
	NJ026		37.36	92.31	1.03	100
SLOPE:						
	1-3		16.49	40.76	0.46	44.15

	0-1		20.41	50.44	0.56	54.64
	3-5		0.45	1.11	0.01	1.21
HRUs						
279	Wetlands-Mixed	WETL/NJ026/1-3	0.83	2.05	0.02	2.22
280	Wetlands-Mixed	WETL/NJ026/0-1	5.49	13.58	0.15	14.71
281	Residential-Low	URLD/NJ026/0-1	1.43	3.54	0.04	3.83
282	Residential-Low	URLD/NJ026/3-5	0.45	1.11	0.01	1.21
283	Residential-Low	URLD/NJ026/1-3	4.85	11.99	0.13	12.99
284	Forest-Mixed	FRST/NJ026/0-1	2.46	6.08	0.07	6.59
285	Forest-Mixed	FRST/NJ026/1-3	4.73	11.68	0.13	12.65
286	Pasture	PAST/NJ026/1-3	6.08	15.04	0.17	16.29
287	Pasture	PAST/NJ026/0-1	11.03	27.25	0.3	29.52
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	16	173.96	429.86	4.8	
LANDUSE:						
	Wetlands-Mixed	WETL	17.86	44.14	0.49	10.27
	Residential-Low	URLD	4.72	11.67	0.13	2.72
	Forest-Mixed	FRST	36.63	90.53	1.01	21.06
	Pasture	PAST	107.36	265.30	2.96	61.72
	Corn	CORN	7.38	18.22	0.2	4.24
SOILS:						
	NJ025		106.98	264.36	2.95	61.5
	NJ026		66.98	165.50	1.85	38.5
SLOPE:						

	1-3		44.57	110.12	1.23	25.62
	0-1		129.39	319.74	3.57	74.38
HRUs						
288	Wetlands-Mixed	WETL/NJ025/1-3	0.84	2.08	0.02	0.48
289	Wetlands-Mixed	WETL/NJ025/0-1	7.86	19.41	0.22	4.52
290	Wetlands-Mixed	WETL/NJ026/1-3	3.08	7.61	0.08	1.77
291	Wetlands-Mixed	WETL/NJ026/0-1	6.09	15.04	0.17	3.5
292	Residential-Low	URLD/NJ025/1-3	0.20	0.49	0.01	0.12
293	Residential-Low	URLD/NJ025/0-1	2.00	4.95	0.06	1.15
294	Residential-Low	URLD/NJ026/0-1	2.10	5.19	0.06	1.21
295	Residential-Low	URLD/NJ026/1-3	0.42	1.04	0.01	0.24
296	Forest-Mixed	FRST/NJ025/1-3	7.00	17.30	0.19	4.03
297	Forest-Mixed	FRST/NJ025/0-1	13.50	33.36	0.37	7.76
298	Forest-Mixed	FRST/NJ026/1-3	6.24	15.41	0.17	3.58
299	Forest-Mixed	FRST/NJ026/0-1	9.90	24.45	0.27	5.69
300	Pasture	PAST/NJ025/0-1	60.40	149.24	1.67	34.72
301	Pasture	PAST/NJ025/1-3	12.50	30.90	0.34	7.19
302	Pasture	PAST/NJ026/0-1	22.62	55.88	0.62	13
303	Pasture	PAST/NJ026/1-3	11.85	29.28	0.33	6.81
304	Corn	CORN/NJ025/0-1	1.82	4.50	0.05	1.05
305	Corn	CORN/NJ025/1-3	0.86	2.13	0.02	0.49
306	Corn	CORN/NJ026/1-3	1.57	3.89	0.04	0.91
307	Corn	CORN/NJ026/0-1	3.12	7.71	0.09	1.79
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	17	113.81	281.22	3.14	
LANDUSE:						

	Wetlands-Mixed	WETL	13.44	33.20	0.37	11.8
	Residential-Low	URLD	4.84	11.96	0.13	4.25
	Forest-Mixed	FRST	13.92	34.40	0.38	12.23
	Pasture	PAST	81.61	201.67	2.25	71.71
SOILS:						
	NJ025		113.81	281.22	3.14	100
SLOPE:						
	1-3		17.24	42.61	0.48	15.15
	0-1		96.56	238.61	2.66	84.85
HRUs						
308	Wetlands-Mixed	WETL/NJ025/1-3	2.29	5.65	0.06	2.01
309	Wetlands-Mixed	WETL/NJ025/0-1	11.15	27.54	0.31	9.79
310	Residential-Low	URLD/NJ025/1-3	1.58	3.90	0.04	1.39
311	Residential-Low	URLD/NJ025/0-1	3.26	8.06	0.09	2.86
312	Forest-Mixed	FRST/NJ025/1-3	5.39	13.31	0.15	4.73
313	Forest-Mixed	FRST/NJ025/0-1	8.53	21.09	0.24	7.5
314	Pasture	PAST/NJ025/0-1	73.62	181.93	2.03	64.69
315	Pasture	PAST/NJ025/1-3	7.99	19.74	0.22	7.02
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	18	121.88	301.18	3.36	
LANDUSE:						
	Wetlands-Mixed	WETL	14.00	34.59	0.39	11.48
	Residential-Low	URLD	20.92	51.69	0.58	17.16
	Forest-Mixed	FRST	15.19	37.52	0.42	12.46

	Pasture	PAST	71.78	177.38	1.98	58.9
SOILS:						
	NJ025		121.88	301.18	3.36	100
SLOPE:						
	0-1		105.20	259.95	2.9	86.31
	1-3		16.68	41.22	0.46	13.69
HRUs						
316	Wetlands-Mixed	WETL/NJ025/0-1	11.80	29.16	0.33	9.68
317	Wetlands-Mixed	WETL/NJ025/1-3	2.20	5.43	0.06	1.8
318	Residential-Low	URLD/NJ025/0-1	19.96	49.32	0.55	16.38
319	Residential-Low	URLD/NJ025/1-3	0.96	2.37	0.03	0.79
320	Forest-Mixed	FRST/NJ025/0-1	11.20	27.68	0.31	9.19
321	Forest-Mixed	FRST/NJ025/1-3	3.98	9.84	0.11	3.27
322	Pasture	PAST/NJ025/1-3	9.54	23.59	0.26	7.83
323	Pasture	PAST/NJ025/0-1	62.24	153.80	1.72	51.06
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	19	234.80	580.20	6.48	
LANDUSE:						
	Wetlands-Mixed	WETL	23.61	58.35	0.65	10.06
	Residential-Low	URLD	15.94	39.40	0.44	6.79
	Forest-Mixed	FRST	17.88	44.19	0.49	7.62
	Pasture	PAST	177.36	438.27	4.89	75.54
SOILS:						

	NJ025		234.80	580.20	6.48	100
SLOPE:						
	1-3		84.33	208.38	2.33	35.92
	0-1		150.47	371.82	4.15	64.08
HRUs						
324	Wetlands-Mixed	WETL/NJ025/1-3	6.82	16.86	0.19	2.91
325	Wetlands-Mixed	WETL/NJ025/0-1	16.79	41.49	0.46	7.15
326	Residential-Low	URLD/NJ025/1-3	7.36	18.19	0.2	3.14
327	Residential-Low	URLD/NJ025/0-1	8.58	21.21	0.24	3.66
328	Forest-Mixed	FRST/NJ025/0-1	12.68	31.34	0.35	5.4
329	Forest-Mixed	FRST/NJ025/1-3	5.20	12.85	0.14	2.21
330	Pasture	PAST/NJ025/0-1	112.41	277.78	3.1	47.88
331	Pasture	PAST/NJ025/1-3	64.95	160.49	1.79	27.66
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	20	167.05	412.80	4.61	
LANDUSE:						
	Wetlands-Mixed	WETL	24.10	59.55	0.66	14.43
	Water	WATR	8.37	20.69	0.23	5.01
	Residential-Low	URLD	17.15	42.39	0.47	10.27
	Forest-Mixed	FRST	58.90	145.56	1.63	35.26
	Pasture	PAST	58.52	144.61	1.61	35.03
SOILS:						
	NJ026		150.66	372.29	4.16	90.19
	NJ025		16.39	40.51	0.45	9.81

SLOPE:						
	0-1		90.21	222.93	2.49	54
	1-3		71.19	175.92	1.96	42.62
	3-5		5.65	13.95	0.16	3.38
HRUs						
332	Wetlands-Mixed	WETL/NJ026/0-1	17.70	43.73	0.49	10.59
333	Wetlands-Mixed	WETL/NJ026/1-3	6.40	15.82	0.18	3.83
334	Water	WATR/NJ026/0-1	5.55	13.71	0.15	3.32
335	Water	WATR/NJ026/1-3	1.44	3.55	0.04	0.86
336	Water	WATR/NJ026/3-5	1.39	3.43	0.04	0.83
337	Residential-Low	URLD/NJ026/1-3	9.27	22.91	0.26	5.55
338	Residential-Low	URLD/NJ026/0-1	7.05	17.42	0.19	4.22
339	Residential-Low	URLD/NJ026/3-5	0.84	2.06	0.02	0.5
340	Forest-Mixed	FRST/NJ025/1-3	0.90	2.23	0.02	0.54
341	Forest-Mixed	FRST/NJ025/0-1	0.94	2.33	0.03	0.56
342	Forest-Mixed	FRST/NJ025/3-5	0.40	1.00	0.01	0.24
343	Forest-Mixed	FRST/NJ026/3-5	3.02	7.46	0.08	1.81
344	Forest-Mixed	FRST/NJ026/0-1	29.00	71.66	0.8	17.36
345	Forest-Mixed	FRST/NJ026/1-3	24.64	60.88	0.68	14.75
346	Pasture	PAST/NJ025/0-1	11.31	27.94	0.31	6.77
347	Pasture	PAST/NJ025/1-3	2.84	7.02	0.08	1.7
348	Pasture	PAST/NJ026/1-3	25.71	63.52	0.71	15.39
349	Pasture	PAST/NJ026/0-1	18.67	46.13	0.51	11.17
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	21	84.61	209.07	2.33	

LANDUSE:						
	Wetlands-Mixed	WETL	11.36	28.06	0.31	13.42
	Residential-Low	URLD	2.16	5.34	0.06	2.55
	Forest-Mixed	FRST	7.70	19.02	0.21	9.1
	Pasture	PAST	59.45	146.91	1.64	70.27
	Corn	CORN	3.94	9.73	0.11	4.66
SOILS:						
	NJ025		57.28	141.55	1.58	67.7
	NJ026		27.32	67.52	0.75	32.3
SLOPE:						
	1-3		34.37	84.93	0.95	40.63
	0-1		49.96	123.46	1.38	59.05
	3-5		0.27	0.67	0.01	0.32
HRUs						
350	Wetlands-Mixed	WETL/NJ025/1-3	3.41	8.43	0.09	4.03
351	Wetlands-Mixed	WETL/NJ025/0-1	3.28	8.11	0.09	3.88
352	Wetlands-Mixed	WETL/NJ026/1-3	2.14	5.29	0.06	2.53
353	Wetlands-Mixed	WETL/NJ026/0-1	2.38	5.89	0.07	2.82
354	Wetlands-Mixed	WETL/NJ026/3-5	0.14	0.35	0	0.17
355	Residential-Low	URLD/NJ025/0-1	0.76	1.89	0.02	0.9
356	Residential-Low	URLD/NJ025/1-3	0.05	0.12	0	0.06
357	Residential-Low	URLD/NJ026/0-1	0.74	1.84	0.02	0.88
358	Residential-Low	URLD/NJ026/1-3	0.60	1.49	0.02	0.71
359	Forest-Mixed	FRST/NJ025/0-1	0.84	2.09	0.02	1
360	Forest-Mixed	FRST/NJ025/1-3	1.71	4.22	0.05	2.02
361	Forest-Mixed	FRST/NJ025/3-5	0.13	0.32	0	0.15
362	Forest-Mixed	FRST/NJ026/0-1	3.75	9.26	0.1	4.43
363	Forest-Mixed	FRST/NJ026/1-3	1.27	3.13	0.03	1.5

364	Pasture	PAST/NJ025/1-3	16.82	41.56	0.46	19.88
365	Pasture	PAST/NJ025/0-1	28.23	69.75	0.78	33.36
366	Pasture	PAST/NJ026/1-3	5.77	14.26	0.16	6.82
367	Pasture	PAST/NJ026/0-1	8.64	21.35	0.24	10.21
368	Corn	CORN/NJ025/0-1	0.82	2.04	0.02	0.97
369	Corn	CORN/NJ025/1-3	1.23	3.03	0.03	1.45
370	Corn	CORN/NJ026/0-1	0.51	1.27	0.01	0.61
371	Corn	CORN/NJ026/1-3	1.38	3.40	0.04	1.63
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	22	151.63	374.69	4.18	
LANDUSE:						
	Wetlands-Mixed	WETL	19.06	47.09	0.53	12.57
	Residential-Low	URLD	4.03	9.96	0.11	2.66
	Agricultural	AGRC	3.52	8.69	0.1	2.32
	Pasture	PAST	125.03	308.95	3.45	82.46
SOILS:						
	NJ025		151.55	374.49	4.18	99.95
	NJ026		0.08	0.20	0	0.05
SLOPE:						
	1-3		44.45	109.84	1.23	29.31
	0-1		107.18	264.85	2.96	70.69
HRUs						
372	Wetlands-Mixed	WETL/NJ025/1-3	4.51	11.14	0.12	2.97
373	Wetlands-Mixed	WETL/NJ025/0-1	14.55	35.95	0.4	9.59

374	Residential-Low	URLD/NJ025/1-3	1.65	4.08	0.05	1.09
375	Residential-Low	URLD/NJ025/0-1	2.30	5.68	0.06	1.52
376	Residential-Low	URLD/NJ026/0-1	0.08	0.20	0	0.05
377	Agricultural	AGRC/NJ025/0-1	1.01	2.48	0.03	0.66
378	Agricultural	AGRC/NJ025/1-3	2.51	6.21	0.07	1.66
379	Pasture	PAST/NJ025/0-1	89.25	220.54	2.46	58.86
380	Pasture	PAST/NJ025/1-3	35.78	88.41	0.99	23.6
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	23	134.83	333.18	3.72	
LANDUSE:						
	Wetlands-Mixed	WETL	9.70	23.97	0.27	7.19
	Water	WATR	10.72	26.50	0.3	7.95
	Residential-Low	URLD	21.36	52.78	0.59	15.84
	Forest-Mixed	FRST	7.91	19.53	0.22	5.86
	Pasture	PAST	81.51	201.42	2.25	60.45
	Corn	CORN	3.63	8.97	0.1	2.69
SOILS:						
	NJ025		105.58	260.89	2.91	78.3
	NJ026		29.25	72.29	0.81	21.7
SLOPE:						
	3-5		2.40	5.94	0.07	1.78
	0-1		83.68	206.79	2.31	62.07
	1-3		48.18	119.06	1.33	35.73
	>5		0.56	1.39	0.02	0.42

HRUs						
381	Wetlands-Mixed	WETL/NJ025/3-5	0.19	0.47	0.01	0.14
382	Wetlands-Mixed	WETL/NJ025/0-1	1.43	3.55	0.04	1.06
383	Wetlands-Mixed	WETL/NJ025/1-3	2.17	5.35	0.06	1.61
384	Wetlands-Mixed	WETL/NJ026/3-5	0.42	1.04	0.01	0.31
385	Wetlands-Mixed	WETL/NJ026/1-3	2.25	5.55	0.06	1.67
386	Wetlands-Mixed	WETL/NJ026/0-1	3.24	8.01	0.09	2.4
387	Water	WATR/NJ025/1-3	2.66	6.58	0.07	1.97
388	Water	WATR/NJ025/0-1	4.89	12.09	0.13	3.63
389	Water	WATR/NJ025/3-5	0.37	0.91	0.01	0.27
390	Water	WATR/NJ026/0-1	1.63	4.02	0.04	1.21
391	Water	WATR/NJ026/3-5	0.26	0.65	0.01	0.19
392	Water	WATR/NJ026/1-3	0.91	2.25	0.03	0.67
393	Residential-Low	URLD/NJ025/0-1	13.21	32.65	0.36	9.8
394	Residential-Low	URLD/NJ025/1-3	6.12	15.12	0.17	4.54
395	Residential-Low	URLD/NJ026/1-3	0.95	2.34	0.03	0.7
396	Residential-Low	URLD/NJ026/0-1	1.08	2.67	0.03	0.8
397	Forest-Mixed	RST/NJ025/5-999	0.40	0.99	0.01	0.3
398	Forest-Mixed	FRST/NJ025/0-1	0.55	1.36	0.02	0.41
399	Forest-Mixed	FRST/NJ025/3-5	0.60	1.49	0.02	0.45
400	Forest-Mixed	FRST/NJ025/1-3	3.76	9.30	0.1	2.79
401	Forest-Mixed	RST/NJ026/5-999	0.16	0.40	0	0.12
402	Forest-Mixed	FRST/NJ026/1-3	0.54	1.32	0.01	0.4
403	Forest-Mixed	FRST/NJ026/0-1	1.89	4.67	0.05	1.4
404	Pasture	PAST/NJ025/1-3	18.71	46.24	0.52	13.88
405	Pasture	PAST/NJ025/0-1	48.16	119.01	1.33	35.72
406	Pasture	PAST/NJ026/0-1	5.85	14.46	0.16	4.34
407	Pasture	PAST/NJ026/1-3	8.23	20.33	0.23	6.1
408	Pasture	PAST/NJ026/3-5	0.56	1.37	0.02	0.41
409	Corn	CORN/NJ025/0-1	1.65	4.07	0.05	1.22

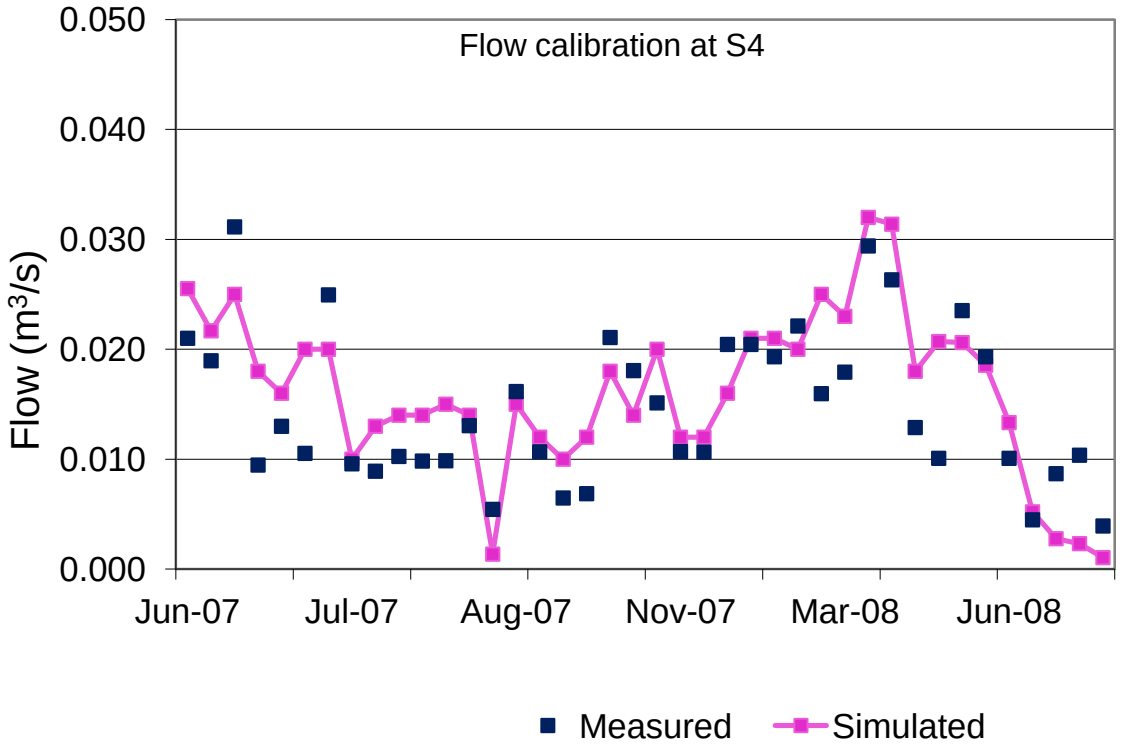
410	Corn	CORN/NJ025/1-3	0.69	1.71	0.02	0.51
411	Corn	CORN/NJ026/1-3	1.20	2.97	0.03	0.89
412	Corn	CORN/NJ026/0-1	0.09	0.22	0	0.07
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	24	181.91	449.52	5.02	
LANDUSE:						
	Wetlands-Mixed	WETL	30.77	76.03	0.85	16.91
	Residential-Low	URLD	42.22	104.33	1.16	23.21
	Forest-Mixed	FRST	6.26	15.47	0.17	3.44
	Pasture	PAST	102.67	253.70	2.83	56.44
SOILS:						
	NJ025		181.91	449.52	5.02	100
SLOPE:						
	1-3		15.94	39.38	0.44	8.76
	0-1		165.70	409.46	4.57	91.09
	3-5		0.27	0.67	0.01	0.15
HRUs						
413	Wetlands-Mixed	WETL/NJ025/1-3	4.30	10.64	0.12	2.37
414	Wetlands-Mixed	WETL/NJ025/0-1	26.46	65.39	0.73	14.55
415	Residential-Low	URLD/NJ025/0-1	38.95	96.25	1.07	21.41
416	Residential-Low	URLD/NJ025/1-3	3.27	8.08	0.09	1.8
417	Forest-Mixed	FRST/NJ025/0-1	4.69	11.58	0.13	2.58
418	Forest-Mixed	FRST/NJ025/1-3	1.30	3.21	0.04	0.71
419	Forest-Mixed	FRST/NJ025/3-5	0.27	0.67	0.01	0.15

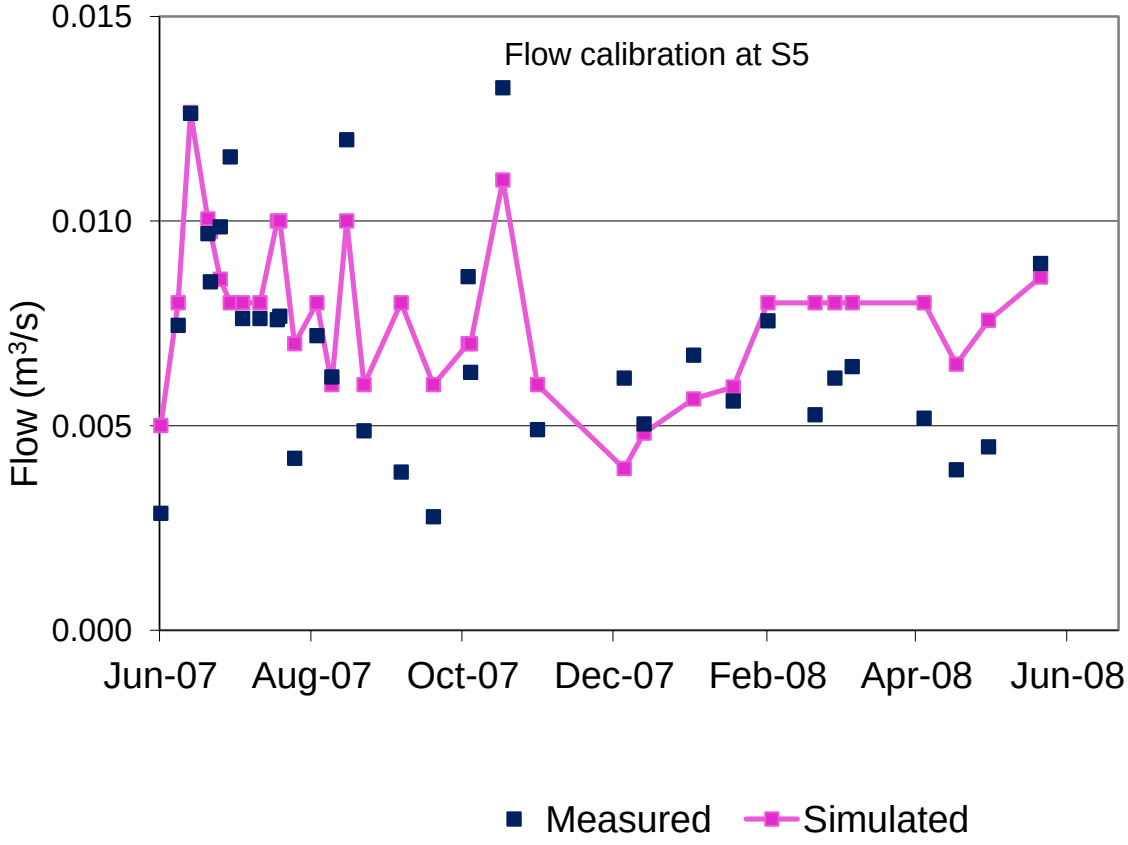
420	Pasture	PAST/NJ025/0-1	95.60	236.24	2.64	52.55
421	Pasture	PAST/NJ025/1-3	7.06	17.46	0.19	3.88
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	25	90.45	223.51	2.5	
LANDUSE:						
	Wetlands-Mixed	WETL	7.58	18.72	0.21	8.38
	Water	WATR	3.29	8.14	0.09	3.64
	Residential-Low	URLD	16.98	41.95	0.47	18.77
	Forest-Mixed	FRST	12.13	29.97	0.33	13.41
	Pasture	PAST	50.47	124.73	1.39	55.8
SOILS:						
	NJ025		90.45	223.51	2.5	100
SLOPE:						
	>5		1.62	4.01	0.04	1.79
	1-3		24.28	60.00	0.67	26.85
	0-1		62.65	154.82	1.73	69.27
	3-5		1.89	4.68	0.05	2.09
HRUs						
422	Wetlands-Mixed	ETL/NJ025/5-99	0.32	0.80	0.01	0.36
423	Wetlands-Mixed	WETL/NJ025/1-3	2.25	5.55	0.06	2.48
424	Wetlands-Mixed	WETL/NJ025/0-1	4.63	11.45	0.13	5.12
425	Wetlands-Mixed	WETL/NJ025/3-5	0.37	0.92	0.01	0.41
426	Water	WATR/NJ025/0-1	1.73	4.27	0.05	1.91
427	Water	WATR/NJ025/1-3	1.57	3.87	0.04	1.73

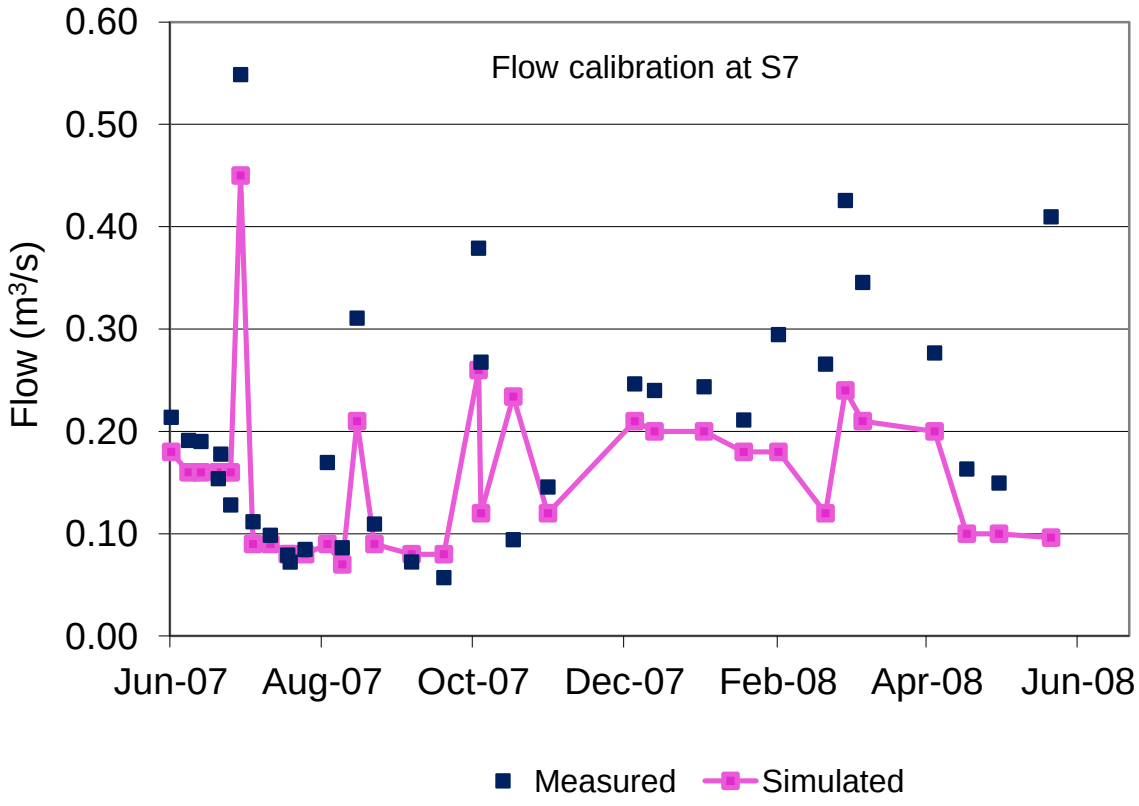
428	Residential-Low	URLD/NJ025/1-3	1.98	4.89	0.05	2.19
429	Residential-Low	URLD/NJ025/0-1	15.00	37.06	0.41	16.58
430	Forest-Mixed	FRST/NJ025/1-3	5.67	14.02	0.16	6.27
431	Forest-Mixed	FRST/NJ025/0-1	3.64	8.99	0.1	4.02
432	Forest-Mixed	FRST/NJ025/3-5	1.52	3.76	0.04	1.68
433	Forest-Mixed	RST/NJ025/5-999	1.30	3.21	0.04	1.44
434	Pasture	PAST/NJ025/1-3	12.82	31.67	0.35	14.17
435	Pasture	PAST/NJ025/0-1	37.66	93.05	1.04	41.63
			Area[ha]	Area[acres]	%Wat.Area	%Sub.Area
SUBBASIN	#	26	150.87	372.81	4.16	
LANDUSE:						
	Wetlands-Mixed	WETL	15.61	38.57	0.43	10.35
	Residential-Low	URLD	14.89	36.78	0.41	9.87
	Forest-Mixed	FRST	3.44	8.51	0.1	2.28
	Pasture	PAST	86.39	213.47	2.38	57.26
	Orchard	ORCD	30.55	75.48	0.84	20.25
SOILS:						
	NJ025		150.87	372.81	4.16	100
SLOPE:						
	3-5		0.73	1.81	0.02	0.49
	1-3		22.15	54.73	0.61	14.68
	0-1		127.99	316.27	3.53	84.83
HRUs						
436	Wetlands-Mixed	WETL/NJ025/3-5	0.73	1.81	0.02	0.49

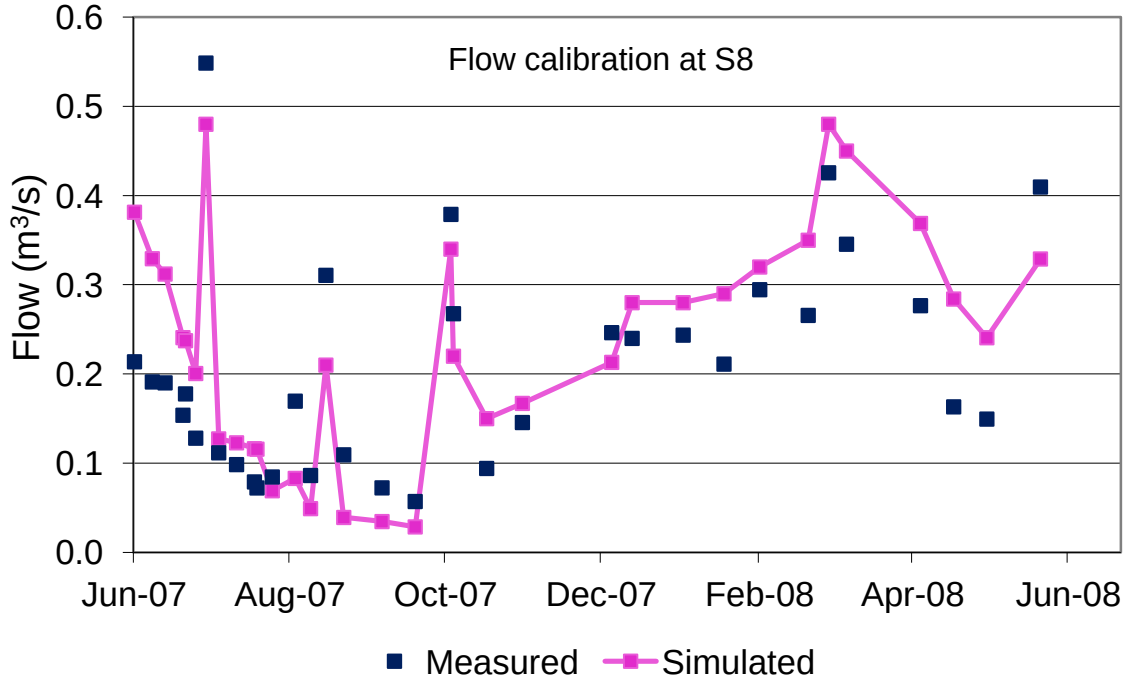
437	Wetlands-Mixed	WETL/NJ025/1-3	3.56	8.79	0.1	2.36
438	Wetlands-Mixed	WETL/NJ025/0-1	11.32	27.97	0.31	7.5
439	Residential-Low	URLD/NJ025/1-3	1.66	4.10	0.05	1.1
440	Residential-Low	URLD/NJ025/0-1	13.22	32.68	0.36	8.77
441	Forest-Mixed	FRST/NJ025/1-3	1.54	3.80	0.04	1.02
442	Forest-Mixed	FRST/NJ025/0-1	1.91	4.71	0.05	1.26
443	Pasture	PAST/NJ025/1-3	13.29	32.83	0.37	8.81
444	Pasture	PAST/NJ025/0-1	73.10	180.64	2.02	48.45
445	Orchard	ORCD/NJ025/0-1	28.44	70.27	0.78	18.85
446	Orchard	ORCD/NJ025/1-3	2.11	5.21	0.06	1.4

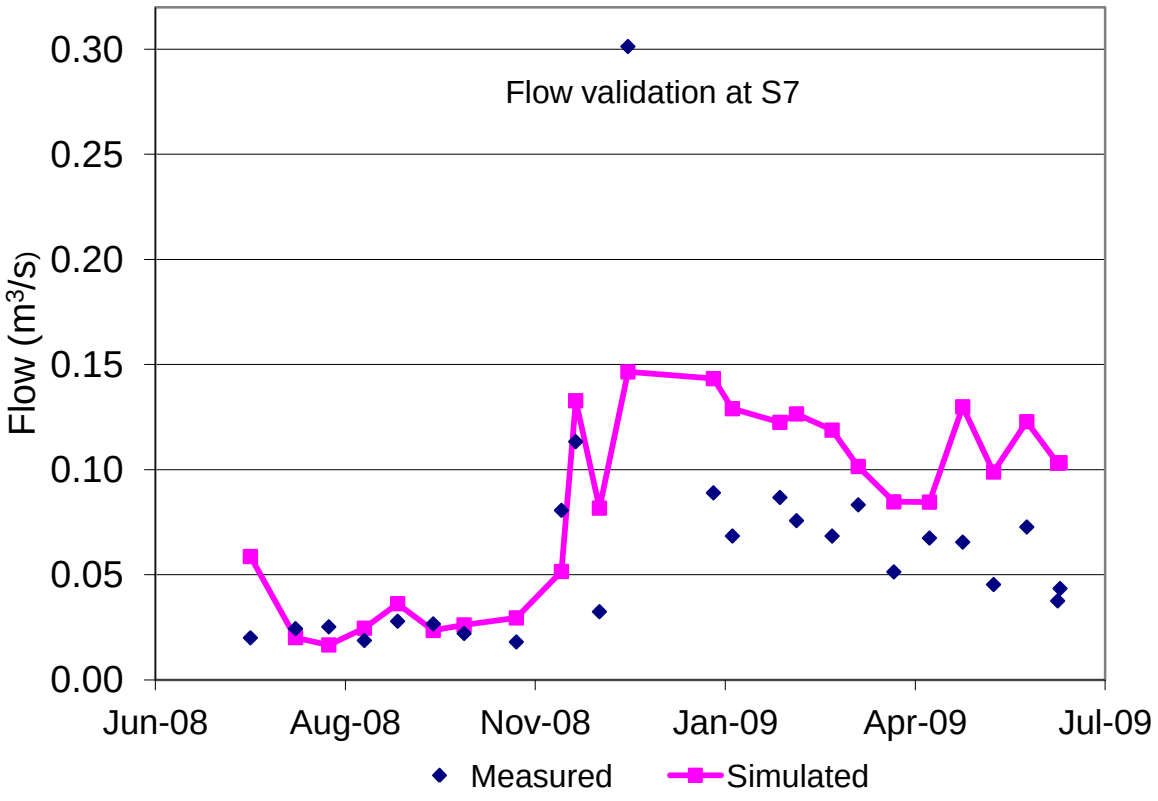
APPENDIX B: Plots of Calibration and Validation for Flow, Fecal Coliform and *E. coli* at the Sampling Stations

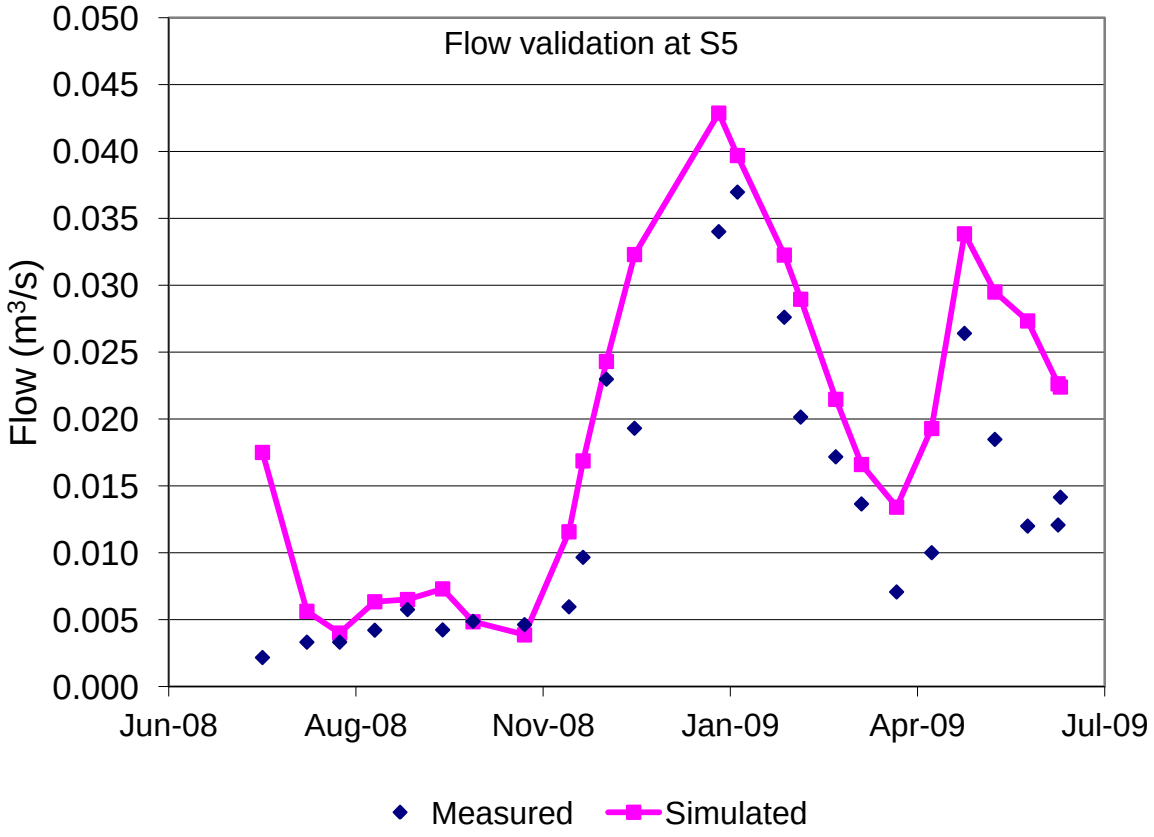

Flow calibration at S4
0.050
0.040
0.030
0.020
0.010
0.000
Flow (m3/s)
Jun-07
Jul-07
Aug-07
Nov-07
Mar-08
Jun-08
Measured
Simulated

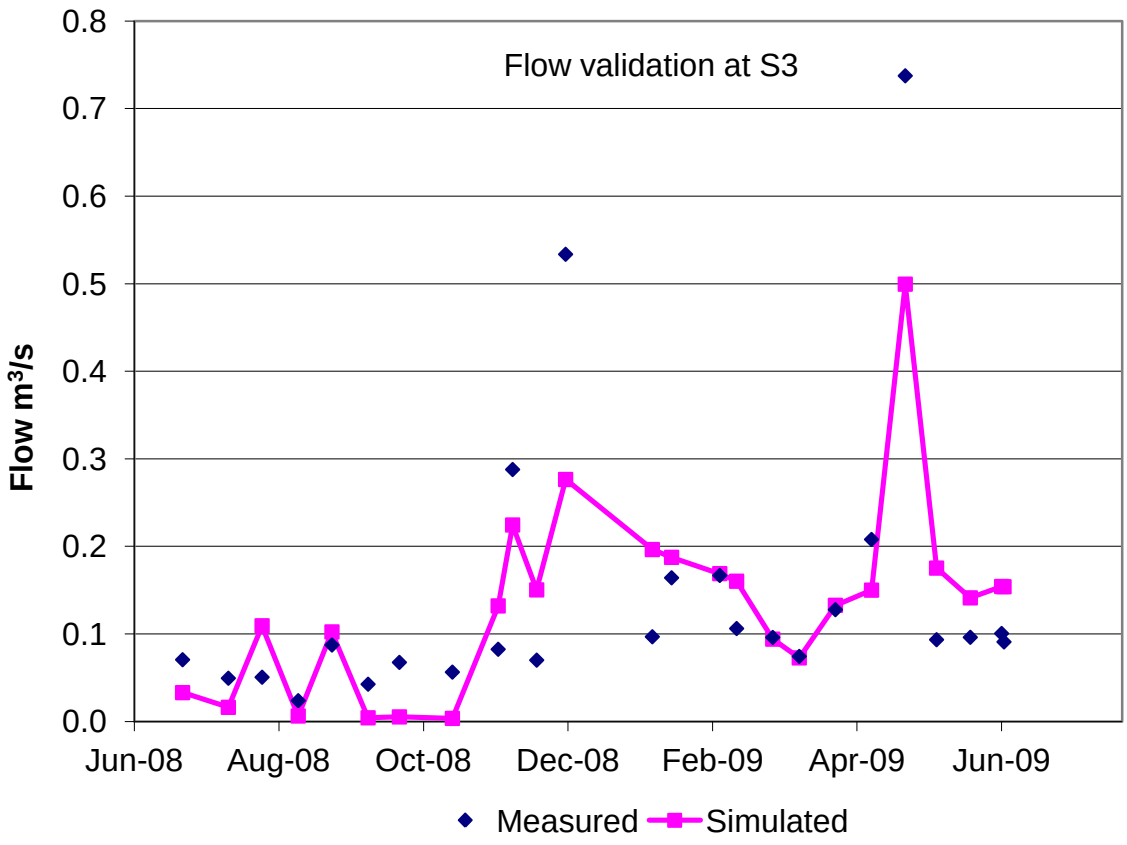

Flow calibration at S5
0.015
0.010
0.005
0.000
Flow (m3/s)
Jun-07
Aug-07
Oct-07
Dec-07
Feb-08
Apr-08
Jun-08
Measured
Simulated

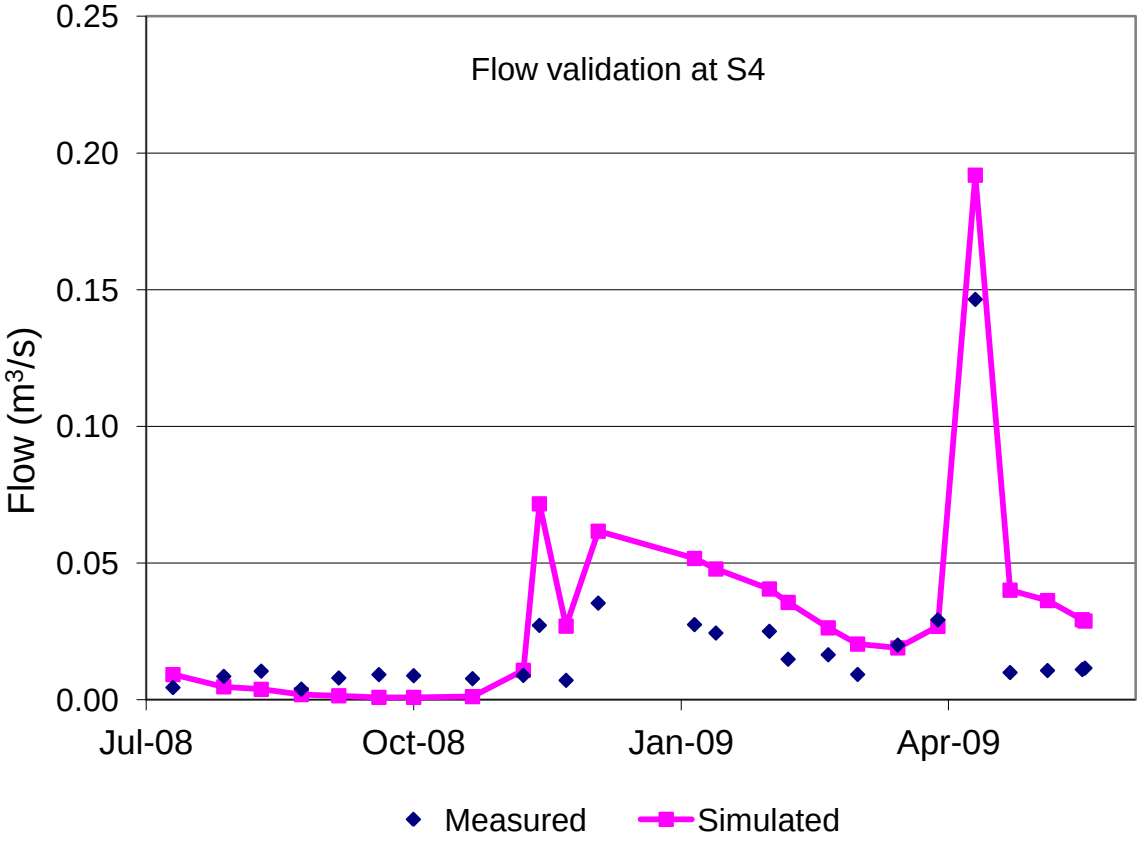

Flow calibration at S7
Flow (m3/s)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Jun-07
Aug-07
Oct-07
Dec-07
Feb-08
Apr-08
Jun-08
Measured
Simulated

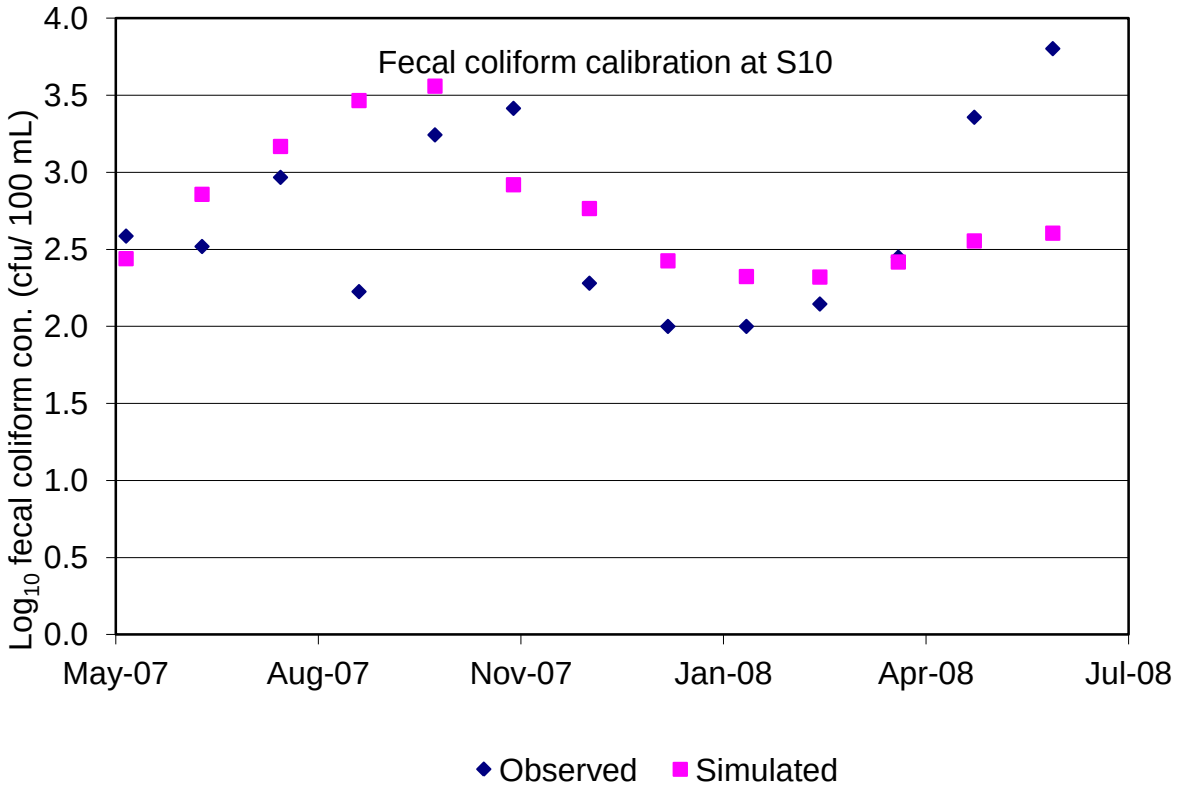

Flow calibration at S8
Flow (m3/s)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Jun-07
Aug-07
Oct-07
Dec-07
Feb-08
Apr-08
Jun-08
Measured
Simulated

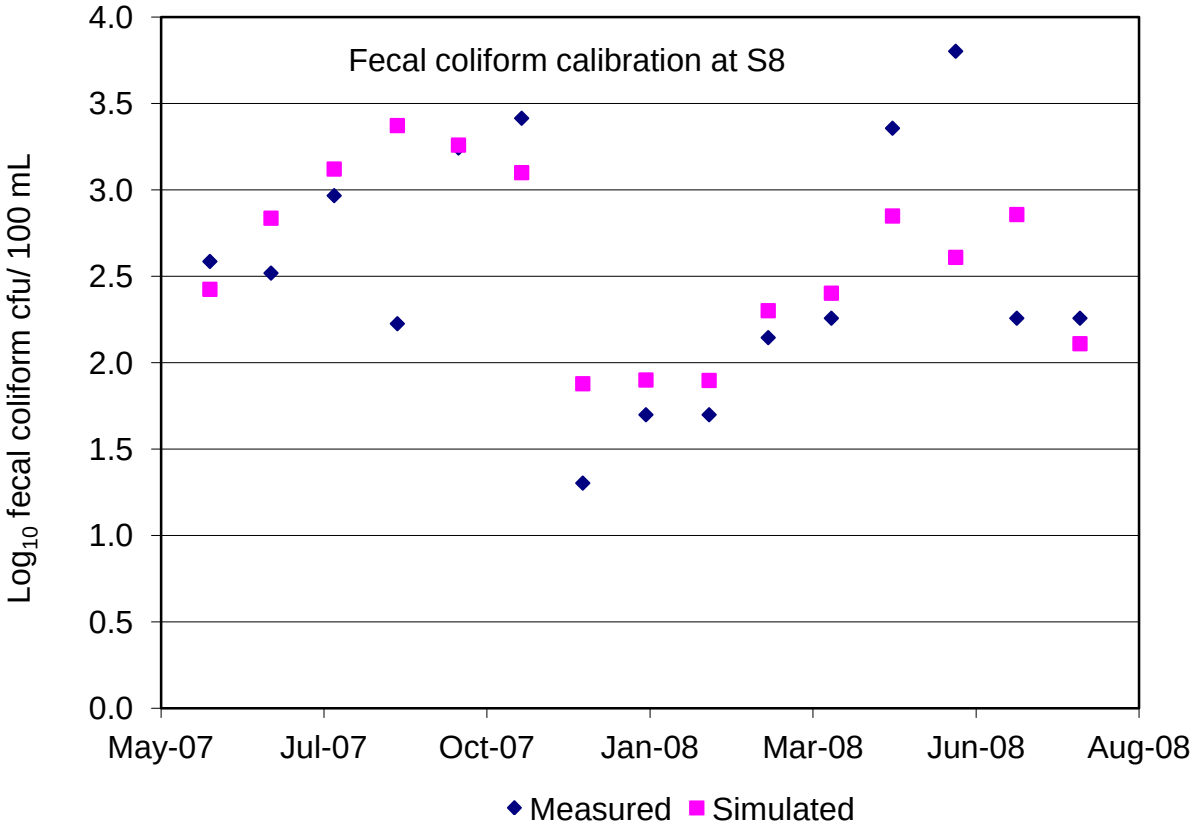

Flow validation at S7
Flow (m3/s)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jun-08
Aug-08
Nov-08
Jan-09
Apr-09
Jul-09
Measured
Simulated

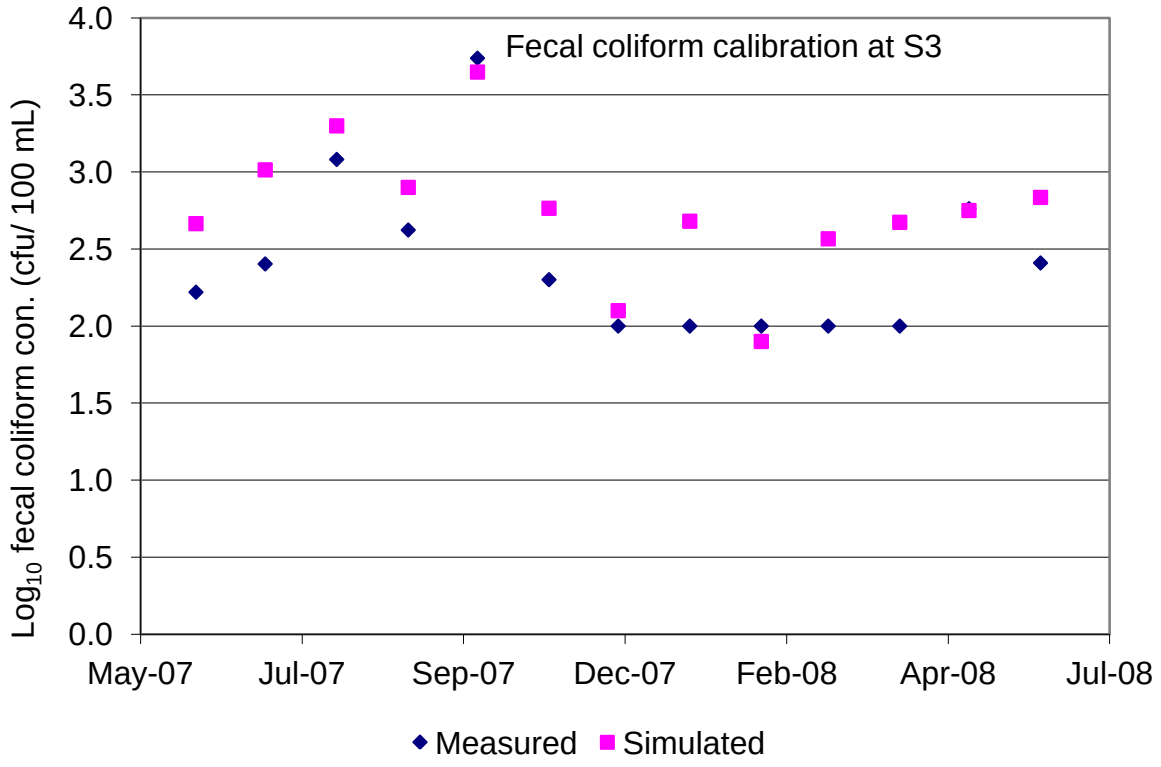

Flow validation at S5
Flow (m3/s)
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Jun-08
Aug-08
Nov-08
Jan-09
Apr-09
Jul-09
Measured
Simulated

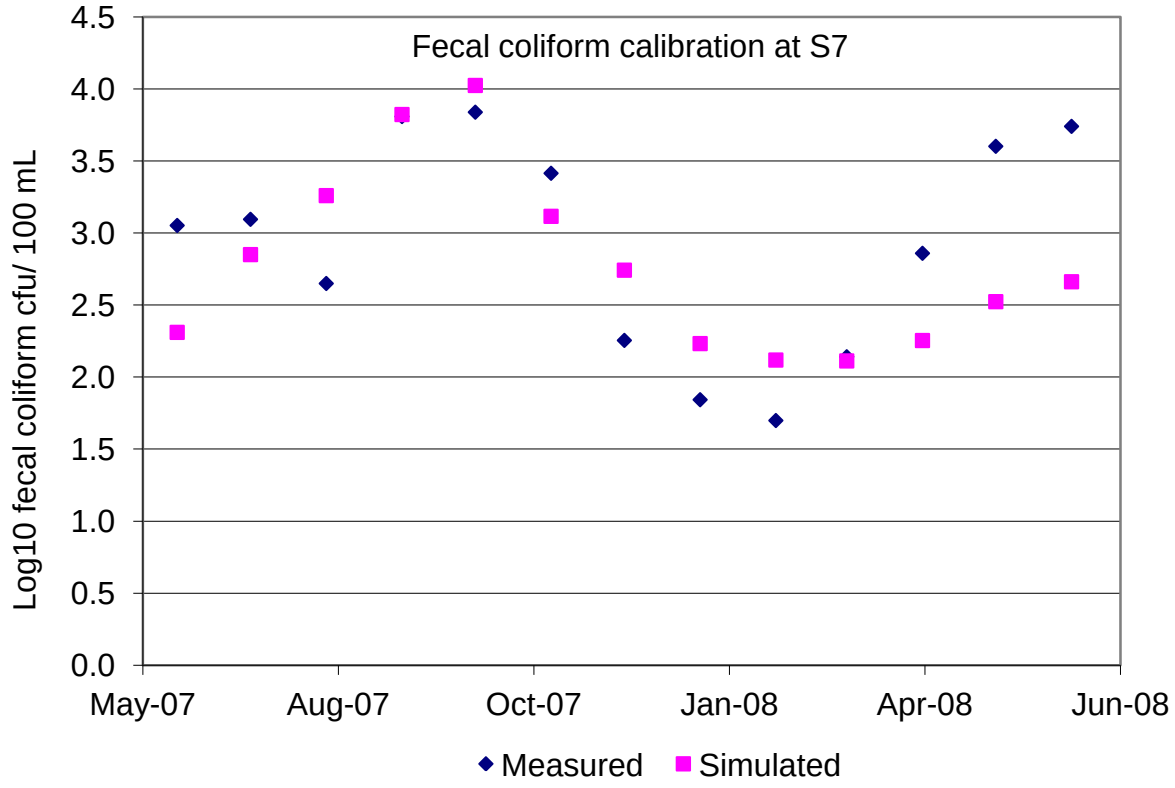

Flow validation at S3
Flow m³/s
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Jun-08
Aug-08
Oct-08
Dec-08
Feb-09
Apr-09
Jun-09
Measured
Simulated

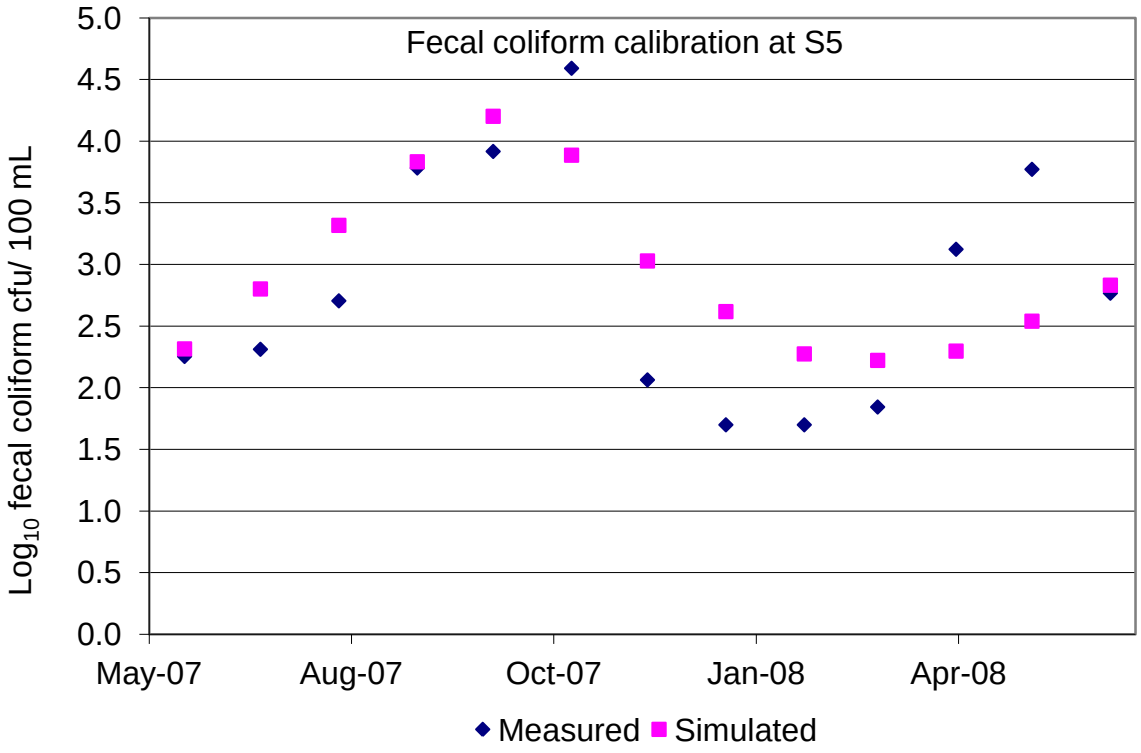

Flow validation at S4
Flow (m³/s)
0.25
0.20
0.15
0.10
0.05
0.00
Jul-08
Oct-08
Jan-09
Apr-09
Measured
Simulated

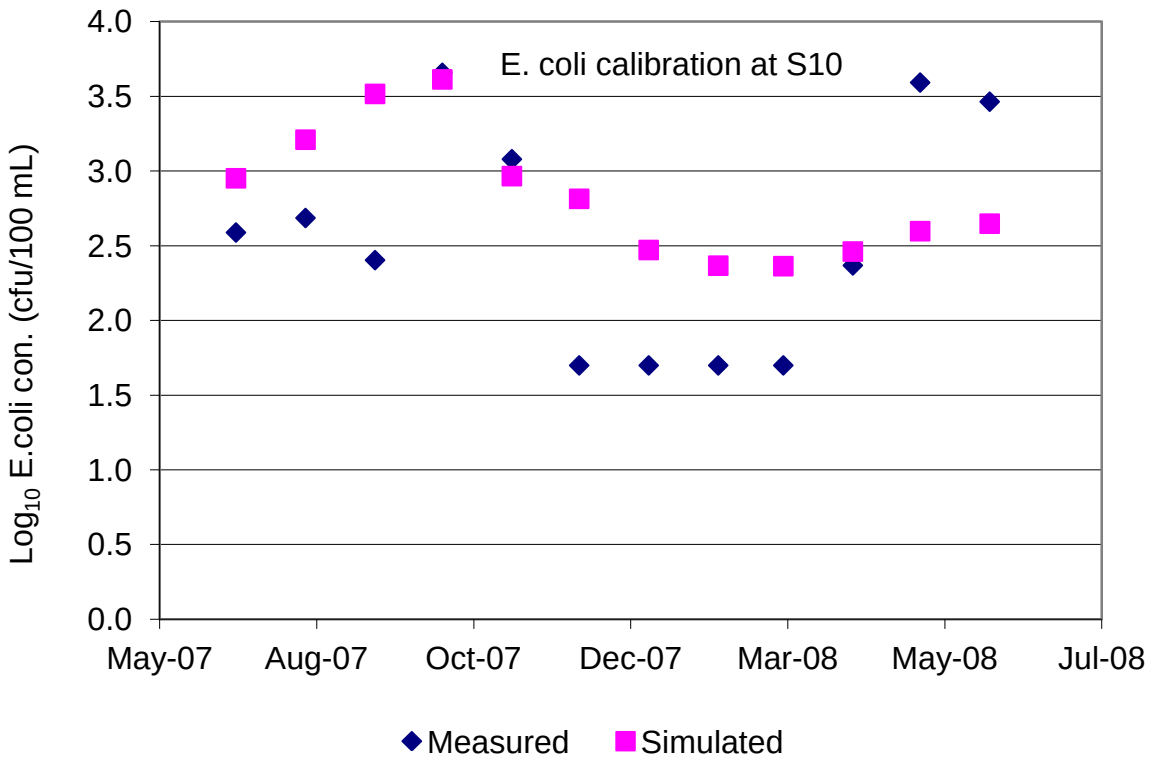

Fecal coliform calibration at S10
Log10 fecal coliform con. (cfu/ 100 mL)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-07
Aug-07
Nov-07
Jan-08
Apr-08
Jul-08
Observed
Simulated

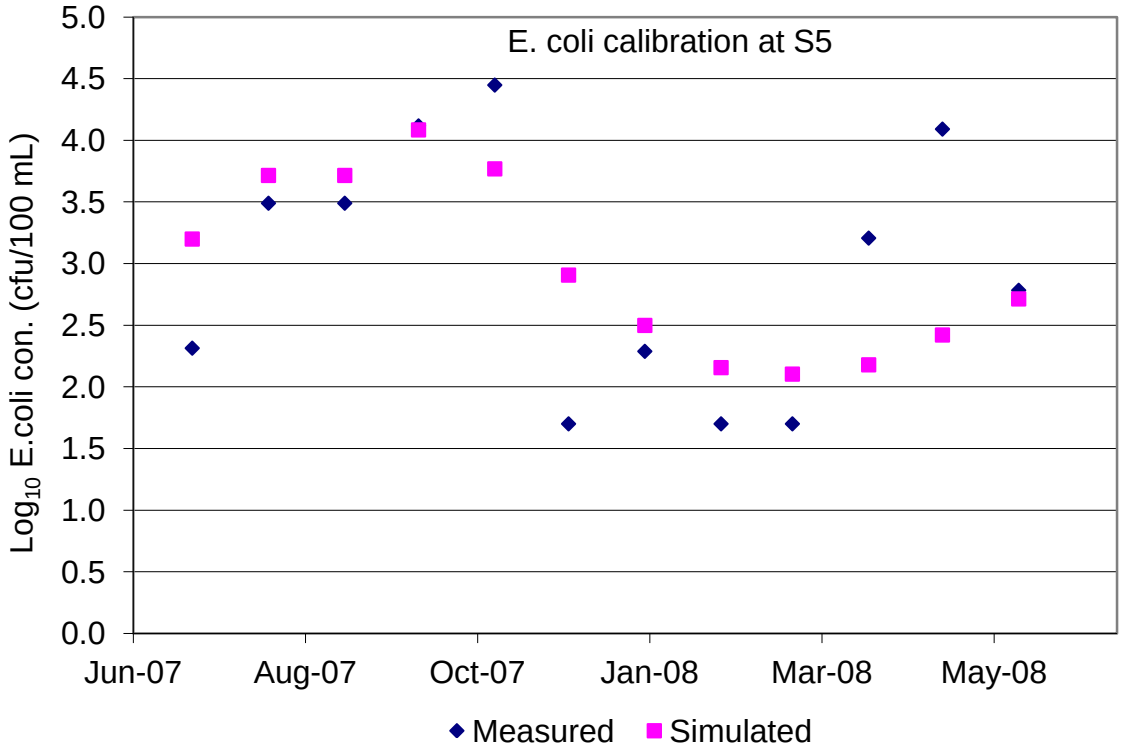

Fecal coliform calibration at S8
Log10 fecal coliform cfu/ 100 mL
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-07
Jul-07
Oct-07
Jan-08
Mar-08
Jun-08
Aug-08
Measured
Simulated

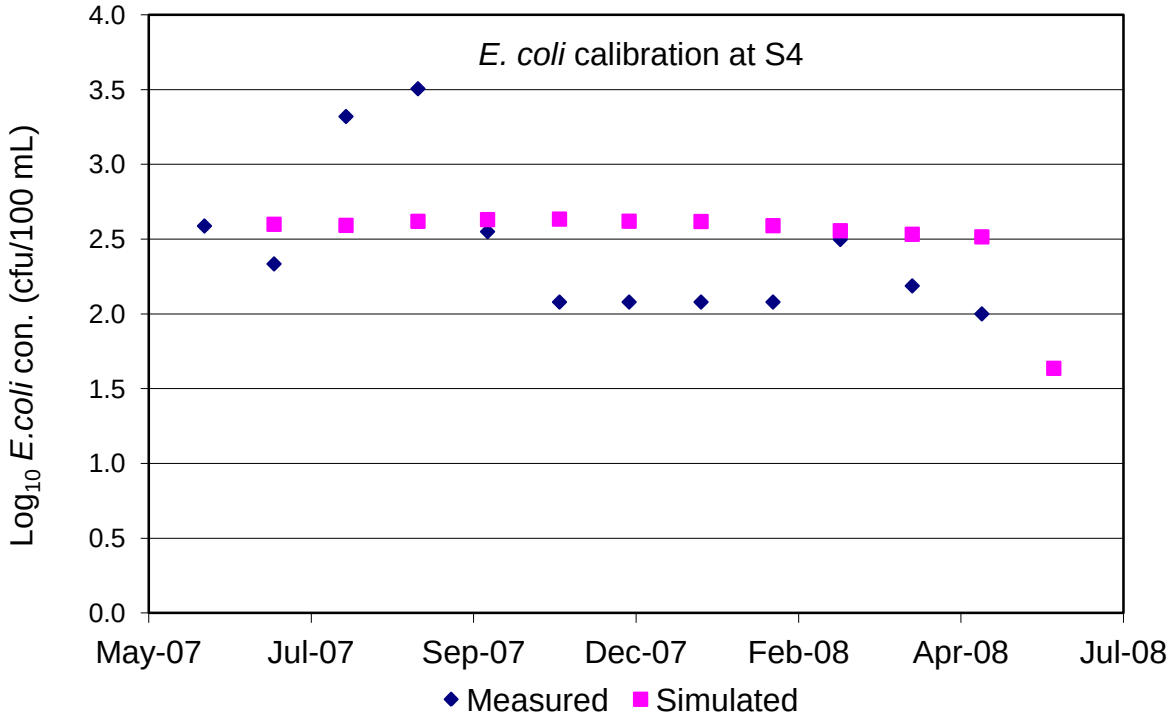

Fecal coliform calibration at S3
Log10 fecal coliform con. (cfu/ 100 mL)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-07
Jul-07
Sep-07
Dec-07
Feb-08
Apr-08
Jul-08
Measured
Simulated

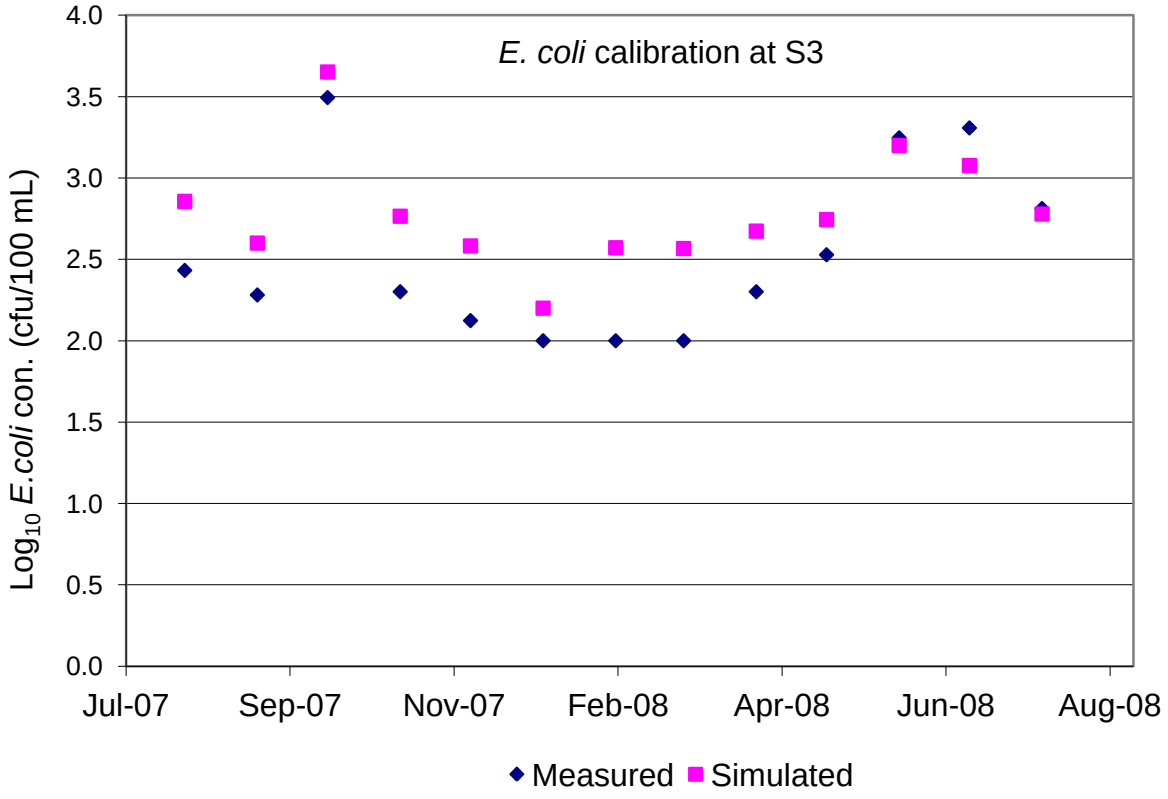

Fecal coliform calibration at S7
Log10 fecal coliform cfu/ 100 mL
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-07
Aug-07
Oct-07
Jan-08
Apr-08
Jun-08
Measured
Simulated

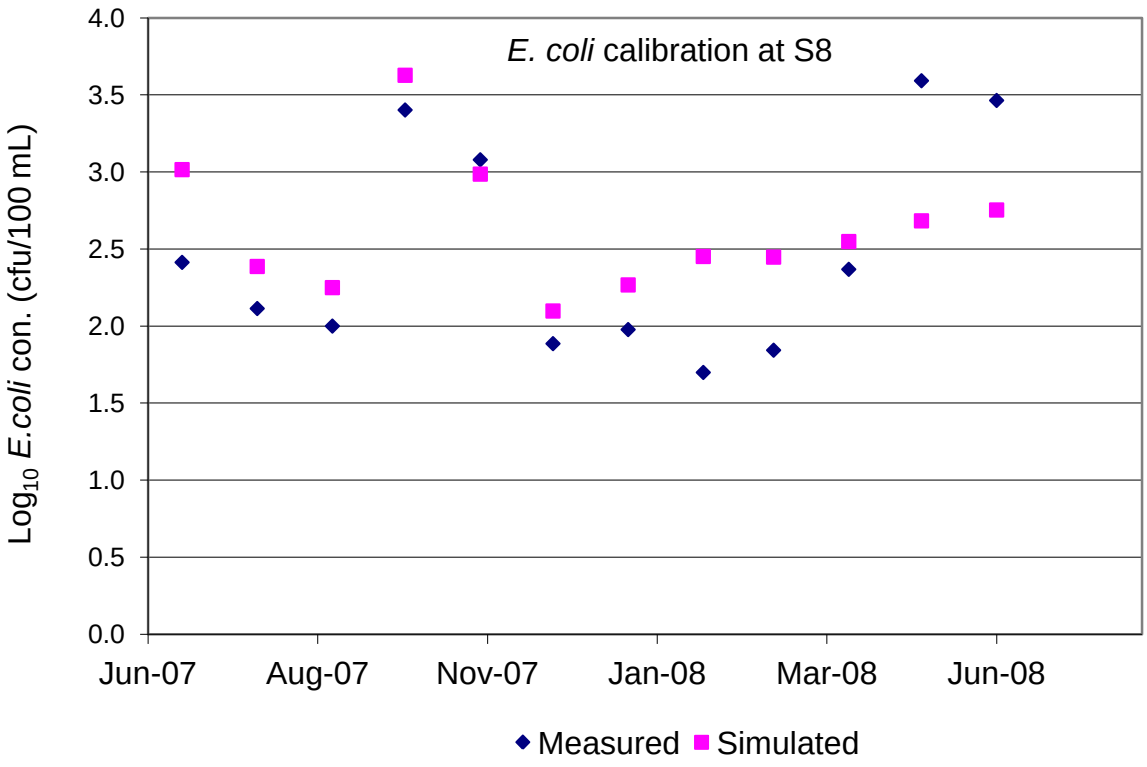

Fecal coliform calibration at S5
Log10 fecal coliform cfu/ 100 mL
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-07
Aug-07
Oct-07
Jan-08
Apr-08
Measured
Simulated

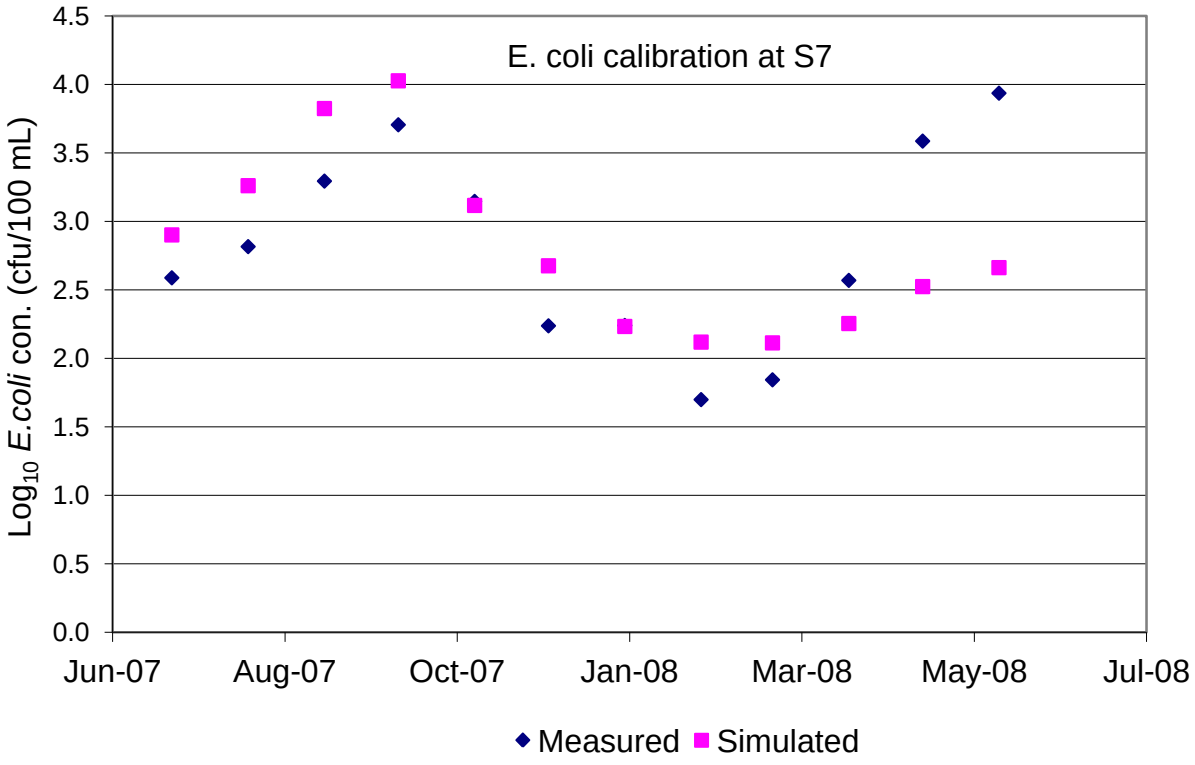

E. coli calibration at S10
Log10 E.coli con. (cfu/100 mL)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-07
Aug-07
Oct-07
Dec-07
Mar-08
May-08
Jul-08
Measured
Simulated

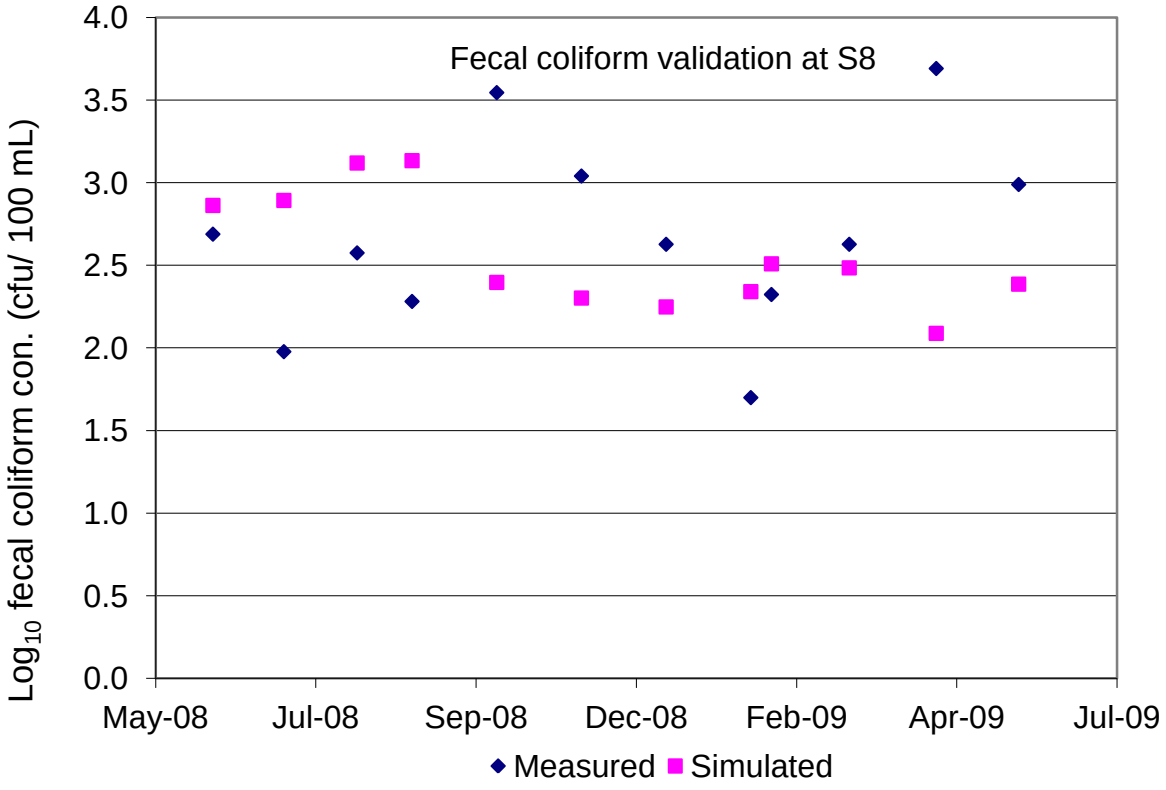

E. coli calibration at S5
Log10 E.coli con. (cfu/100 mL)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jun-07
Aug-07
Oct-07
Jan-08
Mar-08
May-08
Measured
Simulated

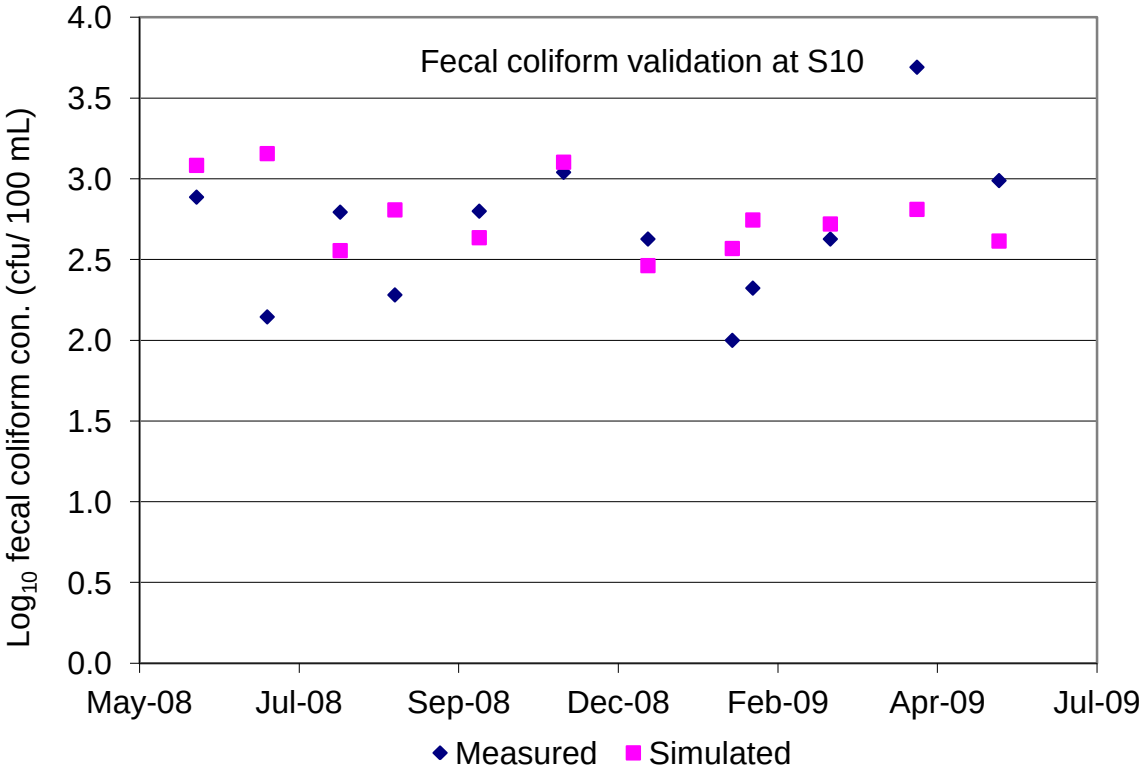

E. coli calibration at S4
Log10 E.coli con. (cfu/100 mL)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-07
Jul-07
Sep-07
Dec-07
Feb-08
Apr-08
Jul-08
Measured
Simulated

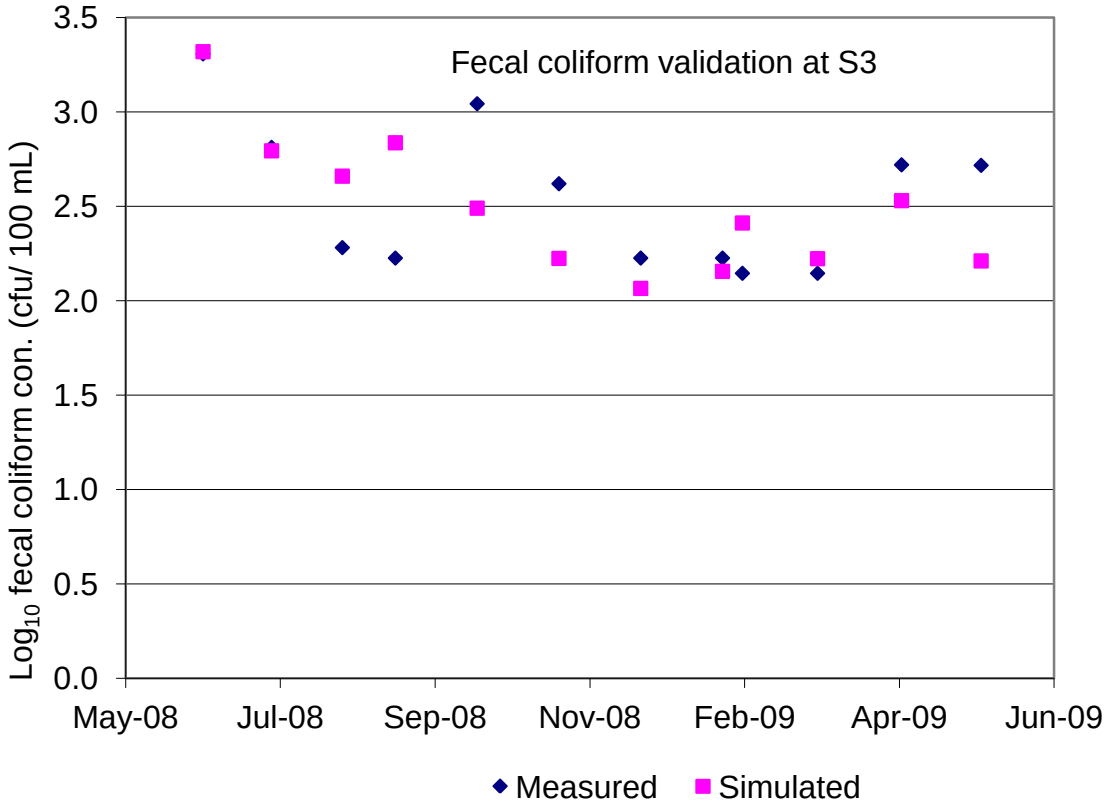

E. coli calibration at S3
Log10 E.coli con. (cfu/100 mL)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jul-07
Sep-07
Nov-07
Feb-08
Apr-08
Jun-08
Aug-08
Measured
Simulated

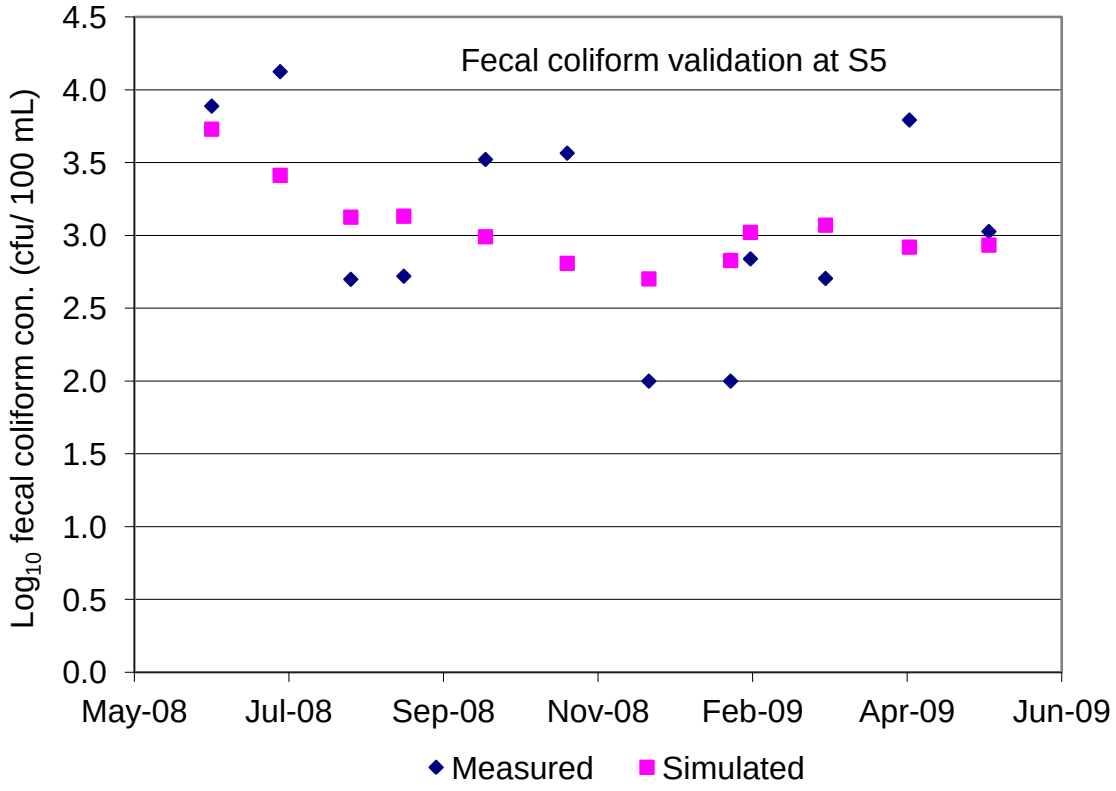

E. coli calibration at S8
Log10 E.coli con. (cfu/100 mL)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jun-07
Aug-07
Nov-07
Jan-08
Mar-08
Jun-08
Measured
Simulated

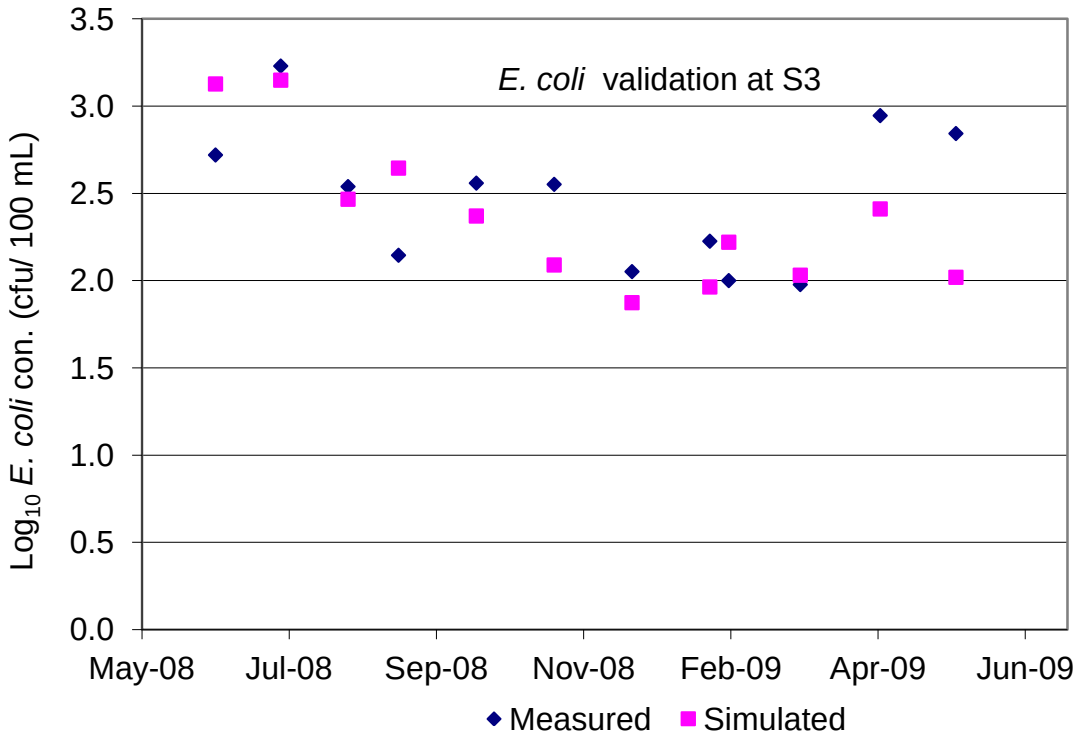

E. coli calibration at S7
Log10 E.coli con. (cfu/100 mL)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jun-07
Aug-07
Oct-07
Jan-08
Mar-08
May-08
Jul-08
Measured
Simulated

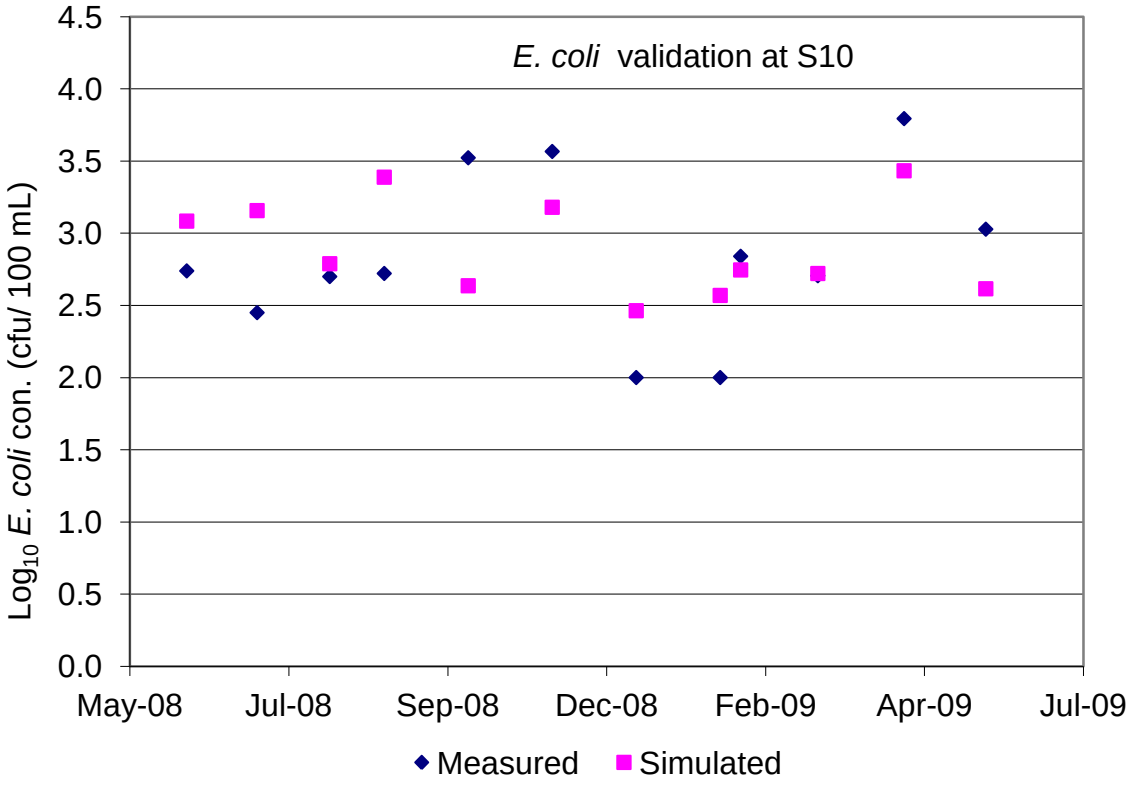

Fecal coliform validation at S8
Log10 fecal coliform con. (cfu/ 100 mL)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Dec-08
Feb-09
Apr-09
Jul-09
Measured
Simulated

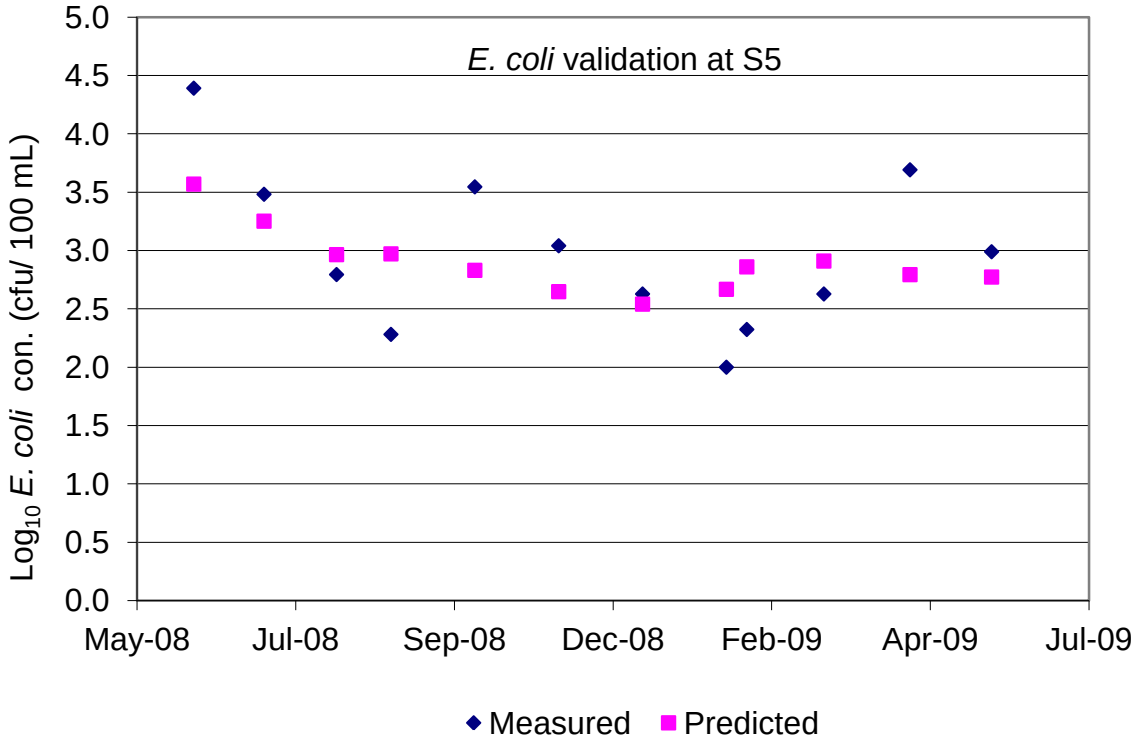

Fecal coliform validation at S10
Log10 fecal coliform con. (cfu/ 100 mL)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Dec-08
Feb-09
Apr-09
Jul-09
Measured
Simulated

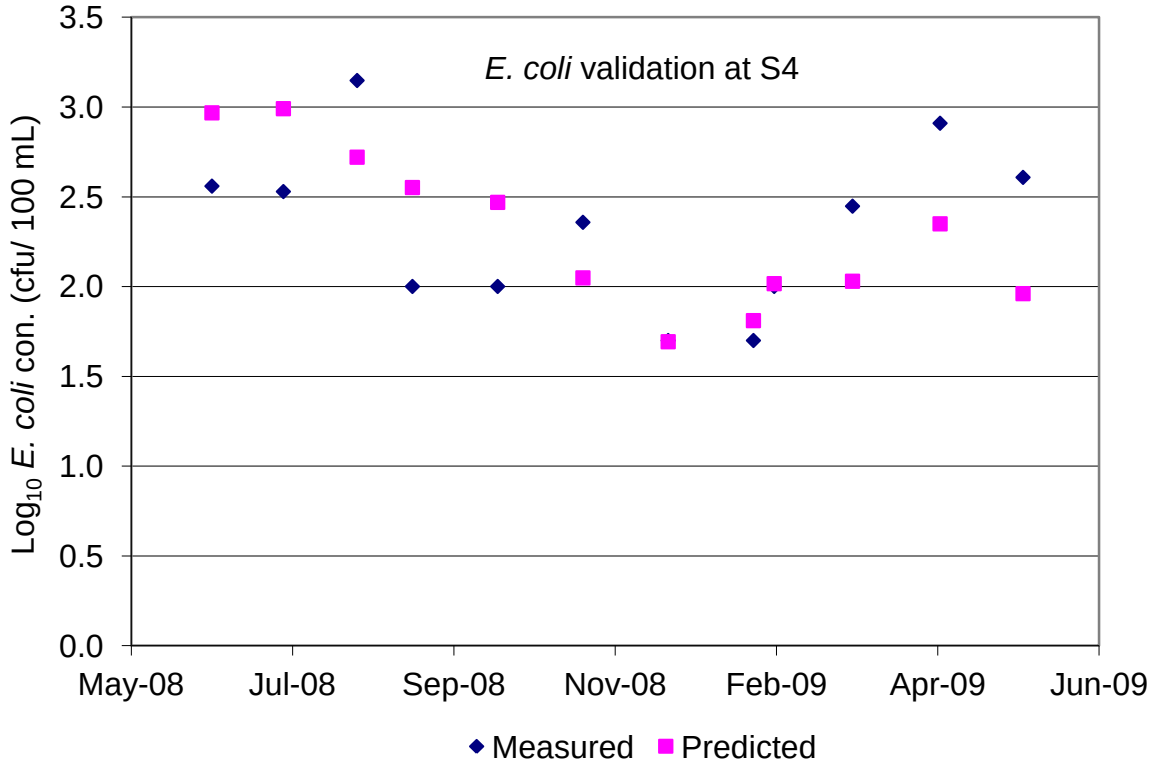

Fecal coliform validation at S3
Log10 fecal coliform con. (cfu/ 100 mL)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Nov-08
Feb-09
Apr-09
Jun-09
Measured
Simulated

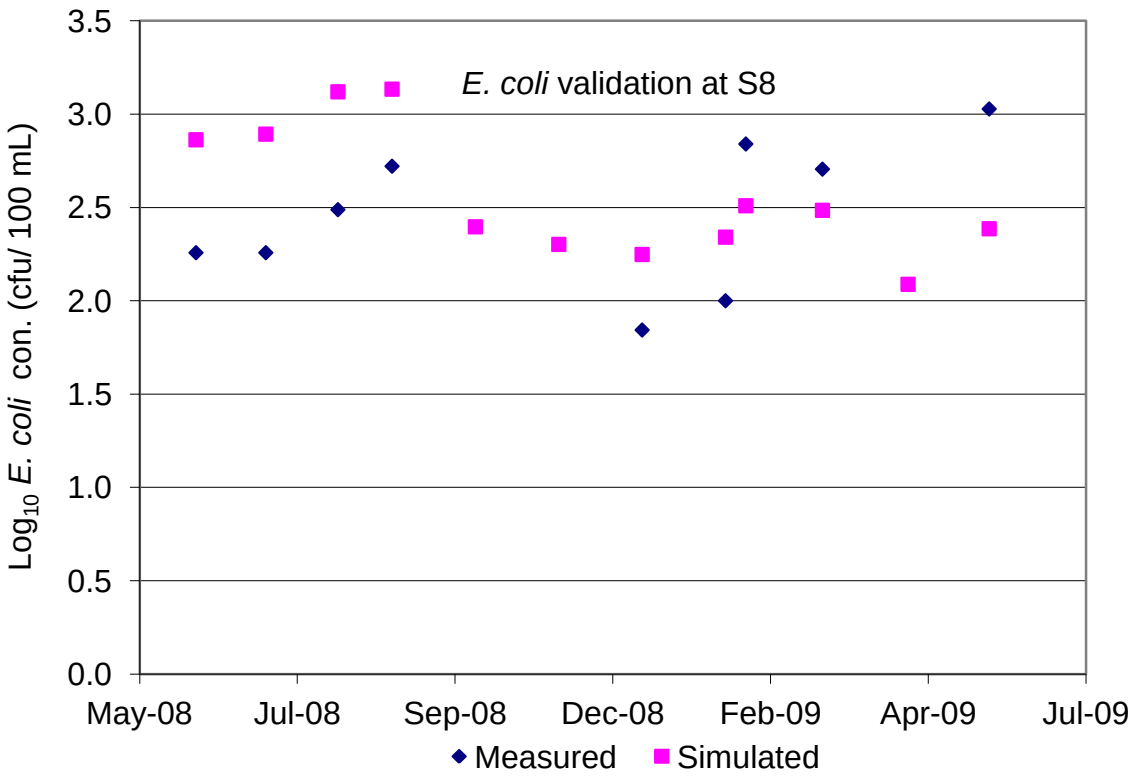

Fecal coliform validation at S5
Log10 fecal coliform con. (cfu/ 100 mL)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Nov-08
Feb-09
Apr-09
Jun-09
Measured
Simulated


E. coli validation at S3
Log10 E. coli con. (cfu/ 100 mL)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Nov-08
Feb-09
Apr-09
Jun-09
Measured
Simulated


E. coli validation at S10
Log10 E. coli con. (cfu/ 100 mL)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Dec-08
Feb-09
Apr-09
Jul-09
Measured
Simulated


E. coli validation at S5
Log10 E. coli con. (cfu/ 100 mL)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Dec-08
Feb-09
Apr-09
Jul-09
Measured
Predicted


E. coli validation at S4
Log10 E. coli con. (cfu/ 100 mL)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Nov-08
Feb-09
Apr-09
Jun-09
Measured
Predicted


E. coli validation at S8
Log10 E. coli con. (cfu/ 100 mL)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-08
Jul-08
Sep-08
Dec-08
Feb-09
Apr-09
Jul-09
Measured
Simulated

APPENDIX C: List of Collected Data from Sampling Stations

S1															
		Flow Rate	pH	Dissolved Oxygen	Temperature	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
Date	Station ID	cfs	S.U.	mg/L	deg C	col/100 ml	col/100 ml	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
6/8/2007	S1	0.71	6.34	5.33	27.50	5		0.50	0.13	0.01	4.79	5.43	0.03	0.04	5.00
6/15/2007	S1	1.02	6.20	7.43	18.00	10		0.50	0.05	0.01	4.76	5.32	0.03	0.04	6.00
6/20/2007	S1	0.64	5.99	6.68	20.30	60									
6/27/2007	S1	0.67	5.97	5.93	24.80	200									
6/28/2007	S1	0.81	6.20	5.66	24.30	280									
7/2/2007	S1	0.44	6.18	6.50	24.90	1,200		1.00	0.18	0.10	5.58	6.86	0.03	0.03	6.30
7/6/2007	S1	0.80	6.37	6.19	23.10	310	60								
7/11/2007	S1	0.68	5.56	7.09	25.00	30	30								
7/18/2007	S1	0.59	6.28	5.78	28.10	120	10	0.50	0.05	0.10	2.74	3.39	0.02	0.02	6.00
7/25/2007	S1	0.73	6.04	6.40	21.60	800	50								
7/26/2007	S1	0.59	7.27	7.04	22.60	200	200								
8/1/2007	S1	0.31	6.76	5.84	20.40	400	300	0.50	0.05	0.10	5.23	5.88	0.05	0.02	4.30
8/10/2007	S1	0.65	6.07	6.38	23.20	200	200								
8/16/2007	S1	0.53	6.47	6.60	23.90	100	400	0.50	0.05	0.10	5.54	6.19	0.01	0.03	5.70
8/22/2007	S1	0.59	5.99	7.53	18.30	300	100								
8/29/2007	S1	0.18	7.03	6.74	21.70	600	50								
9/13/2007	S1	0.27	5.83	7.55	19.40	200	50	0.50	0.05	0.10	5.20	5.85	0.01	0.02	4.70
9/26/2007	S1	0.34	6.47	6.07	23.50	50	50	0.50	0.05	0.01	4.82	5.38	0.01	0.01	3.00
10/10/2007	S1	0.41	6.07	6.69	21.00	2,700	3,500	0.50	0.80	0.01	4.11	5.42	0.03	0.03	4.70
10/10/2007	S1	0.36	5.93	6.78	20.20	1,300	900	0.50	0.05	0.01	4.18	4.74	0.03	0.02	3.30
10/11/2007	S1	0.29	6.23	8.31	14.80	900	2,400	0.50	0.05	0.10	4.41	5.06	0.03	0.03	2.00
10/24/2007	S1	0.32	6.13	6.32	18.00	2,400	1,300	0.50	0.05	0.10	4.47	5.12	0.01	0.04	11.50
10/24/2007	S1	0.57	6.00	6.47	17.40	1,500	1,200	0.50	0.05	0.10	4.54	5.19	0.01	0.05	12.50
10/24/2007	S1	0.40	6.17	6.59	19.50	2,700	500	0.50	0.05	0.10	4.16	4.81	0.01	0.03	5.00
11/7/2007	S1	0.27	6.30	8.70	10.70	100	50	1.26	0.05	0.10	4.83	6.24	0.03	0.02	1.00
12/12/2007	S1	0.28	6.03	7.99	11.20	50	50	0.50	0.05	0.10	4.43	5.08	0.03	0.02	1.00
12/20/2007	S1	0.41	6.22	9.60	6.70	10	5	0.50	0.05	0.10	4.90	5.55	0.01	0.02	3.00
1/9/2008	S1	0.58	6.20	8.35	13.60	50	50	0.50	0.05	0.01	4.40	4.96	0.03	0.03	6.00
1/25/2008	S1	0.43	6.17	11.89	2.40	50	50	0.50	0.05	0.01	5.59	6.15	0.03	0.03	2.70
2/8/2008	S1	0.64	6.24	11.20	8.40	50	50	0.50	0.10	0.01	4.16	4.77	0.03	0.02	3.30
2/27/2008	S1	0.57	5.75	10.60	6.50	50	50	0.70	0.05	0.01	5.28	6.04	0.03	0.02	2.00
3/6/2008	S1	0.53	5.97	9.36	11.10	50	50	0.30	0.05	0.01	4.94	5.30	0.03	0.16	3.00
3/13/2008	S1	0.77	5.92	8.68	10.30	50	50	0.50	0.05	0.10	5.16	5.81	0.03	0.03	3.50
4/11/2008	S1	0.52	6.22	9.80	18.20	50	100	0.50	0.05	0.01	4.10	4.66	0.03	0.03	8.40
4/24/2008	S1	0.52	6.34	7.80	22.10	200	50	0.50	0.05	0.10	4.61	5.26	0.01	0.02	4.00
5/7/2008	S1	0.54	6.26	6.49	27.20	50	50	0.50	0.05	0.10	4.53	5.18	0.03	0.03	9.50
5/28/2008	S1	0.70	6.09	7.86	16.80	100	200	0.50	0.05	0.01	4.56	5.12	0.03	0.04	4.70
6/12/2008	S1	0.67	7.15	5.98	25.00	50	50	0.50	0.10	0.01	4.62	5.23	0.03	0.04	8.00
6/27/2008	S1	0.54	6.44	5.40	28.10	50	50	0.50	0.05	0.03	4.76	5.34	0.04	0.09	6.40
7/11/2008	S1	0.57	6.00	6.36	23.40	300	100	0.50	0.10	0.01	5.09	5.70	0.06	0.03	6.00
7/30/2008	S1	0.47	5.83	6.74	22.30	100	50	0.50	0.10	0.10	4.90	5.60	0.03	0.03	5.50
8/13/2008	S1	0.41	6.50	5.95	23.20	100	50	0.50	0.05	0.10	4.81	5.46	0.03	0.02	5.00
8/28/2008	S1	0.37	6.70	6.89	19.80	50	50	0.50	0.05	0.10	5.08	5.73	0.03	0.02	2.80
9/11/2008	S1	0.48	6.36	7.17	20.40	100	100	0.50	0.10	0.05	4.70	5.35	0.03	0.01	8.00

9/26/2008	S1	0.65	7.32	6.34	15.90	50	50	1.01	0.05	0.01	4.84	5.91	0.03	0.06	4.00
10/9/2008	S1	0.59	6.17	7.34	19.30	100	200	1.08	0.05	0.10	4.92	6.15	0.03	0.02	2.00
10/31/2008	S1	0.65	5.80	7.55	11.40	50	50	0.50	0.05	0.01	4.71	5.27	0.03	0.01	2.40
11/19/2008	S1	0.35	6.45	9.63	6.20	50	50	0.50	0.05	0.10	4.47	5.12	0.03	0.01	2.00
11/25/2008	S1	0.59	6.18	7.76	7.90	100	50	0.50	0.05	0.01	3.28	3.84	0.01	0.03	1.00
12/5/2008	S1	0.45	6.25	9.24	6.50	100	50	0.50	0.05	0.01	4.71	5.27	0.05	0.01	1.00
12/17/2008	S1	1.43	5.94	9.10	6.70	100	700	0.50	0.05	0.01	2.63	3.19	0.03	0.07	20.00
1/22/2009	S1	0.97	6.23	9.87	6.90	50	50	0.50	0.05	0.10	5.47	6.12	0.03	0.01	1.00
1/30/2009	S1	0.81	6.00	10.93	3.90	50	50	0.50	0.05	0.01	4.70	5.26	0.39	0.02	1.00
2/19/2009	S1	0.87	5.78	9.57	7.80	50	50	0.50	0.05	0.01	4.89	5.45	0.03	0.01	2.00
2/26/2009	S1	0.68	5.45	10.19	7.60	50	50	0.50	0.05	0.01	5.20	5.76	0.01	0.02	3.60
3/13/2009	S1	0.60	6.17	10.73	8.20	50	50	0.50	0.10	0.01	5.12	5.73	0.19	0.02	1.00
3/24/2009	S1	0.40	6.07	10.92	7.90	50	50	0.50	0.05	0.10	5.29	5.94	0.03	0.02	2.40
4/8/2009	S1	0.68	6.43	10.35	9.10	50	50	1.77	0.05	0.01	4.88	6.71	0.03	0.03	3.00
4/23/2009	S1	0.67	6.14	9.26	14.50	100	50	0.50	0.05	0.10	4.55	5.20	0.03	0.02	2.80
5/7/2009	S1	1.94	6.23	7.77	17.20	1,200	1,400	0.50	0.05	0.01	2.85	3.41	0.03	0.13	12.50
5/20/2009	S1	0.61	6.51	7.19	21.30	100	50	0.50	0.05	0.10	4.72	5.37	0.03	0.02	3.60
6/3/2009	S1	0.54	6.19	6.96	21.00	50	1,000	0.50	0.05	0.10	4.10	4.75	0.03	0.03	4.80
6/16/2009	S1	0.63	6.23	7.39	18.50	500	200	1.42	0.05	0.10	4.41	5.98	0.01	0.03	5.00
6/17/2009	S1	0.58	6.68	7.75	18.50	700	700	0.50	0.10	0.01	4.51	5.12	0.03	0.03	8.50

S2

Date	Station ID	Flow Rate cfs	pH S.U.	Dissolved Oxygen mg/L	Temperature deg C	Fecal Coliform col/100 ml	*E. coli* col/100 ml	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen as N (mg/L)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	TN (mg/L)	Ortho Phosphate Dissolved (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
6/8/2007	S2	2.33	7.26	6.20	29.10	5		0.16	1.50	0.02	1.05	2.73	0.03	0.10	12.70
6/15/2007	S2	2.29	7.30	7.62	21.10	160		1.10	0.25	0.03	0.63	2.01	0.03	0.11	18.70
6/20/2007	S2	2.57	9.05	8.49	24.10	2,400									
6/27/2007	S2	2.39	8.66	6.71	30.40	110									
6/28/2007	S2	3.01	8.55	6.82	30.40	170									
7/2/2007	S2	1.94	7.86	7.70	24.60	1,500		1.26	1.10	0.10	0.25	2.71	0.03	0.10	15.30
7/6/2007	S2	6.34	8.79	8.09	26.30	70	30								
7/11/2007	S2	1.51	8.03	6.30	32.50	130	600								
7/18/2007	S2	1.19	8.38	5.35	28.90	600	420	2.63	0.14	0.10	0.25	3.12	0.01	0.14	18.50
7/25/2007	S2	1.13	7.96	4.47	29.50	50	50								
7/26/2007	S2	1.73	7.26	4.93	27.90	200	50								
8/1/2007	S2	1.58	8.38	4.62	28.70	1,100	1,200	1.79	0.18	0.10	0.25	2.32	0.01	0.03	16.00
8/10/2007	S2	2.55	8.53	5.06	28.00	100	100								
8/16/2007	S2	1.38	8.43	4.33	25.50	100	600	3.65	0.24	0.10	0.25	4.24	0.01	0.19	21.50
8/22/2007	S2	2.91	6.95	6.27	19.60	50	50								
8/29/2007	S2	1.56	8.70	4.53	26.50	100	50								
9/13/2007	S2	1.33	7.47	3.77	26.00	200	200	0.50	0.55	0.10	0.50	1.65	0.03	0.07	6.00
9/26/2007	S2	1.48	7.24	4.94	27.30	50	200	1.32	0.20	0.05	0.25	1.82	0.01	0.08	8.00
10/10/2007	S2	4.71	7.19	6.77	23.10	400	300	1.25	0.14	0.02	0.25	1.66	0.03	0.10	10.30
10/10/2007	S2	4.30	7.24	6.68	23.50	300	600	1.20	0.15	0.01	0.25	1.61	0.03	0.09	11.00
10/11/2007	S2	3.21	7.07	7.40	17.30	300	100	1.21	0.22	0.10	0.25	1.78	0.03	0.09	10.70
10/24/2007	S2	1.34	6.87	5.82	18.80	200	50	1.23	0.40	0.10	0.56	2.29	0.01	0.05	4.50
10/24/2007	S2	1.65	7.11	6.14	18.20	50	50	1.12	0.40	0.10	0.57	2.19	0.01	0.06	7.50
10/24/2007	S2	2.21	7.08	6.33	21.40	50	50	1.36	0.36	0.10	0.55	2.37	0.01	0.06	8.00

11/7/2007	S2	2.01	7.20	9.15	10.20	50	50	1.15	0.05	0.10	1.24	2.54	0.03	0.04	6.00
12/12/2007	S2	1.83	7.00	10.21	9.00	50	50	1.34	0.34	0.10	2.24	4.02	0.03	0.04	3.50
12/20/2007	S2	1.99	6.93	11.72	6.00	20	5	0.50	0.25	0.10	2.59	3.44	0.01	0.04	6.00
1/9/2008	S2	1.89	6.94	9.91	11.50	50	50	0.50	0.33	0.04	2.95	3.82	0.03	0.07	7.30
1/25/2008	S2	1.60	6.98	14.06	2.50	50	50	1.54	0.23	0.01	3.63	5.41	0.03	0.12	32.00
2/8/2008	S2	2.24	6.69	12.83	7.90	50	50	1.43	0.23	0.03	2.98	4.67	0.03	0.05	7.30
2/27/2008	S2	1.86	6.84	12.71	4.70	50	50	1.70	0.05	0.03	3.74	5.52	0.03	0.10	16.00
3/6/2008	S2	2.45	6.87	10.69	11.90	50	50	1.04	0.13	0.03	3.62	4.82	0.03	0.04	4.00
3/13/2008	S2	3.34	7.32	11.03	10.70	50	50	1.03	0.24	0.10	2.98	4.35	0.03	0.07	12.00
4/11/2008	S2	2.55	6.94	8.96	19.80	50	50	0.50	0.05	0.03	2.35	2.93	0.03	0.04	7.20
4/24/2008	S2	1.86	7.22	8.29	23.10	50	50	0.50	0.05	0.10	1.53	2.18	0.01	0.06	4.80
5/7/2008	S2	2.09	7.31	8.17	24.50	200	50	0.50	0.05	0.10	1.17	1.82	0.03	0.06	7.00
5/28/2008	S2	5.25	7.79	9.25	19.50	300	100	1.03	0.13	0.04	1.15	2.35	0.03	0.05	5.30
6/12/2008	S2	1.60	8.99	7.59	29.90	50	50	3.14	0.05	0.04	0.25	3.48	0.03	0.16	30.00
6/27/2008	S2	1.37	8.13	5.85	32.00	50	50	1.44	0.11	0.10	0.25	1.90	0.13	0.16	16.00
7/11/2008	S2	1.36	7.42	5.81	29.90	50	300	1.48	0.05	0.01	0.25	1.79	0.15	0.09	15.00
7/30/2008	S2	1.15	7.67	5.44	29.90	3,000	600	1.67	0.11	0.10	0.25	2.13	0.03	0.17	19.00
8/13/2008	S2	1.10	7.79	5.94	28.00	1,000	400	2.25	0.12	0.10	0.25	2.72	0.03	0.15	21.00
8/28/2008	S2	1.16	7.20	5.96	23.30	300	400	1.42	0.19	0.10	0.25	1.96	0.03	0.11	14.80
9/11/2008	S2	1.28	7.29	6.06	24.30	50	50	1.14	0.32	0.10	0.25	1.81	0.03	0.07	32.00
9/26/2008	S2	1.51	7.38	6.27	18.50	50	100	1.78	0.05	0.08	0.25	2.16	0.06	0.18	28.00
10/9/2008	S2	1.58	7.33	7.14	22.30	50	200	1.40	0.05	0.10	0.25	1.80	0.03	0.08	12.50
10/31/2008	S2	1.41	6.94	7.95	13.20	50	50	0.50	0.05	0.03	0.87	1.45	0.03	0.05	4.80
11/19/2008	S2	1.24	7.71	13.47	4.90	200	50	0.50	0.43	0.10	1.37	2.40	0.03	0.04	4.40
11/25/2008	S2	4.26	7.27	10.88	5.70	50	50	0.50	0.44	0.05	1.43	2.42	0.02	0.05	3.20
12/5/2008	S2	1.60	7.51	11.33	6.10	400	50	0.50	0.32	0.05	1.87	2.74	0.03	0.05	3.50
12/17/2008	S2	6.94	7.02	11.42	6.00	100	50	0.50	0.05	0.04	2.13	2.72	0.03	0.07	12.00
1/22/2009	S2	2.08	6.75	11.00	4.70	50	50	1.27	0.25	0.10	3.13	4.75	0.03	0.06	10.40
1/30/2009	S2	2.35	6.35	10.55	3.50	400	100	3.00	0.48	0.04	3.43	6.95	0.07	0.14	6.00
2/19/2009	S2	2.41	7.59	12.42	5.70	50	100	1.26	0.40	0.06	2.97	4.69	0.03	0.09	27.50
2/26/2009	S2	1.76	6.22	13.01	7.60	50	100	2.00	0.45	0.01	2.81	5.27	0.01	0.09	7.60
3/13/2009	S2	1.25	7.04	11.92	9.00	50	200	1.71	0.37	0.05	2.50	4.63	0.03	0.09	7.60
3/24/2009	S2	1.87	7.37	12.63	7.80	50	50	1.23	0.39	0.10	2.54	4.26	0.03	0.08	8.80
4/8/2009	S2	1.66	7.45	11.42	9.60	300	100	0.50	0.11	0.04	2.08	2.73	0.03	0.06	12.00
4/23/2009	S2	2.08	6.97	8.66	17.60	50	100	0.50	0.14	0.10	1.76	2.50	0.03	0.04	7.20
5/7/2009	S2	8.89	6.98	8.77	18.90	300	600	0.50	0.10	0.03	1.20	1.83	0.03	0.07	7.00
5/20/2009	S2	1.68	7.93	8.01	24.20	200	50	1.06	0.10	0.05	1.02	2.23	0.03	0.05	5.60
6/3/2009	S2	2.00	7.08	8.19	24.30	500	500	0.50	0.14	0.10	0.81	1.55	0.03	0.05	6.80
6/16/2009	S2	1.45	7.72	8.25	21.70	50	50	1.30	0.10	0.10	0.72	2.22	0.01	0.06	12.50
6/17/2009	S2	1.55	7.48	8.33	20.90	50	200	1.22	0.11	0.01	0.58	1.92	0.03	0.05	14.70

S3

Date	Station ID	Flow Rate cfs	pH S.U.	Dissolved Oxygen mg/L	Temperature deg C	Fecal Coliform col/100 ml	*E. coli* col/100 ml	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen as N (mg/L)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	TN (mg/L)	Ortho Phosphate Dissolved (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
6/8/2007	S3	3.84	6.87	5.87	24.60	5		1.17	0.10	0.03	1.87	3.17	0.03	0.09	10.30
6/15/2007	S3	3.86	7.14	7.67	19.50	120		0.50	0.05	0.03	1.68	2.26	0.03	0.11	16.30
6/20/2007	S3	4.36	8.35	7.30	23.30	430									
6/27/2007	S3	3.16	8.50	6.25	27.30	200									

6/28/2007	S3	3.70	8.63	6.80	26.70	330									
7/2/2007	S3	2.30	7.18	7.29	20.80	270		1.27	0.18	0.10	1.08	2.63	0.03	0.11	16.00
7/6/2007	S3	9.34	7.57	8.10	23.60	380	110								
7/11/2007	S3	2.32	7.73	4.25	29.40	120	20								
7/18/2007	S3	1.45	7.87	4.62	26.30	350	290	1.86	0.13	0.10	0.25	2.34	0.02	0.15	10.30
7/25/2007	S3	1.32	7.42	4.25	24.80	100	1,000								
7/26/2007	S3	2.05	7.43	5.12	25.20	800	1,200								
8/1/2007	S3	1.03	6.97	4.43	26.30	1,200	400	1.42	0.54	0.10	0.25	2.31	0.10	0.21	10.70
8/10/2007	S3	3.97	7.20	3.65	27.10	300	50								
8/16/2007	S3	1.87	7.07	3.15	26.20	100	2,000	1.93	0.49	0.10	0.25	2.77	0.05	0.12	1.00
8/22/2007	S3	4.97	7.06	6.49	18.50	100	100								
8/29/2007	S3	4.16	6.99	3.26	23.50	200	300								
9/13/2007	S3	1.01	7.34	8.94	20.70	600	100	0.50	0.33	0.10	2.33	3.26	0.03	0.10	3.30
9/26/2007	S3	1.25	7.17	5.03	25.30	300	400	1.38	0.18	0.03	0.75	2.34	0.05	0.08	12.00
10/10/2007	S3	8.14	6.90	5.93	22.50	14,000	13,000	1.64	0.43	0.01	0.58	2.66	0.03	0.15	21.70
10/10/2007	S3	6.30	6.92	5.83	22.60	19,000	9,000	1.19	0.27	0.01	0.57	2.04	0.03	0.12	27.30
10/11/2007	S3	6.04	7.18	7.40	17.80	1,900	900	1.01	0.30	0.10	0.90	2.31	0.03	0.12	15.30
10/24/2007	S3	2.29	6.47	6.69	19.60	3,700	2,100	1.23	0.95	0.10	1.38	3.66	0.02	0.10	12.00
10/24/2007	S3	2.71	6.72	6.64	19.60	5,300	3,600	1.78	0.51	0.10	1.33	3.72	0.01	0.08	12.00
10/24/2007	S3	2.58	6.86	6.76	20.00	3,400	1,600	1.42	0.51	0.10	1.38	3.41	0.01	0.08	3.50
11/7/2007	S3	2.24	7.27	10.27	8.90	200	200	0.50	0.26	0.10	1.99	2.85	0.03	0.05	3.00
12/12/2007	S3	3.14	6.93	10.42	10.40	50	50	1.06	0.12	0.10	2.89	4.17	0.03	0.06	5.00
12/20/2007	S3	3.29	6.97	12.78	4.30	70	180	0.50	0.13	0.10	2.71	3.44	0.03	0.06	7.30
1/9/2008	S3	4.37	7.55	10.30	11.30	50	50	0.50	0.11	0.02	3.92	4.55	0.03	0.06	8.00
1/25/2008	S3	3.65	7.10	13.87	0.30	50	50	0.50	0.05	0.01	3.88	4.44	0.03	0.05	3.30
2/8/2008	S3	4.21	6.72	13.42	6.80	50	50	0.50	0.05	0.01	1.63	2.19	0.03	0.06	6.70
2/27/2008	S3	5.70	7.02	13.01	4.60	50	100	1.30	0.05	0.01	4.06	5.42	0.03	0.03	8.50
3/6/2008	S3	5.84	6.81	11.94	9.80	100	50	0.90	0.05	0.01	4.10	5.06	0.03	0.06	7.00
3/13/2008	S3	5.70	6.91	10.69	9.90	50	50	1.01	0.05	0.10	2.94	4.10	0.03	0.06	8.70
4/11/2008	S3	4.49	7.04	9.62	19.50	50	200	0.50	0.05	0.01	2.57	3.13	0.03	0.04	11.20
4/24/2008	S3	4.03	6.92	7.94	21.30	100	200	1.00	0.22	0.10	2.25	3.57	0.01	0.06	7.20
5/7/2008	S3	3.23	6.94	8.39	19.90	300	200	0.50	0.18	0.10	2.17	2.95	0.03	0.06	8.50
5/28/2008	S3	9.61	7.10	8.85	18.30	1,200	600	1.66	0.05	0.03	1.88	3.62	0.03	0.16	20.00
6/12/2008	S3	2.65	7.14	5.39	26.50	800	300	1.51	0.16	0.04	1.11	2.82	0.03	0.08	10.00
6/27/2008	S3	2.27	7.10	3.58	26.90	100	18,000	1.27	0.43	0.01	0.60	2.31	0.01	0.10	6.80
7/11/2008	S3	2.52	7.16	3.99	27.20	100	700	1.65	0.25	0.09	0.25	2.24	0.03	0.11	6.50
7/30/2008	S3	1.76	7.25	5.10	26.70	5,000	7,000	1.17	0.13	0.10	0.25	1.65	0.03	0.11	9.00
8/13/2008	S3	1.81	7.22	6.17	23.30	3,000	9,000	1.71	0.11	0.10	0.25	2.17	0.03	0.11	12.00
8/28/2008	S3	0.85	7.10	5.51	22.20	50	50	3.13	0.15	0.10	0.25	3.63	0.03	0.16	17.20
9/11/2008	S3	3.12	7.17	6.80	21.80	300	100	1.55	0.15	0.10	0.03	1.83	0.03	0.10	10.00
9/26/2008	S3	1.52	7.07	7.20	18.30	400	400	1.29	0.45	0.04	0.92	2.70	0.03	0.10	16.00
10/9/2008	S3	2.41	7.00	6.55	21.70	200	100	1.69	0.10	0.10	1.18	3.07	0.03	0.09	12.50
10/31/2008	S3	2.01	7.10	10.13	9.30	50	50	1.07	0.05	0.03	1.54	2.69	0.03	0.07	8.40
11/19/2008	S3	2.95	7.57	12.31	3.20	200	700	0.50	0.25	0.10	1.72	2.57	0.03	0.06	3.60
11/25/2008	S3	10.28	7.39	11.07	5.40	700	1,800	0.50	0.25	0.03	2.04	2.82	0.02	0.05	6.80
12/5/2008	S3	2.50	7.41	12.36	4.00	50	50	0.50	0.18	0.03	2.49	3.20	0.03	0.06	6.50
12/17/2008	S3	19.06	6.72	11.77	5.10	1,800	2,700	0.50	0.05	0.03	2.22	2.80	0.06	0.15	18.00
1/22/2009	S3	3.46	6.65	13.42	2.70	50	100	0.50	0.15	0.10	4.25	5.00	0.03	0.05	7.60
1/30/2009	S3	5.86	6.43	13.21	1.50	300	300	1.79	0.15	0.01	4.10	6.05	0.06	0.05	2.00

2/19/2009	S3	5.96	6.94	12.41	5.10	50	50	0.50	0.11	0.03	3.69	4.33	0.03	0.04	8.00
2/26/2009	S3	3.79	6.37	12.97	8.30	300	300	0.50	0.05	0.03	3.82	4.40	0.01	0.03	3.60
3/13/2009	S3	3.43	7.20	13.48	6.30	50	50	1.05	0.05	0.03	2.50	3.63	0.03	0.06	11.20
3/24/2009	S3	2.65	7.35	12.60	6.70	100	200	1.26	0.05	0.10	3.44	4.85	0.03	0.07	14.00
4/8/2009	S3	4.56	7.16	11.32	10.20	50	100	0.50	0.05	0.01	2.37	2.93	0.03	0.08	20.50
4/23/2009	S3	7.43	7.09	10.42	12.30	200	200	0.50	0.05	0.10	1.91	2.56	0.03	0.08	18.00
5/7/2009	S3	26.34	6.37	8.02	17.90	5,900	5,000	1.15	0.27	0.04	1.50	2.96	0.03	0.16	20.00
5/20/2009	S3	3.34	6.87	7.84	19.10	200	100	1.09	0.14	0.06	2.08	3.37	0.03	0.08	9.60
6/3/2009	S3	3.43	6.75	7.66	22.20	800	300	0.50	0.05	0.10	1.55	2.20	0.03	0.06	10.00
6/16/2009	S3	3.59	7.00	7.40	20.90	1,100	1,000	1.37	0.13	0.10	1.53	3.13	0.01	0.08	10.50
6/17/2009	S3	3.25	7.26	7.77	19.80	400	500	0.50	0.12	0.03	1.60	2.25	0.03	0.07	9.30
S4															
		Flow Rate	pH	Dissolved Oxygen	Temperature	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
Date	Station ID	cfs	S.U.	mg/L	deg C	col/100 ml	col/100 ml	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
6/8/2007	S4	0.75	6.82	5.76	28.10	5		1.05	1.15	0.05	4.70	6.95	0.03	0.04	2.67
6/15/2007	S4	0.68	6.94	7.71	21.20	150		0.50	0.05	0.05	5.35	5.95	0.03	0.04	3.70
6/20/2007	S4	1.112	8.07	9.08	22.20	230									
6/27/2007	S4	0.338	7.12	7.01	27.80	200									
6/28/2007	S4	0.464	7.49	7.14	28.00	440									
7/2/2007	S4	0.38	6.51	6.78	26.50	900		1.04	0.12	0.10	5.36	6.62	0.03	0.03	4.00
7/6/2007	S4	0.89	7.03	7.70	24.60	360	5								
7/11/2007	S4	0.34	5.93	7.03	30.20	520	5								
7/18/2007	S4	0.32	6.66	4.77	28.00	600	600	1.29	0.20	0.14	2.45	4.08	0.01	0.03	1.00
7/25/2007	S4	0.37	6.85	6.00	26.20	400	3,800								
7/26/2007	S4	0.35	7.26	6.33	26.10	400	500								
8/1/2007	S4	0.35	7.13	5.46	27.7	5,700	5,100	1.06	0.19	0.10	3.18	4.53	0.02	0.06	4.70
8/10/2007	S4	0.47	6.95	6.25	27.20	300	100								
8/16/2007	S4	0.19	6.95	6.20	25.00	50	50	1.23	0.11	0.10	2.72	4.16	0.01	0.07	4.00
8/22/2007	S4	0.58	6.75	7.54	18.50	500	50								
8/29/2007	S4	0.38	6.81	6.19	25.20	200	50								
9/13/2007	S4	0.23	6.88	5.71	25.30	1,200	50	0.50	0.31	0.10	3.01	3.92	0.01	0.11	15.30
9/26/2007	S4	0.25	6.93	4.99	26.90	60,000	200,000	1.48	0.05	0.02	3.56	5.11	0.01	0.04	9.30
10/10/2007	S4	0.76	6.82	6.88	22.30	5,400	5,600	1.02	0.14	0.03	3.25	4.44	0.03	0.08	16.00
10/10/2007	S4	0.74	6.87	6.96	24.50	7,000	9,000	1.19	0.16	0.03	3.26	4.64	0.03	0.08	10.50
10/11/2007	S4	0.65	6.94	7.49	16.60	4,200	3,100	1.09	0.16	0.10	3.44	4.79	0.03	0.07	12.70
10/24/2007	S4	0.21	6.49	6.15	19.20	2,000	400	1.29	0.05	0.10	4.46	5.90	0.01	0.04	6.00
10/24/2007	S4	0.33	6.75	7.36	18.30	6,000	8,000	0.50	0.05	0.10	4.35	5.00	0.01	0.06	14.00
10/24/2007	S4	1.08	7.10	7.90	21.60	5,700	3,400	1.00	0.05	0.10	4.53	5.68	0.01	0.04	12.00
11/7/2007	S4	0.38	7.20	10.23	10.30	300	200	1.24	0.05	0.10	4.57	5.96	0.03	0.05	9.33
12/12/2007	S4	0.38	6.44	10.39	11.10	50	50	1.36	0.28	0.10	2.26	4.00	0.03	0.04	3.50
12/20/2007	S4	0.73	7.05	11.35	5.60	50	5	0.50	0.05	0.10	4.21	4.86	0.03	0.09	7.00
1/9/2008	S4	0.732	6.94	9.22	13.20	50	50	0.50	0.05	0.01	4.76	5.32	0.03	0.04	4.00
1/25/2008	S4	0.691	6.56	13.82	3.50	50	50	0.50	0.05	0.01	5.58	6.14	0.03	0.04	3.30
2/8/2008	S4	0.787	6.43	13.21	7.50	50	50	1.17	0.05	0.01	4.58	5.81	0.03	0.04	10.00
2/27/2008	S4	0.57	6.67	13.75	4.70	50	100	0.65	0.05	0.01	5.53	6.24	0.03	0.03	3.00
3/6/2008	S4	0.64	6.67	11.23	13.00	50	50	1.15	0.05	0.01	5.41	6.62	0.03	0.03	4.00
3/13/2008	S4	1.05	6.48	10.17	11.20	200	50	0.50	0.10	0.10	4.01	4.71	0.03	0.07	6.50

4/11/2008	S4	0.97	6.74	9.88	20.20	50	1,000	0.50	0.05	0.01	4.75	5.31	0.03	0.03	1.00
4/24/2008	S4	0.46	7.13	8.18	25.40	100	50	1.06	0.05	0.10	5.17	6.38	0.01	0.02	1.00
5/7/2008	S4	0.36	6.89	7.15	26.10	50	100	0.50	0.05	0.10	4.89	5.54	0.03	0.03	4.50
5/28/2008	S4	0.84	6.95	8.63	20.4	100	200	1.20	0.05	0.03	5.04	6.32	0.03	0.03	3.30
6/12/2008	S4	0.69	7.44	6.81	25.10	50	100	3.15	0.05	0.03	0.25	3.48	0.03	0.17	26.00
6/27/2008	S4	0.36	6.97	6.12	26.40	100	50	1.42	0.11	0.08	0.25	1.86	0.06	0.12	19.20
7/11/2008	S4	0.16	6.91	5.38	32.60	200	100	1.29	0.10	0.10	3.29	4.78	0.11	0.04	4.50
7/30/2008	S4	0.31	6.75	5.26	29.60	700	400	1.20	0.14	0.10	0.25	1.69	0.03	0.09	7.00
8/13/2008	S4	0.37	6.89	5.93	27.50	600	100	1.26	0.05	0.10	2.08	3.49	0.03	0.08	4.50
8/28/2008	S4	0.14	7.12	5.49	22.10	200	1,000	1.16	0.19	0.10	2.29	3.74	0.03	0.09	3.20
9/11/2008	S4	0.29	6.74	5.83	23.70	1,000	700	1.44	0.15	0.10	2.00	3.69	0.03	0.10	4.00
9/26/2008	S4	0.33	7.33	5.65	17.90	2,000	1,000	0.50	0.05	0.04	3.27	3.86	0.06	0.11	4.00
10/9/2008	S4	0.32	7.06	7.08	22.20	100	50	0.50	0.05	0.10	3.97	4.62	0.03	0.04	2.50
10/31/2008	S4	0.28	7.16	9.96	12.10	50	50	1.32	0.33	0.03	0.87	2.55	0.03	0.04	4.00
11/19/2008	S4	0.32	7.51	11.63	5.70	100	50	0.50	0.32	0.10	1.41	2.33	0.03	0.04	2.80
11/25/2008	S4	0.77	7.22	10.71	5.60	50	50	0.50	0.45	0.05	1.43	2.43	0.01	0.05	4.40
12/5/2008	S4	0.25	7.24	11.72	6.70	50	50	1.10	0.39	0.05	1.91	3.45	0.03	0.05	4.00
12/17/2008	S4	1.26	6.41	11.33	5.80	600	50	0.50	0.05	0.04	2.15	2.74	0.03	0.07	18.00
1/22/2009	S4	0.98	7.34	12.78	3.90	50	50	0.50	0.05	0.10	7.16	7.81	0.03	0.03	9.60
1/30/2009	S4	0.87	6.01	12.82	2.40	50	100	1.75	0.14	0.01	4.91	6.81	0.07	0.05	2.00
2/19/2009	S4	0.90	7.32	11.96	4.90	50	100	1.57	0.39	0.06	3.05	5.07	0.03	0.08	11.50
2/26/2009	S4	0.53	5.84	12.90	7.90	50	100	0.50	0.05	0.01	6.30	6.86	0.01	0.02	2.40
3/13/2009	S4	0.59	6.71	11.35	9.10	50	50	1.13	0.05	0.01	5.54	6.73	0.03	0.03	2.00
3/24/2009	S4	0.33	7.27	12.01	7.4	50	50	0.50	0.38	0.10	2.59	3.57	0.03	0.08	10.00
4/8/2009	S4	0.72	6.82	11.49	9.90	200	100	1.05	0.05	0.01	3.67	4.78	0.03	0.06	9.40
4/23/2009	S4	1.04	6.83	10.64	14.60	400	400	0.50	0.05	0.10	2.63	3.28	0.03	0.09	6.80
5/7/2009	S4	5.23	6.06	8.03	18.60	17,000	21,000	1.59	0.14	0.03	1.67	3.43	0.14	0.30	29.50
5/20/2009	S4	0.36	6.79	7.65	26.60	100	900	1.16	0.13	0.05	4.87	6.21	0.03	0.04	4.00
6/3/2009	S4	0.38	6.54	6.78	24.20	1,000	1,500	1.08	0.05	0.10	4.52	5.75	0.03	0.03	6.00
6/16/2009	S4	0.40	6.60	7.89	20.70	900	700	1.65	0.17	0.10	3.35	5.27	0.01	0.07	10.70
6/17/2009	S4	0.41	6.71	7.74	20.60	100	1,000	1.13	0.05	0.01	0.58	1.77	0.03	0.05	11.00
S5															
		Flow Rate	pH	Dissolved Oxygen	Temperature	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
Date	Station ID	cfs	S.U.	mg/L	deg C	col/100 ml	col/100 ml	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
6/8/2007	S5	0.10	6.10	6.49	29.10	5		1.76	0.16	0.05	8.73	10.70	0.25	0.19	24.30
6/15/2007	S5	0.27	6.11	8.17	20.70	900		2.18	0.25	0.04	8.87	11.34	0.25	0.47	113.00
6/20/2007	S5	0.451	5.93	7.77	21.00	900									
6/27/2007	S5	0.346	5.96	6.25	25.50	1,000									
6/28/2007	S5	0.304	6.03	3.04	25.40	1,500									
7/2/2007	S5	0.35	5.58	7.57	22.00	5		1.30	0.12	0.10	9.55	11.07	0.03	0.06	3.30
7/6/2007	S5	0.41	5.92	6.91	24.50	600	5								
7/11/2007	S5	0.27	5.40	6.98	26.40	600	600								
7/18/2007	S5	0.27	6.03	6.42	25.90	600	600	1.81	0.18	0.10	8.77	10.86	0.01	0.07	8.70
7/25/2007	S5	0.27	5.98	7.73	24.30	1,500	1,000								
7/26/2007	S5	0.27	7.27	7.53	23.80	1,600	3,600								
8/1/2007	S5	0.15	6.20	5.72	25.10	500	200	1.89	0.42	0.10	9.27	11.68	0.04	0.22	47.00
8/10/2007	S5	0.26	5.94	7.38	24.50	50	100								

8/16/2007	S5	0.22	5.94	7.34	23.70	200	300	1.58	0.18	0.10	9.89	11.75	0.02	0.19	31.50
8/22/2007	S5	0.43	5.98	8.16	18.00	4,400	800								
8/29/2007	S5	0.17	5.89	8.23	23.80	5,800	100								
9/13/2007	S5	0.14	6.00	8.38	23.60	18,000	8,100	1.15	0.05	0.10	9.76	11.06	0.03	0.06	13.30
9/26/2007	S5	0.10	6.00	5.08	26.40	2,300	1,300	2.92	0.19	0.04	9.25	12.40	0.01	0.19	35.00
10/10/2007	S5	0.39	5.83	6.80	21.40	12,000	43,000	2.25	0.27	0.03	7.61	10.16	0.08	0.14	15.00
10/10/2007	S5	0.23	6.02	8.15	23.20	8,000	15,000	1.50	0.13	0.02	7.75	9.40	0.06	0.14	20.70
10/11/2007	S5	0.23	6.16	7.49	16.60	16,000	16,800	1.26	0.15	0.10	8.01	9.52	0.07	0.12	10.00
10/24/2007	S5	0.49	6.42	8.36	17.40	6,000	8,000	1.16	0.05	0.10	8.03	9.34	0.05	0.13	17.50
10/24/2007	S5	0.49	6.31	8.19	17.53	6,000	8,000	3.03	0.36	0.10	9.51	13.00	0.65	0.44	141.00
10/24/2007	S5	0.44	6.30	10.70	18.67	6,000	8,000	2.20	0.38	0.10	7.31	9.99	0.22	0.40	40.50
11/7/2007	S5	0.175	6.38	10.42	10.90	39,000	28,000	2.16	0.19	0.10	9.39	11.84	0.03	0.48	214.00
12/12/2007	S5	0.22	6.25	10.69	11.30	50	50	0.50	0.05	0.10	9.45	10.10	0.03	0.04	4.00
12/20/2007	S5	0.18	6.36	10.92	7.90	320	5	1.32	0.12	0.10	9.88	11.42	0.03	0.14	39.00
1/9/2008	S5	0.242	6.25	10.04	14.30	50	1,200	1.38	0.14	0.02	8.92	10.46	0.03	0.11	25.30
1/25/2008	S5	0.196	6.11	14.55	3.00	50	50	0.50	0.05	0.01	10.70	11.26	0.08	0.04	3.30
2/8/2008	S5	0.267	6.26	12.85	7.30	50	50	1.32	0.05	0.01	8.71	10.09	0.03	0.04	1.00
2/27/2008	S5	0.19	6.07	11.96	5.70	50	50	0.65	0.05	0.01	8.85	9.56	0.03	0.04	4.00
3/6/2008	S5	0.22	6.40	11.25	11.90	100	50	1.18	0.10	0.01	8.56	9.85	0.03	0.06	7.00
3/13/2008	S5	0.23	6.65	10.16	10.70	50	50	0.50	0.05	0.10	8.35	9.00	0.03	0.05	4.50
4/11/2008	S5	0.19	6.08	12.49	17.50	2,000	600	0.50	0.05	0.01	7.71	8.27	0.03	0.03	1.00
4/24/2008	S5	0.14	6.11	6.12	19.80	900	5,000	1.33	0.05	0.10	9.04	10.52	0.01	0.08	15.60
5/7/2008	S5	0.16	6.22	9.79	22.00	5,000	9,000	0.50	0.05	0.10	9.40	10.05	0.03	0.06	10.00
5/28/2008	S5	0.32	6.35	9.64	18.40	7,000	17,000	1.17	0.05	0.03	8.57	9.82	0.03	0.10	5.30
6/12/2008	S5	0.14	5.86	6.63	24.30	32,000	36,000	1.99	0.40	0.06	8.55	11.00	0.03	0.14	19.00
6/27/2008	S5	0.10	7.17	5.33	28.90	50	50	1.47	0.11	0.05	0.25	1.88	0.01	0.13	20.40
7/11/2008	S5	0.08	6.03	9.14	26.40	34,000	1,900	1.41	0.12	0.05	9.98	11.56	0.03	0.10	27.50
7/30/2008	S5	0.12	5.88	7.11	25.50	18,000	41,000	3.92	0.36	0.10	9.82	14.20	0.03	0.45	105.00
8/13/2008	S5	0.12	6.04	8.67	22.60	11,000	32,000	1.51	0.10	0.10	9.91	11.62	0.03	0.07	11.50
8/28/2008	S5	0.15	6.33	9.78	20.30	1,000	6,000	0.50	0.05	0.10	10.20	10.85	0.03	0.05	4.00
9/11/2008	S5	0.21	5.98	9.25	20.80	3,000	2,000	0.50	0.05	0.10	9.40	10.05	0.03	0.05	6.00
9/26/2008	S5	0.15	7.13	6.69	17.30	1,200	5,000	0.50	0.05	0.03	9.91	10.49	0.03	0.07	8.70
10/9/2008	S5	0.17	5.90	9.73	20.70	29,000	38,000	1.83	0.24	0.10	9.96	12.13	0.59	0.37	68.00
10/31/2008	S5	0.17	6.04	10.12	13.10	50	15,000	2.43	0.03	0.04	9.84	12.34	0.03	0.24	44.80
11/19/2008	S5	0.21	6.91	12.74	6.50	900	10,000	0.50	0.12	0.10	8.99	9.71	0.03	0.07	7.60
11/25/2008	S5	0.35	6.27	10.86	7.20	50	50	1.20	0.25	0.03	5.96	7.44	0.12	0.22	31.20
12/5/2008	S5	0.22	6.50	12.70	6.20	800	1,400	0.50	0.05	0.02	8.97	9.54	0.03	0.06	12.00
12/17/2008	S5	0.69	6.28	11.40	6.10	4,700	4,200	1.12	0.24	0.03	4.23	5.62	0.20	0.36	50.00
1/22/2009	S5	0.21	5.99	11.26	5.00	50	100	0.50	0.05	0.10	9.70	10.35	0.03	0.03	4.00
1/30/2009	S5	0.32	5.70	11.72	3.10	200	200	1.65	0.19	0.01	7.75	9.60	0.03	0.09	1.00
2/19/2009	S5	0.29	5.84	12.12	6.50	50	50	0.50	0.05	0.01	8.52	9.08	0.03	0.02	2.00
2/26/2009	S5	0.22	5.56	12.36	7.90	50	50	0.50	0.05	0.01	8.40	8.96	0.01	0.02	3.60
3/13/2009	S5	0.21	6.26	12.16	7.40	50	50	0.50	0.05	0.01	9.23	9.79	0.03	0.02	1.00
3/24/2009	S5	0.19	5.95	11.82	8.90	50	50	1.08	0.05	0.10	9.43	10.66	0.03	0.03	4.80
4/8/2009	S5	0.25	7.10	10.24	11.70	3,900	3,600	3.99	0.11	0.03	8.82	12.95	0.03	0.97	506.00
4/23/2009	S5	0.36	6.52	10.23	13.00	3,000	400	0.50	0.05	0.10	7.33	7.98	0.03	0.06	4.00
5/7/2009	S5	0.94	6.84	7.89	18.40	6,000	60,000	3.76	0.65	0.04	3.90	8.35	0.22	0.58	106.00
5/20/2009	S5	0.26	5.73	9.77	20.40	3,700	5,100	1.08	0.05	0.03	8.66	9.82	0.03	0.05	2.40
6/3/2009	S5	0.23	5.82	9.10	20.60	11,000	6,000	1.01	0.05	0.10	8.17	9.33	0.03	0.06	2.80

6/16/2009	S5	0.23	6.06	9.62	18.20	3,400	2,600	1.22	0.05	0.10	8.03	9.40	0.03	0.52	5.50
6/17/2009	S5	0.24	6.54	9.84	18.70	2,500	2,500	1.25	0.05	0.01	8.88	10.19	0.03	0.04	2.50
S6															
		Flow Rate	pH	Dissolved Oxygen	Temperature	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
Date	Station ID	cfs	S.U.	mg/L	deg C	col/100 ml	col/100 ml	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
6/8/2007	S6	1.19	7.18	6.85	23.60	5		1.26	0.05	0.02	7.82	9.15	0.03	0.03	1.00
6/15/2007	S6	1.06	7.18	8.60	18.40	360		1.42	0.05	0.01	7.80	9.28	0.03	0.03	2.70
6/20/2007	S6	1.06	6.89	8.15	20.30	180									
6/27/2007	S6	0.89	6.57	7.42	23.30	320									
6/28/2007	S6	0.74	6.76	7.48	23.80	1,200									
7/2/2007	S6	0.79	6.80	8.60	19.30	700		0.91	0.14	0.10	8.75	9.90	0.03	0.03	2.30
7/6/2007	S6	1.37	6.92	7.62	22.60	140	5								
7/11/2007	S6	0.87	6.13	8.54	24.60	600	600								
7/18/2007	S6	0.77	7.06	6.71	24.30	600	600	0.50	0.05	0.10	7.90	8.55	0.01	0.04	3.70
7/25/2007	S6	0.78	6.93	7.40	23.30	5,800	400								
7/26/2007	S6	0.78	7.27	7.53	23.10	400	800								
8/1/2007	S6	0.74	6.76	7.50	21.70	1,100	400	1.08	0.05	0.10	8.14	9.37	0.01	0.06	4.00
8/10/2007	S6	0.73	6.73	7.19	23.80	1,400	1,800								
8/16/2007	S6	0.65	6.89	7.33	23.70	2,300	50	0.50	0.05	0.10	7.54	8.19	0.01	0.04	4.50
8/22/2007	S6	0.88	6.93	8.11	18.10	1,200	900								
8/29/2007	S6	0.70	6.84	7.46	22.40	800	600								
9/13/2007	S6	0.52	7.13	7.30	23.40	800	700	0.50	0.05	0.10	8.55	9.20	0.03	0.03	1.00
9/26/2007	S6	0.54	7.25	6.13	24.10	500	200	0.50	0.05	0.02	8.32	8.89	0.01	0.03	10.70
10/10/2007	S6	1.02	7.34	7.55	19.30	8,000	27,000	1.19	0.13	0.03	5.02	6.37	0.12	0.18	7.00
10/10/2007	S6	0.89	6.64	7.34	21.80	9,000	38,000	0.50	0.05	0.01	5.60	6.16	0.08	0.12	9.70
10/11/2007	S6	1.25	7.04	8.34	16.30	5,400	49,000	0.50	0.05	0.10	5.14	5.79	0.13	0.18	8.00
10/24/2007	S6	0.98	6.98	9.08	17.90	3,400	2,400	0.50	0.05	0.10	7.39	8.04	0.02	0.06	11.50
10/24/2007	S6	0.94	7.02	8.64	17.93	6,000	4,800	1.05	0.05	0.10	8.11	9.31	0.02	0.07	13.50
10/24/2007	S6	1.42	6.86	9.33	18.30	6,000	8,000	1.63	0.05	0.10	8.13	9.91	0.08	0.07	14.50
11/7/2007	S6	0.76	7.31	10.97	9.30	100	300	0.50	0.05	0.10	7.89	8.54	0.03	0.01	1.00
12/12/2007	S6	1.23	6.97	10.42	9.40	50	50	1.01	0.05	0.10	7.23	8.39	0.03	0.03	1.00
12/20/2007	S6	0.99	6.98	11.82	6.80	20	40	0.50	0.05	0.10	7.71	8.36	0.01	0.03	2.50
1/9/2008	S6	1.03	7.10	9.54	13.60	600	200	0.50	0.05	0.01	7.36	7.92	0.03	0.04	4.00
1/25/2008	S6	0.90	7.11	14.37	1.10	50	50	0.50	0.05	0.01	7.95	8.51	0.03	0.03	1.00
2/8/2008	S6	1.20	6.59	12.94	6.80	50	50	0.50	0.05	0.01	5.10	5.66	0.03	0.03	2.70
2/27/2008	S6	1.60	6.77	12.17	4.90	100	50	0.60	0.05	0.01	6.48	7.14	0.03	0.03	3.50
3/6/2008	S6	1.45	6.70	10.84	11.50	200	50	0.78	0.11	0.01	6.75	7.65	0.03	0.03	5.00
3/13/2008	S6	1.47	6.84	10.01	9.80	50	50	0.50	0.05	0.10	6.67	7.32	0.03	0.04	4.70
4/11/2008	S6	1.07	6.80	10.62	17.10	50	50	0.50	0.05	0.01	5.93	6.49	0.03	0.05	3.60
4/24/2008	S6	0.75	6.99	9.33	19.40	200	500	1.02	0.05	0.10	7.20	8.37	0.01	0.01	1.00
5/7/2008	S6	0.60	6.94	8.17	22.30	100	200	0.50	0.05	0.10	8.05	8.70	0.03	0.03	1.00
5/28/2008	S6	1.48	6.87	7.79	20.10	14,000	69,000	1.62	0.05	0.02	5.75	7.44	0.03	0.12	6.00
6/12/2008	S6	0.59	6.94	7.83	23.70	11,000	10,000	2.15	0.05	0.05	7.49	9.74	0.03	0.05	8.00
6/27/2008	S6	0.54	7.09	7.48	24.90	900	8,000	0.50	0.05	0.02	8.29	8.86	0.01	0.06	10.00
7/11/2008	S6	0.51	7.11	6.92	26.30	1,400	23,000	1.28	0.05	0.01	8.76	10.10	0.03	0.04	5.50
7/30/2008	S6	0.64	6.95	7.36	24.60	5,000	2,000	1.07	0.05	0.10	8.22	9.44	0.03	0.06	8.00
8/13/2008	S6	0.50	7.12	7.91	21.70	3,000	3,000	1.25	0.05	0.10	8.18	9.58	0.03	0.04	4.00

8/28/2008	S6	0.39	7.27	8.32	20.40	900	1,500	0.50	0.05	0.10	8.69	9.34	0.03	0.05	6.40
9/11/2008	S6	0.40	8.03	7.02	20.10	2,900	3,000	1.04	0.05	0.10	7.50	8.69	0.03	0.05	8.00
9/26/2008	S6	0.28	7.04	8.95	16.20	2,000	200	1.02	0.05	0.01	8.01	9.09	0.11	0.13	7.30
10/9/2008	S6	0.44	7.08	7.73	20.50	800	1,500	1.22	0.05	0.10	8.36	9.73	0.03	0.05	5.20
10/31/2008	S6	0.38	7.05	9.04	12.60	50	50	1.04	0.26	0.02	7.96	9.28	0.03	0.04	4.40
11/19/2008	S6	0.70	7.34	11.56	6.30	500	100	0.50	0.05	0.10	6.90	7.55	0.03	0.02	1.00
11/25/2008	S6	1.60	6.82	10.80	6.50	9,000	14,000	1.12	0.15	0.03	3.79	5.09	0.11	0.18	8.00
12/5/2008	S6	0.75	7.37	13.03	4.80	600	500	0.50	0.05	0.01	6.94	7.50	0.03	0.03	3.50
12/17/2008	S6	3.95	6.39	11.65	5.50	2,100	5,200	0.50	0.05	0.03	2.77	3.35	0.10	0.23	32.00
1/22/2009	S6	0.71	7.45	12.36	3.40	50	100	0.50	0.05	0.10	7.94	8.59	0.03	0.02	3.20
1/30/2009	S6	1.43	6.31	12.71	1.90	200	50	1.64	0.11	0.01	6.06	7.82	0.03	0.07	1.00
2/19/2009	S6	1.20	7.26	11.90	5.70	100	100	1.22	0.12	0.03	6.18	7.55	0.03	0.03	3.00
2/26/2009	S6	0.74	6.29	12.35	7.80	50	50	1.24	0.33	0.01	6.88	8.46	0.01	0.02	4.40
3/13/2009	S6	0.70	6.99	12.71	6.20	50	50	1.04	0.05	0.01	7.38	8.48	0.03	0.02	3.20
3/24/2009	S6	0.53	6.90	12.53	7.80	50	50	1.18	0.05	0.10	7.85	9.18	0.03	0.01	2.00
4/8/2009	S6	0.97	7.01	10.33	11.70	50	100	1.00	0.05	0.01	6.28	7.34	0.03	0.04	3.50
4/23/2009	S6	1.69	7.02	10.34	12.90	1,000	100	0.50	0.05	0.10	5.11	5.76	0.03	0.07	11.30
5/7/2009	S6	5.68	6.41	7.91	18.70	38,000	41,000	2.10	0.27	0.04	2.59	5.00	0.09	0.31	57.00
5/20/2009	S6	1.02	6.92	9.38	18.30	400	400	1.00	0.05	0.01	7.36	8.42	0.03	0.05	3.20
6/3/2009	S6	0.81	6.75	7.81	20.90	1,000	1,500	0.50	0.05	0.10	6.66	7.31	0.03	0.05	8.40
6/16/2009	S6	0.83	6.93	8.81	18.90	2,000	700	1.20	0.11	0.10	6.65	8.06	0.02	0.05	8.50
6/17/2009	S6	0.89	7.25	9.05	18.00	600	900	0.50	0.05	0.01	7.43	7.99	0.03	0.04	6.00

S7

Date	Station ID	Flow Rate cfs	pH S.U.	Dissolved Oxygen mg/L	Temperature deg C	Fecal Coliform col/100 ml	*E. coli* col/100 ml	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen as N (mg/L)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	TN (mg/L)	Ortho Phosphate Dissolved (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
6/8/2007	S7	2.17	6.99	7.63	23.10	700		1.43	0.05	0.03	8.99	10.50	0.03	0.04	5.67
6/15/2007	S7	1.74	7.27	8.91	18.60	2,600		1.42	0.11	0.02	9.49	11.04	0.03	0.05	13.30
6/20/2007	S7	2.66	6.89	8.43	20.70	1,000									
6/27/2007	S7	1.61	6.72	8.24	25.10	1,200									
6/28/2007	S7	1.85	6.93	8.32	25.40	900									
7/2/2007	S7	0.99	7.03	9.02	20.80	450		1.22	0.28	0.10	9.50	11.10	0.03	0.02	6.70
7/6/2007	S7	2.84	6.75	8.10	23.60	600	5								
7/11/2007	S7	0.93	6.90	8.20	27.40	600	80								
7/18/2007	S7	1.33	7.27	7.18	25.70	600	600	1.63	0.05	0.03	10.40	12.11	0.01	0.01	13.70
7/25/2007	S7	1.23	7.15	8.41	24.00	18,000	3,700								
7/26/2007	S7	1.17	7.26	5.24	25.40	4,300	4,200								
8/1/2007	S7	0.95	6.34	7.84	27.10	6,000	13,000	1.65	0.16	0.10	9.87	11.78	1.02	0.88	13.30
8/10/2007	S7	1.74	7.03	7.92	25.20	50	50								
8/16/2007	S7	0.84	7.45	8.83	26.00	50	100	1.84	0.05	0.10	8.70	10.69	0.01	0.04	6.50
8/22/2007	S7	1.62	7.22	8.14	18.60	2,800	4,100								
8/29/2007	S7	1.03	7.04	8.63	22.50	3,000	3,200								
9/13/2007	S7	0.78	7.34	8.94	20.70	3,600	1,100	0.50	0.17	0.10	12.00	12.77	0.01	0.03	8.00
9/26/2007	S7	0.90	7.31	8.03	23.40	12,000	3,700	0.50	0.05	0.03	11.30	11.88	0.01	0.07	16.00
10/10/2007	S7	1.83	6.54	6.91	20.50	11,000	20,000	1.23	0.05	0.02	6.25	7.55	0.03	0.07	15.70
10/10/2007	S7	1.69	6.59	6.84	21.70	8,000	11,000	1.38	0.05	0.02	6.65	8.10	0.03	0.06	18.00
10/11/2007	S7	1.47	7.26	8.92	16.90	5,800	400	1.01	0.10	0.10	7.17	8.38	0.03	0.15	32.70
10/24/2007	S7	1.69	7.07	8.74	18.33	6,000	8,000	1.51	0.05	0.10	9.11	10.77	0.02	0.07	19.00

10/24/2007	S7	1.54	7.11	9.20	18.35	6,000	5,700	1.28	0.11	0.10	10.50	11.99	0.02	0.01	29.50
10/24/2007	S7	1.73	6.92	9.89	19.38	6,000	8,000	1.93	0.13	0.10	10.50	12.66	0.06	0.17	42.50
11/7/2007	S7	1.35	7.30	11.79	8.50	2,600	1,400	0.50	0.05	0.10	8.86	9.51	0.03	0.01	3.50
12/12/2007	S7	1.26	6.79	10.75	10.40	400	200	1.34	0.13	0.10	7.69	9.26	0.03	0.03	4.30
12/20/2007	S7	1.31	6.97	12.78	4.30	90	150	1.03	0.05	0.10	7.73	8.91	0.01	0.03	5.30
1/9/2008	S7	1.66	7.15	10.16	12.60	100	900	0.50	0.05	0.01	8.71	9.27	0.03	0.03	3.30
1/25/2008	S7	1.77	6.87	15.47	-0.80	50	50	0.50	0.05	0.01	10.50	11.06	0.03	0.03	8.00
2/8/2008	S7	1.93	6.63	13.13	6.40	50	50	0.50	0.05	0.01	7.03	7.59	0.03	0.03	3.30
2/27/2008	S7	2.89	6.81	12.25	4.70	50	50	0.60	0.05	0.01	7.24	7.90	0.03	0.02	1.00
3/6/2008	S7	2.59	6.76	12.76	7.50	500	100	0.93	0.05	0.01	6.27	7.26	0.03	0.04	6.00
3/13/2008	S7	2.43	6.65	12.06	6.00	50	50	1.03	0.05	0.10	7.19	8.37	0.03	0.03	2.70
4/11/2008	S7	1.07	6.92	10.38	17.30	300	100	0.50	0.05	0.01	6.39	6.95	0.03	0.03	4.00
4/24/2008	S7	1.32	7.20	10.01	17.30	2,000	2,000	1.02	0.05	0.10	7.89	9.06	0.01	0.02	2.00
5/7/2008	S7	1.06	7.15	10.46	18.40	4,000	3,000	1.00	0.05	0.10	8.46	9.61	0.03	0.03	3.00
5/28/2008	S7	1.63	7.02	10.40	15.20	4,000	5,000	1.40	0.05	0.02	7.05	8.52	0.03	0.06	4.70
6/12/2008	S7	0.65	7.21	8.66	24.90	28,000	20,000	2.02	0.11	0.05	8.41	10.59	0.03	0.05	12.00
6/27/2008	S7	0.86	7.72	9.14	26.40	1,400	4,000	1.05	0.05	0.01	9.58	10.69	0.01	0.09	5.20
7/11/2008	S7	0.71	7.58	8.80	25.20	1,200	1,600	1.48	0.05	0.03	9.54	11.10	0.03	0.04	13.00
7/30/2008	S7	0.87	7.12	8.02	25.80	4,000	4,000	1.12	0.05	0.10	8.58	9.85	0.03	0.06	4.50
8/13/2008	S7	0.90	7.25	8.40	23.00	8,000	3,000	1.37	0.05	0.10	8.47	9.99	0.03	0.04	9.00
8/28/2008	S7	0.67	7.33	8.64	21.40	6,000	5,300	1.91	0.11	0.10	11.30	13.42	0.03	0.08	42.00
9/11/2008	S7	1.00	7.27	9.12	20.20	500	4,000	1.12	0.05	0.10	7.60	8.87	0.03	0.04	8.00
9/26/2008	S7	0.95	7.42	8.65	18.50	1,100	4,000	1.00	0.05	0.01	9.76	10.82	0.06	0.05	10.70
10/9/2008	S7	0.79	7.27	9.08	18.40	800	1,500	0.50	0.05	0.10	9.89	10.54	0.03	0.03	5.00
10/31/2008	S7	0.64	7.09	10.97	8.50	300	200	1.15	0.11	0.01	10.10	11.37	0.03	0.02	3.20
11/19/2008	S7	0.88	7.57	12.52	1.90	300	900	0.50	0.05	0.10	7.80	8.45	0.03	0.03	4.40
11/25/2008	S7	4.05	7.47	11.29	6.60	15,000	2,600	1.10	0.10	0.03	4.31	5.54	0.06	0.14	12.40
12/5/2008	S7	1.16	7.15	13.10	4.30	100	50	0.50	0.05	0.01	7.75	8.31	0.03	0.03	6.50
12/17/2008	S7	10.76	6.20	10.39	5.50	5,800	3,000	1.04	0.51	0.03	3.11	4.69	0.08	0.17	36.00
1/22/2009	S7	1.18	6.56	12.53	1.40	100	100	0.50	0.11	0.10	9.53	10.24	0.03	0.02	5.20
1/30/2009	S7	2.44	6.26	12.93	0.50	1,000	100	1.09	0.12	0.01	6.60	7.82	0.03	0.05	8.70
2/19/2009	S7	2.10	6.67	11.76	5.10	50	50	0.50	0.05	0.01	6.96	7.52	0.03	0.02	3.50
2/26/2009	S7	1.71	6.25	12.60	8.60	50	50	0.50	0.05	0.01	8.31	8.87	0.01	0.02	2.80
3/13/2009	S7	1.44	7.37	13.42	4.80	200	300	1.03	0.05	0.01	8.60	9.69	0.03	0.02	2.00
3/24/2009	S7	0.97	6.82	13.87	4.60	50	100	1.22	0.05	0.10	8.79	10.16	0.03	0.02	2.40
4/8/2009	S7	1.83	7.09	11.39	8.80	100	100	0.50	0.05	0.01	6.32	6.88	0.03	0.03	5.00
4/23/2009	S7	2.41	7.07	10.82	11.80	800	500	0.50	0.05	0.10	4.97	5.62	0.03	0.06	11.30
5/7/2009	S7	1.34	6.22	8.44	17.50	15,000	11,000	1.34	0.12	0.05	2.02	3.53	0.08	0.26	49.00
5/20/2009	S7	1.62	6.84	9.86	19.40	900	1,300	1.13	0.05	0.03	8.29	9.50	0.03	0.04	7.20
6/3/2009	S7	1.60	6.64	8.92	20.90	2,600	2,800	0.50	0.05	0.10	8.23	8.88	0.03	0.04	6.80
6/16/2009	S7	1.34	7.03	9.13	19.40	1,800	2,500	1.47	0.10	0.10	7.33	9.00	0.02	0.05	11.30
6/17/2009	S7		7.31	7.63	19.20	1,800	2,100	1.39	0.05	0.03	8.26	9.73	0.03	0.04	6.00
S8															
		Flow Rate	pH	Dissolved Oxygen	Temperature	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
Date	Station ID	cfs	S.U.	mg/L	deg C	col/100 ml	col/100 ml	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
6/8/2007	S8	7.63	6.99	6.03	24.80	1,000		1.34	0.20	0.08	3.43	5.05	0.05	0.17	37.70
6/15/2007	S8	6.83	7.19	7.71	19.30	260		0.50	0.05	0.05	3.24	3.84	0.03	0.12	20.00

6/20/2007	S8	6.79	7.12	6.56	23.10	240									
6/27/2007	S8	5.493	6.63	4.94	27.10	290									
6/28/2007	S8	6.349	6.78	4.76	28.30	530									
7/2/2007	S8	4.58	6.99	6.30	20.90	120		1.29	0.21	0.10	2.80	4.40	0.03	0.16	20.00
7/6/2007	S8	19.59	6.84	7.35	24.50	480	5								
7/11/2007	S8	3.99	6.64	3.90	29.80	330	420								
7/18/2007	S8	3.52	7.05	4.30	27.20	380	270	1.60	0.24	0.10	1.54	3.48	0.05	0.25	21.30
7/25/2007	S8	2.83	6.99	4.56	25.30	300	800								
7/26/2007	S8	2.58	7.26	5.66	26.00	700	400								
8/1/2007	S8	3.02	7.29	4.62	26.80	3,000	500	1.31	0.34	0.10	0.86	2.61	0.06	0.18	19.00
8/10/2007	S8	6.06	6.79	2.91	26.40	800	100								
8/16/2007	S8	3.08	6.91	3.32	27.90	200	100	1.79	0.34	0.10	1.28	3.51	0.07	0.15	2.50
8/22/2007	S8	11.10	6.96	6.96	18.00	1,800	50								
8/29/2007	S8	3.91	6.87	4.63	24.30	1,100	200								
9/13/2007	S8	2.59	7.22	5.54	21.80	100	100	1.04	0.56	0.10	0.64	2.34	0.05	0.14	9.00
9/26/2007	S8	2.04	7.34	4.30	24.30	300	100	0.50	0.05	0.04	2.87	3.46	0.01	0.13	22.70
10/10/2007	S8	15.72	6.68	5.84	21.40	2,400	23,000	1.74	0.53	0.06	1.91	4.24	0.05	0.26	57.50
10/10/2007	S8	11.35	6.69	5.86	21.70	4,100	31,000	1.57	0.49	0.05	1.68	3.79	0.03	0.28	57.00
10/11/2007	S8	9.56	7.34	7.22	18.70	1,300	1,600	1.32	0.33	0.10	2.61	4.36	0.03	0.19	32.70
10/24/2007	S8	3.16	7.06	6.74	20.18	2,400	300	0.50	0.05	0.10	3.33	3.98	0.01	0.09	14.00
10/24/2007	S8	3.52	7.02	6.69	20.07	400	700	1.52	0.13	0.10	3.38	5.13	0.02	0.10	19.50
10/24/2007	S8	3.41	6.34	7.62	20.19	3,000	3,200	1.65	0.15	0.10	3.41	5.31	0.01	0.09	19.00
11/7/2007	S8	5.20	7.54	10.59	8.80	2,600	1,200	0.50	0.21	0.10	4.36	5.17	0.03	0.08	19.00
12/12/2007	S8	8.80	6.75	10.40	10.00	50	100	0.50	0.05	0.10	4.52	5.17	0.03	0.06	8.50
12/20/2007	S8	8.57	7.07	12.22	4.60	10	60	1.18	0.17	0.10	0.25	1.70	0.03	0.09	16.00
1/9/2008	S8	8.699	7.33	9.36	12.70	50	200	1.02	0.10	0.02	4.94	6.08	0.03	0.06	11.30
1/25/2008	S8	7.537	6.94	14.92	0.20	50	50	0.50	0.05	0.01	5.09	5.65	0.03	0.05	5.30
2/8/2008	S8	10.516	6.80	12.66	6.30	50	50	1.03	0.21	0.02	4.28	5.54	0.03	0.12	26.00
2/27/2008	S8	9.49	7.11	11.75	4.70	50	50	0.70	0.10	0.02	5.06	5.88	0.03	0.08	19.00
3/6/2008	S8	15.16	7.01	11.85	8.10	100	100	1.13	0.19	0.03	4.70	6.05	0.03	0.14	31.00
3/13/2008	S8	12.34	7.10	11.74	6.50	200	50	1.28	0.17	0.10	3.87	5.42	0.03	0.10	19.30
4/11/2008	S8	1.60	6.98	9.72	18.60	50	50	1.54	0.12	0.02	3.48	5.16	0.03	0.15	20.40
4/24/2008	S8	5.83	6.93	8.42	19.90	1,000	2,000	1.13	0.05	0.10	3.80	5.08	0.01	0.09	25.20
5/7/2008	S8	5.34	7.07	8.04	20.20	500	1,000	1.30	0.15	0.10	3.32	4.87	0.03	0.12	28.00
5/28/2008	S8	14.63	7.17	8.91	17.40	15,000	20,000	1.67	0.13	0.07	2.89	4.76	0.03	0.17	38.70
6/12/2008	S8	4.70	6.92	5.02	26.80	24,000	10,000	1.40	0.26	0.08	2.03	3.77	0.05	0.18	38.00
6/27/2008	S8	2.53	7.09	4.14	28.10	2,000	1,000	1.62	0.34	0.03	1.16	3.15	0.01	0.21	14.40
7/11/2008	S8	3.17	7.20	3.93	26.50	50	600	1.75	0.36	0.10	0.99	3.20	0.03	0.23	16.00
7/30/2008	S8	3.37	6.86	4.17	26.30	1,000	400	2.03	0.36	0.10	1.29	3.78	0.05	0.23	27.00
8/13/2008	S8	3.58	6.98	5.29	23.40	1,000	200	2.02	0.35	0.10	1.39	3.86	0.03	0.17	24.00
8/28/2008	S8	1.96	7.15	4.68	22.50	50	50	1.09	0.37	0.10	1.79	3.35	0.06	0.18	20.80
9/11/2008	S8	4.38	7.18	6.87	21.40	4,400	8,000	1.01	0.19	0.10	1.40	2.70	0.03	0.13	18.00
9/26/2008	S8	2.24	7.01	6.54	17.50	50	50	1.92	0.23	0.04	2.64	4.83	0.03	0.14	21.30
10/9/2008	S8	2.26	7.14	6.88	18.60	700	400	1.06	0.15	0.10	2.91	4.22	0.03	0.10	14.50
10/31/2008	S8	3.62	6.97	9.57	8.60	400	100	1.28	0.50	0.03	2.91	4.72	0.03	0.07	7.60
11/19/2008	S8	4.98	7.92	12.60	2.00	1,100	900	0.50	0.20	0.10	3.14	3.94	0.03	0.09	7.20
11/25/2008	S8	19.85	7.38	11.60	6.00	12,000	18,000	1.26	0.30	0.05	3.60	5.21	0.09	0.70	28.80
12/5/2008	S8	6.52	7.24	12.80	3.80	800	300	1.18	0.14	0.03	4.46	5.81	0.03	0.08	11.50
12/17/2008	S8	50.32	6.71	12.47	5.70	24,000	5,400	1.32	0.21	0.07	2.17	3.77	0.19	0.40	56.00

1/22/2009	S8	7.16	7.59	12.39	3.80	100	200	1.05	0.20	0.10	6.27	7.62	0.03	0.07	11.60
1/30/2009	S8	8.38	6.35	12.95	0.90	50	1,000	2.54	0.46	0.03	4.10	7.13	0.03	0.20	14.00
2/19/2009	S8	8.05	7.29	11.70	5.80	100	50	1.02	0.20	0.03	4.75	6.00	0.03	0.06	8.50
2/26/2009	S8	6.77	6.29	11.59	8.70	100	50	2.21	0.36	0.04	5.03	7.64	0.03	0.09	12.40
3/13/2009	S8	6.51	7.64	12.24	5.00	800	500	1.67	0.39	0.05	2.50	4.61	0.03	0.12	19.50
3/24/2009	S8	5.07	7.42	12.23	5.10	600	100	1.88	0.55	0.10	4.28	6.81	0.03	0.15	18.40
4/8/2009	S8	10.16	7.07	10.61	10.80	300	200	1.28	0.15	0.03	3.26	4.72	0.03	0.13	22.70
4/23/2009	S8	17.28	6.93	9.49	13.40	900	1,000	0.50	0.12	0.10	2.72	3.44	0.03	0.16	23.30
5/7/2009	S8	80.10	6.35	7.95	18.10	31,000	41,000	2.14	0.24	0.07	1.38	3.83	0.18	0.44	70.00
5/20/2009	S8	6.34	6.79	7.08	20.50	1,600	900	1.18	0.14	0.08	3.49	4.89	0.03	0.12	26.80
6/3/2009	S8	5.53	6.83	5.48	23.10	1,100	1,400	1.17	0.21	2.36	2.88	6.62	0.03	0.18	35.20
6/16/2009	S8	6.68	7.02	7.33	20.40	1,100	500	1.76	0.22	0.10	2.88	4.96	0.04	0.16	28.00
6/17/2009	S8	6.49	7.31	7.63	19.20	1,000	1,400	1.01	0.22	0.06	3.24	4.53	0.03	0.14	24.00
S9															
Date	Station ID	Flow Rate cfs	pH S.U.	Dissolved Oxygen mg/L	Temperature deg C	Fecal Coliform col/100 ml	*E. coli* col/100 ml	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen as N (mg/L)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	TN (mg/L)	Ortho Phosphate Dissolved (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
6/8/2007	S9	10.16	6.80	6.51	23.70	5		1.36	0.41	0.07	2.74	4.58	0.07	0.26	22.30
6/15/2007	S9	9.45	7.18	7.97	18.40	1,000		0.50	0.05	0.04	2.90	3.49	0.03	0.16	26.30
6/20/2007	S9	9.02	6.57	6.60	22.70	11,000									
6/27/2007	S9	6.78	6.54	6.09	26.20	900									
6/28/2007	S9	9.10	6.59	6.13	27.50	1,000									
7/2/2007	S9	7.44	7.41	7.14	22.80	20		1.38	0.29	0.10	2.38	4.15	0.06	0.19	19.00
7/6/2007	S9	28.62	6.73	7.45	25.80	600	5								
7/11/2007	S9	5.98	6.53	5.55	29.30	600	600								
7/18/2007	S9	6.30	6.75	5.35	27.00	370	400	2.07	0.38	0.10	0.89	3.44	0.08	0.35	32.00
7/25/2007	S9	4.14	6.64	5.97	25.40	50	50								
7/26/2007	S9	3.59	7.26	5.35	25.70	300	100								
8/1/2007	S9	7.45	7.28	5.72	28.20	50	100	1.17	0.31	0.10	1.32	2.90	0.11	0.33	10.30
8/10/2007	S9	5.49	6.77	5.47	25.90	500	50								
8/16/2007	S9	3.56	7.15	5.36	27.10	100	50	1.97	0.51	0.10	0.86	3.44	0.08	0.24	31.70
8/22/2007	S9	16.18	6.98	7.96	17.70	3,000	4,900								
8/29/2007	S9	3.36	6.98	6.26	24.30	1,900	3,600								
9/13/2007	S9	4.47	7.65	6.89	22.30	300	1,400	0.50	0.31	0.10	1.94	2.85	0.06	0.16	18.30
9/26/2007	S9	2.72	7.24	6.24	23.20	1,200	500	0.50	0.16	0.08	1.87	2.61	0.03	0.17	36.30
10/10/2007	S9	26.00	6.57	6.06	21.40	8,000	13,000	1.55	0.55	0.09	1.82	4.01	0.06	0.28	53.00
10/10/2007	S9	32.55	6.81	6.27	22.50	7,000	40,000	1.25	0.59	0.08	1.95	3.87	0.06	0.31	46.50
10/11/2007	S9	14.56	7.41	7.87	18.50	11,000	700	1.92	0.38	0.10	1.52	3.92	0.11	0.36	41.30
10/24/2007	S9	4.31	7.34	6.55	19.80	2,500	2,000	1.53	0.40	0.10	1.85	3.88	0.03	0.19	40.00
10/24/2007	S9	6.16	7.25	6.47	19.60	2,100	1,900	1.59	0.31	0.10	1.87	3.87	0.03	0.20	29.50
10/24/2007	S9	5.85	7.58	6.89	20.00	1,500	700	1.16	0.27	0.10	1.84	3.37	0.03	0.21	25.50
11/7/2007	S9	8.69	7.72	9.70	8.80	1,200	1,100	1.40	0.29	0.10	3.97	5.76	0.03	0.15	32.00
12/12/2007	S9	9.36	6.67	10.38	10.20	2,700	2,000	0.50	0.05	0.10	4.22	4.87	0.03	0.11	20.70
12/20/2007	S9	16.08	6.93	11.90	3.90	60	90	0.50	0.16	0.10	4.47	5.23	0.03	0.11	14.00
1/9/2008	S9	13.59	7.52	9.33	12.30	600	300	1.25	0.05	0.03	4.09	5.42	0.03	0.14	32.70
1/25/2008	S9	13.81	6.55	14.21	0.30	50	50	0.50	0.13	0.01	4.98	5.62	0.03	0.07	12.00
2/8/2008	S9	17.20	6.66	12.53	6.30	50	50	0.50	0.30	0.03	3.71	4.54	0.03	0.13	12.00
2/27/2008	S9	16.69	6.93	11.92	4.60	100	300	1.50	0.05	0.03	4.91	6.49	0.03	0.11	12.00

3/6/2008	S9	22.71	7.06	11.32	8.40	200	50	1.74	0.25	0.04	3.68	5.71	0.03	0.20	32.00
3/13/2008	S9	15.12	6.81	10.83	7.40	200	100	0.50	0.18	0.10	3.76	4.54	0.03	0.10	13.30
4/11/2008	S9	15.69	6.69	8.63	17.40	1,000	400	1.01	0.23	0.03	3.14	4.41	0.03	0.23	42.80
4/24/2008	S9	8.82	6.40	7.88	19.40	700	3,000	1.52	0.27	0.10	2.68	4.57	0.05	0.23	40.40
5/7/2008	S9	8.87	7.04	7.58	20.20	600	1,000	1.69	0.53	0.10	2.54	4.86	0.03	0.24	33.00
5/28/2008	S9	16.83	6.74	8.30	18.10	6,000	28,000	1.58	0.31	0.09	2.75	4.73	0.07	0.30	38.70
6/12/2008	S9	7.18	7.17	6.28	26.50	11,000	21,000	2.17	0.72	0.09	1.19	4.17	0.17	0.49	26.00
6/27/2008	S9	4.90	7.12	6.00	27.20	400	800	1.61	0.60	0.01	0.68	2.90	0.01	0.17	21.20
7/11/2008	S9	3.76	7.22	6.37	25.80	22,000	18,000	2.36	0.60	0.12	0.56	3.64	0.03	0.40	17.00
7/30/2008	S9	7.32	6.94	5.92	26.00	3,500	7,000	2.51	0.67	0.10	0.79	4.07	0.10	0.46	32.50
8/13/2008	S9	7.48	7.09	6.23	22.90	2,400	3,000	1.88	0.60	0.10	1.12	3.70	0.09	0.30	29.00
8/28/2008	S9	3.99	7.15	6.13	23.90	200	1,000	2.24	0.79	0.10	1.09	4.22	0.11	0.31	26.40
9/11/2008	S9	6.80	7.11	6.87	21.90	5,000	3,000	1.35	0.46	0.10	1.10	3.01	0.07	0.24	34.00
9/26/2008	S9	3.96	7.14	7.86	17.10	900	500	1.94	0.53	0.01	1.95	4.43	0.03	0.19	24.70
10/9/2008	S9	6.19	7.15	6.67	19.60	4,200	1,700	1.46	0.45	0.10	2.57	4.58	0.03	0.17	27.00
10/31/2008	S9	5.52	6.86	8.10	10.40	1,800	700	1.47	0.19	0.04	2.45	4.15	0.03	0.16	32.40
11/19/2008	S9	8.41	8.03	11.56	3.10	300	600	1.11	0.22	2.89	0.10	4.32	0.03	0.11	14.40
11/25/2008	S9	15.71	7.53	11.20	6.20	15,000	20,000	1.56	0.44	0.04	2.63	4.67	0.19	0.33	23.20
12/5/2008	S9	6.73	6.79	11.97	4.00	700	100	1.05	0.24	0.04	4.16	5.49	0.03	0.18	44.00
12/17/2008	S9	87.45	6.22	11.89	5.60	18,000	8,000	1.53	0.05	0.07	2.39	4.04	0.21	0.49	70.00
1/22/2009	S9	11.40	7.43	12.28	1.40	1,400	1,700	1.45	0.41	0.10	6.04	8.00	0.03	0.15	23.20
1/30/2009	S9	21.35	6.21	12.74	0.40	200	400	2.20	0.45	0.04	3.96	6.65	0.03	0.22	20.00
2/19/2009	S9	19.43	6.92	10.47	5.80	50	100	1.66	0.48	0.07	4.53	6.74	0.03	0.19	30.00
2/26/2009	S9	9.94	6.35	11.23	8.70	100	50	1.88	0.46	0.04	4.99	7.37	0.03	0.09	12.00
3/13/2009	S9	13.01	7.11	11.35	5.10	1,300	1,400	1.38	0.47	0.07	2.50	4.42	0.03	0.17	18.00
3/24/2009	S9	9.71	7.08	11.88	4.00	50	100	1.79	0.54	0.10	3.68	6.11	0.03	0.16	13.60
4/8/2009	S9	16.66	7.16	10.85	9.50	500	500	1.29	0.19	0.04	2.54	4.06	0.03	0.15	22.70
4/23/2009	S9	28.75	6.89	10.04	13.50	1,300	1,400	0.50	0.19	0.10	2.41	3.20	0.07	0.21	32.00
5/7/2009	S9	130.00	6.39	7.95	18.10	6,000	6,000	2.21	0.31	0.08	1.19	3.79	0.25	0.66	89.50
5/20/2009	S9	10.59	6.73	8.28	21.10	2,700	1,600	1.31	0.28	0.09	2.76	4.44	0.07	0.22	24.00
6/3/2009	S9	9.52	6.78	6.59	24.30	2,800	4,300	1.32	0.55	0.10	1.37	3.34	0.09	0.33	36.40
6/16/2009	S9	12.28	7.01	7.80	21.50	3,400	2,800	1.78	0.37	0.10	2.35	4.60	0.10	0.29	47.30
6/17/2009	S9	11.43	7.37	7.98	19.70	2,400	2,200	1.35	0.38	0.07	2.28	4.08	0.10	0.23	34.00

S10

Date	Station ID	Flow Rate cfs	pH S.U.	Dissolved Oxygen mg/L	Temperature deg C	Fecal Coliform col/100 ml	*E. coli* col/100 ml	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen as N (mg/L)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	TN (mg/L)	Ortho Phosphate Dissolved (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
6/8/2007	S10	12.00	7.51	7.07	25.70	800		1.37	0.24	0.08	1.99	3.68	0.05	0.23	16.30
6/15/2007	S10	10.00	7.18	9.29	18.90	30		0.05	0.50	0.06	1.63	2.24	0.03	0.18	27.70
6/20/2007	S10	7.00	6.55	8.45	24.30	180									
6/27/2007	S10	7.00	6.19	6.17	26.40	40									
6/28/2007	S10	7.00	7.16	6.97	29.20	160									
7/2/2007	S10	5.40	7.63	7.53	22.60	20		1.56	0.16	0.10	0.89	2.71	0.06	0.23	20.00
7/6/2007	S10	23.00	6.92	7.70	26.00	100	80								
7/11/2007	S10	5.40	6.38	6.90	27.90	70	80								
7/18/2007	S10	2.10	6.83	5.77	26.10	100	120	1.76	0.14	0.10	0.25	2.25	0.08	0.31	28.00
7/25/2007	S10	2.10	6.78	5.21	26.90	3,800	4,500								
7/26/2007	S10	2.10	7.26	5.35	25.70	200	100								

8/1/2007	S10	5.40	6.88	6.45	26.40	100	50	1.48	0.25	0.10	0.25	2.08	0.07	0.26	31.70
8/10/2007	S10	4.10	6.94	5.51	27.70	600	50								
8/16/2007	S10	1.30	7.54	5.43	28.10	50	50	1.65	0.16	0.10	0.25	2.16	0.06	0.25	20.50
8/22/2007	S10	14.00	7.10	8.29	17.30	600	600								
8/29/2007	S10	3.00	8.03	7.56	26.00	400	300								
9/13/2007	S10	2.90	7.94	7.60	23.60	100	100	0.50	0.69	0.10	0.25	1.54	0.02	0.13	20.70
9/26/2007	S10	2.10	7.89	7.48	24.90	50	50	0.50	0.15	0.07	0.63	1.35	0.01	0.13	17.30
10/10/2007	S10	21.00	7.36	7.07	22.90	1,200	800	1.23	0.13	0.06	0.54	1.96	0.03	0.15	14.00
10/10/2007	S10	21.00	7.37	6.67	23.30	500	50	1.07	0.14	0.08	0.72	2.01	0.03	0.11	15.70
10/11/2007	S10	12.00	7.92	8.37	19.60	300	50	1.79	0.35	0.10	1.31	3.55	0.03	0.15	26.00
10/24/2007	S10	7.00	7.64	6.64	20.20	200	500	1.19	0.11	0.10	1.22	2.62	0.01	0.09	12.50
10/24/2007	S10	8.80	8.31	6.97	20.00	400	100	1.42	0.15	0.10	1.14	2.81	0.01	0.13	27.00
10/24/2007	S10	7.00	8.60	7.70	20.60	200	50	1.47	0.13	0.10	1.14	2.84	0.01	0.15	22.00
11/7/2007	S10	8.80	8.03	10.54	10.20	800	200	1.11	0.38	0.10	2.54	4.13	0.03	0.11	17.00
12/12/2007	S10	8.80	6.27	10.58	9.90	100	200	0.50	0.05	0.10	3.67	4.32	0.03	0.10	11.00
12/20/2007	S10	8.80	6.30	11.82	6.70	570	600	0.50	0.20	0.10	3.61	4.41	0.03	0.13	13.30
1/9/2008	S10	8.80	7.34	9.82	12.10	50	400	0.50	0.25	0.03	4.32	5.10	0.03	0.13	13.30
1/25/2008	S10	8.80	6.18	12.49	6.20	50	50	0.50	0.10	0.01	4.85	5.46	0.03	0.08	9.00
2/8/2008	S10	12.00	6.27	11.61	8.40	50	50	0.50	0.05	0.04	4.37	4.96	0.03	0.16	28.00
2/27/2008	S10	16.00	7.09	12.42	4.60	50	50	1.70	0.05	0.01	4.26	6.02	0.07	0.17	18.00
3/6/2008	S10	21.00	7.13	11.15	8.80	800	200	1.46	0.26	0.05	3.69	5.46	0.03	0.25	40.00
3/13/2008	S10	14.00	6.72	9.98	10.80	200	50	1.01	0.20	0.10	3.03	4.34	0.08	0.20	21.30
4/11/2008	S10	12.00	6.65	9.87	17.60	50	50	0.50	0.05	0.03	2.86	3.44	0.03	0.13	19.60
4/24/2008	S10	7.00	7.82	9.22	21.40	50	50	1.23	0.05	0.10	1.38	2.76	0.03	0.14	20.00
5/7/2008	S10	5.40	7.43	8.52	22.90	50	50	1.01	0.05	0.10	1.47	2.63	0.03	0.15	19.00
5/28/2008	S10	12.00	6.81	8.31	17.90	21,000	27,000	1.68	0.28	0.09	2.61	4.66	0.07	0.30	37.30
6/12/2008	S10	5.40	7.90	8.73	26.10	60,000	80,000	1.91	0.05	0.04	0.25	2.25	0.03	0.20	12.00
6/27/2008	S10	3.00	7.16	7.74	26.60	100	1,000	1.09	0.23	0.01	0.25	1.58	0.01	0.27	16.80
7/11/2008	S10	3.00	7.61	8.25	23.90	50	50	2.70	0.05	0.01	0.25	3.01	0.03	0.30	21.30
7/30/2008	S10	4.10	8.10	8.16	24.90	300	1,000	2.20	0.05	0.10	0.25	2.60	0.03	0.31	30.00
8/13/2008	S10	4.10	7.32	8.32	23.50	200	1,000	1.78	0.32	0.10	0.80	3.00	0.03	0.20	32.00
8/28/2008	S10	0.77	7.65	7.78	24.10	50	50	1.84	0.05	0.10	0.25	2.24	0.03	0.22	29.00
9/11/2008	S10	4.10	7.34	8.37	22.50	100	300	1.40	0.35	0.10	0.50	2.35	0.03	0.17	16.00
9/26/2008	S10	0.77	7.19	8.47	17.50	400	1,000	1.46	0.05	0.01	20.70	22.22	0.03	0.18	26.70
10/9/2008	S10	4.10	8.42	9.64	18.10	100	50	1.39	0.05	0.10	0.68	2.22	0.03	0.14	20.00
10/31/2008	S10	4.10	7.05	10.67	8.20	2,100	800	0.50	0.05	0.04	1.95	2.54	0.03	0.14	16.80
11/19/2008	S10	7.00	7.91	10.35	8.10	200	700	1.15	0.32	1.86	0.10	3.43	0.09	0.23	16.80
11/25/2008	S10	14.00	8.00	12.88	4.40	100	50	1.18	0.36	0.05	2.77	4.36	0.04	0.12	8.80
12/5/2008	S10	7.00	6.39	10.57	8.10	600	400	1.30	0.28	0.05	2.83	4.46	0.03	0.18	22.50
12/17/2008	S10	88.00	6.03	11.67	6.30	2,400	11,000	1.93	0.31	0.01	2.76	5.01	0.17	0.40	52.00
1/22/2009	S10	5.40	6.16	12.27	2.90	50	100	1.31	0.38	0.10	5.32	7.11	0.17	0.26	13.60
1/30/2009	S10	16.00	6.05	12.26	4.20	600	200	2.59	0.47	0.04	3.42	6.52	0.03	0.51	11.30
2/19/2009	S10	14.00	6.76	10.21	9.10	50	100	1.70	0.48	0.06	3.71	5.95	0.23	0.33	15.50
2/26/2009	S10	7.00	6.36	10.17	9.10	100	100	1.83	0.50	0.06	4.30	6.69	0.03	0.13	13.20
3/13/2009	S10	8.80	6.90	11.04	8.10	50	50	1.79	0.40	0.07	2.50	4.76	0.03	0.37	25.50
3/24/2009	S10	8.80	7.05	9.86	12.10	50	50	1.37	0.28	0.10	3.19	4.94	0.17	0.34	24.80
4/8/2009	S10	16.00	6.81	9.45	12.00	400	100	1.72	0.21	0.05	2.40	4.38	0.22	0.39	34.00
4/23/2009	S10	26.00	6.59	9.66	12.10	1,700	2,200	1.06	0.20	2.01	0.10	3.37	0.26	0.48	45.50
5/7/2009	S10	144.00	6.21	8.33	17.60	6,000	6,000	2.16	0.36	0.08	1.21	3.81	0.47	0.87	96.00

5/20/2009	S10	8.80	6.92	8.30	21.70	400	200	1.13	0.19	0.09	2.05	3.46	0.24	0.25	20.40
6/3/2009	S10	8.80	6.67	6.70	24.50	2,400	3,100	1.30	0.49	0.10	1.39	3.28	0.09	0.31	37.20
6/16/2009	S10	10.00	6.84	8.53	21.80	900	500	2.40	0.34	0.10	1.91	4.75	0.08	0.28	30.00
6/17/2009	S10	8.80	6.94	8.44	21.60	4,800	2,700	1.34	0.39	0.07	2.24	4.04	0.10	0.22	29.00