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PERFORMANCE OF STORM WATER STAGE AND QUALITY MEASURING INSTRUEMTNATION OF A SMALL WATERSHED USING A REMOTE MONITORING STATION

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PERFORMANCE OF STORM WATER STAGE AND QUALITY MEASURING INSTRUEMTNATION OF A SMALL WATERSHED USING A REMOTE MONITORING STATION

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by
Rebecca Katherine Crane
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Accepted by:
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ABSTRACT

As economic development proceeds special care must be taken to preserve and sustain our water resources. Monitoring the storm water from a watershed during a rainfall event can help quantify any changes in water quantity and quality. An accurate means of measuring flow is necessary for all watershed monitoring projects. This study was conducted to analyze the performance of stage, turbidity, and temperature measuring devices in a laboratory setting as well as on Honeycutt Creek in Clemson, South Carolina.

The stage measuring devices under study include: a radar level sensor, ultrasonic transmitter, pressure transducer, and a bubbler module. A remote small watershed monitoring station gathered weather, stage, turbidity, and temperature data at Honeycutt Creek. An analysis of the performance of the stage measuring devices and water quality sensors in the field would be conducted.

The analyses of the stage measuring devices were conducted in a controlled laboratory setting using regulated water levels in a tank. In Honeycutt Creek the water level was recorded by hand and compared to the output of the devices. Water quality trends of turbidity and temperature were analyzed based on stage.

Results concluded that laboratory analyses proved the pressure transducer to be the most accurate method of measuring stage. The bubbler module had field results that were more accurate and had the best correlation to the accurate. Given the chaotic nature of the bubbler field data, the recommended stage measuring device for field applications is the pressure transducer.

DEDICATION

This manuscript is dedicated to my parents and my sister.

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CHAPTER I

INTRODUCTION

There is no question that water is one of our most important natural resources. In 1948, the United States government enacted the Federal Water Pollution Control Act. The act was the first in United States to shed light on water pollution management. Its goals included recognizing, preserving, and protecting the rights and responsibilities of States to prevent, reduce, and eliminate pollution, to plan the development and use of water resources (Federal Water Pollution Control Act, 2002). More notable, perhaps, are the amendments made in 1972, known as the Clean Water Act (CWA). The amendments were in regards to maintaining the chemical, physical, and biological integrity of the surface waters of the United States. Shortly after the amendments, there was increased action for point source pollution and chemical constituent control. Within the last decade or so, water quality monitoring programs have been focused on the biological and physical integrity of our Nation’s water resources (EPA, 2008).

There is a direct relationship between economic development and environmental degradation. As land continues to be developed, there is a greater need to protect and sustain our natural water resources. Monitoring the quantity and quality of storm water within creeks, streams, and rivers coming from a watershed can help discern the effects, positive or negative, of development on the natural environment.

There are many different characteristics of storm water runoff. Water quantity characteristics include stage (depth of flow), velocity, volume of flow, and flow rate.

Water quality characteristics include temperature, total suspended solids, dissolved nutrients, temperature, turbidity, and the variety of aquatic biota. A need for the identification and quantification of water quality and quantity parameters exists.

The success of watershed storm water runoff monitoring programs requires the accurate and precise measurement flow. Water flow is a very important physical characteristic of creeks, streams, and rivers. The volume of water flow helps to quantify the loading of constituents in the storm water. Loading is calculated by multiplying the concentration by the volume of flow (McFarland et al., 2001). The flow rate of water during a rainfall event can reflect how land development is altering the hydrology of a watershed. The discharge from a watershed after land development must be the same as pre-development (Privette, 2007).

Precise and accurate measurements of water quality are needed to reflect how land development is altering the health of creeks, streams, and rivers. The Environmental Protection Agency (EPA) has recently added new guidelines to regulate turbidity levels in storm water runoff (Hayes, 2009). Thus, there is an increased importance for reliable instruments to accurately measure the turbidity of storm water runoff.

A monitoring program was desired for Honeycutt Creek near Clemson University campus in Clemson, South Carolina. Honeycutt Creek drains an area that is approximately 1000 acres. The creek has four reaches that converge. Land uses within the watershed include residential neighborhoods, deciduous, evergreen, and mixed forests, grasslands, and pastures, as well as Clemson University campus and facilities.

The monitoring program on Honeycutt Creek is interested in stage and water quality. A remote monitoring station that is designed to be self sustaining is in place. Solar energy powers the sensors and the data logger. The data logger collects and stores the data and can transmit the data via a wireless connection.

The intention of this study is to determine which water stage device is best to deploy on a remote watershed monitoring station. Qualifications to determine the best device include accuracy of depth measurement in the field, cost, ease of installation, and reliability. The four stage measuring devices are commercially available. They include a radar level sensor, ultrasonic transmitter, pressure transducer, and a bubbler module. Another intention of this study is to deploy water quality measuring devices such as a turbidity sensor and temperature sensors on the remote monitoring station. The presence of any relationships between turbidity, temperature, duration of storm, and stage will be studied.

CHAPTER II

OBJECTIVES

The purpose of this study was to successfully deploy and evaluate a small digital watershed remote monitoring system on Honeycutt Creek in Clemson, South Carolina and to strengthen the idea of testing and evaluating stage measuring devices for open channel flow characterization. The remote monitoring system is equipped with commercially available sensors to characterize stage and water quality in Honeycutt Creek. Comparisons are made of the performance of the sensors in a controlled lab setting versus the field location. The goal is to determine if the small watershed remote monitoring system is a useful tool for making decisions concerning natural water resources in the area.

The objectives for this study are to:

1. compare the performance of the depth measuring sensors in a controlled laboratory setting and their performance in the field,
2. equip the monitoring system with stage measuring sensors such as a radar level sensor, ultrasonic transmitter, pressure transducer, and bubbler module,
3. successfully deploy a self-sustaining small watershed monitoring system on Honeycutt Creek at Clemson University, and
4. use turbidity and temperature sensors to collect storm water quality data.

CHAPTER III

LITERATURE REVIEW

The quantity and quality of storm water from watersheds can have an effect on the economic, social, physical or political security (Costa et al., 2006, Carter et al., 1989). The water in rivers and creeks are sources for drinking, irrigation, navigation, and power generation. Public safety becomes a concern when banks and levees are breached and flooding occurs. Accurate measurements of stream flow assist in determining uses of the water as well as predicting the frequency of flood events (Costa et al. 2006).

Watershed Monitoring

It can be discerned that there is a direct relationship between economic development and environmental degradation. As land development continues there is a greater need to protect and sustain our natural environments. There are many different characteristics of water to monitor. Water quantity characteristics include stage, volume of flow, and flow rate. Water quality characteristics include temperature, total suspended solids, turbidity, dissolved nutrients, and temperature.

There is a need for watershed monitoring programs when attempting to observe and maintain the integrity of surface water systems. Three degrees of integrity are defined by the Clean Water Act. They include the chemical, physical, and biological state of the water (Federal Water Pollution Control Act).

Watershed monitoring was concerned with the chemical integrity of surface waters after the 1977 Amendments to the Clean Water Act (EPA: Clean Water Act

Module, 2008). Early on, monitoring programs were initiated to target point sources of pollution. Examples of point sources include discharge pipes from industrial sites, water treatment plants, large construction sites, and etc. More difficult, however, was the task in determining nonpoint source pollution. Nonpoint sources of pollution are more irregular than point sources and contribute to receiving water bodies at many points. Runoff from agricultural lands, ranges and pastures, small construction sites, urban areas, abandoned mines and logging sites are examples of nonpoint source pollution (Masters et al., 2007). Runoff from these sites carry nutrients such as nitrogen and phosphorous. High levels of these nutrients contribute to eutrophication in surface water.

Eutrophication occurs when there is an increase in nutrient concentrations in surface waters. The growth of algae increases as a result of nutrient loading which decreases the amount of dissolved oxygen in the water. Fish kills can occur, the quality of the water decreases, and algal blooms arise on the surface of the lakes and rivers making their aesthetic value decrease. As a result of the problems posed by nonpoint sources of pollution, monitoring programs have been focused on identifying contributing sources and harnessing their outputs.

The United States Environmental Protection Agency stated that recent efforts of water monitoring programs have targeted quantifying the physical and biological integrity of the country’s creeks, streams, and rivers (EPA: Clean Water Act Module, 2008). Sediments exist in nonpoint source runoff as do nutrients, bacteria, and heavy metals. Deposited sediment includes materials such as aggregates, organic materials, and associated chemicals (Haan et al., 1994). Sediment particles in runoff can deposit in creeks, streams, and rivers. The settling of these particles depends on the transport capacity of the flow which relies on fluid properties, sediment characteristics, and hydraulic parameters (Hann et al., 1994). Sediment can alter the physical integrity of streams causing morphological changes to the geometry of creeks, streams, and rivers. A problem of premature flooding can arise as creeks, streams, and rivers lose water holding capacity due to sediment buildup.

Monitoring programs' initiatives can quantify the biological integrity of creeks, streams, and rivers. Biologically, creeks, streams, and rivers can be affected by the amount of suspended solids as well as the solids that deposit. Aquatic wildlife is very sensitive to the presence of sediment in the aquatic environment (Bilotta et al., 2008). Suspended solids from storm runoff can reduce the amount of light that penetrates the water which may affect phytoplankton, periphyton, and macrophytes. Benthic invertebrates such as insects, mollusks, and crustaceans can be buried under deposited sediment. Organisms can find that their feeding mechanisms can clog due to the suspended solids causing stress which inevitably may lead to death (Bilotta et al., 2008). Salmonid fish eggs can be smothered by sediment as well as may be scraped by the abrasive suspended solids. The absence of salmonid fish can have an effect on recreation sites that allow fishing in the creeks and streams.

Monitoring programs have been designed and modified to be appropriate for the area under surveillance and what is to be monitored. A monitoring program in China covered the upper basin of the Miyun and Guanting reservoir. It covered more than 15300 km^2 including 12 counties (Zhou et al. 2005). It monitored soil and water conservation effects and results. In Emden, Germany, a monitoring program was focused on water level measurement in tidal reaches (Kranz, et al. 2001). In Minnesota, the Department of Forest Resources at the University of Minnesota used a sentinel watershed-systems approach to assess Minnesota's water bodies (Magner et al., 2008). The sentinel approach, by definition, kept watch/monitored physical, chemical, and biological aspects of small watersheds in the state. Their goal was to understand the relationship between natural and anthropogenic watershed processes.

The United States Department of Agriculture conducted a nonpoint source runoff monitoring program in North Bosque River watershed of north central Texas, known as the Lake Waco-Bosque River Initiative (McFarland et al., 2001). This area was noted for its water quality impairments since 1992. The United States Department of Agriculture (USDA) addresses common objectives of monitoring programs of all sizes and purpose in its Lake Waco-Bosque River Initiative. Objectives included identifying water quality problems and the pollutants that contribute to the water impairment; defining what levels or loads of pollutants is acceptable and how current conditions vary from desired; determining the sources of pollution and how much is contributed; measuring how much pollution is allowable per source to meet desired pollutant loads or concentrations; and assessing how water quality is improving or declining (McFarland et al., 2001).

The USDA reports that to successfully meet the objectives of a watershed monitoring program there are some primary points to consider when planning the program. Knowing what to monitor is key, as is deciding where in the watershed to monitor. The research team has to determine what type of monitoring to implement. It must be decided how often systems monitor, how long monitoring takes place, and what resources are available for monitoring (McFarland et al., 2001). The resources available will determine most of how monitoring programs are developed.

The success of monitoring projects is often times dependent upon the trade off of resources available for data collection and accurate characterization of water quality, quantity, and discharge. A balance between these should be made which requires careful decision-making on the type, amount, and quality of data collected (Harmel et al. 2006b). Considerations should be made towards the allocation of monitoring resources to site establishment, equipment purchase and maintenance, personnel requirements, and samply analysis (Harmel et al., 2006b).

Watershed monitoring projects have several components, that when properly combined can yield a successful monitoring program. Two components are stream flow measurement and constituent measurement. In the following sections, these will be discussed in further detail. Other variables that are taken into account when establishing successful monitoring projects will be explained as well.

Streamflow Measurement

Measurement of streamflow was begun by the United States Geological Survey (USGS) as early as 1888 as part of a special study relating to the irrigation of public lands (Carter et al., 1989). Since then, stream flow data has assisted in providing current information for use in every day management of water supplies and for use in forecasting flood events. The quantity of water coming off of a watershed can sometimes be used to calculate the quality of the water. For instance, stream flow is directly related to determining the loads of a pollutant in a creek, river, or stream (McFarland et al., 2001). Stream flow data, discharge data, are vital to most water quality monitoring programs (Harmel et al. 2006a). Some considerations when planning to monitor stream flow include site establishment, equipment deployment, and the uncertainties present in data collection.

Site Establishment

The place where streamflow measurement will occur requires great consideration. The decision of location can be a costly mistake, of both time and money, if a location has unstable beds and banks. According to the USGS, consideration should be given to channel characteristics, the opportunity to install an artificial control, the possibility of backwater, availability of a nearby cross section, proper placement of stage staff gage, suitability of existing structures, the possibility of flow bypassing the site, and accessibility of the site by roads (Carter et al., 1989). A stretch of the channel that is fixed and not subject to morphology is most ideal. The installation of an artificial control, such as a calibrated flume or weir, simplifies the procedure of determining discharge based on the stage of flow. These structures are equipped with an established stage-discharge relationship. A nearby cross section, a culvert for example, would allow for good stage measurements to be made (Carter et al., 1989). The placement of a staff gage in the artificial control device or culvert allows for manual readings of stage height, to which instrument measurements can be compared. The presence of an existing structure, allows for high-flow depths to be recorded, thus allowing for a discharge estimate. A site that allows flow to bypass either through ground water or in flood channels would not be ideal. During storm events, sites that are not accessible by roads can be precarious. Sites that are close to roadways allow for safer data collection and maintenance.

The establishment of field-scale sampling sites at the boundaries of homogeneous land use areas and within a natural drainage way is ideal (Harmel et al. 2006b). Consideration of what is upstream of the site, specifically, what will be sources of constituents is important. The location of water treatment facilities located on the hydrologic network of concern must be known. Knowledge of construction sites, industrial discharges, and agricultural lands within the watershed is important. This can all assist in characterizing water quality trends.

Monitoring sites that are located at existing flow gages or hydraulic flow control structures is ideal. The USGS has gages all over the United States which have established stage-discharge relationships. The presence of a flow control structure allows for easier discharge determination compared to a site without one.

Equipment

For over a century, the basic method for measuring streamflow included wading across a creek, stream, or river with a current meter (Costa et al., 2006). The USGS measured depth, using a staff stream gage (Carter et al., 1989). The depth values obtained were later used to determine discharge at a point. Now there are technological advances that allow for continuous streamflow and depth measurement. These instruments, however useful, are costly and can prove to be unreliable.

Measuring velocity in streams has been conducted using an array of devices. Velocity, or current, meters may use revolving cups that spin at a rate proportional to the velocity, or may use radar technology (Harmel et al., 2006b). It may be the case that current measurements are taken across the cross section of the creek, stream, or river rather than in one location. The mean flow velocity per section area must be known. The total discharge at the recorded depth is the sum of discharges per section (Carter et al., 1989). Ultrasonic velocity meters (UVM) allow for the ultrasonic measurement of the average velocity along an acoustic path crossing the creek, stream, or river (Simpson et al., 2000). Ultrasonic transducers are mounted on pilings across the water. The signal emitted is timed from one transducer to another, and current velocity is computed.

Streamflow measurements are also taken by installing an acoustic Doppler current profiler (ADCP) on moving vessels. Water velocity is recorded through the water column by measuring the Doppler shift in the frequency of acoustic signals reflected from materials in the water column as they flow by (Costa et al., 2006). This method still requires personnel to operate and has expensive instrumentation in the water. Both are subject to danger and harm during high flow situations that can carry debris. Also the ADCP cannot measure velocity near the water surface. The instrument must be submerged at least 75 cm below the water surface.

Ground penetrating radar (GPR) has been used to determine channel cross section. Channel cross section is needed for determining the cross sectional area of flow. GPR is helpful for monitoring sites that are substantial in size. GPR involves the transmission of an electromagnetic pulse with carrier frequency in the MHz range toward the ground from a transmitting antenna at the surface (Costa et al., 2006). A month-long experiment in the San Joaquin River in Vernalis, California employed GPR to measure the channel cross section. The GPR was operated from a cableway, suspended .5-2m above the surface, which allowed the antenna to be moved across the river (Costa et al., 2006).

The depth of flow, or stage, above a datum plane is just as important a characteristic of creeks, streams, and rivers as stream velocity. The recording of stage is a common task in hydrological research (Schumann et al., 2002). Stream stage is used in determining records of stream discharge (Buchanan et al., 1976). The reliability of the discharge record is thus dependent upon the reliability of stage record. Automatic devices can continuously measure water levels with short intervals and quick response time. Devices include bubblers, pressure transducers, float sensors, or sonic sensors.

The United States Geological Survey (USGS) has been using a bubbler gage since 1968 (Carter et al., 1989). They can use a differential pressure transducer and a flow of bubbles through a bubble line to measure depth of water. Essentially the gas pressure in the tube is equal to the piezometric head on the bubble tube at any gage height (Carter et al., 1989). The bubbler gage is also known as a gas-purge system.

Submersible pressure transducers were developed back in the 1960's and have allowed for convenient collection of water level. Nowadays, electrical pressure transducers consist of a force-summing device which is coupled to an electrical transduction element (Freeman et al., 2006). A very prevalent force-summing device in pressure transducers is the strain-gage. The strain gage is often referred to as a resistive transducer. Mechanical displacement of the gage is translated into electrical resistance of a circuit (Freeman et al., 2006). The strain gage can be fixed upon a membrane or diaphragm. A diaphragm is a type of elastic deformation device. The water level above is a function of the local strain which is related to the diaphragm deflection and pressure differential (Holman, 2001).

Float sensors are indicative of early systems that recorded continuous water level changes. They were comprised of a tape or cable passing over a pulley with a float in a stilling well attached to on end of the tape or cable and a counter weight connected to a drum (Buchanan et al., 1976). The drum rotates and turns a wheel on which a pen;, that is usually connected to a clock, records water levels on a paper chart (Freeman et al., 2003). The float follows the rise and fall of the water level in the stilling well which reflects the water level in the creek, stream, or river. The water level can be read by using an index and graduated tape. Stilling wells protect instruments and dampens the fluctuations (waves) in the stream caused by wind and turbulence. They can be made of concrete, PVC, steel pipe, and occasionally wood (Buchanan et al., 1976). In the bottom is an intake hole where water enters and leaves, so that the water in the well is at the same level as in the creek, river, or stream.

Sonic sensors, such as radars and ultrasonic transducers emit signals and echoes towards the water surface. The time it takes for the signals and echoes to return is sensed and read usually as an electrical output. The outputs are then converted to distances. As such, these sensors are employed above the water surface. There are many varieties of these sonic sensors available for purchase.

Often times, monitoring sites do not have pre-existing control structures in which stage monitoring can occur. In the event of such, a pre-calibrated structure like a flume or weir can be installed. This has been applied for small watershed sites because the structures have an associated stage-discharge relationship (Harmel et al., 2006b). These structures can be expensive to purchase and tedious to implement into a creek or stream. There is also the chance of flow ponding directly behind the structure and directly at the outlet which can affect sediment transport. Some considerations that should be made concerning implementing a flow control structure include: range of flows to be expected, presence of floating debris, costs of construction and maintenance, expected life of the project, and potential benefits of flow measurement standardization within the project (Harmel et al., 2006b).

Uncertainty

There exists uncertainty in the streamflow and discharge measurement process. Uncertainties exist in the instruments used to measure velocity, channel geometry, and stage. Ambient temperature, wind, and moisture accumulation can have an effect on the instrumentation. The computation of discharge can be stricken with uncertainty because of the measurements.

Uncertainty also exists when there is not an established stage-discharge relationship available for the monitoring location. The USGS has been keeping records at gaging stations across the United States for years. Monitoring sites which have a gaging station will have access to stage-discharge relationships or rating curves. When there is not an available stage-discharge relationship, a flow control structure with an established stage-discharge relationship should be implemented into the creek, stream, or river. If this is unfeasible, then it is necessary to construct a stage-discharge relationship.

Developing a stage-discharge relationship is a time consuming, long term task. The United States Geological Survey created a handbook that details how to measure peak discharge at culverts by indirect methods (Bodhaine, 1982). Flow through the culvert has to be classified as either critical depths at inlet or outlet, tranquil flow throughout, a submerged inlet, rapid flow at inlet, or full flow with a free outfall.

In open channel flow situations, Manning's equation is applied with the knowledge of stage and other physical characteristics of the channel. Stage of flow is not a parameter in the equation, but is needed to determine area of flow (A) and hydraulic radius (R). Other parameters such as slope (S) and a variable known as Manning's *n* needed to be known to apply Manning's equation,

$$Q = \frac{1.49}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} A .$$

Manning's *n* is influenced by the physical roughness of the channel surface, irregularity of the channel cross section, channel alignment and bends, vegetation, silting and scouring, and obstructions within the channel (Haan et al., 1994). This method of determining discharge should be a final alternative because accurate channel roughness is hard to estimate. Manning's equation is not precise because of the uncertainty involved with choosing an adequate Manning's *n.* The use of Manning's equation should be avoided (Harmel et al., 2006a).

Constituent Measurement

Storm water runoff can contain a variety of chemicals and particulate matter. Suspended sediment, nitrogen and phosphorous, heavy metals, temperature, and biological compounds are all constituents of concern when determining the health of a creek, stream, or river. They have been monitored with an infinite amount of combinations of sampling strategies for a large number of different watersheds (Miller, et al., 2007). Constituent determination has consisted of measuring temperature and particulate matter by sensors and collecting manual and automated water samples.

Temperature

Water temperature has an influence on the quality of water for domestic utility, aquatic wildlife, and integration of constituents from urban, agricultural, and industrial uses. Temperature changes can be caused by storm water run off from developed lands. As land development proceeds, there are more impervious surfaces such as roads and parking lots and there is a reduction in the overall shading of land surfaces (Herb et al., 2008). Temperature variation in creeks, streams, and rivers depend on the climate and location. During autumn and winter months, water temperatures will obviously be low. However, temperatures of runoff during summer months will relatively high (Stevens et al., 1978).

Temperature influences almost every physical process and most chemical reactions in water, as well as influences biologic organisms (Stevens et al., 1978). Physical characteristics of water that are functions of temperature include density, specific heat, latent heats of fusion and vaporization, viscosity, vapor pressure, surface tension, oxygen and nitrogen solubility, and gas diffusion (Stevens et al., 1978). These all influence thermal stratification, evaporation, particle settling velocity, and the rate of replacement of dissolved oxygen. Water temperature influences chemical reactions in water. Chemical reaction rates are doubled for every 10°C rise in temperature (Stevens et al., 1978). In an irreversible reaction, the length of time to produce final products will decrease with increasing temperatures. In reversible reactions, temperature affects the length of time to reach equilibrium and the proportion of reactants and products at equilibrium (Stevens et al., 1978). Temperature also affects the conductivity, dissociation, solubility, and corrosion characteristics of water. Biologically, water influences photosynthesis, the biological oxygen demand, and ultimately organism mortality.

The USGS suggests two major consideration when planning and conducting field temperature measurements. These include the proper selection of instruments and the proper field application and procedures (Stevens et al., 1978). Sensors should be placed in the stream, but not on the stream bed. It should not come into contact with direct sunlight or air. Temperature measurement by sensors are popular forms of data collection because a signal is furnished that is easily detected and can be easily amplified (Holman 2001).

There exist electrical-resistance thermometers, or resistance temperature detectors (RTDs). There is a resistive element which is exposed to the temperature to be measured. The resistance measurement may be conducted with a type of bridge circuit. In a bridge circuit, for example a Wheatstone bridge circuit, there are 4 resistances. Two resistances are known, one is variable, and the unknown resistance is associated with a transducer output (Holman 2001). A primary source of error in the electrical-resistance thermometer is the effect of the resistance of the leads which connect the element to the bridge circuit (Holman 2001).

Another electrical device to measure temperature is a thermistor, which takes the form of a rod, bead, or disk. The change in resistance value changes with temperature. The relationship between resistance and temperature is exponential in a thermistor. A thermistor is made of a solid semiconductor with a high temperature coefficient of resistivity (Stevens et al., 1978). Thermistors known to be sensitive devices which can have accuracy within 0.01°C. The thermistor is different for RTDs in that it is a semiconductor device which employs ceramic or polymeric resistance material. Thermistors can measure high resistances which mean smaller currents are required for the measurement thus there are small errors due to self-heating (Holman 2001).

Thermocouples are common electrical methods of temperature measurements based on thermoelectricity (Holman 2001). Two different materials are joined together and the electromotive forces (emf) between the two materials are a function of the junction temperature. The output of thermocouples is usually in millivolts (Holman 2001). An advantage in using thermocouples is that they can be separated a considerable distance from the measuring instruments (Stevens et al., 1978). The use in liquids requires they be sealed in a case thus slowing down their response time. There are also problems associated with the various junctions of different metals, and are thus not usually employed as portable measuring devices or installed in liquids.

Turbidity

Water that is high is suspended sediment content is considered to be turbid. Turbidity is an indicator of how much suspended solid content there is based on the refraction of light transmitted in the water. Clear waters will have little to no light refraction where as more turbid waters will have more light refracted off of the particles in the water. Turbid waters can transport organic pollutants and heavy metals that originate from industrial, urban, or agricultural sources (Pfannkuche et al. 2003). Sediments that settle are considerable substrate sources for aquatic organisms (Long et al. 1998). Contaminants, such as polynuclear aromatic hydrocarbons and chlorinated organic compounds, in the sediment can be ingested by the bottom feeder organisms and retained. Some compounds can prove to be highly toxic (Long et al. 1998). With polynuclear aromatic hydrocarbons, the more rings there are, the more toxic the compound. Chlorinated organic compounds such as the pesticide dichlorodiphenyltrichloroethane (DDT) are persistent in the environment and partition to fat cells in organisms and move up through the food chain (Freedman, 2008).

Turbidity has been measured by the USGS using a variety of sampling techniques. A fixed suspended-sediment sampler is submerged with the nozzle pointing directly into the flow (Edwards et al. 1999). When the creeks, streams, or rivers are able to be safely traversed, sample bottles are lowered into the water by use of cables or wading rods. However, there are now electric devices that determine suspended sediment levels that do not collect water samples.

The turbidity meter is a device that measures turbidity based on the amount of scattering and adsorption of light rays caused by suspended solids (Mylvaganam et al. 2001). Turbidity meters can have outputs in current, milliamps, which can be translated into Nephelometric Turbidity Units (NTU). Some turbidity meters emit infrared light in pulses at wavelengths of 860nm to 880nm. The infrared light emitted by an LED illuminates the water and a photodiode receives the reflected light. Turbidity measurement this way allows for continuous measurement without the hassle of receiving water samples, collecting the samples from the site, sample storage, and sample lab analysis.

Baseflow Water Sampling

Periodic baseflow sampling to monitor constituents is common at monitoring sites. Baseflow water quality samples should be taken as often as possible at regular time intervals. Sampling on a weekly basis for a year or more is advised to better understand concentration variability (Harmel et al., 2006b). Manual grab samples should be made at the center point of flow, assuming that constituents are uniform across the cross section (Harmel et al., 2006a).

Manual samples are generally taken one foot below the surface by dipping a narrow-mouthed bottle into the water. This is called a dip sample (McFarland et al. 2001). Samples can be made from the bank or by wading in the water. They can be made at one point in the creek or at multiple locations and multiple depths. Manual samples require a substantial amount of time for the collection of each sample.

There exists vertical and horizontal variability of constituent concentrations in water. Samples can be taken manually at varying depths of the water column and at varying widths of the cross section. The USGS method of Equal-Width-Increment takes multiple-depth integrated, flow proportional samples across the cross section and produce accurate measurements of dissolved and particulate concentrations (Harmel et al., 2006a). This type of sampling can be intense and impractical at high flows when a sampler cannot be lowered through the vertical or horizontal profile (McFarland et al., 2001).

Manual techniques require personnel to be at the monitoring site. During a storm event, this has potential to be a hazardous method depending on the size of the creek, river, or stream, depth of flow, and the intensity of flow. Manual samples do not capture the spatial and temporal variability in constituent concentrations and therefore produce a substantial amount of uncertainty (Harmel et al., 2006a). Manual sampling is better for establishing baseflow measurements.

Storm Sampling

Storm sampling quantifies constituent transport in runoff events and to differentiate between various processes such as channel, point source, and non-point source (Harmel et al, 2006b). Storm water quality characterization can be more difficult than baseflow characterization. Automated samplers are helpful in that they can be triggered by the flow or time and allow for collection of water samples without the presence of personnel.

Automated samplers are instruments that can be placed in the field and take samples without manual operation. They are most often used for monitoring storm runoff when changes in discharge occur rapidly making it difficult and dangerous for personnel to manually take samples (McFarland et al., 2001). Automated samplers are able to be programmed to a sampling schedule to take multiple samples through out the duration of the storm event. They are ideal for small watersheds in the fact that they can sample within the quick hydrologic response time of a small watershed (Harmel et al., 2003). Automated samplers have a controller which has a control panel which allows for programming and data storage, a desiccant to prevent moisture damage to the electronics, a pump, and a distributor system. Often times a peristaltic pump extracts water in a suction line. The distributing system consists of a rotating arm that situates the line over bottles which collect the samples.

A certain degree of uncertainty arises when using automated samplers in the fact that they only intake from one point in the flow. It must be assumed that the constituents are well mixed vertically in the water column and across the cross section. The suction line should be placed as close to the center of flow as possible (Harmel et al. 2006b).

Samples are described as discrete or composite. Discrete samples allow for one sample per bottle. Composite sampling allows for more than one sample per bottle. It reduces analysis cost while intensively sampling the entire storm event (Harmel et al. 2006b). However, composited samples may provide a skewed characterization of water quality during a storm event (McFarland et al., 2001).

An important component of storm sampling is programming the threshold at which automated samplers are initiated. For small watershed studies, it is common to impose a minimum stage or discharge threshold (Harmel et al. 2006b). As flow exceeds this threshold, sampling begins and continues as long as the flow does not fall below the threshold. The interval of sampling can be set by time or by the amount of flow.

Time-interval sampling, which is also known as time-weighted and time-proportional sampling, occurs with samples being taken on time increments (Harmel et al. 2006b). This method is considered to be simple and reliable. Care should be taken to determine the correct time interval so that sampling occurs throughout the whole storm duration.

Flow-interval sampling also known as flow-weighted or flow-proportional sampling is set to trigger automated sampling by flow volume increments (Harmel et al. 2006b). Sampling intervals rely heavily on continuous discharge measurement. Flow-interval sampling represents storm loads more accurately than time-interval sampling. The reason being, more samples are taken at higher flows. Higher flows are usually prone to have higher constituent transport. However, flow-weighted sampling can be more complicated than time-weighted sampling (McFarland et al. 2001). Flow-weighted sampling requires measurement of stream stage and an established stage-discharge relationship for that site to determine flow, which thus triggers the automated sampler.

The comparison the accuracies of various sampling strategies without a known assumed value is not possible (Harmel et al. 2006b). To reduce uncertainty on small watersheds, it is suggested to use automated samplers to take frequent samples of the runoff based on small time intervals (Harmel et al. 2006a). Time intervals must be so as to allow for sampling throughout various durations.

Sample Preservation/Storage

There lies a certain degree of uncertainty with techniques of sample preservation/storage. A disadvantage to automated storm sampling is that it might be some time between sample collections. Samples are prone to physical, chemical, and biological processes during the period of collection and analysis (Kotlash et al. 1998). Factors include container characteristics, storage environment, chemical preservatives, and filtration methodology.

Phosphorous has a high affinity to absorb onto container walls. The reason being, phosphorous has a high charge density. The amount is dependent upon the pre-treatment or washing of the containers (Harmel et al. 2006a). Phosphate-free detergents should be used. Plastic bottles should be rinsed with dilute acetic or hydrochloric acid (HCL) because sorption sites are saturated. Glass bottles should be treated with hydrofluoric acid, but there are health and safety issues.

The storage environment can have an effect on nutrients in samples. Light that penetrates bottles may initiate photosynthesis. Thus, sample should be stored where there is no light. Low temperatures are most ideal for storing samples. Temperatures below 4 °C or 39.2 ° F inhibit the growth of microbes. Freezing should only be conducted for long term storage (Harmel et al. 2006a). Refrigeration has been used as an effective method of preservation. Up to two days of refrigeration has proven to have some success at not altering some constituent concentrations (Kotlash et al. 1998). However, ammonic nitrogen and filterable phosphorous have had low results when refrigerated (Kotlash et al. 1998).

Chemical preservatives such as chloroform, inorganic acids, and mercuric chloride, can be used during storage to halt metabolic processes (Kotlash et al. 1998). These techniques can be used in the place of refrigeration. The suggested practice is to place preservatives in the sample bottles prior to sampling. This technique of preservation is limited due to the potential of contamination. Chloroform releases dissolved phosphorous from the constituents in the samples. Inorganic acids and mercuric chloride can precipitate bacteria and proteins. These all have an adverse affect on determining the actual phosphorous levels in the samples (Kotlash et al. 1998).

Filtration is conducted to determine dissolved nutrients in the lab once samples are collected. There are recommendations of in the field filtration for dissolved phosphorous (Harmel et al. 2006a). Filter papers of 0.45 μm can have too large pore sizes that allow for fine particulate matter and colloidal material to pass through into the filtrate. Papers can also contribute themselves to nitrogen and phosphorous, thus pre-washing with de-ionized water is recommended. Sometimes the suction can prove too much and can break cells and alter colloidal material (Harmel et al. 2006a).

There exist infinite possibilities with which to design a watershed monitoring system. Considerations should be made to the site of monitoring, which parameters are of importance, and monitoring equipment. The degree of uncertainty relies on these considerations and the conscientious practice of data collection. This literature review has briefly described watershed monitoring techniques. There is much room for improvement and thus current research is being conducted.

CHAPTER IV

MATERIALS AND METHODS

The purpose of this study was to successfully deploy and evaluate a remote monitoring system on Honeycutt Creek watershed in Clemson, South Carolina. The monitoring system employed several sensors to measure water depth, turbidity, temperature, and weather conditions. This chapter will discuss the materials and methods used in sensor evaluation, site establishment, sensor deployment and data acquisition.

In the early stages of the project, the decision was made to monitor on Honeycutt Creek. Stage data is an important physical characteristic of open channel flow and is recorded during storm events. Weather data was important to measure in order to have rainfall data for each storm event. Turbidity and water temperature data would be collected which would reflect storm water quality off the watershed.

Equipment

There was a substantial initial monetary investment made for this digital watershed monitoring project. The monitoring system was outfitted with the following: radar sensor, ultrasonic transmitter, pressure transducer, turbidity sensor, temperature sensor, and an automated sampler with a bubbler module. A weather station was purchased that monitored rainfall, wind speed, relative humidity, solar radiation, soil moisture content, and air temperature. Accessories to the project included a solar panel, solar charger, battery, and a stream staff gage.

Stage is critical information when determining the quantity of flow and the loading of pollutants. For locations with a developed stage-discharge relationship, discharge is estimated based on the stage of the creek, stream, or river. In the event a control structure such as a flume or weir is integrated, there exist discharge equations based on the stage of flow. Manning's equation takes into account physical characteristics of a channel such as friction factors, slope, and cross sectional area of flow to determine discharge. Discharge data, based on stage of flow, is multiplied with constituent concentrations to determine the loading at the site of monitoring (McFarland et al. 2001). Loading of a constituent is important information for estimating water quality impacts when water discharges into larger streams, rivers , or to reservoirs that have long retention periods. Individual states are responsible for regulating the Total Maximum Daily Load (TMDL) of constituents into water bodies. The TMDL is a calculation of the amount of a constituent that can go into a water body and still have sufficient water quality (EPA, 2008). When TMDLs are surpassed, there are consequences to water quality. For example there can be a decrease in dissolved oxygen due to eutrophication which is the growth of algae do to high concentrations of nutrients such as nitrogen and phosphorous. The following describes the sensors used to measure stage in Honeycutt Creek.

Depth Measuring Sensors

A continuous radar level sensor was obtained from Omega Engineering Inc. The LVRD501-RS232 was designed for applications requiring non-contact liquid level measurement and employs microwave-pulse technology, Figure 1. Temperature, vacuums, methane, steam, pressure, carbon dioxide, vapors and condensation do not affect the sensor based on a signal processing feature called an echo marker (OMEGA ENGINEERING INC. 2008c). Specifications of the LVRD501-RS232 are summarized in Table 1.

Table 1. Continuous radar level sensor: LVRD501-RS232
(OMEGA ENGINEERING INC. 2008c).

Accuracy	±0.25%
Power	12 to 30 Vdc
Output	4 to 20 mA
Calibration	Push button
Antenna	Dielectric rod
Beam Angle	n/a
Wiring	DC: 3 wire
Range (ft)	50
Resolution (in)	0.22
Price	$1,561.00

This instrument has a calibration switch on the top of the wiring console. The LVRD501 was calibrated according to the equipment specifications (OMEGA ENGINEERING INC. 2008a). The output of the LVRD501 has a range of 4 to 20 mA. Zero level was defined at 4mA output and 4 feet was defined at a 20mA output.

Figure 1. Ultrasonic transmitter (left) and radar level sensor (right).

An ultrasonic non-contact level transmitter was also obtained from Omega Engineering Inc., Figure 1. The LVU41 has a range from 1 to 60 feet. Echoes are emitted by the ultrasonic transmitter that bounce off the water surface and return to the instrument. The time it takes for the echo to travel is recorded and transmitted as an output of distance. Specifications of the LVU41 are summarized in Table 2.

Table 2. Ultrasonic Non-contact level transmitter: LVU41
(OMEGA ENGINEERING INC. 2008b).

Accuracy	±0.25%
Power	12 to 30 Vdc
Output	4 to 20 mA
Calibration	Push Button
Antenna	n/a
Beam Angle	6 to 12°
Wiring	DC: 3 wire
Range (ft)	1-60
Resolution (in)	0.27
Price	$756

This instrument has push button calibration similar to that of the radar level sensor. Calibration of the sensor was conducted by following the equipment specifications (OMEGA ENGINEERING INC. 2008a). The output range of the LVU41 was 4-20 mA. Zero level was defined at 4mA and 4 feet was defined at a 20 mA output. There are some disadvantages to this instrument in that it has a minimum range of 1ft. Also, there is a beam angle and special care must be given to the installation of the instrument so as to not have the beam come into contact with any sides of the channel or flow control devices.

Another instrument that is being used to measure flow depth is a pressure transducer which is obtained by Omega Engineering Inc. The PX309-002G5V is a stainless steel transducer that has a gage pressure range of 2 pounds per square inch (psig). Gage pressure is measured in reference to atmospheric pressure at mean sea level (Freeman et al., 2004). Values of gage pressure are positive for pressures greater than sea-level pressure and negative when less than sea level. Gage pressure is sometimes used to describe pressure measurements referenced to ambient atmospheric pressure other than sea level (Freeman et al., 2004).

This particular device was chosen based on its range of 0-2 psi which is about 4.62 ft. The scope of the project is concerned with depths of 0-4 ft. Also, the manufacturers suggest the PX309 has a rugged stainless steel design which gives it the ability to be durable in the field, Figure 2. The PX309 contains a high-accuracy silicon sensor which is protected by a fluid filled stainless steel diaphragm. A diaphragm is a type of elastic deformation device which can be outfitted with an electrical-resistance strain gage. The output of the gage is a function of the local strain which is related to the diaphragm deflection and pressure differential (Holman, 2001). The pressure transducer is immersed in the water at a predetermined elevation or level. Specifications of the PX309-002G5V are found in Table 3.

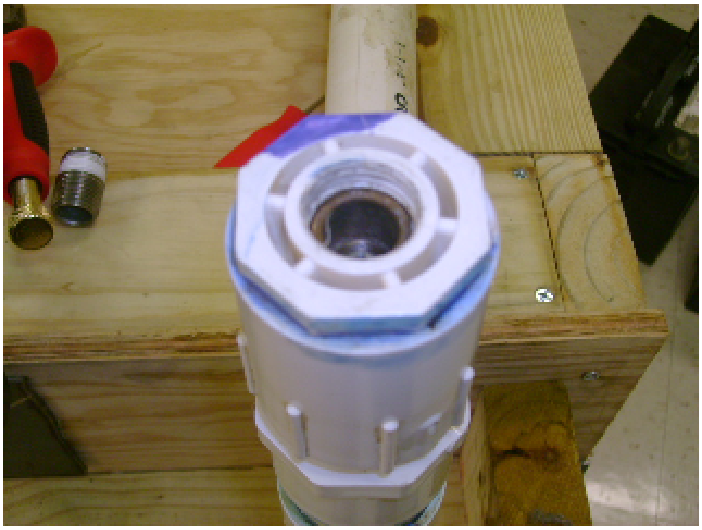

Figure 2. Pressure transducer inside protective fitting.

Table 3. Stainless steel pressure transducer: PX309-002G5V (OMEGA ENGINEERING INC. 2008d).

Accuracy	±0.25%
Output	0 to 5 Vdc
Range	0 to 2 psi
Life	10 million cycles
Operating Temperature	-40 to 185°F
Response Time	< 1 ms
Wire	3-conductor cable
Price	$325

Flow depth in Honeycutt Creek is also measured by using a 730 Bubbler Module, which is attached to an ISCO 6712 automated sampler. This device is used because it is a common addition to the widely used ISCO 6712. The module uses a differential pressure transducer and a flow of bubbles through vinyl tubing to measure depth of water up to ten feet. The gas pressure in the tube was equal to the piezometric head on the bubble tube at any gage height (Carter et al., 1968). The bubbler gage is also known as a gas-purge system. The United States Geological Survey (USGS) has been using bubbler gages since 1968 (Carter et al., 1968). A stilling well is not required for a bubbler gage. The bubble line on the ISCO is a standard 25 feet in length. The manufacturers recommend that lengths longer than 25 feet not be used. Some advantages of bubblers are they operate despite wind, fluctuations in air or liquid temperatures, turbulence, stream, foam on the surface, corrosive chemicals, debris, oil, floating grease, and lightening. The 730 Bubbler Module was easily installed on the main console of the ISCO 6712, Figure 3. Calibration of the module was done by measuring the depth of water above the bubbler tube and adjusting the reading to match it on the digital control panel. It was recommended for open channel installation that the bubble line be attached to the side of the flow channel and at a maximum height of 1-inch from the channel bottom. Specifications of the ISCO bubbler are in Table 4.

Figure 3. ISCO with bubbler module.

Table 4. Bubbler module: ISCO 730
(Teledyne ISCO. 2007).

Operating Temperature	32 to 120°F
Power	Provided by sampler
Bubble Line	Vinyl, 1/8" inside diameter, 25' length
Range	0.010 to 10 ft
Accuracy	0.01 to 5.0 ft : 0.01 ft 0.01 to 10 ft: 0.035 ft
Level Resolution	0.001 ft
Automatic Drift Correction	±0.0002ft at 15 minute intervals

It was recommended by the USGS that due to the possibility of plugged intakes or malfunctions in the sensors, a staff gage, also known as a non-recording gage, should be installed so that the water level in the creek can be directly measured (Carter et al., 1968). Advantages associated with employing a staff gage are the low initial cost compared to the sensors and the ease of installation. The gage used in Honeycutt Creek is 4 feet in length and can be read to 0.01 foot. The staff gage is a very accurate method; however it is not practical for continuous recordings. The use of only a staff gage as the means of stage measurement requires employing personnel to take continuous readings. Thus, the staff gage was used to obtain readings to compare with the digital sensors.

Water Quality Sensors

Parameters of water quality that are studied on Honeycutt Creek consisted of turbidity and temperature. A turbidity sensor, model WQ750, was selected from Global Water Incorporated, Figure 4. This device was chosen based on manufacturer reports of in the field usage, operation of a bio-wiper, and price. Although it is considerably more expensive than a laboratory turbidmeter, say a HACH instrument, the WQ750 was not the most expensive turbidity sensor commercially available. It employs a 90 degree pulse scattered light method with a measuring frequency in the near-infrared light range of 880 nm. It measures turbidity in the range of 1-1000 NTU, where NTU is the Nephelometric Turbidity Unit. The output range of the turbidity sensor is 4-20 mA. The WQ750 contains an external timer which controls a rubber bio-wiper. The bio-wiper inhibits bio-film accumulation on the lens. An excitation power was supplied and configured using HOBOware Pro software. Specifications for the WQ750 turbidity sensor are in Table 5.

Table 5. Turbidity sensor: WQ750
(Global Water Instrumentation Inc. 2007).

Output	4 to 20 mA
Power	10 -24 Vdc
Range	1-1,000 NTU
Operating Temperature	32 to 122°F
Operating Pressure	87 psi maximum
Wire	7-conductor cable
Price	$1795.50

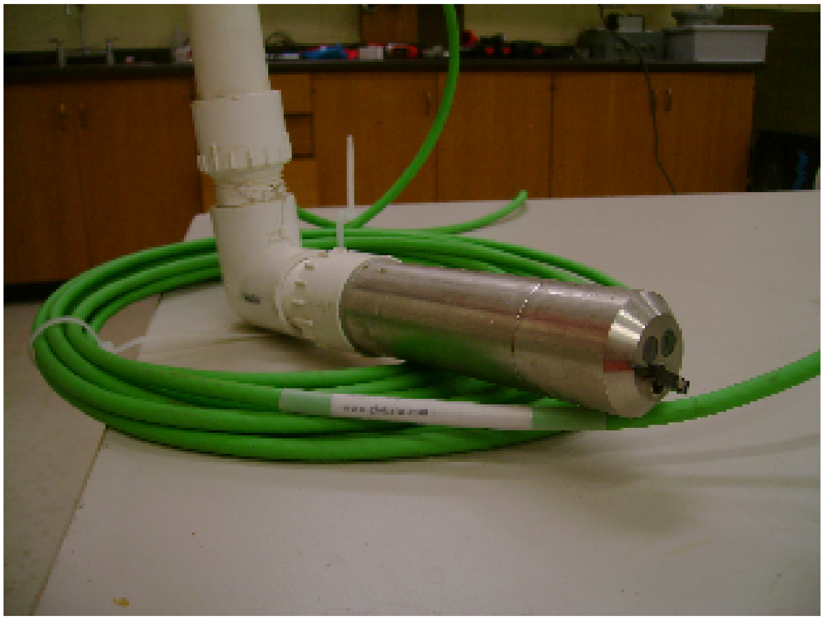

Figure 4. WQ750 turbidity sensor.

The temperature of the water in Honeycutt Creek is monitored with a temperature sensor from Onset®. The sensor employs a thermistor . The TMB-M006 was immersed in the creek. Care is taken into the situating of the sensor in the creek so debris and flow will not detach it. The sensor was not equipped with extra protective . Table 6 contains specifications for TMB-M006.

Table 6. Temperature Sensor: TMB-M006.
(Onset Computer Corporation 2008c)

Accuracy	< ±0.36°F from 32° to 122°F
Measurement Range	-40° to 212°F
Resolution	< ±0.054°F from 32° to 122°
Response Time	< 30 seconds typical to 90% in stirred water

Weather Monitoring and Data Acquisition

A HOBO U30 GSM Remote Monitoring System is the data acquisition system on Honeycutt Creek, which also serves as the weather monitoring station. The station is a self sustaining system with a power supply which is charged by a solar panel, Figure 5. The U30 connects to a cellular signal to transmit the data.

Figure 5. HOBO Onset U30 GSM data logger and weather station.

The weather station is outfitted with a variety of sensors that monitor ambient temperature, wind speed, rain fall, solar radiation, etc. The *Smart Sensors* for the HOBO weather station data logger are listed in Table 7.

Table 7. HOBO Smart Sensors

Model	Product	Cost
S-TMB-M006	12-Bit Temperature Sensor	$105
S-RGA-M002	Tipping Bucket Rain Gauge	$410
S-LIB-M003	Silicon Pyranometer (Solar Radiation)	$210
M-RSA	Solar Radiation Shield	$105
S-THB-M002	Temperature Relative Humidity	$185
S-WSA-M003	Wind Speed Sensor	$239
S-SMA-M005	20-cm Probe Smart Soil Moisture	$139
S-VIA-CM14	DC Voltage Input Adapter	$75
S-CIA-CM14	4-20 mA Input Adapter	$85

The tipping bucket rain gauge is mounted on the main shaft of the weather station. The rain gage is able to record up to 5” of rain per hour with a resolution of 0.01 inch. Rain collects in the upper tin and funnels onto the tipping mechanism (Onset Computer Corporation 2008a).

Solar radiation is measured with a silicon photodiode to measure solar power per unit area. The S-LIB-M003sensor has a maximum measurement of 1289 W/m^2 with a spectral range of 300 to 1100 nm (Onset Computer Corporation 2009a). A solar radiation shield was employed in conjunction with a temperature and relative humidity sensor (Onset Computer Corporation 2008b). Solar radiation can have an effect on temperature and relative humidity readings. The relative humidity sensor, S-THB-M002 has a range of 0-100% relative humidity which is the measurement of water vapor in the air (Onset Computer Corporation 2008b). Wind speed is measured with a 3 cup anemometer. The S-WSA-M003 measures both average wind speed and gust wind speed (Onset Computer Corporation 2003). Gust wind speed is the maximum wind speed for the logging interval and average wind speed is the average over the logging interval. The soil moisture sensor uses the dielectric constant of soil in order to determine its volumetric water content (Onset Computer Corporation 2009b). The $ECH_2O^®$ Dielectric Aquameter probe is inserted into the ground at the base of the weather station. The range of the instrument is 0- 0.450 m^3/m^3 volumetric water content. A value of 0- 0.1 m^3/m^3 represents oven-dry soil where 0.3 m^3/m^3 or higher indicates saturated soil (Onset Computer Corporation 2009b).

All of the sensors, minus those connected to the ISCO 6712, log data into the HOBO U30. The HOBO U30 is easy to configure with 10 channel ports for data collection. Two analog sensor ports allow data collection of sensors that have 4-20 mA output and that also require excitation power. The turbidity sensor is connected to the analog port because the bio-wiper requires an excitation power. HOBO Onset input adapters are used to connect the radar level sensor, ultrasonic transmitter, and pressure transducer that have 0-5 Vdc and 4-20 mA outputs.

A Global Systems for Mobile (GSM) communications radio module that uses a cellular phone network to establish an internet connection with HOBOlink.com was contained within the HOBO U30 Station. HOBOlink.com allowed for continuous logging and transmission of data using the mobile network technology. Communication with the U30 system was also conducted with a computer that had HOBOware Pro software. HOBOlink.com was used for launching devices, setting up readout schedules, configuring alarms, and checking data and sensor status (HOBO onset®). The HOBOware Pro software was used to configure the analog sensor ports, changing the default system-wide relay operation, checking cellular signal strength, testing individual sensors, and additional plotting and analysis of data files.

The power supply for the weather station, data logging system, and all the sensors is provided by a marine deep cycle battery, Figure 6. A solar panel charges the battery during the day so that during night the system may still operate. A charge controller manages the voltage from solar panel and provided 12 Vdc.

Figure 6. Weather and data logging station with solar panel.

The 12 Vdc power supplied by the solar panel and battery is enough to operate the sensors. However, the HOBO U30 system requires 4.5Vdc to charge its battery. Four voltage regulators were installed inside the power supply box. They convert the 12 Vdc into 6 Vdc. First, the 12 Vdc power supply was connected to a uA7808 regulator which produced 8 Vdc. The output of the uA7808 was connected to a uA7806 to produce a 6Vdc. This system was duplicated in order that a current of 2 Amps was provided to charge the HOBO U30 logging battery. A dry box housed the wiring provided to power the sensors and to the logger. Figures 7 and 8 depict the wiring scheme to power the sensors and the logger.

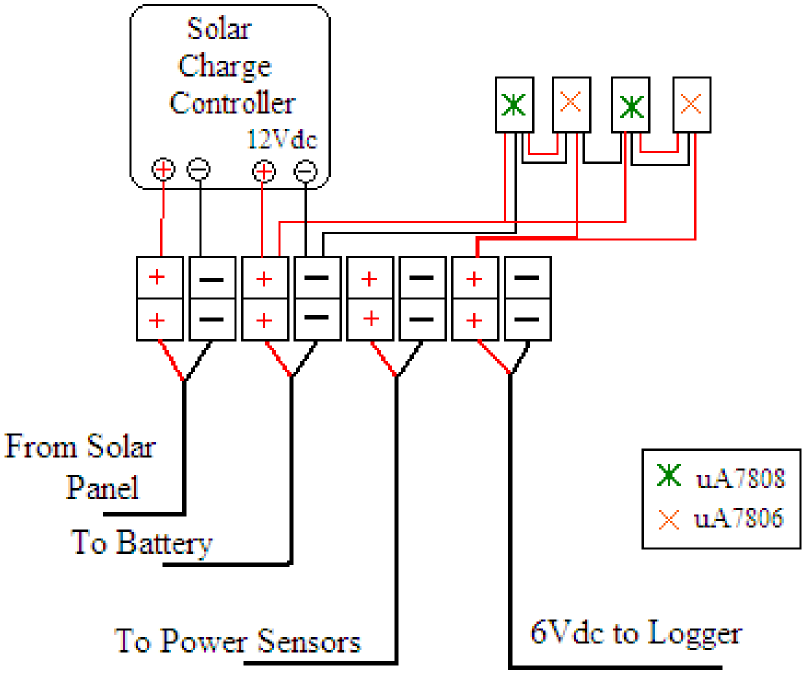

Figure 7. Wiring diagram of incoming and outgoing power supply.

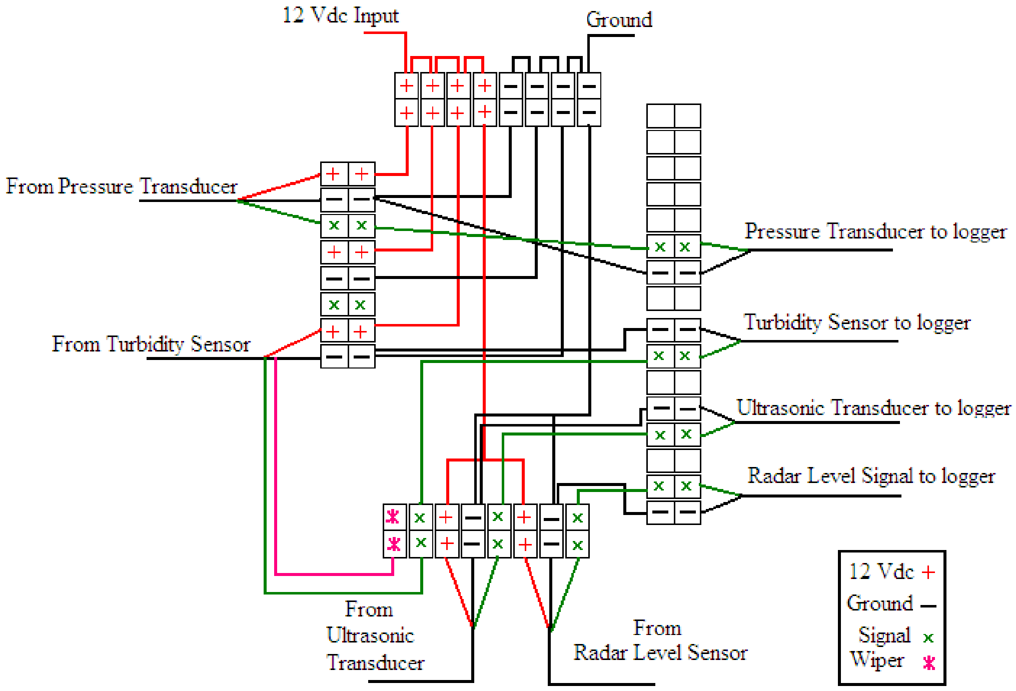

Figure 8. Wiring diagram for power supply and signal transfer for sensors.

Sensor Comparison

For sensor evaluation, two separate tests are constructed. The first compares the accuracy of the radar level sensor, the ultrasonic transmitter, pressure transducer, and bubbler in a controlled laboratory environment with predetermined depths. The second test utilizes the remote monitoring system deployed on Honeycutt Creek to monitor the performance of the depth sensors.

Laboratory Analysis Methods

For the laboratory study, shallow depths of $^1/_8$, ¼, ½, and 1-9 inches in 1 inch increments are measured in a shallow fiber glass tank. Analysis is conducted on both the rising and receding level to determine any hysteresis of the sensors. The sensor platform which held the radar level and ultrasonic transmitter is elevated 5 feet above the bottom of the tank. The ultrasonic transmitter has a beam angle of 6°, Figure 9. When the ultrasonic transmitter is elevated 5 feet, the echoes transmitted would not come into contact with the side walls before coming into contact with the bottom of the tank. The following expression shows that the wall distance of the tank must be at least 6.31" from the center line of the ultrasonic transmitter.

$$\begin{aligned} &\tan\theta = \frac{\text{wall\_distance}}{\text{sensor\_height}} \\ &\tan 6^{\circ} = \frac{\text{wall\_distance}}{60''} \qquad \text{Equation (1)} \\ &\text{Wall\_Distance} = 6.31'' \end{aligned}$$

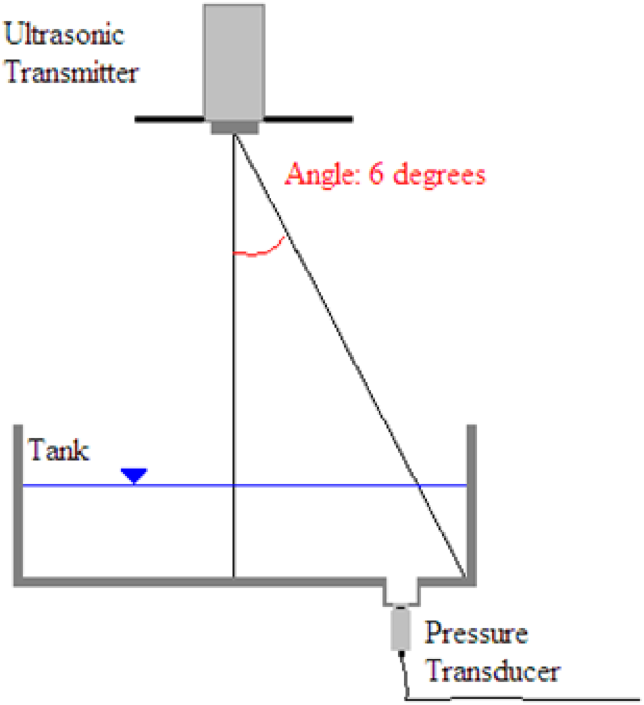

Figure 9. Ultrasonic transmitter beam angle and pressure transducer

While the radar and ultrasonic sensors are suspended above the tank, the pressure transducer is fixed to the outside of the tank at the bottom. PVC and brass pipe fittings are used and Teflon tape creates a water tight seal. It was determined how far below the bottom of the tank the pressure transducer was by filling the hole and launching the pressure transducer via HOBOware Pro software. The average reading of the transducer over a half hour was 0.4980 Volts.

The pressure transducer has an output that ranged 0-5 volts and the radar and ultrasonic sensors have an output of 4-20mA. These outputs are converted into depth using units of feet and inches. The range of depth used in the laboratory analysis is 0-48". Thus for the pressure transducer, the 0-5 volt range is converted over 0-48" depth. The PX309-002G5V has a range of 0 to 2 psi or 4.62 feet. The resulting conversion was 1.082 Volts/ft or .0902 Volts/in. Thus the conversion equation for voltage to feet was

$$Depth(ft) = \frac{output(V)}{1.082\left(\frac{V}{ft}\right)}. \qquad \text{Equation (2)}$$

The conversion from voltage to inches was

$$Depth(in) = \frac{output(V)}{.0902\left(\frac{V}{in}\right)}. \qquad \text{Equation (3)}$$

The .498 V reading of the pressure transducer was 5.52 inches which means that the instrument is 5.52" below the bottom of the fiberglass tank. The voltage reading of .498V can be subtracted from future pressure transducer readings from the shallow tank.

The radar level sensor has an output of 4-20 mA. HOBOware Pro software did not automatically convert the radar level sensor readings of 4-20 mA to depth. The equation to convert 4-20 mA to 0-48" was calculated in Microsoft Excel and resulted in the following equation

$$Depth = 3*(\text{output in mA})-12. \qquad \text{Equation (4)}$$

The HOBOware Pro software converted the ultrasonic transmitter output of 4-20 mA to feet.

The tank is set up in a temperature controlled room and leveled. First, the sensors are launched with only water filling the hole which the pressure transducer is connected. The water level was first 1/8" deep. Then ¼ and ½ inch depths were recorded. Depths 1-9" were increased in 1" increments. The water level was measured from the bottom of the tank by employing a Mitutoyo SDV-8"A digital depth recorder which is accurate to ten thousandths of an inch. When the water is at the desired depth, the recorder is relocated and the sensors are launched for a period of 30 minutes using the HOBOware Pro software. The logging interval is set to record every 30 seconds. Thus, every depth has 60 ± 2 data points. The ISCO 6712 unit with the 730 Bubbler Module sampled every minute over a 30 minute time period.

After the tank is filled to 9", it is emptied in 1" increments. The sensors were launched and logged every 30 seconds for 30 minutes. The ½", ¼", and 1/8" readings were also taken as the tank was emptied. This determined if there is any hysteresis in the instruments, especially in the pressure transducer which employs a strain gauge. The 730 Bubbler Module would not make readings below .5in.

Once the shallow depths are recorded, another tank is used made of stainless steel. The tank is approximately 26”x26”x48” in dimension. As with the shallow tank, the pressure transducer is fixed to the outside at the bottom of the tank via pipe fittings and Teflon tape. The pressure transducer is determined to be .57 inches below the bottom of the tank. The platform that held the radar and ultrasonic sensors is elevated 5 feet above the bottom of the tank. The tank is first filled to 9 inches and the sensors are run for 30 minutes with a 30 second logging interval. The water level is then raised one inch up to a depth of 12 inches. After reaching the 12 inch level, the water level is raised in 6 inch increments to 48 inches. Once the tank is filled to 48”, it is emptied and the descending depths are recorded.

All the data is collected by the HOBO U30 logging system. HOBO Pro software retrieves and converts the data to Microsoft Excel files. The data from both tanks was combined and the accuracy of the sensors in the laboratory controlled setting was determined.

Field Methods

The small watershed monitoring system is comprised of an ISCO bubbler module, a HOBO weather station, radar level sensor, ultrasonic transmitter, pressure transducer, and turbidity meter. The system is stationed on Honeycutt Creek in Clemson, South Carolina. The point where the system is established serves as an outlet for a small watershed which includes part of Clemson University campus and surrounding areas. The Honeycutt Creek watershed, Figure 10, is approximately 933 acres. Land use in the watershed is characterized in Figure 4 and Table 8. The slope of the watershed ranges from 0% to 15% with an average of 5.6%, Figure 11.

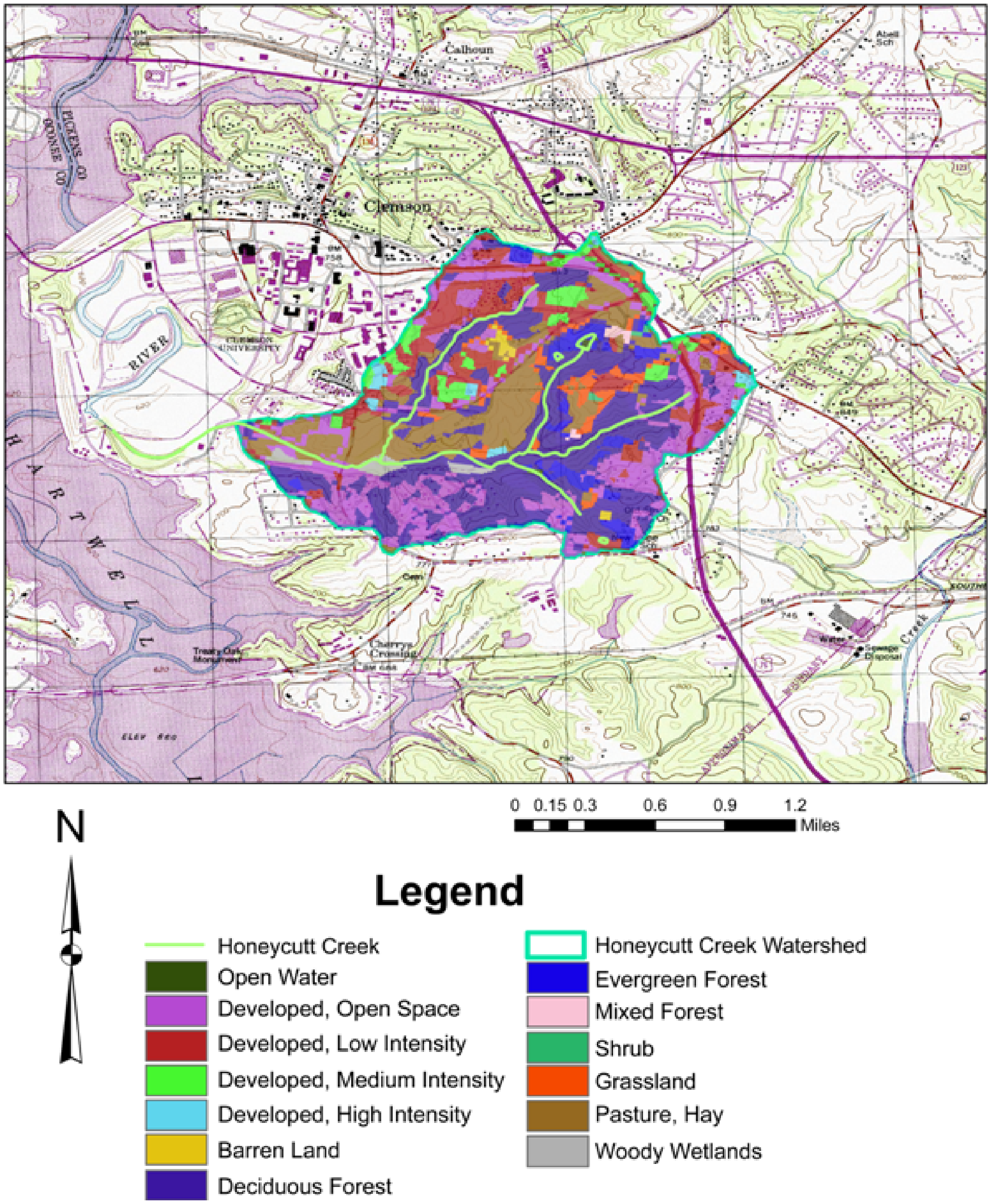

Figure 10. Honeycutt Creek watershed, Clemson, SC.

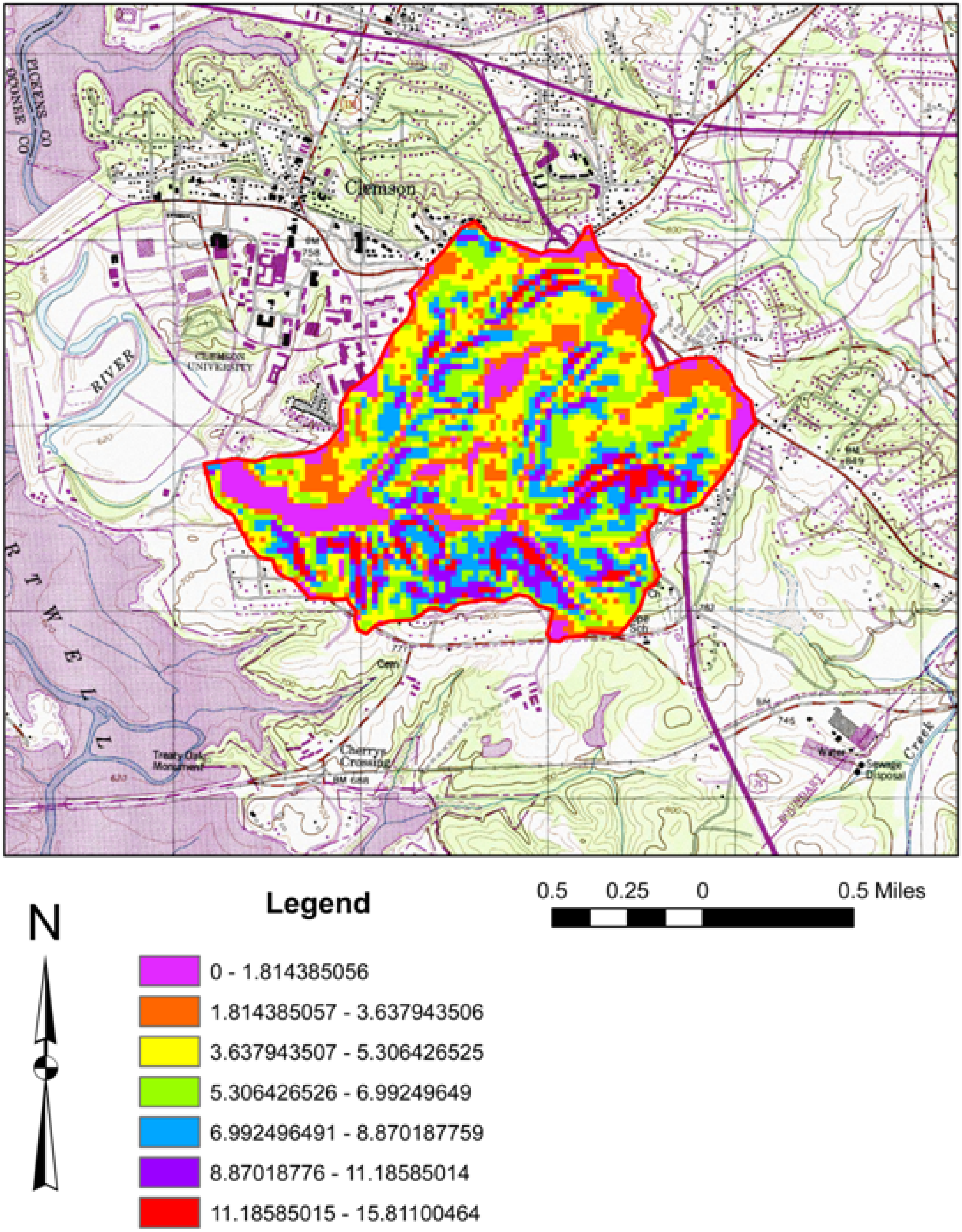

Figure 11. Honeycutt Creek watershed percent slopes.

Table 8 describes the percent of the watershed that is partitioned to which land uses. ArcMap was employed to delineate the watershed for Honeycutt Creek. All of the land characteristics and hydrology data information is gathered from National Land Cover Data available from the United States Geological Survey at www.seamless.usgs.gov. No ground truthing was conducted to confirm the GIS data.

Table 8. Honeycutt Creek watershed characteristics.

Landuse	Occurrence	Area, m^2	Area, acre	% of Area	Min. Slope, %	Max. Slope, %	Mean Slope, %
Open water	9	7931.04	1.96	0.21	1.3	9.9	5.106
Developed, Open Space	892	800299.84	197.78	21.19	0.0	15.8	5.585
Developed, Low Intensity	622	562787.55	139.08	14.90	0.0	15.1	5.020
Developed, Medium Intensity	177	163236.88	40.34	4.32	0.0	8.8	3.721
Developed, High Intensity	48	44030.10	10.88	1.17	0.3	7.7	3.726
Barren Land	21	19533.03	4.83	0.52	0.2	8.1	3.430
Deciduous Forest	1341	1210744.76	299.21	32.05	0.0	15.7	6.930
Evergreen Forest	197	171697.54	42.43	4.55	0.3	12.3	6.175
Mixed Forest	16	13839.98	3.42	0.37	3.5	11.5	6.891
Shrub	8	7067.49	1.75	0.19	1.3	4.5	3.063
Grassland	133	121430.31	30.01	3.21	0.1	12.9	5.372
Pasture, Hay	663	604916.83	149.49	16.02	0.0	10.9	4.059
Woody Wetlands	56	49601.31	12.26	1.31	0.0	11.3	2.442

As advised, the site will minimize traveling time and is located in a natural drainage way with an existing control structure (Harmel et al., 2006b). It was suggested by the USGS that the site have little possibility of the flow by-passing the control structure in ground water or in flood channels (Carter et al., 1968). Also, there should be a constant cross section where good discharge measurements could be made. It was also suggested by the USGS that the site provide proper placement of a stream staff gage with respect to the measuring section.

The remote monitoring station exists above a box culvert that lies beneath Old Stadium Road. The culvert is located at the discharge point of the Honeycutt Creek watershed. The culvert's dimensions are 10.7 ft tall, 11.5 ft wide and 84 ft long. The slope is approximately 2%. The base of the culvert is concrete. This is beneficial in that the channel in the culvert is not morphologically active. The culvert has a pre-existing channel constructed in it, Figure 12. Base flow is shallow over top of the existing channel, 1" or less. Sediment has deposited on the left side of the culvert. The stage measuring devices, turbidity sensor, and temperature sensor are located within the culvert, Figure 13.

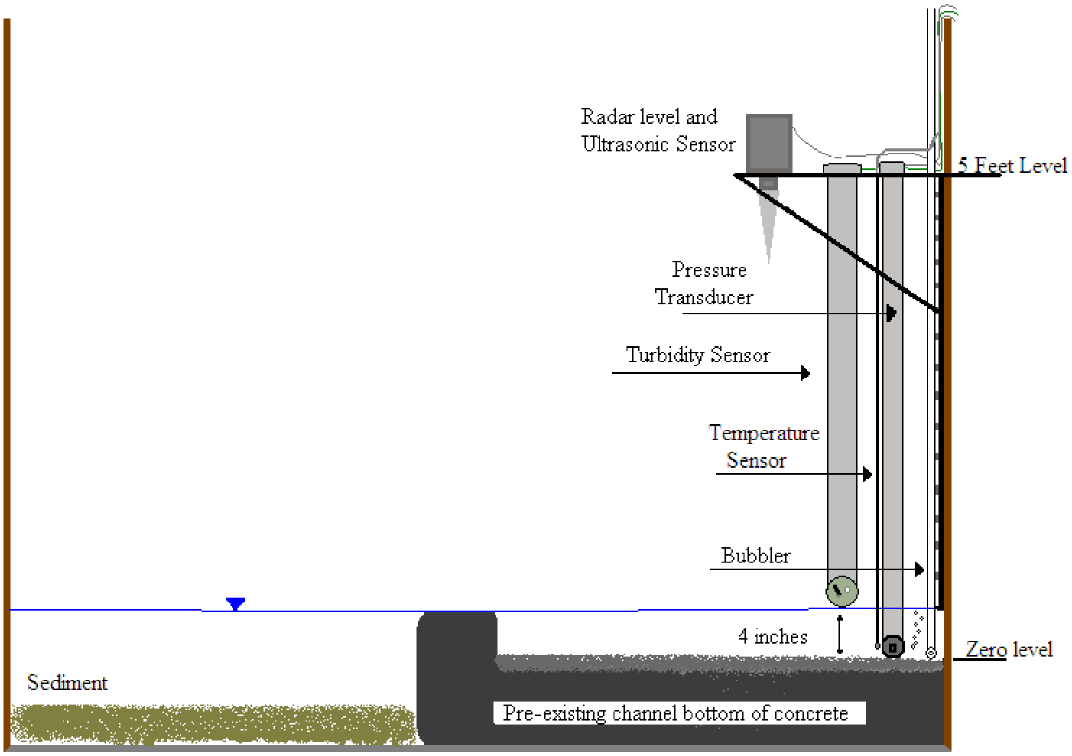

Figure 12. Cross section view of culvert on Honeycutt Creek looking upstream.

Figure 13. Instrumentation in Honeycutt Creek.

Sensor Deployment Methods

Installation of the devices was not a hard task. Once the weather station was installed on Old Stadium Road, the devices were taken into the culvert and placed on brackets. The radar and ultrasonic sensors are fitted onto a platform which sits on brackets that are fastened to the right side of the culvert looking upstream, Figure 6. The turbidity sensor is elevated 4 inches off the bottom of the channel as suggested by the manufacturer. The turbidity sensor faces downstream so as to not have debris damage the lens or the bio-wiper. The pressure transducer is immersed in the creek and fastened to the side of the culvert. The center of the pressure transducer is 1 inch above the datum line. This will be taken into account when pressure transducer readings are collected and analyzed. The bubbler tube of the ISCO is attached along side the pressure transducer positioned at the bottom of the culvert facing downstream so as to not have the tube clogged with sediment. An 8 foot tall and 4 inch wide stream depth gauge is attached to the right side of the culvert. This makes for easy and safe manual measurements during a storm event.

The culvert is located under Old Stadium Road. The weather station/data acquisition system is located off the shoulder of the road so as to not interfere or obstruct traffic but is still conveniently placed near the sensors. This location will receive direct sunlight. The ISCO is located near the wing wall of the culvert.

Over the weeks of data collection, maintenance checks of the site were made. Clean ups of debris occurred as necessary. The sensors immersed in the creek were checked for clogging and damage. There was less chance for lost data and equipment malfunctions when there was routine check up and maintenance of the instrumentation and logging system.

Data Acquisition Methods

The deployed sensors began taking readings as soon as the weather station and logger were initiated. The logging interval was set at one minute, and the logger read out to HOBOlink.com 20 times when needed. Alarms are configured on HOBOlink.com to alert when a connection fails; a sensor fails to make a reading, or when the battery is running low. The bubbler module’s data is collected in the ISCO 6712. Transfer of the data reports is done with a Teledyne ISCO 581 RTD, rapid transfer device, and a computer running Flowlink software.

During a storm event, manual depth recordings were made from the creek bank. The start time and depth was recorded. Then measurements of the creek depth were made every minute. Binoculars were used to measure depth of water against the stream depth gauge. Readings were made out to the hundredth place of a foot. The sensor readings are compared to the manual readings.

CHAPTER V

RESULTS AND DISCUSSION

A goal of this study is to determine what stage measuring device performs with the most accuracy and reliability to be recommended for future remote monitoring small watershed stations. The four stage measuring devices under consideration are a LVRD501 radar level sensor, LVU41 ultrasonic transmitter, PX309 pressure transducer, and an ISCO 730 bubbler module.

Before the sensors are installed on the Honeycutt Creek monitoring station in Clemson, South Carolina analyses are conducted in a laboratory environment.

Laboratory Analysis

The stage measuring devices were run using tanks where the water level was elevated and lowered to known depths, Figure 7. The results from the laboratory tests for the devices can be found in Appendix A, Tables A1-A21.

All of the sensors report an accuracy of measurement, Table 9. The range of depth the devices measured was 48 inches. An accuracy of ±0.25% means the radar, ultrasonic, and pressure transducer devices should measure within .12 inches of the actual depth. The bubbler module has an accuracy of 0.12 inches as well for the range of 48 inches.

Table 9. Advertised accuracies of stage measuring sensors.

Device	Accuracy
Radar level sensor LVRD501-RS232	±0.25% of max range
Ultrasonic transmitter LVU41	±0.25% of max range
Pressure transducer PX309-002G5V	±0.25% of max range
Bubbler module ISCO 730	±0.25% of max range

An average percent error was computed for all four sensors to reflect the accuracy. The increasing and decreasing water level data was all combined into one data set. The absolute value of the difference between the sensors' readings and the actual depth was computed and then divided by the actual depth, Equation 5. The literature for the devices reports an accuracy of ±.25%. Table 10 presents the calculated average percent error for the sensors over a maximum range of 48 inches.

$$Accuracy = \left| \frac{Actual - SensorOutpu}{Actual} \right| \qquad \text{Equation (5)}$$

Table 10. Calculated percent error for stage measuring devices.

Device	Percent Error
Radar level sensor	23.46
Ultrasonic transmitter	31.06
Pressure transducer	10.26
Bubbler module	54.55

A correlation analysis of the radar level sensor, ultrasonic transmitter, pressure transducer, and bubbler devices to the actual water levels both increasing and decreasing is in Figure 14.

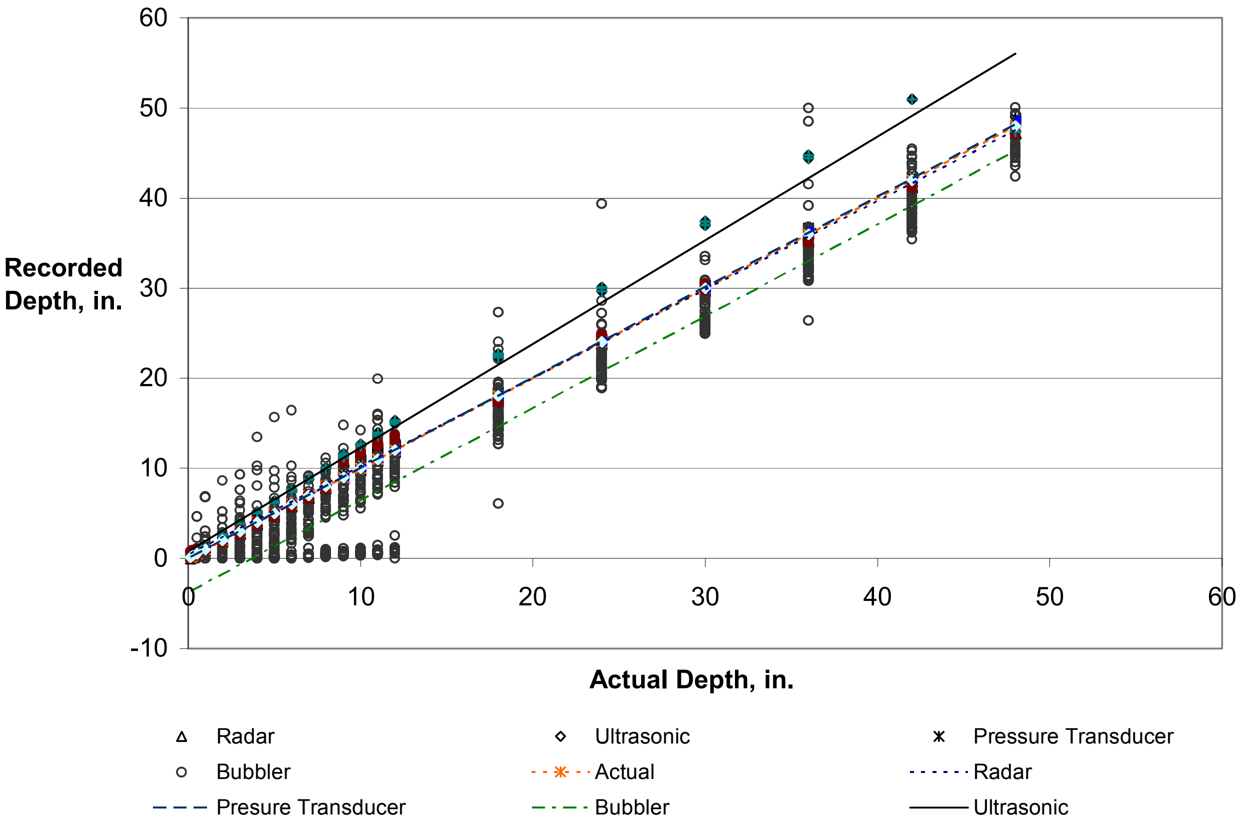

Figure 14.Correlation of recorded depth to actual depth for stage measuring devices.

Linear regression lines were constructed for each of the sensors. Each line has a coefficient of determination, R^2. The coefficient of determination is the square of the correlation coefficient, R. The correlation coefficient conveys how good a fit the observed depth data is to the actual. A perfect fit between the observed and actual would result in a R^2 value of 1 and reflects no deviations from the sensor readings and the actual depths. The R^2 values, slopes, and intercepts are displayed in Table 11 for the sensors. These values were obtained from the statistical analysis program SAS 9.2.

Table 11. SAS 9.2 output for laboratory depths.

Device	Y-Intercept	R^2	P-value	Slope	Standard Error	T-stat
Radar Sensor	0.4187	0.9969	<.0001	0.9819	0.002157	-8.496
Ultrasonic Transmitter	0.7705	0.9862	<.0001	1.1515	0.002157	41.155
Pressure Transducer	0.0419	0.9999	0.2904	1.0003	0.002157	0.829
Bubbler Module	-3.765	0.9299	<.0001	1.0216	0.00313	-4.477

SAS 9.2 was run to produce P-values and T-stats for the intercepts and slopes. For this analysis a confidence interval of 0.05 was used. A P-value greater than .05 means that there is no significant difference between the intercept of the regression line and that of the actual which is zero. It can be seen in Table 11 that the pressure transducer is the only sensor with intercept P-values greater than .05. Thus it can be asserted that the pressure transducer is the only sensor with intercepts not significantly different from zero.

A comparison of the slopes is performed using the calculated T-stat and a two tail test. For this analysis a confidence interval of 0.05 is used. This means that there is 95% confidence that the value will lie within an interval bounded by ±1.96. The T-stat is calculated by subtracting 1 from the slope and dividing by the standard error. The null hypothesis of this analysis is that the slope will be equal to 1, and the alternative is the slope is not equal to 1. If the T-stat lies in the rejection region which is greater than 1.96 and less than -1.96, then the null hypothesis is rejected. As can be seen in Table 11, the pressure transducer is the only sensor that does not lie in the rejection region. Thus, the pressure transducer's slope of the regression line is not significantly different from one. This analysis proves that during the laboratory experiment, the pressure transducer has the slope closest to the value 1 and intercept closest to zero. The pressure transducer is the sensor that measures closest to the actual depth.

An analysis of any hysteresis was conducted. Hysteresis exists when there is a difference in a measured value when approached from below and above. Graphs of the sensor readings were constructed and can be seen in Figures 15, 16, 17, and 18.

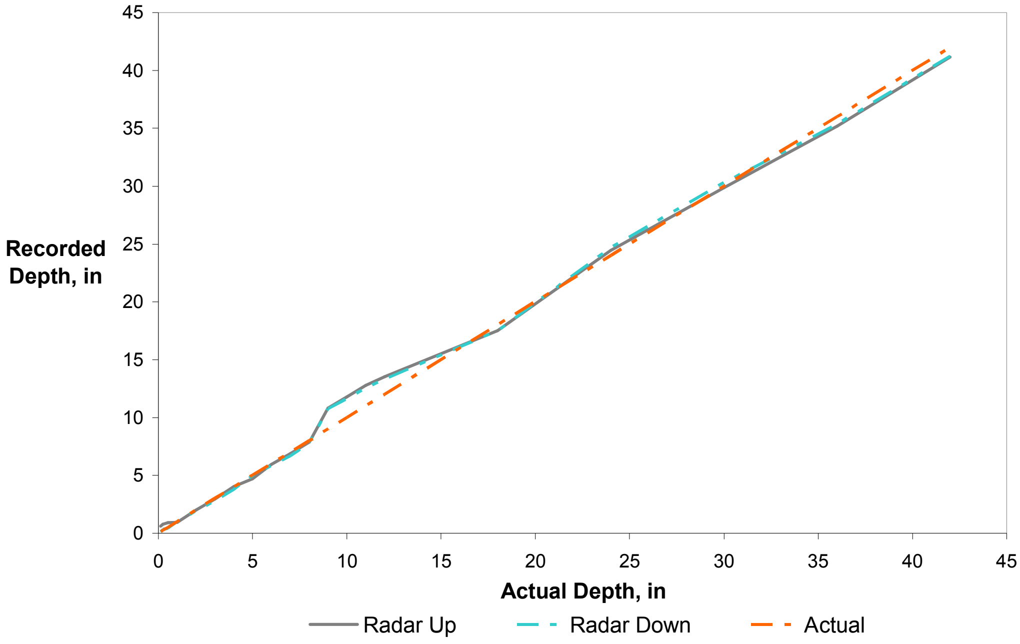

Figure 15. Hysteresis: radar level sensor.

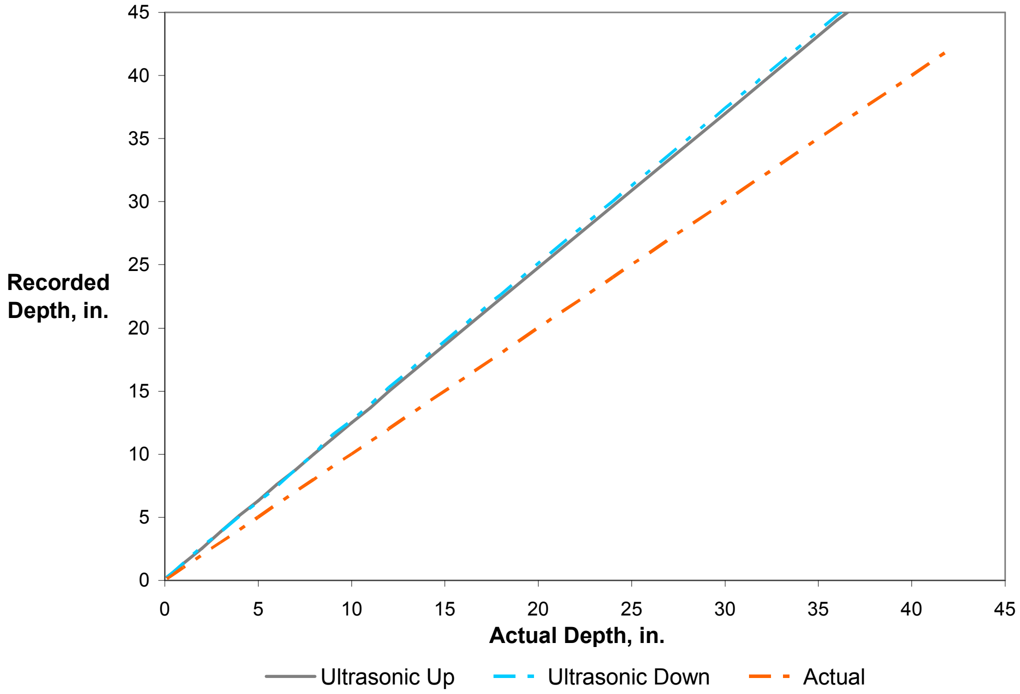

Figure 16. Hysteresis: ultrasonic transmitter.

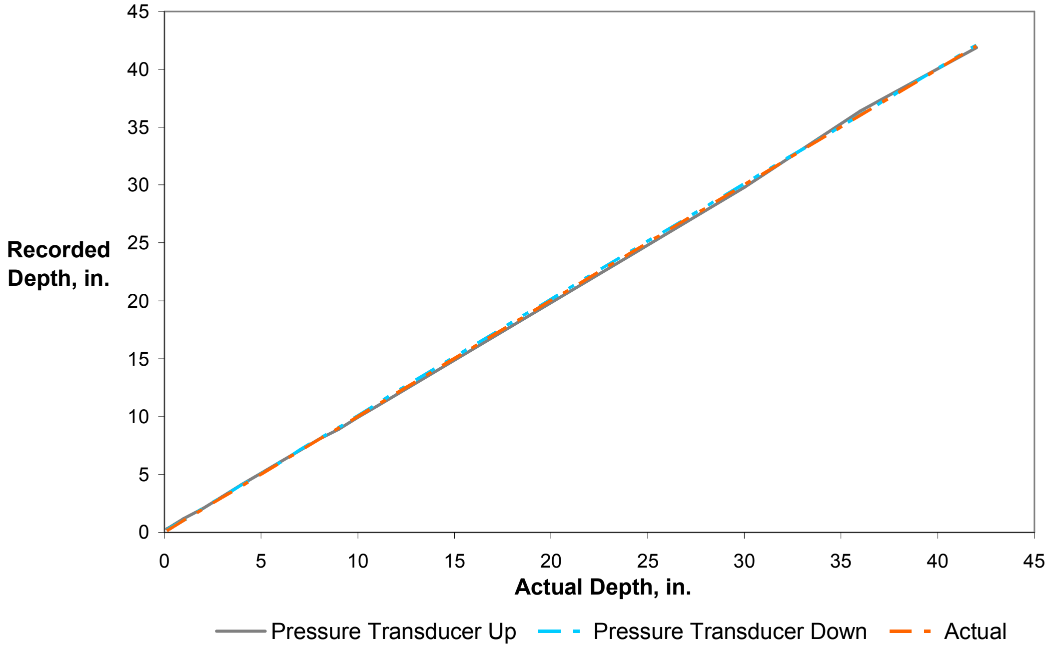

Figure 17. Hysteresis: pressure transducer.

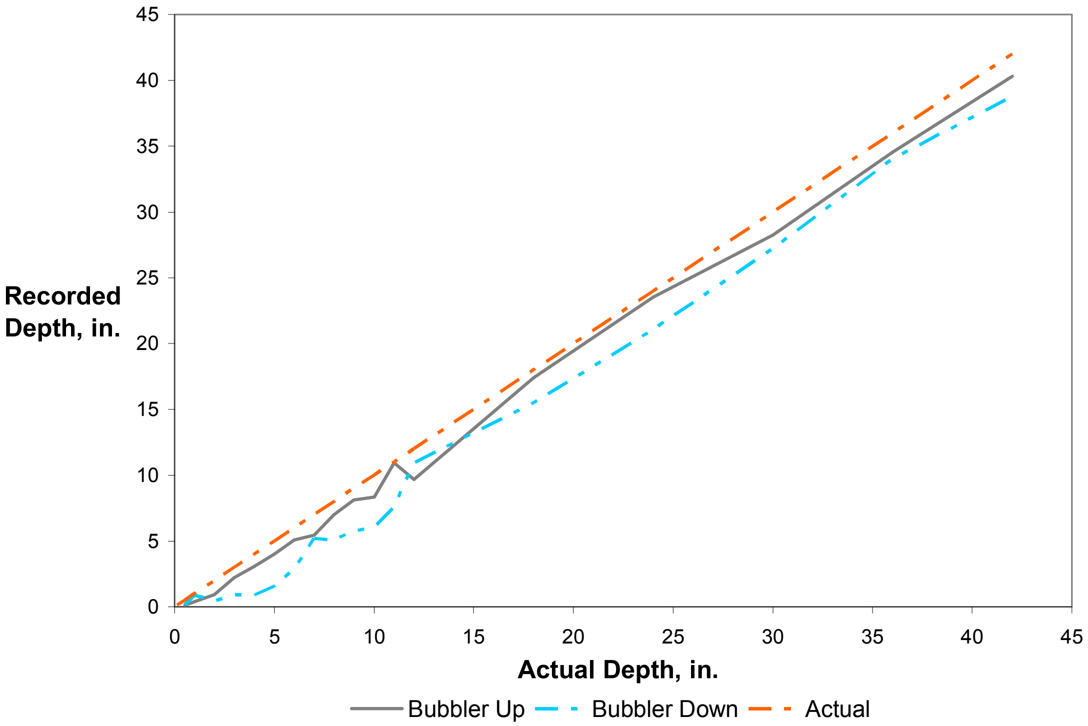

Figure 18. Hysteresis: bubbler module.

Visually, the bubbler module appears to have the greatest difference between lines of data. The pressure transducer is the only instrument that employs a strain measuring device with a flexing diaphragm. This analysis proves that the pressure transducer has little to no hysteresis, despite having the force flexing devices that are prone to stretching.

Taking into account the various analyses performed on the sensors in the laboratory, the PX309 pressure transducer out performed the other devices. This device also proved to be the least expensive. Note that during the course of laboratory analysis two pressure transducers failed to operate. It was determined after sending the sensors to the manufacturer that the diaphragms on the two were broken. This could have been caused by over pressurization and water hammers. Over pressurization could not have been possible because the 2 psi gage is 4.62 feet and the water level above the device did not exceed 50 inches or 4.16 feet.

Field Results

After laboratory analysis was completed, the stage, turbidity, and weather measuring devices were deployed on Honeycutt Creek, Figure 19. There were three rain events where observations of creek depth were made. Saturday October 31, 2009 was the first observed rain event. There is no bubbler module information because the bubbler module was not installed, Table B1. There are 152 data points recorded, one per minute, as shown in Figure 20. The maximum observed depth of the creek was .41 feet or 5.02 inches

Figure 19. Honeycutt Creek monitoring station instrumentation.

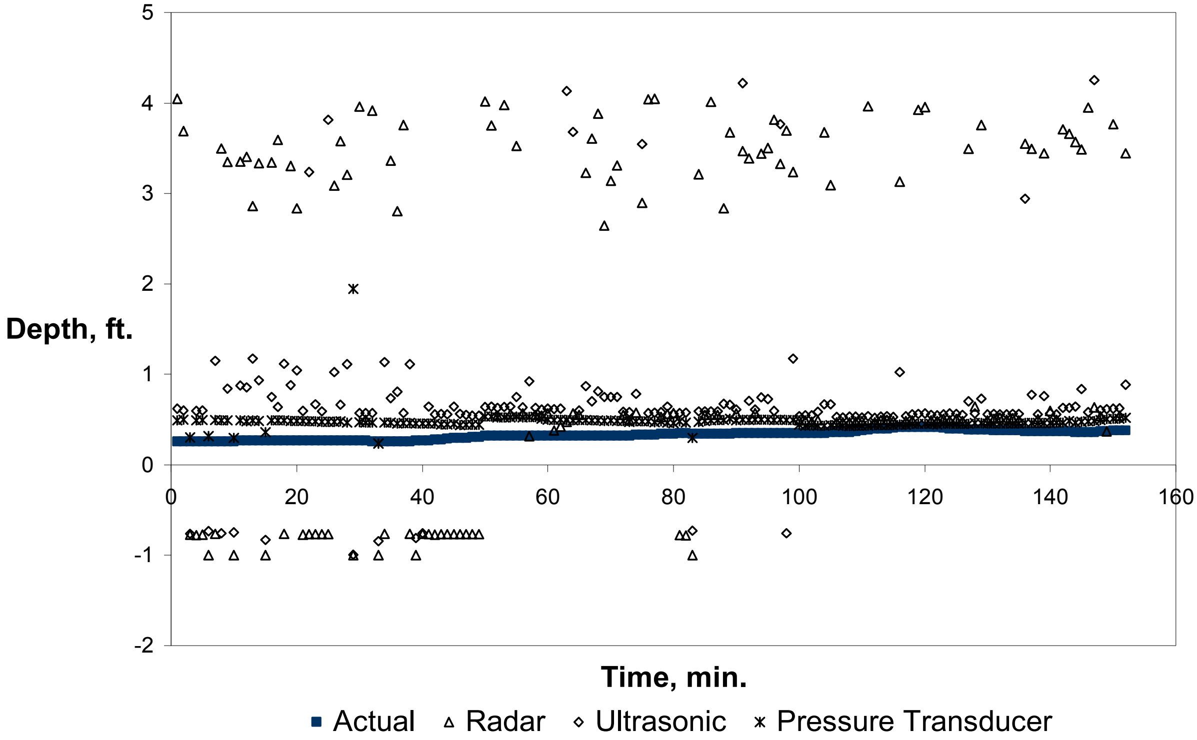

Figure 20. October 31, 2009 Honeycutt Creek depths.

On November 10, 2009 three observations were made during the rain event which lasted for the better part of the entire day. Ninety-one observations were made at 10:39 A.M.- 12:09 P.M. as seen in Table B2. The maximum observed depth of the creek was 0.54 feet or 6.48 inches, Figure 21. At 1:39 P.M. 91 observations were made and, as seen in Table B3. The maximum observed depth of the creek was 0.53 feet or 6.36 inches, Figure 22.

Only the pressure transducer and bubbler recordings are present during these observations. The data was downloaded from the logger using the HOBOware Pro software after these two observations, and it was apparent the radar level sensor and ultrasonic transmitter were not logging during the observations. An explanation for this may be the solar panel was supplying a limited amount of voltage that was not enough to run all three instruments. The bubbler module was operating on its own ISCO and was not inhibited by this malfunction.

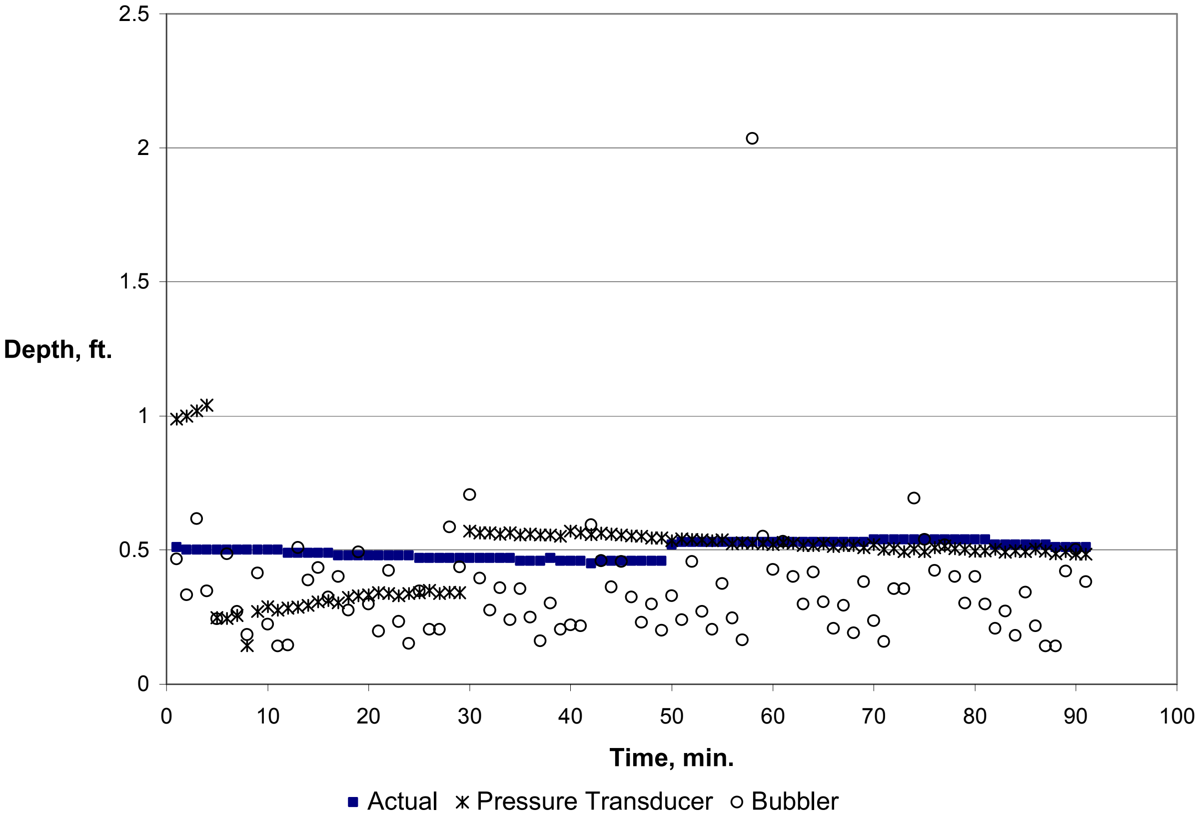

Figure 21. November 10, 2009 (10:39A.M.-12:09P.M.) Honeycutt Creek depths.

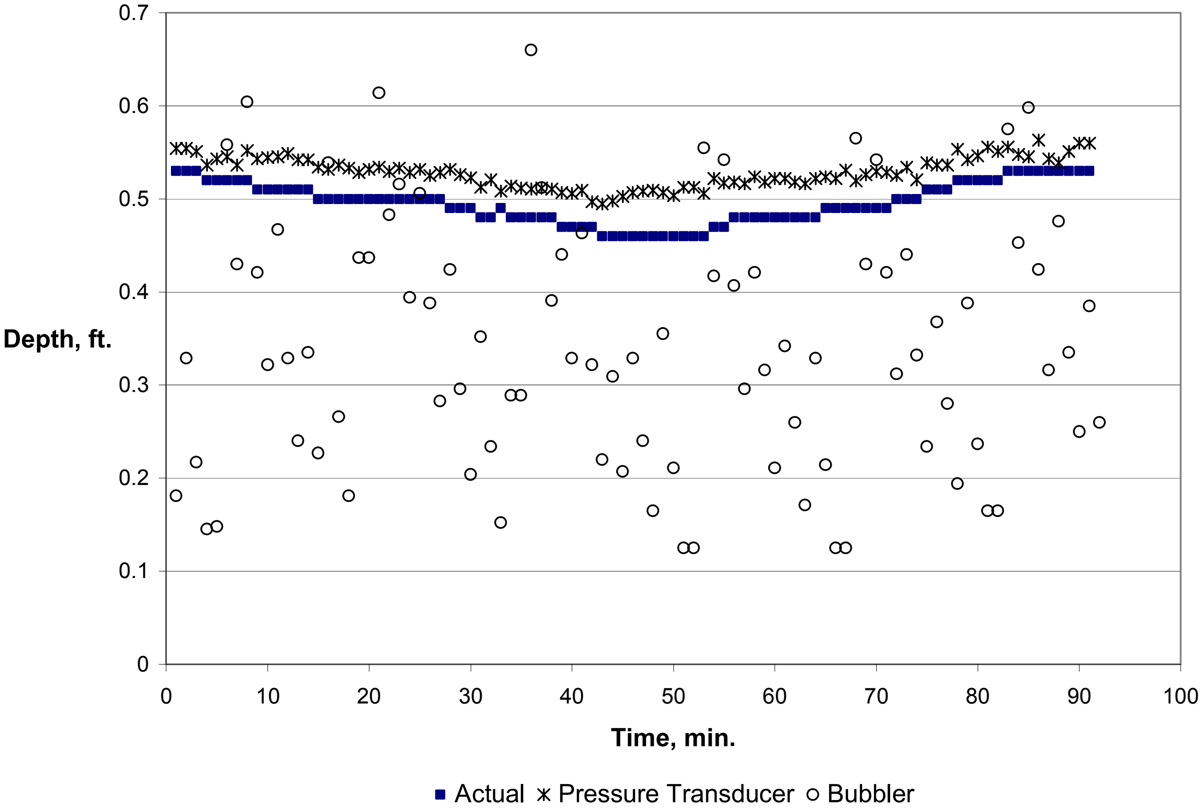

Figure 22. November 10, 2009 (1:39 P.M.-3:09P.M.) Honeycutt Creek depths.

The deep cycle battery was taken to the laboratory after the data was downloaded and the problem was noticed. The battery charged before being taken out to the station for a third observation, shown in Table B4. All four devices were operating, as seen in Figure 23. The maximum observed height of the creek was 0.45 feet or 5.52 inches.

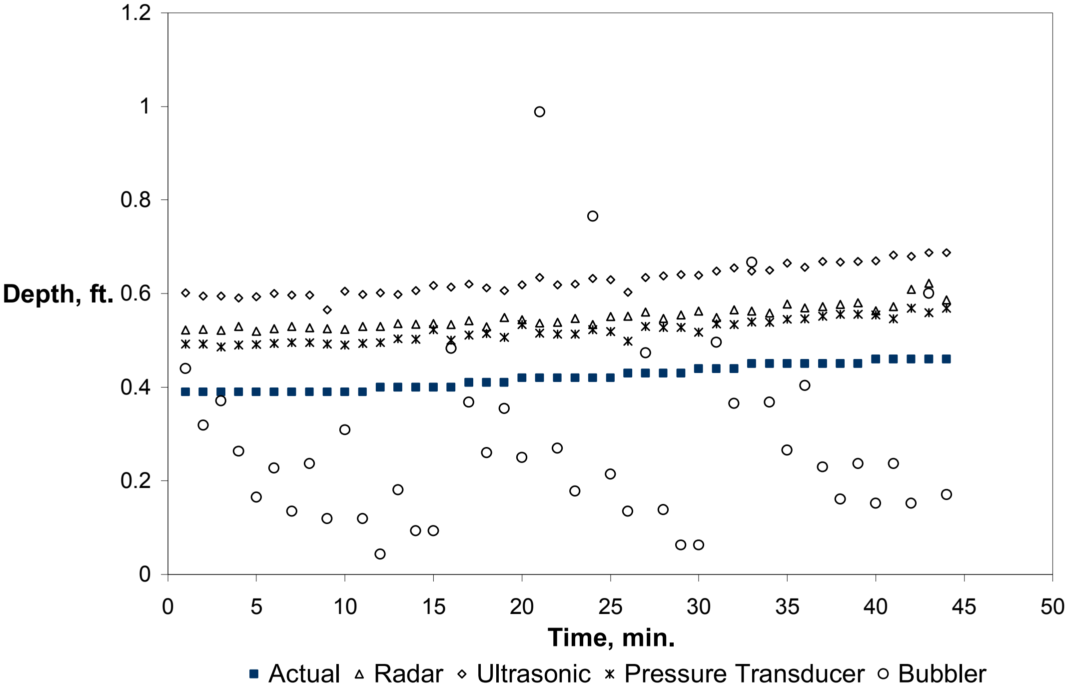

Figure 23. November 10, 2009 (5:32 P.M.-6:15 P.M.) Honeycutt Creek depths.

November 18, 2009 saw a rain event that had increasing and decreasing creek levels during the data collection period, Figure 24. The maximum height of the creek during the data collection period was 0.66 feet or 8.02 inches, Table B3. All four devices were running during this rain event.

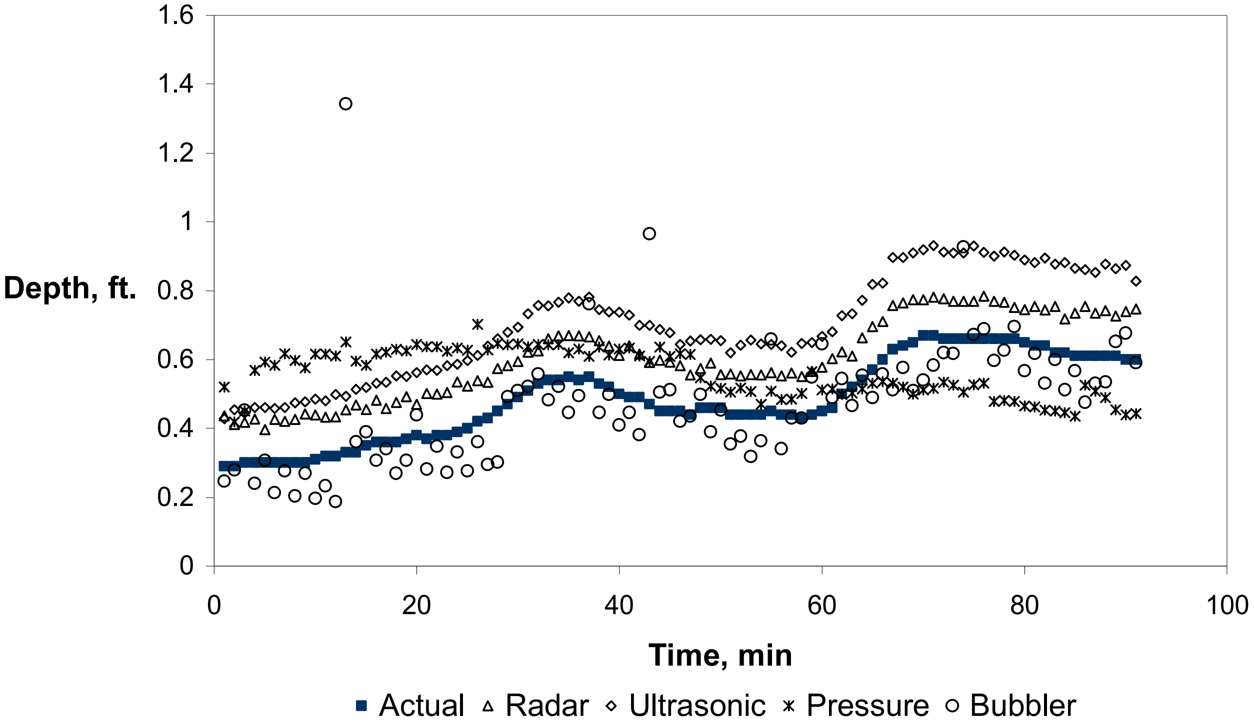

Figure 24. November 18, 2009 Honeycutt Creek depths.

An analysis on the accuracies of the instruments within the creek was performed. The procedure used for the laboratory was performed with the field data using Equation 5. Table 12 shows that the radar level sensor is the device with the least accurate measurement being about 274% off from the observed values. The percent error values for the laboratory in the table represent the range of 0.2-0.8 feet, because this is the range of depths within Honeycutt Creek during observations.

Table 12. Calculated percent errors of devices in field and laboratory: range 0.2-0.8 ft.

Device	Percent Error (Field)	Percent Error (Laboratory)
Radar level sensor	273.63%	6.48%
Ultrasonic level transmitter	114.87%	29.56%
Pressure transducer	30.88%	1.66%
Bubbler module	19.29%	70.45%

A correlation analysis for the combined field data was conducted using SAS 9.2. The confidence interval is 0.05. A graph of the correlation can be seen in Figure 25. SAS 9.2 was run using the same program as the laboratory analysis with outputs of intercepts, slopes, P, and T values. The SAS 9.2 program output can be seen in Appendix C.

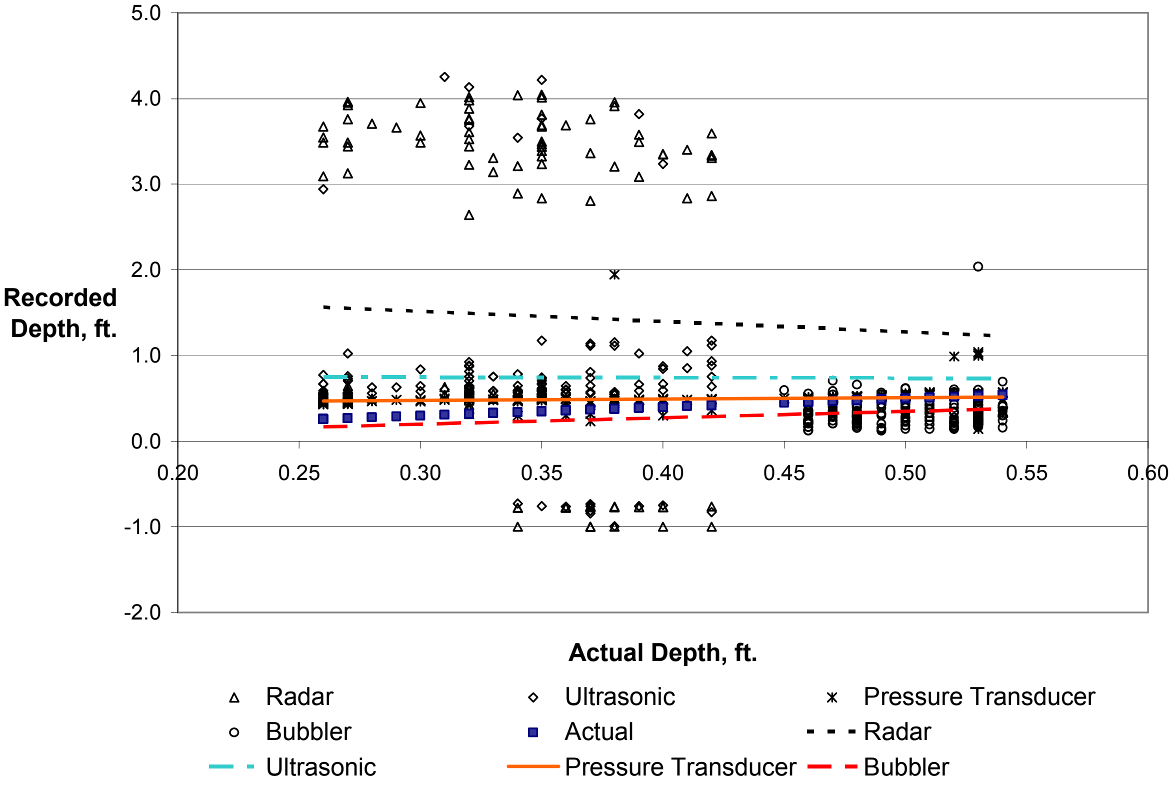

Figure 25. Correlation of recorded sensor depths to actual Honeycutt Creek depths.

Outputs of the SAS 9.2 program of the combined field data show that the bubbler module has the only P value greater than .05 for its intercept which means it is not significantly different from 0, Table 13. The T-stat for the bubbler module lies within the range of -1.96 to 1.96 for a two-tail test. Thus, statistically, the bubbler module has a Y-intercept not different from zero and that the slope is not significantly different from one. Note the trend in the bubbler data for all the observations. There is a downward diagonal trend in the data. This could be due to the module resetting or clearing the bubble tube. The manufacturers do not present any information on this in the operation guide (Teledyne ISCO, 2007).

Table 13. SAS 9.2 outputs for combined field data.

Device	Y-Intercept	R^2	P-value	Slope	Standard Error	T-stat
Radar Sensor	2.0453	0.0351	<0.0001	-2.5101	0.5422	-6.9322
Ultrasonic Transmitter	-.5767	0.0035	0.0004	0.3394	0.3305	-2.750
Pressure Transducer	0.4693	0.0067	0.0015	0.09112	0.3967	-8.848
Bubbler Module	0.07095	0.1033	0.7891	0.6465	0.3967	-.6519

The accuracy and correlation analyses of the field data suggest that the bubbler module out performs the other devices. However, given how the data looks, the pressure transducer appears to perform more consistently than the scatter of the bubbler module.

Turbidity was also measured in Honeycutt Creek using a Global Water WQ750 turbidity sensor. Safe drinking water has a maximum turbidity level of 5 Nephelometric Turbidity Units (NTU) as stated by the World Health Organization (World Health Organization, 2009). The range of turbidity levels for the November 10 (5:32 P.M.-6:15 P.M.) and 18, 2009 observations are displayed in Table 14. The water flowing in Honeycutt Creek during the two rain events is well out of safe drinking water range. The October 31, 2009 and two earlier observations on November 10, 2009 are not displayed. There was sensor malfunction most likely due to low power supply. Figure 26 displays the turbidity levels during the rain events mimicked the trends of the stage in Honeycutt Creek.

Table 14. Turbidity levels in Honeycutt Creek.

Date	Minimum, NTU	Maximum, NTU
November 10, 2009	40.39	51.28
November 18, 2009	28.61	146.33

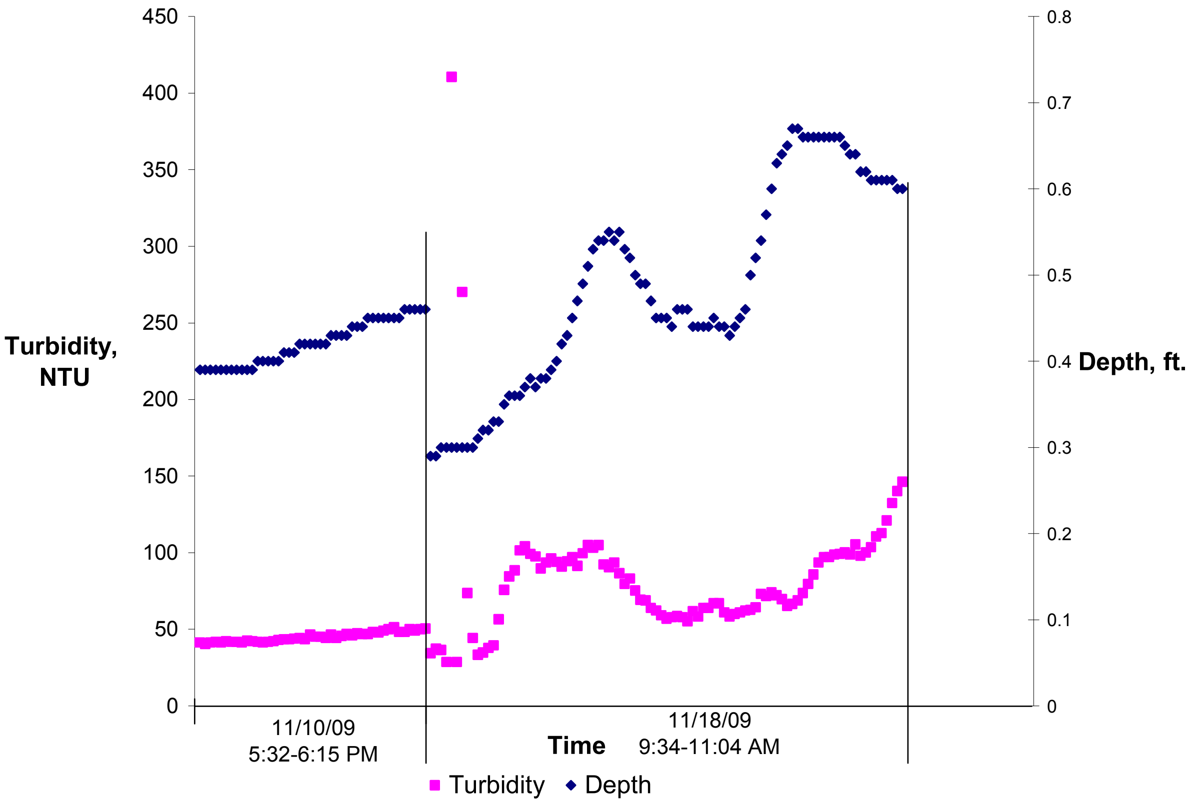

Figure 26. Turbidity trends versus time and depth in Honeycutt Creek.

Temperature was also measured in Honeycutt Creek. The trends of temperature versus time and depth can be seen in Figure 27. Data from November 10 was combined into one set. The temperature was considerably constant during the November 10 rain event. The breaks in the data points represent the three different observations made that day. October 31 temperature data shows an increase in temperature by about 1 degree Fahrenheit when there were peaks in creek depth. The same can be said for November 18. However, the temperature trends on November 18 only mimicked the first peak in creek depth.

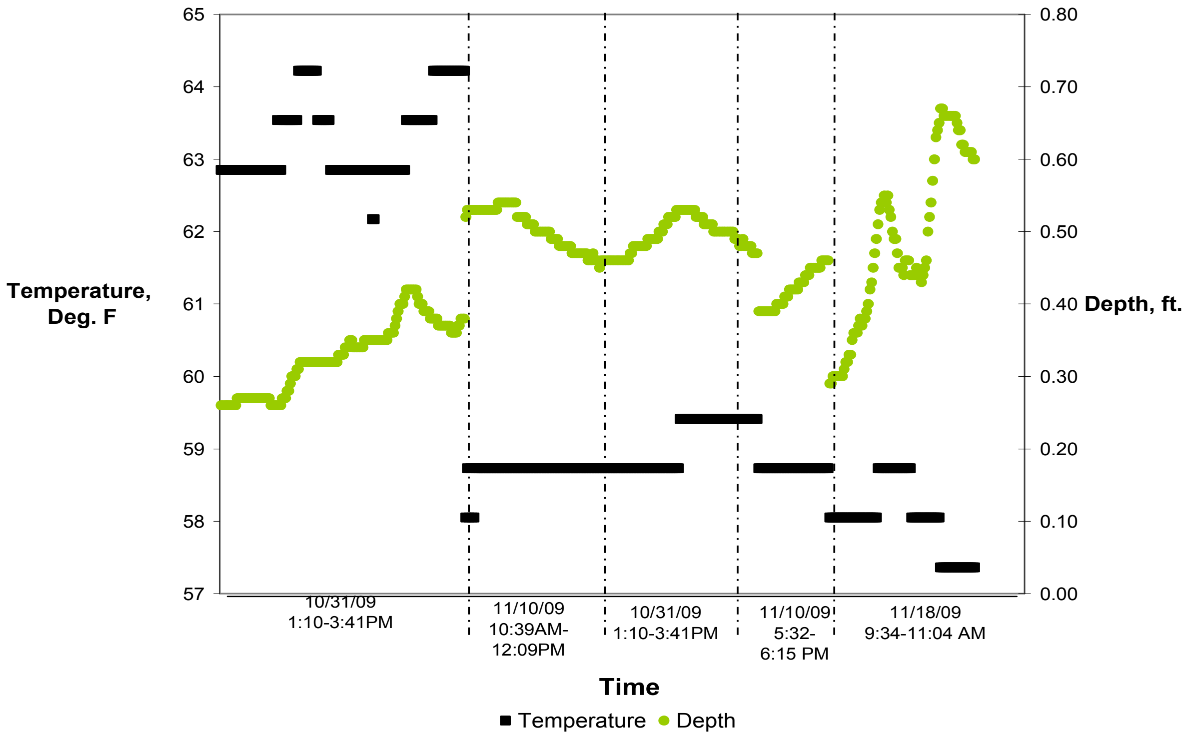

Figure 27. Temperature trends versus time and depth in Honeycutt Creek.

Note that the turbidity sensor and temperature sensors were stationary in one fixed point in the creek, Figure 28. When using a turbidity sensor, one has to assume that the creek is well mixed and that the turbidity level represents the entire cross section of flow. The same can be said for using one temperature sensor. The assumption is made that the temperature recorded is a representation of the entire depth of flow. This however is not always the case due to solar radiation in creeks and the presence of thermoclines in large rivers. The installation of several temperature sensors would allow for a better representation of the temperature changes throughout the water column.

Figure 28. Turbidity sensor, bubbler, temperature sensor, and pressure transducer installed in Honeycutt Creek.

As can be seen in Figures 26 and 27, estimating trends in turbidity and temperature require the knowledge of the amount of flow. Water flow rate, Q, is a factor of cross sectional area of flow and velocity. Stage of flow is critical for calculating cross sectional area of flow. Thus the importance of having water flow rate data is evident when trying to determine water quality using turbidity and temperature trends.

CHAPTER VI

CONCLUSION

There is a direct relationship between economic development and the degradation of the environment and its natural resources. Changes occur to the water quality and quantity in nearby creeks, streams, and rivers as land is developed. Watershed monitoring programs have been put in place to characterize changes to the chemical, physical, and biological integrity of our natural water resources due to storm water runoff. As a result, a remote small watershed monitoring system was developed and installed in Honeycutt Creek in Clemson, SC. A goal of this is study to determine the best method to monitor stage depth and water quality parameters such as turbidity and temperature.

Four different stage measuring devices were employed on the monitoring station on Honeycutt Creek. Turbidity meter and temperature sensors were also deployed to collect water quality data. A summary of attributes of the devices can be seen in Table 15. Some of the attributes are given ratings of high, medium, and low as compared to one another.

Accuracy and correlation analyses were conducted on the stage measuring devices in a laboratory setting before being installed in Honeycutt Creek. The results of the accuracy analysis proved that the pressure transducer has the least percent error of readings with a value of 10.26%. A statistical analysis of correlation between the outputs of the devices to the actual was conducted using the statistical analysis program SAS 9.2. The results from this analysis proved the pressure transducer was the device with a Y-intercept that is not significantly different from zero. Also, the SAS 9.2 correlation output proved that the pressure transducer was the only device that had a slope not significantly different from zero. Thus, given the situation of a laboratory setting, the pressure transducer out performed the other three stage measuring devices.

Table 15. Stage, turbidity, and temperature measuring device attributes.

Device	Manufacturer	Output	Difficulty of Installation	Cost	Field Accuracy	Reliability	Other
Radar level sensor	Omega Engineering Inc.	Analog	High	High	Low	Low	Push button calibration, non-contact sensor
Ultrasonic level transmitter	Omega Engineering Inc.	Analog	High	High	Low	Low	push button calibration, beam angle
Pressure Transducer	Omega Engineering Inc.	Analog	Low	Low	Medium	Medium	no calibration installed in creek
Bubbler Module	Teledyne ISCO	Digital	Medium	High	Medium	Medium	operates on ISCO sample installed in creek
Turbidity Sensor	Global Water Inc.	Analog	Low	High	n/a	Medium	bio-wiper
Temperature Sensor	HOBO Onset	Analog	Low	Low	n/a	High	n/a

After the stage measuring devices were analyzed in the laboratory, they were installed in the field. A culvert under Old Stadium Road in Clemson, SC serves as the location of the monitoring station. The culvert is located at the discharge point of the Honeycutt Creek watershed that is approximately 1000 acres. Land uses within the water shed include residential areas, forested lands, pastures, and some Clemson University facilities. A HOBO Onset U30 serves as logger collects the data from all of the devices. It is attached to a weather station mast that measures different weather characteristics such as rain fall amount, wind, solar radiation, temperature, etc. The monitoring station is designed to be self sustaining in that it is powered by a solar panel that charges a deep cycle battery. During the day, the solar panel powers the station and in the evening the battery powers the station. Installation of the weather station mast, logger, and solar panel was not difficult. The installation of the devices is summarized in Table 15.

Once all the devices were installed in the creek, observations of creek depth during storm events were made. A staff gage was installed on the wall of the culvert to allow for manual depth observations. The depth observations were compared to the stage measuring device outputs.

Accuracy and correlation analyses were conducted for the field data similar to the laboratory analysis. The accuracy analysis included calculating the percent error. It was surprising to see the bubbler module accuracy was better in the field than in the laboratory. The non-contact sensors, radar and ultrasonic, had more error in the field than in the laboratory. The correlation analysis between the sensor data and the actual creek depth resulted in the bubbler module having the best correlation. The Y-intercept for the bubbler module is not significantly different from zero, and the slope is not significantly different from 1. The pressure transducer had a surprisingly low correlation. However, the plotting of the data showed an offset exists. This offset should be determined and corrected for in the output. The radar level sensor and the ultrasonic non-contact level sensor proved to be insufficient devices to measure stage in Honeycutt Creek. These devices are not recommended for future remote watershed monitoring stations due to their lack in accuracy, degree of difficulty to install, and price. For example, about 5 pressure transducers can be purchased for the price of one radar level sensor.

The turbidity and temperature devices were installed in one point in the creek. The creek is assumed to be well mixed and that the outputs reflect the entire cross sectional area of the flow. The turbidity and temperature data were used and trends were acknowledged. As the stage went up, so did the turbidity. Temperature changed very little as a result of the depth. More temperature readings throughout the water column might reflect more of a change due to storm water during rain events.

Future efforts should include more observations during storm events and sensor comparisons. Determination of the offsets of the devices such as the pressure transducer, radar level sensor, and ultrasonic level transmitter should be conducted to determine if the sensors prove to be more accurate. A stage-discharge relationship for the culvert on Honeycutt Creek should be developed based on the stage data. The discharge off the watershed will help quantify any changes in storm water coming of the watershed due to land use changes. Installation of more than one temperature sensor might give a better understanding to the changes of temperature throughout the water column based on amount of flow.

In conclusion, a remote monitoring station was successfully deployed on Honeycutt Creek. Storm water characteristics such as stage, turbidity, and temperature were measured. As a result of this study, it is recommended that to remotely monitor storm water from a watershed the following devices should be used: HOBO Onset U30 GSM logger, Omega Engineering Inc. PX309-002G5V pressure transducer, Global Water

WQ750 turbidity sensor, and Hobo Onset temperature smart sensor S-TMB-M006. When possible use an already existing flow control device such as a culvert that does not have a morphologically active bed. Maintenance checks should be made after every rain event to clear any debris and to assess the state of the devices. Given the nature of the pressure transducers in the laboratory exercises, having two or more on hand is recommended in the event the diaphragm breaks suddenly due to over pressurization, clogging, or water hammers.

APPENDICES

Appendix A

Depth Measuring Device Analysis in Laboratory

Table A1. 0.125inch depth.

	.125 Up				.125 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
0.607	0.281	0.320	n/a	0.119	0.206	0.226	n/a
0.710	0.281	0.320	n/a	0.030	0.206	0.198	n/a
0.710	0.319	0.267	n/a	0.030	0.206	0.212	n/a
0.592	0.281	0.280	n/a	0.030	0.206	0.198	n/a
0.592	0.281	0.293	n/a	0.030	0.224	0.226	n/a
0.607	0.281	0.320	n/a	0.119	0.224	0.185	n/a
0.503	0.281	0.267	n/a	0.030	0.224	0.212	n/a
0.503	0.281	0.307	n/a	0.119	0.224	0.226	n/a
0.503	0.281	0.320	n/a	0.030	0.224	0.239	n/a
0.592	0.281	0.307	n/a	0.119	0.224	0.198	n/a
0.503	0.281	0.280	n/a	-0.059	0.224	0.198	n/a
0.592	0.281	0.293	n/a	0.237	0.224	0.212	n/a
0.592	0.281	0.307	n/a	0.119	0.224	0.212	n/a
0.592	0.281	0.320	n/a	0.030	0.244	0.198	n/a
0.592	0.281	0.293	n/a	0.119	0.224	0.226	n/a
0.592	0.281	0.293	n/a	0.119	0.224	0.226	n/a
0.592	0.281	0.307	n/a	0.119	0.244	0.212	n/a
0.592	0.281	0.320	n/a	0.119	0.224	0.226	n/a
0.710	0.281	0.280	n/a	0.030	0.224	0.212	n/a
0.592	0.281	0.307	n/a	0.030	0.224	0.212	n/a
0.710	0.281	0.293	n/a	0.030	0.224	0.212	n/a
0.592	0.281	0.307	n/a	0.119	0.224	0.198	n/a
0.592	0.281	0.307	n/a	0.119	0.224	0.198	n/a
0.592	0.281	0.280	n/a	0.030	0.224	0.212	n/a
0.710	0.263	0.320	n/a	0.119	0.224	0.212	n/a
0.592	0.281	0.307	n/a	0.030	0.244	0.198	n/a
0.592	0.281	0.307	n/a	0.119	0.244	0.212	n/a
0.503	0.263	0.307	n/a	0.030	0.224	0.212	n/a
0.592	0.281	0.307	n/a	0.223	0.244	0.212	n/a
0.710	0.281	0.307	n/a	0.119	0.224	0.198	n/a
0.710	0.281	0.293	n/a	0.030	0.244	0.212	n/a
0.592	0.281	0.307	n/a	0.119	0.224	0.226	n/a
0.710	0.281	0.320	n/a	0.030	0.224	0.239	n/a
0.503	0.281	0.320	n/a	0.030	0.244	0.212	n/a
0.607	0.281	0.307	n/a	0.237	0.224	0.212	n/a
0.592	0.281	0.320	n/a	-0.059	0.224	0.226	n/a
0.592	0.281	0.293	n/a	0.119	0.244	0.239	n/a
0.592	0.281	0.320	n/a	0.237	0.244	0.226	n/a
0.710	0.281	0.307	n/a	0.119	0.244	0.239	n/a
0.710	0.281	0.307	n/a	0.119	0.244	0.212	n/a
0.592	0.281	0.307	n/a	0.030	0.244	0.212	n/a
0.607	0.281	0.334	n/a	0.119	0.244	0.212	n/a
0.503	0.281	0.307	n/a	0.001	0.244	0.212	n/a
0.592	0.281	0.307	n/a	0.030	0.244	0.198	n/a
0.592	0.263	0.307	n/a	0.119	0.244	0.226	n/a
0.710	0.263	0.307	n/a	0.030	0.244	0.212	n/a
0.592	0.281	0.293	n/a	0.030	0.244	0.226	n/a
0.592	0.263	0.293	n/a	0.030	0.244	0.198	n/a
0.607	0.263	0.320	n/a	0.119	0.244	0.198	n/a
0.503	0.281	0.320	n/a	0.030	0.244	0.226	n/a
0.710	0.263	0.293	n/a	0.119	0.224	0.226	n/a
0.592	0.281	0.293	n/a	0.119	0.244	0.212	n/a
0.592	0.263	0.307	n/a	0.119	0.224	0.226	n/a
0.710	0.263	0.320	n/a	0.119	0.244	0.212	n/a
0.592	0.263	0.307	n/a	0.119	0.244	0.185	n/a
0.592	0.263	0.280	n/a	0.119	0.244	0.212	n/a
0.607	0.281	0.293	n/a	0.119	0.224	0.226	n/a
0.592	0.263	0.307	n/a	0.119	0.244	0.212	n/a
0.710	0.263	0.293	n/a	0.119	0.244	0.226	n/a
0.592	0.281	0.320	n/a	0.030	0.244	0.212	n/a

Note: 730 Bubbler Module was unable to measure depths below 0.5in.

Table A2. 0.25 inch depth.

	.25 Up				.25 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
0.888	0.413	0.415	n/a	0.326	0.394	0.348	n/a
0.799	0.413	0.402	n/a	0.326	0.413	0.348	n/a
0.710	0.413	0.415	n/a	0.326	0.394	0.334	n/a
0.799	0.413	0.415	n/a	0.326	0.394	0.348	n/a
0.710	0.394	0.415	n/a	0.326	0.394	0.361	n/a
0.799	0.394	0.429	n/a	0.326	0.394	0.334	n/a
0.799	0.413	0.415	n/a	0.326	0.394	0.334	n/a
0.799	0.413	0.429	n/a	0.326	0.394	0.361	n/a
0.799	0.394	0.388	n/a	0.311	0.394	0.348	n/a
0.799	0.394	0.415	n/a	0.326	0.394	0.334	n/a
0.696	0.413	0.415	n/a	0.430	0.413	0.361	n/a
0.799	0.413	0.402	n/a	0.326	0.394	0.361	n/a
0.710	0.413	0.415	n/a	0.267	0.394	0.348	n/a
0.799	0.394	0.402	n/a	0.326	0.394	0.334	n/a
0.799	0.413	0.415	n/a	0.503	0.394	0.334	n/a
0.799	0.413	0.402	n/a	0.326	0.413	0.348	n/a
0.799	0.413	0.415	n/a	0.326	0.413	0.361	n/a
0.710	0.394	0.415	n/a	0.326	0.394	0.361	n/a
0.799	0.413	0.415	n/a	0.326	0.394	0.348	n/a
0.888	0.413	0.402	n/a	0.223	0.394	0.374	n/a
0.710	0.413	0.415	n/a	0.223	0.394	0.361	n/a
0.888	0.413	0.402	n/a	0.237	0.394	0.348	n/a
0.799	0.394	0.402	n/a	0.326	0.394	0.334	n/a
0.799	0.413	0.415	n/a	0.326	0.394	0.348	n/a
0.799	0.413	0.415	n/a	0.311	0.394	0.361	n/a
0.799	0.413	0.415	n/a	0.326	0.394	0.348	n/a
0.799	0.394	0.415	n/a	0.326	0.394	0.334	n/a
0.799	0.394	0.415	n/a	0.326	0.413	0.348	n/a
0.799	0.413	0.429	n/a	0.326	0.413	0.374	n/a
0.710	0.413	0.429	n/a	0.415	0.394	0.361	n/a
0.710	0.394	0.415	n/a	0.326	0.394	0.348	n/a
0.799	0.394	0.415	n/a	0.311	0.413	0.361	n/a
0.799	0.413	0.415	n/a	0.415	0.394	0.361	n/a
0.799	0.413	0.402	n/a	0.223	0.394	0.334	n/a
0.710	0.413	0.415	n/a	0.223	0.413	0.348	n/a
0.799	0.413	0.402	n/a	0.237	0.394	0.361	n/a
0.799	0.413	0.415	n/a	0.237	0.394	0.361	n/a
0.799	0.394	0.402	n/a	0.223	0.394	0.348	n/a
0.888	0.413	0.388	n/a	0.237	0.394	0.348	n/a
0.799	0.394	0.415	n/a	0.223	0.394	0.348	n/a
0.799	0.394	0.388	n/a	0.415	0.413	0.361	n/a
0.799	0.413	0.415	n/a	0.326	0.394	0.348	n/a
0.799	0.413	0.348	n/a	0.326	0.413	0.361	n/a
0.799	0.413	0.402	n/a	0.326	0.394	0.361	n/a
0.710	0.394	0.415	n/a	0.326	0.413	0.348	n/a
0.799	0.413	0.415	n/a	0.237	0.413	0.361	n/a
0.710	0.413	0.388	n/a	0.223	0.394	0.348	n/a
0.799	0.394	0.429	n/a	0.311	0.413	0.361	n/a
0.799	0.394	0.429	n/a	0.326	0.413	0.320	n/a
0.799	0.413	0.402	n/a	0.415	0.394	0.334	n/a
0.710	0.413	0.429	n/a	0.326	0.394	0.361	n/a
0.799	0.413	0.415	n/a	0.326	0.394	0.348	n/a
0.888	0.413	0.429	n/a	0.326	0.394	0.334	n/a
0.799	0.413	0.442	n/a	0.326	0.413	0.334	n/a
0.799	0.413	0.415	n/a	0.326	0.394	0.374	n/a
0.799	0.413	0.442	n/a	0.415	0.394	0.348	n/a
0.888	0.413	0.429	n/a	0.237	0.394	0.334	n/a
0.710	0.413	0.415	n/a	0.326	0.394	0.348	n/a
0.799	0.413	0.402	n/a	0.326	0.413	0.348	n/a
0.799	0.413	0.402	n/a	0.415	0.394	0.348	n/a

Note: 730 Bubbler Module was unable to measure depths below 0.5in.

Table A3. 0.5 inch depth.

	.5 Up				.5 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
0.977	0.694	0.659	0.000	0.518	0.731	0.510	0.000
0.977	0.694	0.659	0.000	0.503	0.731	0.523	0.000
0.888	0.713	0.659	0.000	0.503	0.731	0.510	0.000
0.799	0.713	0.659	0.000	0.415	0.731	0.510	0.000
0.888	0.713	0.686	0.000	0.415	0.750	0.496	0.000
0.888	0.694	0.673	0.000	0.415	0.731	0.510	0.000
0.888	0.713	0.659	0.000	0.415	0.731	0.564	0.408
0.888	0.713	0.659	0.000	0.503	0.750	0.523	0.000
0.888	0.713	0.699	0.000	0.415	0.731	0.510	0.000
0.888	0.713	0.686	0.000	0.415	0.731	0.496	0.000
0.977	0.713	0.673	0.000	0.415	0.731	0.496	0.000
0.977	0.694	0.673	0.000	0.415	0.750	0.510	0.000
1.065	0.694	0.699	0.000	0.415	0.731	0.523	0.000
0.888	0.713	0.686	0.000	0.415	0.750	0.523	0.000
0.888	0.713	0.673	2.268	0.415	0.750	0.537	0.000
0.799	0.694	0.673	0.612	0.415	0.750	0.564	0.000
0.888	0.694	0.659	0.000	0.326	0.731	0.564	0.000
0.888	0.694	0.632	0.000	0.503	0.731	0.496	0.000
0.888	0.713	0.673	0.000	0.415	0.731	0.483	0.000
0.799	0.713	0.673	0.000	0.415	0.750	0.523	0.000
0.888	0.694	0.673	0.000	0.503	0.750	0.523	0.000
1.065	0.713	0.659	0.000	0.415	0.731	0.551	4.620
0.799	0.694	0.673	0.000	0.415	0.731	0.510	0.000
1.065	0.713	0.686	0.000	0.503	0.731	0.510	0.000
0.977	0.694	0.659	0.000	0.415	0.731	0.577	0.000
0.888	0.694	0.673	0.000	0.415	0.731	0.577	0.000
0.977	0.694	0.686	0.000	0.503	0.731	0.564	0.000
0.977	0.694	0.673	0.000	0.503	0.731	0.551	0.000
0.977	0.694	0.659	0.000	0.415	0.713	0.564	0.000
0.888	0.694	0.645	0.648	0.503	0.713	0.577	0.000
0.888	0.694	0.686	0.000	0.415	0.694	0.510	0.000
0.977	0.713	0.686		0.415	0.694	0.510	
0.799	0.713	0.673		0.415	0.674	0.564	
0.977	0.694	0.673		0.415	0.694	0.551	
0.888	0.694	0.686		0.415	0.674	0.605	
0.888	0.713	0.673		0.385	0.674	0.564	
0.888	0.694	0.673		0.503	0.694	0.510	
0.977	0.713	0.659		0.311	0.694	0.591	
0.888	0.694	0.686		0.503	0.674	0.591	
0.977	0.713	0.645		0.503	0.656	0.564	
0.799	0.694	0.673		0.503	0.674	0.591	
0.977	0.694	0.659		0.503	0.694	0.591	
0.977	0.694	0.686		0.503	0.656	0.605	
0.977	0.694	0.673		0.415	0.674	0.605	
0.977	0.713	0.645		0.415	0.674	0.591	
0.799	0.713	0.686		0.503	0.656	0.605	
0.888	0.694	0.673		0.415	0.694	0.591	
0.888	0.694	0.659		0.415	0.656	0.618	
0.888	0.694	0.673		0.415	0.694	0.591	
0.888	0.694	0.673		0.415	0.694	0.605	
0.888	0.694	0.673		0.503	0.694	0.591	
0.888	0.694	0.673		0.415	0.656	0.618	
0.977	0.694	0.673		0.415	0.674	0.577	
0.888	0.694	0.659		0.326	0.674	0.605	
0.799	0.694	0.673		0.415	0.674	0.591	
0.888	0.694	0.699		0.503	0.674	0.591	
0.888	0.713	0.673		0.503	0.656	0.591	
0.888	0.694	0.659		0.326	0.656	0.577	
0.977	0.713	0.645		0.415	0.674	0.605	
0.888	0.713	0.659		0.415	0.656	0.605	

Note: Bubbler Module took readings once a minute over the course of 30 minutes.

Table A4. 1.0 inch depth.

	1 Up				1 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
0.888	1.350	1.159	0.000	0.977	1.350	1.024	0.000
0.977	1.331	1.173	0.000	0.977	1.350	1.011	0.000
0.977	1.350	1.159	0.000	0.888	1.350	1.011	0.000
0.888	1.350	1.159	0.000	1.065	1.350	1.024	0.000
0.888	1.331	1.159	0.000	0.977	1.350	1.024	0.000
0.977	1.331	1.187	0.000	1.080	1.350	0.997	0.000
0.977	1.350	1.173	0.000	0.977	1.350	1.011	0.000
0.977	1.350	1.133	0.000	0.977	1.350	1.011	0.000
0.977	1.331	1.173	0.000	0.977	1.350	1.037	0.000
0.977	1.350	1.187	0.000	0.977	1.350	1.011	1.944
0.977	1.350	1.173	0.000	0.991	1.350	0.997	0.252
0.991	1.350	1.146	2.424	1.080	1.350	1.011	0.000
0.991	1.350	1.173	0.804	0.977	1.350	1.011	6.756
1.065	1.350	1.187	2.376	0.977	1.350	0.997	0.000
0.977	1.350	1.187	0.492	0.977	1.350	1.011	0.000
0.991	1.350	1.159	0.000	0.991	1.350	1.024	0.000
1.065	1.350	1.173	0.732	1.065	1.350	0.997	0.000
1.065	1.350	1.173	0.000	1.080	1.350	0.997	0.000
0.977	1.350	1.187	0.000	1.065	1.350	1.011	0.000
0.977	1.331	1.159	0.648	0.977	1.350	0.997	0.000
0.977	1.331	1.173	0.000	0.977	1.350	1.011	0.000
0.977	1.331	1.173	0.000	1.080	1.350	1.011	0.000
0.991	1.313	1.173	0.000	1.065	1.350	0.983	6.828
0.977	1.313	1.187	0.000	0.977	1.350	1.024	6.828
0.977	1.331	1.159	0.000	0.977	1.350	1.011	3.048
0.977	1.331	1.187	0.000	1.065	1.350	0.970	0.612
0.977	1.313	1.173	1.872	1.065	1.369	0.997	0.000
0.888	1.313	1.187	0.336	1.080	1.350	1.011	0.888
0.977	1.313	1.173	2.028	0.977	1.350	1.011	0.000
0.977	1.313	1.159	0.804	0.977	1.350	0.983	0.000
0.977	1.313	1.159	0.000	0.991	1.369	0.997	0.000
0.977	1.313	1.173		1.065	1.350	0.983	
0.977	1.313	1.200		0.977	1.350	1.011	
0.977	1.313	1.187		1.065	1.350	0.983	
0.888	1.313	1.173		1.065	1.350	0.997	
0.977	1.331	1.173		1.065	1.350	1.011	
0.888	1.313	1.173		0.991	1.350	1.011	
0.977	1.313	1.173		1.080	1.350	1.011	
0.977	1.313	1.159		0.888	1.350	1.011	
0.888	1.350	1.187		0.977	1.350	0.997	
0.977	1.331	1.173		1.065	1.350	1.011	
0.977	1.350	1.173		1.065	1.350	0.997	
0.888	1.331	1.159		0.977	1.350	0.997	
0.977	1.331	1.159		0.991	1.369	1.011	
0.977	1.331	1.159		1.065	1.350	1.011	
0.977	1.350	1.159		0.977	1.350	1.011	
0.977	1.350	1.173		0.977	1.350	0.997	
0.977	1.350	1.173		0.977	1.350	1.024	
0.977	1.350	1.173		0.977	1.350	0.997	
0.888	1.331	1.159		1.065	1.350	0.997	
0.977	1.350	1.173		1.080	1.350	1.011	
0.888	1.350	1.173		0.888	1.350	0.997	
0.977	1.350	1.159		1.080	1.350	1.011	
0.977	1.350	1.159		0.991	1.369	0.997	
0.977	1.350	1.187		0.977	1.369	1.011	
0.888	1.350	1.173		1.080	1.369	1.011	
0.888	1.350	1.159		0.888	1.350	0.997	
0.991	1.350	1.159		1.080	1.350	0.997	
0.991	1.331	1.187		0.991	1.350	1.011	
0.977	1.331	1.173		1.154	1.350	1.024	

Table A5. 2.0 inch depth.

	2 Up				2 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
2.115	2.494	2.040	0.216	1.938	2.644	2.040	0.408
2.115	2.474	1.985	0.000	1.849	2.663	2.040	0
2.115	2.494	1.958	0.000	1.938	2.681	2.040	0
2.027	2.494	2.053	0.000	1.938	2.681	2.080	5.172
2.027	2.513	2.040	0.000	1.849	2.681	2.080	0
2.027	2.513	2.053	0.000	2.027	2.681	2.066	0
2.115	2.550	2.025	0.000	2.027	2.663	2.093	0
2.027	2.550	2.093	0.000	1.938	2.663	2.080	0
2.027	2.531	2.093	0.000	1.938	2.663	2.066	0
2.027	2.513	2.080	2.892	1.938	2.681	2.053	0
2.027	2.513	2.040	1.392	1.849	2.681	2.053	0
2.027	2.531	2.093	3.372	1.938	2.663	2.080	4.392
2.027	2.531	2.080	1.200	1.849	2.681	2.053	1.236
1.938	2.531	2.093	0.000	1.938	2.663	2.053	0
1.938	2.531	2.066	0.924	1.849	2.663	2.066	0
2.027	2.550	2.080	0.000	1.938	2.663	2.080	0
1.938	2.550	2.080	0.000	2.027	2.663	2.066	0
2.027	2.550	2.053	0.000	1.849	2.681	2.080	0.336
1.938	2.550	2.107	0.000	1.938	2.663	2.080	0
2.027	2.531	2.093	1.872	1.849	2.663	2.080	0
1.938	2.550	2.107	0.000	1.938	2.663	2.080	0
1.938	2.531	2.080	0.000	1.938	2.663	2.053	0
2.027	2.550	2.093	0.000	1.938	2.663	2.093	0
2.027	2.550	2.080	0.000	1.849	2.663	2.080	0
2.027	2.531	2.080	3.444	1.849	2.663	2.053	0
2.027	2.569	2.080	1.872	1.849	2.681	2.066	0
2.027	2.550	2.093	8.640	1.938	2.681	2.066	0.648
1.938	2.531	2.080	1.752	1.938	2.681	2.093	1.596
1.938	2.531	2.093	0.372	1.849	2.681	2.053	0.18
2.027	2.550	2.093	0.000	1.849	2.681	2.080	0
2.027	2.531	2.040	0.684	1.849	2.681	2.080	0
2.027	2.531	2.093		1.938	2.681	2.080	
1.938	2.531	2.080		1.849	2.681	2.093	
1.938	2.513	2.093		1.849	2.681	2.066	
2.027	2.624	2.066		1.938	2.681	2.053	
1.938	2.513	2.093		1.849	2.681	2.080	
1.938	2.513	2.093		1.938	2.681	2.093	
2.027	2.513	2.093		1.938	2.681	2.080	
1.938	2.513	2.066		1.938	2.681	2.066	
1.938	2.494	2.080		1.849	2.681	2.080	
2.027	2.513	2.093		1.760	2.681	2.066	
2.027	2.494	2.107		1.938	2.681	2.080	
2.027	2.624	2.080		1.938	2.663	2.066	
2.027	2.606	2.093		1.938	2.681	2.066	
2.027	2.513	2.093		1.849	2.681	2.080	
1.938	2.644	2.093		1.849	2.663	2.066	
2.115	2.624	2.080		1.938	2.663	2.093	
1.938	2.531	2.093		1.938	2.663	2.066	
2.027	2.624	2.080		1.938	2.663	2.093	
1.938	2.494	2.093		1.849	2.663	2.093	
1.938	2.513	2.066		1.938	2.663	2.053	
2.027	2.644	2.080		1.938	2.663	2.080	
2.027	2.644	2.093		1.938	2.663	2.093	
2.027	2.513	2.080		1.849	2.663	2.066	
2.027	2.663	2.080		1.938	2.663	2.066	
2.027	2.531	2.080		1.938	2.663	2.066	
2.027	2.644	2.093		1.938	2.663	2.093	
2.027	2.663	2.093		1.938	2.663	2.066	
2.027	2.531	2.093		1.938	2.663	2.080	
1.938	2.644	2.080		2.027	2.663	2.066	

Table A6. 3.0 inch depth.

	3 Up				3 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
2.988	3.881	3.068	2.976	2.692	3.863	3.054	0
2.988	3.881	3.082	1.440	2.796	3.863	3.041	0.96
2.988	3.881	3.082	0.336	2.796	3.881	3.054	0
2.884	3.881	3.095	2.148	2.884	3.863	3.054	0
2.973	3.844	3.068	0.648	2.796	3.863	3.028	0.648
3.077	3.863	3.082	0.000	2.796	3.863	3.041	0
2.988	3.844	3.082	1.356	2.796	3.863	3.054	0
2.884	3.863	3.095	0.096	2.796	3.863	2.987	1.356
2.973	3.844	3.082	0.000	2.796	3.863	3.054	0
2.884	3.844	3.082	3.480	2.884	3.844	3.054	0
2.884	3.844	3.082	3.480	2.796	3.844	3.068	0
3.077	3.844	3.082	6.120	2.796	3.844	3.014	0
2.884	3.844	3.082	4.272	2.796	3.844	3.054	0
2.884	3.844	3.095	2.856	2.692	3.844	3.014	2.772
2.988	3.844	3.082	4.548	2.899	3.844	3.054	1.284
2.884	3.824	3.082	2.616	2.796	3.844	3.041	0
3.077	3.844	3.095	1.356	2.796	3.844	3.028	1.2
2.988	3.824	3.095	2.892	2.692	3.844	3.054	0
2.988	3.844	3.095	1.512	2.796	3.844	3.041	0
2.988	3.844	3.068	0.336	2.796	3.824	3.041	0.492
2.973	3.844	3.082	4.116	2.796	3.824	3.068	0
2.973	3.844	3.095	0.804	2.796	3.824	3.028	0
2.884	3.844	3.082	0.000	2.692	3.824	3.054	0
2.988	3.844	3.095	0.000	2.796	3.824	3.028	0
2.973	3.844	3.082	0.000	2.692	3.824	3.014	0
2.973	3.863	3.082	0.000	2.796	3.824	3.041	7.584
2.973	3.863	3.082	3.876	2.692	3.806	3.041	0
2.973	3.863	3.095	5.340	2.796	3.806	3.068	0
2.884	3.844	3.082	3.444	2.796	3.824	3.041	1.836
2.973	3.863	3.082	2.064	2.796	3.824	3.041	9.312
3.077	3.863	3.082	6.360	2.796	3.806	3.041	0.576
2.973	3.863	3.082		2.884	3.806	3.028	
2.988	3.863	3.082		2.796	3.806	3.068	
2.884	3.863	3.082		2.796	3.806	3.028	
2.899	3.881	3.095		2.796	3.806	3.054	
2.973	3.863	3.095		2.796	3.806	3.041	
2.973	3.881	3.068		2.884	3.806	3.041	
2.973	3.881	3.095		2.692	3.806	3.041	
2.884	3.881	3.095		2.692	3.806	3.041	
2.884	3.881	3.082		2.796	3.806	3.028	
2.988	3.881	3.109		2.796	3.806	3.014	
2.973	3.863	3.054		2.692	3.806	3.028	
2.884	3.863	3.068		2.796	3.806	3.054	
2.988	3.881	3.068		2.899	3.806	3.041	
2.973	3.863	3.082		2.796	3.806	3.041	
2.988	3.863	3.054		2.796	3.806	3.014	
2.884	3.863	3.082		2.796	3.806	3.041	
2.973	3.863	3.109		2.884	3.806	3.054	
2.973	3.844	3.082		2.796	3.824	3.041	
3.077	3.844	3.068		2.796	3.806	3.028	
2.884	3.863	3.109		2.692	3.824	3.028	
2.988	3.844	3.082		2.884	3.824	3.068	
2.973	3.844	3.095		2.796	3.824	3.014	
2.884	3.844	3.082		2.884	3.806	3.028	
2.884	3.844	3.068		2.796	3.806	3.028	
2.884	3.844	3.068		2.603	3.824	3.041	
2.988	3.844	3.109		2.884	3.824	3.014	
2.884	3.844	3.068		2.796	3.824	3.054	
2.973	3.824	3.068		2.796	3.824	3.041	
2.988	3.844	3.122		2.796	3.824	3.041	

Table A7. 4.0 inch depth.

	4 Up				4 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
4.112	5.137	4.110	13.440	3.846	5.006	4.097	0.422
3.934	5.137	4.124	2.340	3.757	5.063	4.124	0.235
4.023	5.137	4.110	1.128	3.757	4.987	4.097	0.126
4.023	5.137	4.097	0.132	3.757	5.063	4.083	0.034
4.023	5.137	4.124	1.908	3.757	5.044	4.097	0.139
4.023	5.137	4.124	0.648	3.757	5.024	4.110	0.041
4.023	5.137	4.110	0.000	3.846	5.024	4.097	0
4.112	5.137	4.097	0.000	3.638	5.063	4.070	0.11
4.112	5.137	4.097	5.880	3.846	5.044	4.083	0
4.023	5.137	4.070	4.116	3.757	5.044	4.083	0
4.023	5.137	4.097	2.772	3.846	5.024	4.110	0.205
4.023	5.137	4.124	3.756	3.757	5.044	4.097	0
4.023	5.137	4.138	2.268	3.757	5.044	4.097	0
4.023	5.137	4.138	10.260	3.757	5.156	4.097	0
4.023	5.137	4.138	2.544	3.846	5.063	4.042	0
4.023	5.156	4.070	1.356	3.846	5.063	4.097	0.231
4.127	5.137	4.097	0.336	3.846	5.044	4.110	0.123
4.023	5.137	4.124	1.440	3.846	5.063	4.097	0.028
4.023	5.137	4.124	0.336	3.742	5.063	4.056	0.136
4.023	5.137	4.056	2.496	3.742	5.063	4.083	0.038
3.934	5.137	4.110	0.960	3.846	5.156	4.110	0
4.023	5.137	4.110	0.000	3.846	5.044	4.097	0.054
4.023	5.119	4.124	0.000	3.757	5.063	4.083	0
4.112	5.137	4.097	8.052	3.757	5.063	4.097	0
4.038	5.137	4.110	4.704	3.846	5.156	4.110	0.015
4.023	5.137	4.097	3.288	3.831	5.063	4.097	0
4.112	5.119	4.110	9.780	3.846	5.063	4.056	0
4.112	5.137	4.124	2.820	3.757	5.176	4.110	0.084
4.112	5.119	4.138	1.596	3.742	5.044	4.097	0
4.023	5.137	4.110	4.740	3.757	5.024	4.097	0
4.127	5.137	4.110	2.376	3.846	5.176	4.056	0.297
3.934	5.137	4.124		3.846	5.044	4.110	
4.112	5.137	4.124		3.638	5.024	4.097	
4.127	5.137	4.097		3.846	5.044	4.097	
4.023	5.119	4.110		3.757	5.063	4.070	
4.023	5.137	4.110		3.742	5.044	4.097	
4.023	5.137	4.138		3.846	5.044	4.110	
4.023	5.137	4.110		3.757	5.156	4.097	
4.023	5.137	4.097		3.757	5.044	4.083	
4.038	5.119	4.110		3.757	5.044	4.097	
4.023	5.137	4.110		3.757	5.044	4.083	
4.023	5.137	4.097		3.846	5.156	4.070	
4.023	5.137	4.110		3.846	5.156	4.097	
4.023	5.137	4.124		3.757	5.156	4.097	
4.023	5.137	4.097		3.846	5.156	4.083	
4.023	5.137	4.097		3.742	5.156	4.070	
4.023	5.137	4.097		3.742	5.156	4.083	
4.127	5.137	4.110		3.757	5.156	4.097	
4.023	5.137	4.097		3.757	5.176	4.097	
4.023	5.137	4.097		3.757	5.156	4.083	
4.023	5.137	4.097		3.742	5.063	4.097	
4.023	5.119	4.110		3.638	5.156	4.097	
4.127	5.137	4.110		3.757	5.176	4.070	
3.934	5.137	4.110		3.846	5.063	4.097	
3.934	5.137	4.110		3.757	5.081	4.083	
4.038	5.137	4.124		3.846	5.156	4.097	
4.127	5.137	4.110		3.757	5.156	4.083	
4.127	5.137	4.097		3.846	5.156	4.070	

Table A8. 5.0 inch Depth.

	5 Up				5 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
4.688	6.337	5.126	1.668	4.881	6.226	5.030	0.228
4.881	6.337	5.085	2.736	4.984	6.226	5.045	0.09
4.688	6.263	5.085	1.668	4.881	6.226	5.030	0.008
4.777	6.300	5.112	0.684	4.984	6.206	5.030	0.244
4.807	6.319	5.071	2.460	4.881	6.226	5.045	0.018
4.792	6.281	5.098	1.284	4.984	6.226	5.030	0
4.688	6.300	5.112	1.284	4.984	6.187	5.030	0.094
4.688	6.281	5.098	7.860	4.984	6.226	5.030	0
4.688	6.263	5.098	5.616	4.984	6.226	5.045	0
4.688	6.281	5.071	4.236	4.984	6.226	4.990	0
4.792	6.263	5.112	5.532	4.984	6.244	5.017	0.303
4.688	6.281	5.112	4.152	4.984	6.206	5.030	0.195
4.688	6.300	5.071	2.928	4.984	6.226	5.030	0.93
4.792	6.263	5.085	5.340	4.881	6.244	5.017	0.202
4.792	6.300	5.085	3.204	4.881	6.226	5.045	0.107
4.688	6.263	5.098	2.064	5.073	6.206	5.058	0.025
4.600	6.319	5.085	9.708	5.073	6.226	5.017	0.166
4.792	6.281	5.098	2.580	4.984	6.206	5.017	0.057
4.688	6.281	5.112	1.512	4.984	6.226	5.030	0
4.674	6.300	5.098	0.528	4.984	6.244	5.017	0.126
4.688	6.319	5.058	1.752	4.984	6.226	5.058	0.025
4.600	6.319	5.085	1.716	4.984	6.226	5.045	0
4.792	6.337	5.071	6.672	5.073	6.206	5.030	0
4.792	6.300	5.112	5.136	5.073	6.226	5.017	0
4.792	6.356	5.085	8.724	4.895	6.206	5.045	0
4.792	6.356	5.098	4.944	4.984	6.226	5.030	0.313
4.688	6.319	5.098	3.636	4.984	6.206	5.017	0.205
4.688	6.356	5.098	15.648	4.970	6.226	5.045	0.277
4.688	6.394	5.071	3.876	4.984	6.206	5.017	0.153
4.688	6.337	5.098	2.616	4.895	6.244	5.045	0.064
4.688	6.374	5.098	2.652	4.895	6.206	5.030	0.176
4.688	6.356	5.098		4.984	6.206	5.017	
4.688	6.319	5.085		4.895	6.226	5.030	
4.792	6.319	5.085		4.984	6.206	5.030	
4.688	6.300	5.098		4.881	6.226	5.045	
4.792	6.300	5.085		4.984	6.206	5.045	
4.792	6.319	5.071		4.881	6.226	5.030	
4.688	6.319	5.098		4.984	6.226	5.045	
4.688	6.300	5.085		4.792	6.206	5.017	
4.688	6.263	5.085		4.984	6.206	5.030	
4.792	6.281	5.085		4.881	6.226	5.030	
4.688	6.263	5.098		4.984	6.244	5.017	
4.688	6.263	5.085		4.984	6.244	5.017	
4.688	6.263	5.085		4.984	6.226	5.045	
4.688	6.263	5.085		5.073	6.226	5.058	
4.688	6.263	5.085		4.984	6.206	5.030	
4.792	6.263	5.112		4.984	6.226	5.030	
4.792	6.263	5.112		4.984	6.226	5.045	
4.792	6.281	5.085		4.970	6.206	5.017	
4.688	6.281	5.098		4.984	6.206	5.017	
4.792	6.281	5.112		4.970	6.206	5.045	
4.792	6.281	5.098		4.984	6.226	5.030	
4.688	6.281	5.098		4.984	6.226	5.058	
4.688	6.281	5.098		4.984	6.206	5.045	
4.688	6.319	5.098		4.984	6.206	5.030	
4.792	6.319	5.085		4.984	6.226	5.030	
4.792	6.281	5.098		4.984	6.206	5.030	
4.674	6.319	5.098		4.984	6.226	5.030	
4.688	6.337	5.085		4.895	6.206	5.045	
4.792	6.300	5.085		4.970	6.187	5.030	

Table A9. 6.0 inch depth.

	6 Up				6 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler,in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler,in
6.108	7.574	6.100	3.012	5.842	7.387	6.046	0.214
6.020	7.594	6.113	2.028	5.842	7.406	5.992	0.155
6.020	7.574	6.113	3.804	5.842	7.387	6.046	0.179
6.020	7.594	6.046	2.580	5.842	7.406	6.046	0.1
5.916	7.574	6.100	2.580	5.724	7.406	6.018	0.025
5.827	7.574	6.100	6.756	5.842	7.406	6.033	0.149
5.931	7.574	6.113	8.604	5.842	7.406	6.059	0.067
5.916	7.574	6.087	6.360	5.842	7.406	6.005	0
5.916	7.574	6.087	4.980	5.842	7.406	6.033	0.153
5.916	7.574	6.087	7.776	5.724	7.424	6.046	0.057
6.020	7.556	6.087	4.548	5.931	7.424	6.018	0.054
6.005	7.594	6.072	3.372	5.827	7.406	6.018	0.356
5.916	7.574	6.087	4.548	5.931	7.406	6.018	0.727
5.916	7.574	6.100	3.168	5.827	7.406	6.046	0.336
5.916	7.594	6.100	10.296	5.931	7.406	6.033	0.235
5.931	7.594	6.087	3.720	5.842	7.406	6.046	0.146
5.916	7.613	6.087	2.616	5.931	7.424	6.033	0.267
5.916	7.594	6.087	1.668	5.931	7.406	6.046	0.166
5.916	7.574	6.100	2.820	5.931	7.406	6.033	0.084
5.842	7.613	6.087	2.820	5.842	7.406	6.033	0.218
5.916	7.594	6.087	7.416	5.842	7.406	6.033	0.087
6.020	7.574	6.100	5.880	5.842	7.406	6.046	0.018
5.827	7.594	6.087	6.756	5.842	7.406	6.018	0.159
6.020	7.594	6.100	5.136	5.931	7.406	6.046	0.067
5.931	7.594	6.072	9.036	5.827	7.406	6.046	0
5.916	7.613	6.087	5.220	5.842	7.406	6.046	2.223
5.916	7.631	6.072	3.960	5.842	7.406	6.033	0.382
5.916	7.613	6.087	16.440	5.931	7.406	6.033	0.271
5.916	7.613	6.087	4.356	5.931	7.406	6.046	0.359
5.931	7.613	6.087	3.168	5.827	7.424	6.033	0.149
5.916	7.594	6.087	2.184	5.842	7.406	6.033	0.061
6.020	7.594	6.087		5.842	7.406	6.046	
6.020	7.594	6.087		5.842	7.387	6.059	
6.020	7.594	6.087		5.842	7.387	6.033	
5.827	7.613	6.100		5.842	7.424	6.046	
5.827	7.613	6.100		5.842	7.406	6.018	
6.020	7.613	6.087		5.842	7.406	6.046	
6.020	7.594	6.087		5.724	7.387	6.059	
5.931	7.574	6.087		5.842	7.406	6.046	
5.916	7.574	6.087		5.842	7.406	6.033	
5.916	7.574	6.087		5.827	7.424	6.033	
5.916	7.574	6.087		5.724	7.406	6.059	
6.020	7.594	6.087		5.827	7.387	6.046	
6.020	7.594	6.113		5.931	7.387	6.059	
5.931	7.594	6.100		5.842	7.406	6.033	
6.020	7.574	6.072		5.827	7.406	6.046	
5.842	7.613	6.072		5.827	7.387	6.046	
5.916	7.574	6.100		5.931	7.406	6.033	
5.916	7.574	6.087		5.842	7.406	6.033	
5.931	7.594	6.087		5.842	7.387	6.033	
6.020	7.574	6.072		5.827	7.387	6.033	
6.020	7.594	6.072		5.724	7.406	6.018	
6.020	7.594	6.059		5.724	7.406	6.033	
5.842	7.613	6.072		5.842	7.424	6.046	
5.931	7.574	6.087		5.842	7.406	6.033	
6.020	7.574	6.087		5.842	7.406	6.018	
6.020	7.613	6.059		5.842	7.406	6.033	
5.916	7.613	6.100		5.931	7.424	6.046	
5.916	7.594	6.113		5.842	7.387	6.046	
5.916	7.574	6.072		5.842	7.424	6.033	

Table A10. 7.0 inch depth.

	7 Up				7 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
6.863	8.774	7.101	3.168	6.596	8.737	7.101	0.225
6.863	8.737	7.115	5.136	6.670	8.774	7.142	0.333
6.877	8.737	7.060	3.720	6.670	8.737	7.101	0.238
6.877	8.737	7.088	2.736	6.670	8.774	7.115	0.159
6.877	8.737	7.075	2.736	6.581	8.737	7.101	0.303
6.966	8.737	7.075	8.016	6.685	8.774	7.101	0.195
6.877	8.737	7.034	6.516	6.788	8.737	7.115	0.123
6.877	8.737	7.088	9.156	6.581	8.774	7.115	0.284
6.877	8.737	7.075	6.396	6.788	8.737	7.115	0.176
7.070	8.737	7.088	5.136	6.670	8.756	7.101	0.1
6.966	8.737	7.075	7.380	6.685	8.756	7.128	0.038
6.877	8.756	7.075	5.412	6.670	8.756	7.115	2.99
6.877	8.737	7.075	4.272	6.670	8.756	7.128	0.471
6.877	8.737	7.101	9.156	6.670	8.756	7.101	0.363
6.877	8.774	7.075	4.272	6.670	8.774	7.115	0.451
6.877	8.756	7.075	3.204	6.670	8.756	7.115	0.317
6.863	8.756	7.075	5.568	6.670	8.774	7.115	2.485
6.966	8.756	7.088	3.840	6.788	8.756	7.115	0.333
6.877	8.756	7.101	2.856	6.670	8.756	7.128	0.238
6.863	8.756	7.075	2.856	6.670	8.756	7.115	0.159
6.877	8.774	7.088	8.724	6.581	8.756	7.075	0.258
6.877	8.774	7.088	7.104	6.788	8.756	7.128	0.159
6.966	8.756	7.075	5.772	6.877	8.756	7.115	1.15
6.863	8.756	7.088	6.672	6.670	8.756	7.128	0.212
6.877	8.774	7.088	5.256	6.788	8.756	7.128	0.13
6.863	8.756	7.088	6.792	6.581	8.756	7.128	0.064
6.774	8.774	7.060	4.980	6.581	8.756	7.060	0.064
6.877	8.756	7.075	3.876	6.670	8.756	7.088	0.422
6.788	8.756	7.088	5.172	6.788	8.756	7.101	0.32
6.877	8.756	7.088	3.804	6.581	8.756	7.128	0.441
7.055	8.756	7.060	9.036	6.581	8.774	7.088	0.235
6.877	8.756	7.075		6.670	8.756	7.115	
6.877	8.756	7.088		6.581	8.756	7.128	
6.966	8.737	7.101		6.670	8.756	7.142	
6.877	8.737	7.075		6.788	8.756	7.088	
6.774	8.737	7.075		6.685	8.756	7.115	
6.951	8.737	7.088		6.670	8.756	7.101	
6.877	8.737	7.088		6.670	8.756	7.101	
6.877	8.737	7.047		6.670	8.756	7.101	
6.863	8.737	7.075		6.670	8.756	7.101	
6.877	8.737	7.075		6.670	8.756	7.115	
6.981	8.737	7.088		6.685	8.756	7.128	
6.877	8.756	7.075		6.670	8.756	7.115	
6.877	8.737	7.088		6.670	8.756	7.115	
6.981	8.737	7.075		6.685	8.756	7.115	
6.788	8.737	7.088		6.670	8.756	7.101	
6.877	8.737	7.088		6.788	8.756	7.075	
6.788	8.756	7.088		6.788	8.756	7.101	
6.877	8.737	7.088		6.670	8.756	7.115	
6.877	8.756	7.088		6.788	8.756	7.101	
6.877	8.774	7.101		6.670	8.756	7.101	
6.788	8.756	7.088		6.596	8.756	7.115	
6.774	8.756	7.060		6.788	8.756	7.128	
6.966	8.756	7.075		6.670	8.756	7.101	
6.966	8.774	7.088		6.670	8.774	7.101	
6.877	8.756	7.101		6.670	8.756	7.101	
6.877	8.774	7.075		6.670	8.756	7.115	
6.877	8.756	7.088		6.685	8.756	7.101	
6.877	8.774	7.101		6.670	8.756	7.115	
6.877	8.774	7.088		6.670	8.756	7.088	

Table A11. 8.0 inch depth.

	8 Up				8 Down		
Radar, in	Ultrasonic, ,in	Pressure,in	Bubbler, in	Radar,in	Ultrasonic, in	Pressure, in	Bubbler, in
7.912	10.050	8.049	10.572	7.824	10.013	8.089	0.448
7.912	10.031	8.063	9.384	7.809	10.031	8.089	0.556
7.912	9.994	8.063	11.124	7.824	10.031	8.076	0.438
7.912	9.994	8.063	8.796	7.824	10.031	8.063	0.346
7.912	10.013	8.076	7.380	7.824	10.013	8.089	0.986
7.824	10.013	8.063	8.016	8.016	10.031	8.076	0.369
7.824	9.994	8.076	6.792	7.824	10.013	8.076	0.284
7.912	10.031	8.063	5.532	7.720	10.031	8.089	0.208
7.912	10.031	8.049	6.480	7.824	10.031	8.076	0.303
7.824	10.013	8.063	5.220	7.824	10.013	8.076	0.215
7.824	10.031	8.076	6.984	7.720	10.013	8.063	0.802
7.927	10.031	8.063	5.652	7.824	10.013	8.063	0.271
7.912	10.050	8.063	4.548	7.824	10.013	8.076	0.271
7.824	10.050	8.076	8.484	7.720	10.031	8.063	0.641
7.912	10.050	8.063	5.220	7.824	10.013	8.063	0.517
7.912	10.031	8.076	5.220	7.824	10.013	8.076	0.415
8.016	10.031	8.063	9.624	7.824	10.031	8.063	0.49
8.001	10.050	8.049	8.088	7.927	10.013	8.063	0.369
7.912	10.050	8.049	8.760	7.720	10.031	8.089	0.937
7.912	10.050	8.063	7.224	7.927	10.031	8.089	0.353
7.912	10.050	8.063	8.328	7.927	10.031	8.063	0.271
7.824	10.050	8.035	6.756	7.720	10.013	8.063	0.395
7.824	10.050	8.049	5.568	7.824	10.031	8.076	0.3
8.001	10.050	8.076	7.140	7.912	10.031	8.049	0.225
7.912	10.050	8.076	5.772	7.824	10.031	8.063	0.677
7.809	10.050	8.063	4.704	7.912	10.013	8.063	0.238
8.016	10.050	8.063	5.964	7.824	10.013	8.076	0.169
7.809	10.050	8.063	4.668	7.838	10.013	8.089	0.169
7.824	10.050	8.076	9.864	7.720	10.013	8.049	0.628
7.912	10.031	8.049	4.740	7.927	10.013	8.076	0.497
7.912	10.031	8.089	4.788	7.824	10.013	8.063	0.313
7.824	10.031	8.063		7.824	10.031	8.049	
7.912	10.031	8.076		7.824	10.013	8.063	
8.001	10.031	8.063		7.824	10.013	8.049	
7.824	10.050	8.063		7.824	10.013	8.076	
7.912	10.013	8.063		7.824	10.013	8.035	
7.824	10.031	8.049		7.720	10.013	8.063	
7.912	10.013	8.063		7.720	10.013	8.076	
7.824	10.013	8.063		7.927	10.013	8.049	
7.912	10.013	8.063		7.824	10.031	8.035	
7.824	9.994	8.063		7.883	10.031	8.049	
7.912	10.013	8.063		7.912	10.050	8.076	
7.824	10.031	8.022		7.824	10.031	8.063	
7.824	9.994	8.063		7.720	10.031	8.063	
7.824	10.013	8.076		7.824	10.031	8.049	
7.824	10.013	8.049		7.824	10.013	8.049	
7.927	10.013	8.035		7.824	10.013	8.063	
7.912	10.013	8.049		7.720	10.031	8.076	
7.927	10.050	8.076		7.720	10.031	8.076	
7.824	10.013	8.076		7.927	10.013	8.035	
7.927	10.013	8.035		7.838	9.994	8.063	
7.912	10.031	8.063		7.720	10.031	8.063	
7.824	10.013	8.049		7.838	10.013	8.063	
7.912	10.031	8.063		7.720	9.994	8.089	
7.824	10.031	8.063		7.720	10.013	8.063	
7.824	10.013	8.076		7.824	10.013	8.076	
7.824	10.031	8.089		7.824	10.013	8.063	
7.912	10.050	8.076		7.912	10.031	8.063	
7.838	10.050	8.049		7.824	10.013	8.063	
7.927	10.031	8.063		7.705	10.013	8.063	

Table A12. 9.0 inch depth.

	9 Up				9 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
10.855	11.213	8.855	10.380	10.678	11.494	9.261	0.707
10.855	11.231	9.086	8.880	10.693	11.494	8.909	0.566
10.796	11.231	9.112	9.660	10.781	11.513	9.018	0.464
10.870	11.231	8.733	8.088	10.707	11.513	9.031	1.104
10.826	11.231	8.774	9.468	10.796	11.494	9.004	0.477
10.766	11.231	9.112	7.620	10.796	11.513	9.004	0.382
10.781	11.231	9.086	6.480	10.707	11.513	9.018	0.303
10.781	11.231	8.706	8.208	10.707	11.494	9.031	0.435
10.885	11.231	8.774	6.756	10.722	11.587	9.031	0.336
10.885	11.231	8.815	5.688	10.796	11.494	9.045	0.264
10.855	11.231	8.855	7.692	10.752	11.494	9.031	0.454
10.855	11.231	8.855	6.204	10.796	11.474	9.004	0.313
10.855	11.231	8.855	5.220	10.752	11.474	9.018	0.241
10.841	11.231	8.868	6.984	10.811	11.474	9.045	0.553
10.826	11.231	8.868	6.984	10.855	11.456	9.031	0.553
10.826	11.231	8.883	12.228	10.855	11.437	9.031	0.763
10.870	11.231	8.855	10.332	10.648	11.456	9.031	0.622
10.811	11.231	8.883	8.880	10.811	11.550	9.031	0.513
10.870	11.231	8.868	9.708	10.826	11.550	9.031	0.609
10.885	11.231	8.868	8.124	10.707	11.550	9.004	0.507
10.870	11.231	8.883	11.244	10.737	11.550	9.045	0.412
10.826	11.231	8.855	7.692	10.870	11.531	9.018	0.776
10.841	11.231	8.855	6.480	10.707	11.569	9.031	0.435
10.841	11.231	8.896	7.812	10.855	11.474	9.018	0.346
10.855	11.231	8.868	6.360	10.722	11.569	9.004	0.274
10.841	11.231	8.868	14.784	10.855	11.606	9.004	0.399
10.796	11.231	8.883	6.876	10.752	11.569	9.248	0.31
10.826	11.231	8.868	5.724	10.693	11.587	9.261	0.244
10.826	11.231	8.868	4.788	10.678	11.569	8.868	0.412
10.796	11.231	8.868	4.788	10.737	11.587	8.950	0.412
10.841	11.231	8.883	11.088	10.693	11.587	9.234	0.727
10.811	11.231	8.868		10.693	11.569	9.275	
10.781	11.231	8.855		10.766	11.606	8.868	
10.796	11.231	8.883		10.826	11.606	8.923	
10.855	11.231	8.868		10.766	11.606	8.964	
10.885	11.231	8.868		10.722	11.587	9.004	
10.900	11.231	8.855		10.737	11.606	9.004	
10.855	11.231	8.868		10.707	11.624	8.990	
10.811	11.231	8.855		10.766	11.624	8.990	
10.841	11.231	8.855		10.722	11.624	9.045	
10.826	11.231	8.868		10.737	11.624	9.031	
10.855	11.231	8.842		10.722	11.624	9.031	
10.752	11.231	9.112		10.752	11.624	8.990	
10.766	11.231	9.086		10.707	11.624	9.031	
10.781	11.231	8.733		10.707	11.624	9.031	
10.811	11.231	8.774		10.737	11.606	9.004	
10.766	11.231	9.099		10.752	11.624	9.004	
10.781	11.231	9.112		10.634	11.606	9.058	
10.781	11.231	8.748		10.870	11.624	9.031	
10.900	11.231	8.774		10.766	11.624	9.031	
10.796	11.231	8.828		10.796	11.624	9.031	
10.811	11.231	8.855		10.781	11.606	9.004	
10.766	11.231	8.868		10.707	11.624	9.045	
10.707	11.231	8.855		10.811	11.606	9.018	
10.826	11.231	8.868		10.707	11.606	9.031	
10.826	11.231	8.842		10.841	11.606	9.004	
10.811	11.231	8.868		10.737	11.606	9.045	
10.811	11.231	8.868		10.707	11.587	9.018	
10.737	11.231	8.909		10.663	11.606	9.018	
10.841	11.231	8.868		10.678	11.606	9.045	

Table A13. 10.0 inch depth.

	10 Up				10 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler ,in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
11.743	12.487	10.155	12.456	11.654	12.694	10.060	0.372
11.861	12.506	9.735	10.056	11.565	12.674	10.060	0.927
11.831	12.506	9.843	8.724	11.521	12.637	10.033	0.674
11.772	12.487	9.884	10.02	11.491	12.637	10.277	0.573
11.876	12.487	9.897	8.64	11.595	12.637	10.250	0.481
11.757	12.487	10.141	7.344	11.654	12.637	9.897	0.54
11.861	12.487	10.141	8.484	11.683	12.656	9.978	0.448
11.846	12.506	9.762	7.308	11.654	12.619	10.033	0.536
11.698	12.506	9.803	8.244	11.550	12.619	10.060	0.435
11.846	12.506	10.114	7.188	11.550	12.637	10.033	0.359
11.757	12.506	10.155	6.156	11.654	12.637	10.060	0.497
11.846	12.524	9.749	7.26	11.595	12.619	10.046	0.399
11.802	12.506	9.789	6.204	11.624	12.619	10.046	0.33
11.802	12.487	9.884	6.204	11.669	12.619	10.060	0.55
11.683	12.506	9.884	10.452	11.609	12.600	10.277	0.382
11.757	12.487	9.871	11.004	11.698	12.600	10.290	0.382
11.698	12.487	9.911	9.504	11.683	12.637	9.884	0.733
11.846	12.487	9.911	8.244	11.743	12.637	9.911	0.618
11.772	12.487	9.925	9.072	11.683	12.637	9.993	1.12
11.905	12.487	9.925	7.812	11.639	12.637	10.046	0.609
11.772	12.487	9.897	9.276	11.580	12.637	10.006	0.51
11.831	12.506	9.911	7.536	11.757	12.656	10.060	0.431
11.831	12.487	9.884	6.552	11.624	12.656	10.046	0.507
11.698	12.506	9.884	7.536	11.713	12.656	10.046	0.415
11.683	12.487	9.925	6.396	11.609	12.656	10.046	0.655
11.683	12.487	9.938	8.088	11.639	12.674	10.033	0.451
11.728	12.487	9.897	6.516	11.831	12.674	10.060	0.372
11.846	12.487	9.884	5.568	11.772	12.674	10.033	0.307
11.802	12.506	9.897	5.532	11.491	12.674	10.046	0.392
11.846	12.506	10.168	11.004	11.743	12.694	10.060	0.317
11.950	12.487	10.141	14.232	11.491	12.694	10.019	0.317
11.861	12.524	9.789		11.595	12.694	10.046	
11.802	12.487	9.816		11.639	12.694	10.074	
11.891	12.524	9.911		11.535	12.694	10.033	
11.831	12.487	9.857		11.654	12.694	10.033	
11.757	12.524	9.897		11.728	12.694	10.074	
11.772	12.487	9.897		11.565	12.674	10.074	
11.831	12.487	9.938		11.654	12.674	10.046	
11.698	12.506	9.884		11.654	12.674	10.046	
11.787	12.487	9.884		11.550	12.656	10.060	
11.816	12.524	9.884		11.654	12.656	10.060	
11.831	12.506	9.897		11.580	12.656	10.060	
11.846	12.487	9.911		11.698	12.637	10.006	
11.757	12.487	9.911		11.683	12.637	10.060	
11.713	12.487	9.911		11.595	12.619	10.277	
11.846	12.506	9.897		11.698	12.619	10.209	
11.772	12.506	9.897		11.654	12.619	9.884	
11.743	12.487	9.911		11.580	12.619	9.993	
11.654	12.506	9.897		11.565	12.619	10.019	
11.891	12.506	9.897		11.580	12.619	10.019	
11.772	12.487	10.128		11.669	12.619	10.019	
11.846	12.487	10.141		11.654	12.619	10.074	
11.935	12.506	9.708		11.698	12.619	10.060	
11.876	12.487	9.816		11.683	12.619	10.060	
11.728	12.506	9.843		11.624	12.637	10.019	
11.757	12.487	9.884		11.698	12.619	10.046	
11.787	12.450	9.911		11.595	12.600	10.250	
11.816	12.469	9.897		11.506	12.600	10.236	
11.787	12.469	9.911		11.669	12.619	10.236	
11.802	12.506	9.978		11.609	12.619	10.277	

Table A14. 11.0 inch depth.

11 Up				11 Down			
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
12.689	13.669	10.885	14.316	12.615	13.950	10.966	0.602
12.733	13.669	10.885	10.332	12.467	13.969	11.062	0.602
12.659	13.669	10.872	9.072	12.452	13.931	11.305	0.917
12.659	13.669	10.872	15.372	12.497	13.931	11.305	0.792
12.659	13.669	10.926	8.916	12.571	13.950	10.940	0.687
12.659	13.669	10.885	7.86	12.482	13.931	10.981	0.786
12.792	13.669	10.899	9.936	12.497	13.931	11.048	0.677
12.792	13.687	10.885	8.328	12.467	13.931	11.062	0.589
12.704	13.669	10.872	7.26	12.556	13.931	11.062	0.723
12.719	13.669	10.926	9.072	12.571	13.931	11.062	0.602
12.837	13.669	10.913	9.12	12.526	13.950	11.088	0.52
12.733	13.669	10.885	15.852	12.556	13.950	11.088	0.655
12.792	13.669	10.831	12.732	12.556	13.950	11.088	0.517
12.733	13.669	10.885	11.244	12.571	13.950	11.062	0.441
12.822	13.669	10.899	15.3	12.556	13.950	11.116	0.533
12.733	13.669	10.872	11.088	12.497	13.969	11.116	0.458
12.792	13.650	10.899	9.744	12.497	13.969	11.075	0.458
12.748	13.650	10.872	19.944	12.541	13.969	11.116	0.845
12.778	13.650	10.899	10.02	12.556	13.969	11.088	0.727
12.792	13.650	10.872	8.76	12.541	13.987	11.075	0.625
12.852	13.650	10.845	7.692	12.512	13.969	11.088	0.687
12.689	13.650	10.899	9.312	12.556	13.969	11.088	0.589
12.837	13.650	10.899	8.124	12.571	13.969	11.116	0.756
12.748	13.631	11.129	7.104	12.571	13.969	11.103	0.605
12.837	13.631	11.088	8.952	12.556	13.969	11.103	0.52
12.837	13.650	10.723	8.952	12.497	13.950	11.129	1.426
12.733	13.650	10.791	16.008	12.556	13.950	11.116	0.559
12.748	13.631	11.143	12.66	12.467	13.950	11.088	0.481
12.763	13.631	11.088	11.196	12.571	13.950	11.088	0.412
12.733	13.650	10.737	13.368	12.556	13.950	11.062	0.461
12.748	13.650	10.763	11.472	12.482	13.950	11.075	0.372
12.778	13.650	10.831		12.571	13.931	11.075	
12.837	13.650	10.872		12.556	13.931	11.319	
12.748	13.650	11.129		12.659	13.931	11.291	
12.748	13.650	11.116		12.556	13.950	10.940	
12.837	13.669	10.737		12.482	13.950	11.021	
12.763	13.669	10.804		12.482	13.931	11.062	
12.733	13.669	10.831		12.585	13.931	11.103	
12.837	13.669	10.885		12.659	13.931	11.103	
12.733	13.669	10.913		12.482	13.931	11.088	
12.837	13.669	10.872		12.556	13.931	11.103	
12.748	13.669	10.872		12.482	13.950	11.075	
12.837	13.669	10.885		12.571	13.931	11.116	
12.822	13.669	10.885		12.571	13.931	11.291	
12.733	13.669	10.899		12.556	13.931	11.291	
12.733	13.669	10.872		12.467	13.931	10.872	
12.822	13.669	10.885		12.482	13.950	10.953	
12.866	13.669	10.885		12.556	13.931	11.035	
12.852	13.669	10.885		12.497	13.931	11.062	
12.733	13.669	10.885		12.556	13.950	11.062	
12.940	13.669	10.899		12.482	13.950	11.103	
12.852	13.669	10.872		12.571	13.950	11.075	
12.926	13.669	10.913		12.512	13.950	11.062	
12.837	13.669	10.872		12.482	13.950	11.088	
12.822	13.650	10.885		12.571	13.969	11.075	
12.866	13.669	10.859		12.585	13.969	11.062	
12.822	13.669	10.899		12.497	13.969	11.103	
12.822	13.669	10.899		12.556	13.950	11.103	
12.748	13.650	10.899		12.571	13.969	11.062	
12.748	13.669	10.885		12.556	13.987	11.075	

Table A15. 12 inch depth.

12 Up				12 Down			
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
13.473	14.906	11.847	10.212	13.295	15.281	12.158	0.504
13.576	15.000	11.820	11.088	13.310	15.263	12.117	1.127
13.443	15.000	11.833	9.744	13.310	15.263	12.130	1.006
13.473	15.000	11.873	10.608	13.207	15.281	12.117	1.179
13.443	15.000	11.833	9.504	13.399	15.281	12.130	0.989
13.458	15.000	11.860	8.448	13.310	15.281	12.130	0.887
13.443	15.000	11.914	10.104	13.325	15.281	12.130	0.956
13.547	15.000	11.847	8.916	13.221	15.281	12.104	0.855
13.443	15.000	11.888	7.932	13.280	15.281	12.145	0.763
13.473	15.000	11.888	7.932	13.266	15.281	12.104	0.901
13.547	15.000	11.873	12.816	13.207	15.281	12.117	0.796
13.487	15.000	11.901	11.364	13.192	15.281	12.130	0.714
13.547	15.000	11.873	12.144	13.295	15.281	12.117	0.871
13.502	15.000	11.860	10.692	13.221	15.281	12.117	0.756
13.591	15.000	11.820	11.676	13.310	15.281	12.130	0.674
13.576	14.887	11.873	10.296	13.399	15.281	12.076	0.674
13.487	15.000	11.914	9.192	13.280	15.281	12.130	1.143
13.517	15.000	11.873	10.14	13.295	15.281	12.130	1.019
13.562	15.000	11.928	8.952	13.295	15.281	12.091	2.498
13.547	15.000	11.860	10.644	13.221	15.281	12.117	0.966
13.562	15.000	11.833	9.432	13.310	15.281	12.104	0.865
13.473	14.887	11.833	8.364	13.399	15.244	12.361	1.032
13.428	15.019	11.873	10.812	13.384	15.281	12.333	0.874
13.487	15.000	11.833	9	13.310	15.263	11.955	0.782
13.458	15.019	11.833	9	13.207	15.263	11.995	0.871
13.562	14.981	11.847	13.608	13.369	15.263	12.063	0.776
13.443	15.000	11.833	12.108	13.399	15.263	12.104	0.687
13.443	15.000	11.873	13.764	13.280	15.263	12.104	0.782
13.487	15.000	11.901	11.832	13.310	15.244	12.104	0.697
13.487	15.000	11.901	0	13.295	15.244	12.130	0.697
13.547	14.981	12.130	0	13.207	15.244	12.158	0.782
13.650	14.981	12.076		13.325	15.244	12.130	
13.562	15.000	11.752		13.325	15.244	12.076	
13.473	15.000	11.806		13.280	15.244	12.104	
13.576	15.000	11.847		13.384	15.263	12.145	
13.443	15.000	11.792		13.192	15.224	12.361	
13.473	14.981	12.104		13.192	15.244	12.293	
13.547	14.981	12.091		13.295	15.244	11.982	
13.547	15.000	11.725		13.280	15.244	12.036	
13.562	15.000	11.779		13.369	15.263	12.063	
13.532	14.981	12.091		13.399	15.263	12.104	
13.458	14.981	12.130		13.325	15.244	12.117	
13.562	15.000	11.711		13.310	15.263	12.091	
13.562	15.000	11.766		13.384	15.263	12.104	
13.473	14.981	12.076		13.310	15.263	12.091	
13.547	14.981	12.104		13.310	15.263	12.158	
13.562	15.000	11.738		13.384	15.263	12.130	
13.562	15.000	11.766		13.295	15.263	12.158	
13.473	14.981	12.063		13.295	15.263	12.104	
13.532	14.981	12.104		13.207	15.263	12.091	
13.547	15.000	11.725		13.384	15.263	12.130	
13.458	15.000	11.752		13.177	15.263	12.117	
13.562	14.981	12.091		13.280	15.281	12.104	
13.562	14.981	12.063		13.192	15.281	12.145	
13.547	15.000	11.738		13.310	15.281	12.104	
13.562	14.981	11.752		13.295	15.281	12.117	
13.562	14.981	12.063		13.325	15.281	12.130	
13.473	14.981	12.036		13.310	15.281	12.104	
13.562	14.981	11.711		13.295	15.263	12.117	
13.487	14.981	11.725		13.251	15.281	12.104	

Table A16. 18.0 inch depth.

	18 Up			
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Bubbler, in
17.465	22.369	17.829	16.836	13.524
17.495	22.369	17.856	15.3	13.524
17.540	22.369	17.856	18.096	18.756
17.421	22.369	17.843	15.576	17.22
17.495	22.369	17.856	15.576	15.888
17.406	22.369	17.856	18.96	16.596
17.392	22.369	17.829	19.512	15.3
17.540	22.369	17.829	17.856	17.184
17.465	22.350	17.829	19.308	15.456
17.613	22.350	17.870	17.028	14.316
17.421	22.350	17.843	24	15.924
17.569	22.350	17.856	17.028	14.196
17.510	22.350	17.815	15.852	27.3
17.569	22.331	17.856	22.14	14.7
17.436	22.331	17.870	16.08	13.608
17.540	22.331	17.843	14.976	12.696
17.569	22.331	17.856	23.208	12.66
17.510	22.331	17.870	15.456	18.444
17.436	22.331	17.829	14.352	16.992
17.451	22.331	17.856	14.352	17.82
17.613	22.331	18.100	19.308	16.2
17.421	22.331	18.086	17.736	18.408
17.687	22.331	17.721	18.72	15.684
17.421	22.331	17.761	16.908	14.544
17.525	22.331	17.815	19.584	16.2
17.540	22.331	17.829	16.392	14.784
17.525	22.331	18.072	15.18	13.764
17.540	22.313	18.059	16.128	15.648
17.451	22.331	17.721	14.904	14.148
17.569	22.350	17.761	16.752	13.164
17.584	22.350	17.815	16.512	6.048
17.554	22.350	17.829		
17.628	22.350	17.829		
17.465	22.350	17.829		
17.495	22.350	17.843		
17.510	22.350	17.843		
17.584	22.350	17.843		
17.569	22.369	17.870		
17.540	22.369	17.829		
17.628	22.369	17.829		
17.421	22.369	17.815		
17.436	22.369	17.843		
17.510	22.369	17.829		
17.569	22.369	17.870		
17.540	22.369	17.843		
17.421	22.369	17.829		
17.569	22.369	17.829		
17.421	22.369	17.856		
17.495	22.369	17.856		
17.599	22.350	17.829		
17.377	22.350	17.843		
17.451	22.350	17.829		
17.465	22.350	17.843		
17.613	22.350	17.829		
17.510	22.350	17.815		
17.599	22.331	17.843		
17.392	22.331	17.843		
17.643	22.331	17.856		
17.628	22.331	17.843		
17.495	22.331	17.829		

	18 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
17.421	22.669	18.140	13.524
17.525	22.669	18.127	13.524
17.540	22.687	18.140	18.756
17.525	22.687	18.127	17.22
17.406	22.687	18.140	15.888
17.451	22.687	18.127	16.596
17.421	22.669	18.153	15.3
17.525	22.669	18.127	17.184
17.495	22.669	18.153	15.456
17.525	22.669	18.140	14.316
17.421	22.669	18.127	15.924
17.406	22.669	18.127	14.196
17.613	22.669	18.153	27.3
17.613	22.669	18.140	14.7
17.525	22.650	18.140	13.608
17.599	22.650	18.127	12.696
17.436	22.650	18.127	12.66
17.451	22.650	18.140	18.444
17.510	22.650	18.140	16.992
17.554	22.650	18.127	17.82
17.510	22.650	18.153	16.2
17.421	22.650	18.140	18.408
17.525	22.650	18.127	15.684
17.465	22.669	18.127	14.544
17.451	22.650	18.127	16.2
17.362	22.650	18.357	14.784
17.540	22.650	18.357	13.764
17.421	22.650	18.371	15.648
17.421	22.650	18.330	14.148
17.495	22.650	17.992	13.164
17.525	22.650	17.992	6.048
17.495	22.650	18.072	
17.510	22.650	18.086	
17.525	22.669	18.100	
17.421	22.669	18.113	
17.436	22.669	18.127	
17.525	22.669	18.127	
17.406	22.669	18.127	
17.510	22.669	18.113	
17.540	22.669	18.113	
17.347	22.669	18.140	
17.495	22.669	18.153	
17.421	22.669	18.100	
17.362	22.669	18.113	
17.347	22.669	18.127	
17.421	22.669	18.140	
17.525	22.669	18.140	
17.525	22.669	18.113	
17.525	22.669	18.127	
17.451	22.669	18.113	
17.554	22.669	18.140	
17.436	22.650	18.100	
17.540	22.669	18.127	
17.436	22.650	18.127	
17.525	22.669	18.113	
17.540	22.650	18.330	
17.436	22.650	18.357	
17.599	22.650	18.018	
17.495	22.650	18.072	
17.406	22.650	18.086	

Table A17. 24.0 inch depth.

	24 Up				24 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
24.460	29.644	23.798	22.032	24.786	30.019	24.339	19.98
24.386	29.644	24.001	25.848	24.727	30.037	24.001	18.996
24.490	29.644	24.028	24.228	24.712	30.056	24.041	20.1
24.505	29.644	24.028	24.984	24.771	30.019	24.095	19.032
24.460	29.644	24.015	23.292	24.771	30.037	24.110	19.032
24.579	29.663	23.663	28.608	24.697	30.056	24.123	23.64
24.460	29.663	23.703	22.5	24.741	30.037	24.136	22.188
24.386	29.681	23.757	21.276	24.653	30.037	24.123	23.4
24.534	29.663	23.757	22.104	24.608	30.037	24.136	21.948
24.446	29.663	23.785	20.88	24.638	30.056	24.150	20.772
24.490	29.663	23.757	22.776	24.608	30.056	24.110	21.516
24.401	29.663	23.825	21.12	24.653	30.056	24.123	20.34
24.446	29.681	23.771	20.064	24.623	30.056	24.136	21.396
24.446	29.644	23.798	21.24	24.668	30.056	24.123	20.1
24.431	29.644	23.798	19.98	24.756	30.074	24.150	21.276
24.505	29.663	23.798	19.98	24.741	30.074	24.123	19.944
24.460	29.663	23.798	25.968	24.712	30.056	24.136	18.96
24.490	29.663	23.798	23.676	24.712	30.056	24.150	19.896
24.460	29.663	23.812	22.38	24.727	30.056	24.136	18.876
24.505	29.663	23.798	23.448	24.727	30.074	24.110	18.876
24.520	29.663	23.812	22.104	24.653	30.056	24.150	24
24.520	29.663	23.825	26.004	24.712	30.074	24.123	22.584
24.490	29.663	23.812	21.672	24.668	30.074	24.136	23.088
24.446	29.663	23.798	20.568	24.712	30.074	24.123	21.828
24.520	29.663	23.798	22.104	24.800	30.056	24.136	27.228
24.327	29.663	23.798	20.808	24.638	30.056	24.136	21.36
24.446	29.663	23.798	19.824	24.712	30.056	24.123	20.172
24.460	29.663	23.812	21.276	24.682	30.037	24.136	21.204
24.386	29.663	23.798	20.136	24.712	30.037	24.123	19.896
24.401	29.663	23.812	39.348	24.608	30.037	24.123	21.516
24.520	29.663	23.825	39.348	24.682	30.037	24.123	19.74
24.520	29.700	23.825		24.638	30.056	24.123	
24.460	29.663	23.812		24.697	30.056	24.123	
24.534	29.681	23.798		24.712	30.056	24.136	
24.460	29.681	23.798		24.668	30.056	24.123	
24.460	29.681	23.812		24.727	30.056	24.123	
24.460	29.681	23.825		24.579	30.037	24.313	
24.327	29.681	23.812		24.786	30.019	24.353	
24.401	29.681	23.812		24.860	30.037	23.973	
24.460	29.663	23.825		24.771	30.037	24.041	
24.446	29.663	23.812		24.830	30.037	24.326	

Note: For 24.0 inch depth, less than 60 data points were collected.

Table A18. 30.0 inch depth.

30 Up				30 Down			
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
29.7546	36.9936	29.7536	30.528	30.2130	37.3692	30.2947	28.644
29.7693	36.9936	29.7536	28.956	30.2868	37.3872	29.9565	27.42
29.7693	36.9936	29.7669	29.784	30.3018	37.3872	30.0242	28.956
29.7249	36.9936	29.7802	28.164	30.3165	37.4064	30.2814	26.904
29.9616	36.9936	29.7669	30.456	30.2130	37.3872	30.2548	25.812
29.9763	36.9936	29.7802	28.008	30.3165	37.4064	29.9565	26.52
29.9172	36.9936	29.7669	26.868	30.3018	37.4064	30.2271	25.452
29.7840	36.9936	29.7802	27.936	30.2277	37.4064	30.3224	26.316
29.7840	36.9936	29.7935	26.556	30.3165	37.4064	29.9022	25.14
29.8431	36.9936	29.7935	29.04	30.3165	37.4064	29.9432	26.244
29.7840	36.9936	29.7802	26.712	30.2130	37.4064	30.2947	25.02
29.9469	36.9936	29.7935	25.692	30.2130	37.4064	30.2814	25.968
29.8431	36.9936	29.7802	25.692	30.3018	37.4064	29.8479	25.968
29.8581	36.9744	29.9976	29.82	30.3165	37.4064	29.9299	29.388
29.8728	36.9744	29.9831	30.888	30.2130	37.4064	30.3224	29.748
29.8728	36.9936	29.6450	29.316	30.3165	37.4064	30.2947	28.248
29.8728	36.9936	29.6317	28.008	30.2277	37.4064	29.8479	29.268
29.8728	36.9744	29.9565	28.992	30.4200	37.4064	29.9565	27.384
29.8728	36.9744	30.0109	27.348	30.2130	37.4064	30.2814	28.212
29.7990	36.9936	29.6317	28.092	30.2130	37.4064	30.2814	26.832
29.8728	36.9936	29.6317	26.868	30.2277	37.4064	29.8889	29.82
29.8728	36.9744	29.9698	28.284	30.3165	37.4064	29.9432	26.364
29.8728	36.9744	30.0109	26.592	30.2130	37.4064	30.3080	25.332
29.9763	36.9936	29.5773	33.096	30.2130	37.4064	30.3080	26.124
29.7990	37.0128	29.6727	26.316	30.2277	37.4064	29.8756	25.02
29.8728	36.9744	29.9831	25.38	30.3018	37.4064	29.9299	26.244
29.8728	36.9744	30.0109	26.316	30.2277	37.4064	30.2814	24.936
29.7990	36.9936	29.6184	26.316	30.3018	37.4064	30.2947	24.936
29.8728	36.9936	29.6317	29.976	30.3165	37.3872	29.9155	30.18
29.8728	36.9744	30.0109	30.804	30.3312	37.3872	29.9432	28.608
29.8728	36.9936	30.0242	28.836	30.2277	37.3872	30.3080	33.528
29.8728	36.9936	29.6050		30.2277	37.3872	30.2814	
29.8875	36.9936	29.6450		30.4200	37.3872	29.8889	
29.7840	36.9936	30.0109		30.3756	37.3872	29.9831	
29.9763	36.9936	29.9831		30.3165	37.3872	30.2681	
29.8581	36.9936	29.6184		30.2130	37.3872	30.2947	
29.7693	37.0128	29.6583		30.2424	37.3872	29.9432	
29.8875	36.9936	29.9698		30.1983	37.3872	29.9299	
29.8728	36.9744	30.0109		30.3903	37.3872	30.0242	
29.9469	37.0128	29.6050		30.3459	37.3872	30.0242	
29.9763	36.9936	29.6050		30.3018	37.3872	30.0375	
29.8728	36.9744	29.9831		30.3459	37.3872	30.0652	
29.8728	36.9744	29.9698		30.3018	37.3872	30.0785	
29.8728	36.9936	29.6050		30.3609	37.3872	30.0652	
29.8728	36.9936	29.6727		30.2130	37.3872	30.0652	
29.8728	36.9744	30.0109		30.3609	37.3872	30.0918	
29.8728	36.9744	30.0109		30.2424	37.3872	30.0652	
29.9763	36.9936	29.6184		30.2424	37.3872	30.0918	
29.8728	36.9936	29.6317		30.3018	37.3872	30.0918	
29.7840	36.9744	29.9698		30.3018	37.3872	30.0652	
29.8728	36.9744	29.9976		30.3756	37.3872	30.0785	
29.7693	36.9936	29.6317		30.1983	37.3872	30.0918	
29.8728	36.9936	29.6860		30.3609	37.3872	30.0918	
29.7840	36.9744	30.0109		30.3609	37.3872	30.0918	
29.7840	36.9744	29.9698		30.2277	37.3872	30.0785	
29.8875	36.9936	29.6184		30.3459	37.3872	30.0785	
29.8875	37.0128	29.6860		30.3312	37.3872	30.0652	
29.8728	36.9744	29.9831		30.2868	37.4064	30.0652	
29.9319	36.9936	29.9976		30.3609	37.3872	30.1051	
29.8728	36.9936	29.6450		30.2424	37.4064	30.1051	

Table A19. 36.0 inch depth.

	36 Up				36 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure,in	Bubbler, in
35.182	44.381	36.375	34.464	35.330	44.756	36.263	34.032
35.182	44.381	36.375	32.376	35.345	44.756	36.278	34.08
35.167	44.381	36.429	32.376	35.330	44.737	35.871	36.432
35.270	44.381	36.403	36	35.256	44.756	35.925	34.824
35.182	44.381	36.429	36.432	35.433	44.756	35.993	36.156
35.270	44.381	36.443	34.824	35.330	44.737	36.060	33.804
35.270	44.381	36.375	35.616	35.256	44.756	36.047	36.6
35.270	44.381	36.416	33.996	35.345	44.756	36.034	33.096
35.078	44.381	36.647	35.136	35.345	44.756	36.047	48.48
35.167	44.381	36.660	33.288	35.345	44.756	36.021	32.46
35.167	44.381	36.322	33.84	35.330	44.756	36.034	31.356
35.167	44.381	36.362	32.772	35.418	44.737	36.047	32.064
35.270	44.381	36.403	33.636	35.433	44.756	36.060	31.044
35.093	44.381	36.403	32.376	35.433	44.756	36.060	31.872
35.093	44.381	36.403	33.96	35.345	44.756	36.047	30.804
35.167	44.381	36.457	32.148	35.522	44.756	36.047	31.836
35.167	44.381	36.429	35.808	35.345	44.756	36.034	31.836
35.167	44.381	36.403	35.844	35.418	44.756	36.060	35.448
35.078	44.381	36.443	36.12	35.330	44.756	36.060	39.156
35.093	44.381	36.390	36.792	35.345	44.756	36.034	34.272
35.167	44.381	36.390	35.292	35.345	44.756	36.034	50.016
35.167	44.381	36.416	36.756	35.345	44.756	36.047	33.48
35.182	44.400	36.416	34.896	35.330	44.756	36.088	32.34
35.167	44.400	36.647	33.684	35.345	44.737	36.047	32.892
35.345	44.400	36.647	35.22	35.433	44.756	36.047	31.752
35.167	44.400	36.268	33.6	35.418	44.737	36.115	32.544
35.182	44.400	36.322	32.544	35.433	44.737	36.088	31.284
35.182	44.400	36.349	33.168	35.345	44.737	36.047	32.184
35.167	44.400	36.375	32.028	35.345	44.737	36.047	31.008
35.078	44.400	36.416	34.356	35.433	44.737	36.034	31.2
35.167	44.400	36.416	41.52	35.345	44.737	36.034	26.364
35.182	44.400	36.416		35.345	44.737	36.047	
35.078	44.400	36.375		35.330	44.737	36.047	
35.167	44.400	36.390		35.345	44.737	36.047	
35.063	44.400	36.403		35.345	44.737	36.291	
35.167	44.381	36.403		35.330	44.737	35.871	
35.078	44.400	36.416		35.345	44.737	35.980	
35.182	44.400	36.443		35.345	44.737	36.007	
35.256	44.400	36.416		35.345	44.737	36.088	
35.270	44.400	36.429		35.330	44.737	36.047	
35.167	44.400	36.390		35.167	44.737	36.047	
35.167	44.381	36.390		35.256	44.737	36.304	
35.182	44.400	36.390		35.330	44.737	36.278	
35.078	44.381	36.443		35.330	44.737	36.278	
35.167	44.381	36.416		35.345	44.737	36.237	
35.167	44.381	36.375		35.345	44.737	35.925	
35.078	44.381	36.362		35.389	44.737	35.899	
35.256	44.381	36.375		35.345	44.737	35.953	
35.078	44.381	36.416		35.345	44.737	35.993	
35.078	44.381	36.606		35.345	44.756	36.034	
35.078	44.381	36.619		35.345	44.737	36.021	
35.182	44.381	36.254		35.345	44.737	36.007	
35.167	44.381	36.307		35.330	44.737	36.088	
35.167	44.381	36.403		35.433	44.737	36.060	
35.182	44.381	36.403		35.345	44.737	36.060	
35.093	44.381	36.390		35.256	44.737	36.060	
35.256	44.381	36.416		35.433	44.737	36.060	
35.167	44.381	36.375		35.345	44.737	36.060	
35.167	44.381	36.390		35.330	44.737	36.034	
35.078	44.381	36.416		35.330	44.737	36.034	

Table A20. 42.0 inch depth.

	42 Up				42 Down		
Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in	Radar, in	Ultrasonic, in	Pressure, in	Bubbler, in
41.112	50.963	41.841	45.216	41.289	50.963	42.057	38.724
41.201	50.963	41.908	40.608	41.289	50.981	42.070	37.068
41.201	50.981	41.881	43.332	41.186	50.981	42.070	38.724
41.201	50.981	42.098	39.744	41.097	50.981	42.057	36.756
41.201	50.981	42.111	42.660	41.186	50.981	42.098	39.12
41.112	50.981	41.719	39.000	41.289	50.981	42.044	36.6
41.112	50.981	41.800	42.660	41.289	50.981	42.057	36.6
41.112	50.981	41.827	38.400	41.201	50.981	42.098	40.26
41.201	50.981	41.867	42.696	41.275	50.981	42.057	41.196
41.112	50.981	41.922	37.896	41.186	50.981	42.070	39.708
41.186	50.981	41.895	45.492	41.186	50.981	42.070	44.508
41.201	50.981	41.881	38.016	41.201	50.981	42.083	38.952
41.201	50.981	41.935	38.016	41.201	50.981	42.057	43.872
41.289	50.981	41.867	43.872	41.201	50.981	42.287	38.328
41.201	50.981	41.895	40.920	41.201	50.981	42.273	44.664
41.201	50.981	41.895	42.024	41.201	50.981	41.922	37.812
41.201	50.981	41.908	39.780	41.201	50.981	42.083	36.792
41.201	50.981	41.908	40.884	41.201	50.981	42.301	37.464
41.112	50.981	41.841	38.880	41.201	50.981	42.260	36.396
41.201	50.981	41.867	39.936	41.289	50.981	41.895	37.224
41.201	50.981	41.922	38.172	41.201	50.981	41.948	36.24
41.097	50.981	41.881	39.432	41.201	50.981	42.260	36.204
41.097	50.981	41.854	37.584	41.201	50.981	42.287	40.536
41.112	50.981	41.867	39.156	41.289	50.981	41.895	40.728
41.201	50.981	41.881	37.140	41.289	50.981	41.948	39.312
41.201	50.981	41.854	39.000	41.289	50.981	42.273	39.744
41.275	50.981	41.881	36.756	41.201	50.981	42.260	38.4
41.201	50.981	41.881	36.756	41.201	50.981	41.895	38.88
41.201	50.981	41.895	41.832	41.201	50.981	41.948	37.776
41.201	50.981	41.854	40.140	41.186	50.981	42.273	38.292
41.201	50.981	41.867	43.644	41.289	50.981	42.273	35.412
41.112	50.981	41.881		41.289	50.981	41.908	
41.201	50.981	42.083		41.201	50.981	41.976	
41.112	50.981	42.098		41.289	50.981	41.989	
41.112	50.981	41.719		41.186	50.981	42.016	
41.201	50.981	41.786		41.201	50.981	42.030	
41.112	50.981	41.854		41.289	50.981	42.030	
41.112	50.981	41.841		41.201	50.981	42.030	
41.201	50.981	41.867		41.186	50.981	42.057	
41.201	50.981	41.895		41.289	50.981	42.044	
41.112	50.981	41.881		41.201	50.981	42.083	
41.201	50.981	41.881		41.201	50.981	42.044	
41.289	50.981	41.881		41.289	50.981	42.044	
41.112	50.981	41.881		41.275	50.981	42.057	
41.201	50.981	42.083		41.289	50.981	42.070	
41.201	50.981	42.098		41.304	50.981	42.057	
41.112	50.981	41.719		41.378	50.981	42.057	
41.112	50.981	41.800		41.289	50.981	42.070	
41.289	50.981	41.827		41.289	50.981	42.057	
41.201	50.981	41.867		41.289	50.981	42.083	
41.112	50.981	41.854		41.201	50.981	42.057	
41.201	50.981	41.854		41.289	50.981	42.044	
41.201	50.981	41.867		41.186	50.981	42.044	
41.097	50.981	41.854		41.289	50.981	42.057	
41.201	50.981	41.867		41.186	50.981	42.057	
41.275	50.981	41.854		41.289	50.981	42.044	
41.201	50.981	41.854		41.201	50.981	42.070	
41.201	50.981	41.841		41.289	50.981	42.057	
41.201	50.981	41.881		41.289	50.981	42.057	
41.112	50.981	41.854		41.378	50.981	42.044	

Table A21. 48 inch depth.

	48 In		
Radar, in	Ultrasonic, in	Pressure,in	Bubbler, in
47.234	47.419	48.557	49.356
47.116	47.419	48.584	47.34
47.131	47.419	48.584	47.376
47.131	47.419	48.625	45.492
47.131	47.419	48.597	46.716
47.219	47.419	48.625	45.408
47.219	47.419	48.625	45.804
47.131	47.419	48.625	48.324
47.219	47.419	48.612	45.024
47.131	47.419	48.612	46.044
47.116	47.419	48.612	46.044
47.131	47.419	48.828	50.064
47.131	47.419	48.855	48.204
47.131	47.419	48.449	49.152
47.131	47.419	48.503	46.944
47.131	47.419	48.557	47.496
47.131	47.419	48.584	45.96
47.219	47.419	48.612	46.944
47.219	47.419	48.612	45.132
47.219	47.400	48.597	45.852
47.131	47.419	48.597	44.472
47.219	47.381	48.612	45.336
47.131	47.381	48.597	43.992
47.131	47.381	48.612	44.7
47.219	47.381	48.625	43.56
47.131	47.381	48.612	43.56
47.219	47.419	48.625	48.048
47.131	47.381	48.612	46.596
47.131	47.381	48.612	47.148
47.116	47.381	48.597	45.612
47.219	47.381	48.625	42.384
47.219	47.381	48.625	
47.131	47.381	48.597	
47.131	47.363	48.612	
47.219	47.381	48.612	
47.116	47.381	48.625	
47.234	47.381	48.597	
47.219	47.381	48.815	
47.219	47.381	48.828	
47.131	47.381	48.490	
47.131	47.381	48.557	
47.116	47.381	48.597	
47.205	47.381	48.625	
47.131	47.381	48.625	
47.131	47.381	48.612	
47.219	47.381	48.597	
47.308	47.381	48.612	
47.116	47.381	48.612	
47.131	47.363	48.625	
47.131	47.363	48.612	
47.131	47.381	48.638	
47.131	47.363	48.612	
47.131	47.363	48.828	
47.219	47.381	48.828	
47.131	47.363	48.815	
47.131	47.363	48.815	
47.042	47.363	48.449	
47.219	47.381	48.475	
47.219	47.363	48.530	
47.131	47.363	48.557	

APPENDIX B

Honeycutt Creek Monitoring Station Reports

Table B1. October 31, 2009 monitoring station report.

Oct. 31 Saturday 1:10pm-3:41pm

	Observed, (ft)	Radar, ft	Ultrasonic, ft	Pressure, ft	Bubbler, ft	Turbidity Meter, NTU/FNU	Rain, in	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m²	Water Temp, °F	Air Temp, °F	Water Content, m³/m³
1	0.26	0.493	0.538	0.441558842	N/A	-1.03	N/A	0	0	94.6	41.9	62.85	66.13	-0.10144
2	0.26	0.493	0.547	0.43250154	N/A	0.71	N/A	0	0.85	94.6	40.6	62.85	65.745	-0.10144
3	0.26	0.478	0.547	0.435921134	N/A	-35.47	N/A	0	0.85	94.7	35.6	62.85	65.658	-0.10186
4	0.26	0.493	0.588	0.434719655	N/A	-149.27	N/A	0	1.7	94.6	31.9	62.85	65.53	-0.10186
5	0.26	3.674	0.667	0.434719655	N/A	-222.08	N/A	0.85	2.55	94.6	28.1	62.85	65.444	-0.10186
6	0.26	3.093	0.669	0.435921134	N/A	-283.55	N/A	0	2.55	94.6	41.9	62.85	65.444	-0.10144
7	0.26	0.471	0.528	0.435921134	N/A	719.66	N/A	0	1.7	94.7	66.9	62.85	65.53	-0.10144
8	0.26	0.471	0.527	0.434719655	N/A	389.61	N/A	0	1.7	94.7	73.1	62.85	65.658	-0.10186
9	0.26	0.471	0.536	0.430283426	N/A	786.36	N/A	0	0	94.7	70.6	62.85	65.872	-0.10186
10	0.26	0.478	0.536	0.434719655	N/A	273.64	N/A	0	0	94.6	64.4	62.85	65.872	-0.10186
11	0.27	0.486	0.525	0.433610598	N/A	650.34	N/A	0	0	94.7	60.6	62.85	65.745	-0.10186
12	0.27	3.965	0.538	0.43250154	N/A	-118.75	N/A	0	0	94.6	59.4	62.85	65.615	-0.10229
13	0.27	0.470	0.520	0.437030191	N/A	314.62	N/A	0	0	94.7	63.1	62.85	65.745	-0.10229
14	0.27	0.494	0.533	0.437030191	N/A	765.87	N/A	0	0	94.6	71.9	62.85	65.829	-0.10229
15	0.27	0.500	0.539	0.438139248	N/A	-283.55	N/A	0	0	94.6	69.4	62.85	65.916	-0.10229
16	0.27	0.486	0.531	0.439248306	N/A	706.14	N/A	0	0	94.7	61.9	62.85	65.959	-0.10271
17	0.27	3.129	1.027	0.446087492	N/A	-283.55	N/A	0	0	94.7	58.1	62.85	66.043	-0.10229
18	0.27	0.486	0.539	0.444886014	N/A	709.19	N/A	0	0	94.7	59.4	62.85	66.173	-0.10229
19	0.27	0.493	0.556	0.4517252	N/A	-283.55	N/A	0	0	94.6	40.6	62.85	66.087	-0.10271
20	0.27	3.925	0.563	0.452834258	N/A	-133.57	N/A	0	0	94.7	39.4	62.85	66	-0.10186
21	0.27	3.956	0.569	0.452834258	N/A	-129.21	N/A	0	0	94.7	40.6	62.85	65.829	-0.10186
22	0.27	0.493	0.555	0.452834258	N/A	259.69	N/A	0	0	94.7	51.9	62.85	65.829	-0.10229
23	0.27	0.486	0.550	0.448305607	N/A	434.96	N/A	0	0	94.7	51.9	62.85	65.788	-0.10186
24	0.27	0.509	0.558	0.457362908	N/A	-22.83	N/A	0	0	94.7	38.1	62.85	65.872	-0.10102
25	0.27	0.493	0.566	0.450523722	N/A	-141.42	N/A	0	1.7	94.6	31.9	62.85	65.829	-0.09974
26	0.27	0.509	0.561	0.453943315	N/A	-283.55	N/A	0	1.7	94.6	35.6	62.85	65.745	-0.09974
27	0.27	0.486	0.555	0.453943315	N/A	132.81	N/A	0	2.55	94.7	44.4	62.85	65.745	-0.09932
28	0.27	3.490	0.705	0.450523722	N/A	-283.55	N/A	0	0	94.6	45.6	62.85	65.788	-0.09974
29	0.27	0.643	0.569	0.459581023	N/A	63.06	N/A	0	0	94.6	43.1	62.85	65.829	-0.10017
30	0.27	3.759	0.731	0.46069008	N/A	-283.55	N/A	0	0	94.6	51.9	62.85	65.916	-0.10059
31	0.27	0.493	0.556	0.458471965	N/A	753.67	N/A	0	0	94.7	65.6	62.85	65.872	-0.10059
32	0.26	0.509	0.563	0.458471965	N/A	184.7	N/A	0	0	94.7	66.9	62.85	66	-0.10059
33	0.26	0.523	0.559	0.458471965	N/A	738.84	N/A	0	0	94.7	66.9	62.85	65.959	-0.0972
34	0.26	0.502	0.558	0.458471965	N/A	206.5	N/A	0	0	94.6	70.6	62.85	66	-0.09847
35	0.26	0.515	0.563	0.456161429	N/A	819.06	N/A	0	0	94.7	86.9	62.85	66	-0.09847
36	0.26	0.493	0.561	0.457362908	N/A	809.47	N/A	0	0	94.7	103.1	63.54	66.043	-0.09932
37	0.26	3.548	2.942	0.459581023	N/A	49.54	N/A	0	0	94.7	119.4	62.85	66.214	-0.09974
38	0.26	3.490	0.773	0.461799137	N/A	54.34	N/A	0	0	94.7	133.1	62.85	66.472	-0.10017
39	0.27	0.503	0.556	0.46069008	N/A	59.13	N/A	0	0	94.7	136.9	63.54	66.729	-0.10059
40	0.27	3.443	0.759	0.463000616	N/A	48.67	N/A	0	0	94.8	128.1	63.54	66.686	-0.10102
41	0.27	0.599	0.569	0.461799137	N/A	62.62	N/A	0	0	94.8	126.9	63.54	66.686	-0.10102
42	0.28	0.500	0.559	0.466327788	N/A	56.52	N/A	0	0	94.7	129.4	63.54	66.643	-0.10102
43	0.28	3.709	0.630	0.467436845	N/A	56.08	N/A	0	0	94.8	124.4	63.54	66.985	-0.10144
44	0.29	3.661	0.630	0.485551448	N/A	131.94	N/A	0	0	94.8	125.6	63.54	67.114	-0.10144
45	0.30	3.570	0.645	0.465218731	N/A	65.67	N/A	0	0	94.7	120.6	63.54	67.114	-0.10144
46	0.30	3.488	0.838	0.474276032	N/A	57.82	N/A	0	0	94.7	105.6	63.54	67.158	-0.10144
47	0.30	3.949	0.584	0.47991374	N/A	217.4	N/A	0	0	94.8	90.6	63.54	67.071	-0.10144
48	0.31	0.636	4.255	0.485551448	N/A	909.31	N/A	0	0	94.7	88.1	63.54	67.114	-0.10144
49	0.31	0.537	0.606	0.496826864	N/A	684.78	N/A	0	0	94.8	83.1	64.22	67.071	-0.10144

Table B1. October 31, 2009 monitoring station report cont.

Oct. 31 Saturday 1:10pm-3:41pm

	Observed, (ft)	Radar, ft	Ultrasonic, ft	Pressure, ft	Bubbler, ft	Turbidity Meter, NTU/FNU	Rain, in	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m²	Water Temp, °F	Air Temp, °F	Water Content, m³/m³
50	0.32	0.372	0.617	0.503573629	N/A	843.92	N/A	0	0	94.8	69.4	64.22	66.985	-0.10144
51	0.32	3.769	0.622	0.510320394	N/A	-208.56	N/A	0	0	94.9	54.4	64.22	67.028	-0.10186
52	0.32	0.546	0.625	0.510320394	N/A	208.24	N/A	0	0	94.9	48.1	64.22	66.9	-0.10186
53	0.32	3.442	0.884	0.519377696	N/A	-283.55	N/A	0	0	94.8	44.4	64.22	66.729	-0.10186
54	0.32	4.018	0.642	0.532963648	N/A	-32.86	N/A	0	0	94.8	48.1	64.22	66.729	-0.10229
55	0.32	3.754	0.644	0.535181762	N/A	-119.18	N/A	0	0	94.6	63.1	64.22	66.515	-0.10271
56	0.32	0.546	0.633	0.525015404	N/A	761.95	N/A	0	0	94.7	64.4	64.22	66.558	-0.10271
57	0.32	3.979	0.641	0.523906346	N/A	-119.62	N/A	0	0	94.7	60.6	64.22	66.772	-0.10271
58	0.32	0.561	0.645	0.522797289	N/A	382.64	N/A	0	0	94.7	54.4	64.22	66.772	-0.10271
59	0.32	3.527	0.753	0.532963648	N/A	-283.55	N/A	0	0	94.8	53.1	64.22	66.857	-0.10271
60	0.32	0.568	0.636	0.522797289	N/A	380.89	N/A	0	0	94.8	55.6	64.22	66.857	-0.10271
61	0.32	0.319	0.925	0.527233518	N/A	-137.93	N/A	0	0	94.8	54.4	63.54	66.857	-0.10271
62	0.32	0.553	0.628	0.529544054	N/A	331.63	N/A	0	0	94.7	56.9	63.54	66.643	-0.10271
63	0.32	0.546	0.613	0.509211337	N/A	634.64	N/A	0	0	94.7	65.6	63.54	66.686	-0.10271
64	0.32	0.568	0.619	0.501355514	N/A	707.01	N/A	0	0	94.6	73.1	63.54	66.6	-0.10314
65	0.32	0.381	0.614	0.49340727	N/A	714.43	N/A	0	0	94.5	75.6	63.54	66.558	-0.10314
66	0.32	0.425	0.619	0.502464572	N/A	803.37	N/A	0	0	94.6	80.6	63.54	66.643	-0.10314
67	0.32	0.476	4.133	0.494516328	N/A	882.28	N/A	0	0	94.5	100.6	63.54	66.772	-0.10314
68	0.32	0.567	3.680	0.492298213	N/A	935.04	N/A	0	0	94.6	124.4	63.54	66.814	-0.10314
69	0.32	0.552	0.600	0.494516328	N/A	35.59	N/A	0	0	94.6	134.4	62.85	66.943	-0.10314
70	0.32	3.228	0.872	0.494516328	N/A	53.9	N/A	0	0	94.6	125.6	62.85	66.985	-0.10314
71	0.32	3.607	0.703	0.492298213	N/A	43	N/A	0	0	94.8	120.6	62.85	67.372	-0.10314
72	0.32	3.884	0.813	0.490080099	N/A	43.44	N/A	0	0	94.6	125.6	62.85	67.242	-0.10356
73	0.32	2.642	0.753	0.487769563	N/A	43.87	N/A	0	0	94.6	108.1	62.85	67.071	-0.10356
74	0.33	3.143	0.753	0.48887862	N/A	40.38	N/A	0	0	94.7	88.1	62.85	67.285	-0.10356
75	0.33	3.309	0.753	0.487769563	N/A	-283.55	N/A	0	0	94.6	79.4	62.85	66.9	-0.10356
76	0.33	0.553	0.589	0.485551448	N/A	813.83	N/A	0	0	94.7	80.6	62.85	66.814	-0.10356
77	0.33	0.493	0.583	0.477603204	N/A	56.08	N/A	0	0	94.5	86.9	62.85	66.943	-0.10356
78	0.34	0.577	0.786	0.47991374	N/A	888.82	N/A	0	0	94.6	99.4	62.85	66.943	-0.10356
79	0.34	2.892	3.545	0.483240912	N/A	41.26	N/A	0	0	94.6	135.6	62.85	67.114	-0.10356
80	0.34	4.040	0.572	0.482131855	N/A	57.39	N/A	0	0	94.6	183.1	62.85	67.5	-0.10356
81	0.35	4.045	0.578	0.471965496	N/A	63.06	N/A	0	0	94.6	281.9	62.85	67.586	-0.10356
82	0.35	0.531	0.581	0.481022797	N/A	54.77	N/A	0	0	94.6	438.1	62.85	68.4	-0.10356
83	0.34	0.562	0.647	0.467436845	N/A	102.3	N/A	0	0	94.6	413.1	62.85	69.085	-0.10356
84	0.34	0.574	0.564	0.464109673	N/A	73.96	N/A	0	0	94.9	329.4	62.85	70.158	-0.10356
85	0.34	-0.778	0.573	0.482131855	N/A	75.7	N/A	0	0	94.9	280.6	62.85	70.459	-0.10399
86	0.34	-0.779	0.578	0.467436845	N/A	82.68	N/A	0	0	94.8	339.4	62.85	70.803	-0.10399
87	0.34	-0.999	-0.730	0.298213185	N/A	-283.55	N/A	0	0	94.6	305.6	62.85	70.459	-0.10399
88	0.34	3.213	0.594	0.476494147	N/A	58.7	N/A	0	0	94.6	238.1	62.85	70.887	-0.10399
89	0.34	0.553	0.592	0.484442391	N/A	72.65	N/A	0	0	94.5	224.4	62.85	70.502	-0.10399
90	0.35	4.011	0.594	0.491189156	N/A	77.01	N/A	0	0	94.6	491.9	62.85	70.072	-0.10399
91	0.35	0.555	0.594	0.495717807	N/A	90.52	N/A	0	0	94.5	251.9	62.85	70.115	-0.10399
92	0.35	2.836	0.673	0.496826864	N/A	91.83	N/A	0	0	94.5	279.4	62.85	70.201	-0.10399
93	0.35	3.674	0.664	0.50810228	N/A	973.84	N/A	0	0	94.3	275.6	62.85	70.072	-0.10399
94	0.35	0.569	0.609	0.491189156	N/A	826.48	N/A	0	0	94.3	214.4	62.85	70.201	-0.10441
95	0.35	3.468	4.220	0.497935921	N/A	97.5	N/A	0	0	94.1	401.9	62.17	69.858	-0.10399
96	0.35	3.387	0.706	0.494516328	N/A	109.71	N/A	0	0	94	483.1	62.17	71.103	-0.10399
97	0.35	0.573	0.611	0.497935921	N/A	106.66	N/A	0	0	94.2	663.1	62.85	72.523	-0.10399
98	0.35	3.438	0.744	0.497935921	N/A	110.14	N/A	0	0	94.6	454.4	62.85	72.61	-0.10399
99	0.35	3.500	0.728	0.501355514	N/A	98.37	N/A	0	0	94.1	523.1	62.85	73.645	-0.10399

Table B1. October 31, 2009 monitoring station report cont.

Oct. 31 Saturday 1:10pm-3:41pm

	Observed, (ft)	Radar, ft	Ultrasonic, ft	Pressure, ft	Bubbler, ft	Turbidity Meter, NTU/FNU	Rain, in	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m^2	Water Temp, °F	Air Temp, °F	Water Content, m^3/m^3
100	0.35	3.813	0.598	0.49340727	N/A	791.6	N/A	0	0	94.6	454.4	62.85	72.61	-0.10399
101	0.35	3.327	3.769	0.500154036	N/A	91.83	N/A	0	0	94.1	523.1	62.85	73.645	-0.10399
102	0.35	3.695	-0.756	0.496826864	N/A	148.51	N/A	0	0	94.1	164.4	62.85	72.178	-0.10399
103	0.35	3.239	1.177	0.49340727	N/A	91.83	N/A	0	0	94	189.4	62.85	71.577	-0.10441
104	0.35	4.045	0.619	0.490080099	N/A	95.76	N/A	0	0	93.7	181.9	62.85	71.231	-0.10441
105	0.36	3.688	0.602	0.500154036	N/A	99.24	N/A	0	0	93.1	171.9	62.85	70.543	-0.10441
106	0.36	-0.771	-0.761	0.303850893	N/A	-283.55	N/A	0	0	93	161.9	62.85	70.459	-0.10441
107	0.36	-0.778	0.598	0.48887862	N/A	89.65	N/A	0	0	93.2	158.1	62.85	70.243	-0.10441
108	0.36	-0.774	0.603	0.49340727	N/A	87.91	N/A	0	0	92.6	158.1	62.85	69.685	-0.10483
109	0.37	-0.999	-0.731	0.318545903	N/A	-283.55	N/A	0	0	92.8	164.4	62.85	69.858	-0.10441
110	0.38	-0.763	1.153	0.49340727	N/A	73.08	N/A	0	0	92.7	158.1	62.85	69.814	-0.10441
111	0.39	3.495	-0.758	0.48887862	N/A	195.6	N/A	0	0	92.7	141.9	62.85	69.557	-0.10483
112	0.40	3.346	0.842	0.491189156	N/A	99.68	N/A	0	0	92	136.9	62.85	69.427	-0.10483
113	0.40	-0.999	-0.747	0.295995071	N/A	-283.55	N/A	0	0	92.2	150.6	62.85	69.557	-0.10483
114	0.40	3.353	0.875	0.491189156	N/A	75.7	N/A	0	0	92.5	166.9	62.85	69.6	-0.10483
115	0.41	3.405	0.855	0.483240912	N/A	73.96	N/A	0	0	92.2	160.6	62.85	69.343	-0.10483
116	0.42	2.860	1.173	0.48887862	N/A	64.36	N/A	0	0	92	139.4	63.54	69.256	-0.10483
117	0.42	3.331	0.933	0.487769563	N/A	74.39	N/A	0	0	92	120.6	63.54	69.3	-0.10483
118	0.42	-0.999	-0.830	0.360320394	N/A	-283.55	N/A	0	0	92.4	121.9	63.54	69.514	-0.10483
119	0.42	3.341	0.753	0.492298213	N/A	80.06	N/A	0	0	92.8	141.9	63.54	69.643	-0.10483
120	0.42	3.592	0.639	0.490080099	N/A	73.96	N/A	0	0	92.4	155.6	63.54	69.557	-0.10483
121	0.42	-0.762	1.119	0.490080099	N/A	19.89	N/A	0	0	92.2	143.1	63.54	69.6	-0.10483
122	0.42	3.305	0.883	0.484442391	N/A	78.75	N/A	0	0	92.4	130.6	63.54	69.728	-0.10483
123	0.41	2.837	1.047	0.485551448	N/A	61.75	N/A	0	0	92.5	128.1	63.54	69.685	-0.10483
124	0.40	-0.770	0.595	0.484442391	N/A	826.04	N/A	0	0	91.8	116.9	63.54	69.386	-0.10483
125	0.40	-0.769	3.236	0.483240912	N/A	891.44	N/A	0	0	91.7	101.9	63.54	69.17	-0.10483
126	0.40	-0.768	0.667	0.47991374	N/A	825.17	N/A	0	0	91.9	96.9	63.54	69.042	-0.10483
127	0.39	-0.768	0.591	0.475385089	N/A	841.74	N/A	0	0	91.3	96.9	63.54	68.614	-0.10483
128	0.39	-0.769	3.817	0.477603204	N/A	852.64	N/A	0	0	91.9	94.4	63.54	68.913	-0.10483
129	0.39	3.087	1.025	0.476494147	N/A	69.16	N/A	0	0	91.9	95.6	63.54	68.871	-0.10526
130	0.39	3.578	0.664	0.478804683	N/A	71.78	N/A	0	0	92.3	104.4	63.54	68.828	-0.10526
131	0.38	3.207	1.114	0.467436845	N/A	46.92	N/A	0	0	92.4	119.4	63.54	69.042	-0.10483
132	0.38	-0.999	-0.995	1.9465496	N/A	-283.55	N/A	0	0	92.4	134.4	63.54	69.042	-0.10483
133	0.38	3.957	0.572	0.471965496	N/A	65.24	N/A	0	0	92.4	144.4	64.22	69.042	-0.10526
134	0.38	0.500	0.570	0.467436845	N/A	60	N/A	0	0	92.1	151.9	64.22	69.17	-0.10526
135	0.38	3.914	0.575	0.466327788	N/A	67.42	N/A	0	0	92.2	154.4	64.22	69.17	-0.10526
136	0.37	-0.999	-0.844	0.235089341	N/A	-283.55	N/A	0	0	92.2	174.4	64.22	69.129	-0.10526
137	0.37	-0.762	1.138	0.468638324	N/A	41.26	N/A	0	0	91.6	189.4	64.22	68.956	-0.10526
138	0.37	3.364	0.738	0.465218731	N/A	62.62	N/A	0	1.7	92.3	156.9	64.22	69.3	-0.10526
139	0.37	2.805	0.809	0.458471965	N/A	45.62	N/A	0	1.7	92.5	126.9	64.22	69.3	-0.10526
140	0.37	3.756	0.572	0.464109673	N/A	64.8	N/A	0	0	92.3	121.9	64.22	69.386	-0.10526
141	0.37	-0.760	1.114	0.459581023	N/A	54.34	N/A	0	0	92.5	129.4	64.22	69.514	-0.10526
142	0.37	-0.999	-0.811	0.456161429	N/A	-283.55	N/A	0	0	92.3	148.1	64.22	69.728	-0.10526
143	0.37	-0.762	-0.758	0.458471965	N/A	44.74	N/A	0	0	92.6	155.6	64.22	69.643	-0.10526
144	0.36	-0.766	0.645	0.455052372	N/A	960.32	N/A	0	0	92.4	144.4	64.22	69.728	-0.10526
145	0.36	-0.770	0.558	0.457362908	N/A	855.69	N/A	0	0	92.3	134.4	64.22	69.557	-0.10526
146	0.36	-0.769	0.563	0.448305607	N/A	808.16	N/A	0	0	92.3	138.1	64.22	69.557	-0.10526
147	0.36	-0.769	0.558	0.449414664	N/A	858.74	N/A	0	0.85	92.4	133.1	64.22	69.471	-0.10526
148	0.37	-0.769	0.647	0.4517252	N/A	867.89	N/A	0	0.85	92.4	124.4	64.22	69.085	-0.10526
149	0.37	-0.768	0.561	0.438139248	N/A	878.36	N/A	0	0	92.8	125.6	64.22	68.999	-0.10526
150	0.38	-0.769	0.552	0.442667899	N/A	861.35	N/A	0	0.85	92.8	119.4	64.22	68.999	-0.10526
151	0.38	-0.769	0.545	0.443776956	N/A	339.04	N/A	0	0	92.8	114.4	64.22	68.999	-0.10526
152	0.38	-0.769	0.545	0.443776956	N/A	839.99	N/A	0	0	92.8	109.4	64.22	68.871	-0.10526

Table B2. November 10, 2009 (10:39 am- 12:09 pm) monitoring station report.

Nov. 10 Tuesday 10:39 am - 12:09 am

	Time	Observed, ft.	Radar, ft.	Ultrasonic, ft.	Pressure, ft.	Bubbler, ft.	Turbidity Meter, NTU/FNU	Rain, in.	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m2	Water Temp, °F	Air Temp, °F	Water Content, m3/m3
1	10:39 AM	0.52	n/a	n/a	0.989	0.329	n/a	0.01	0.85	3.4	94.2	31.9	58.050	58.582	0.240
2	10:40 AM	0.53	n/a	n/a	1.000	0.240	n/a	0	0	0	94.2	34.4	58.730	58.626	0.240
3	10:41 AM	0.53	n/a	n/a	1.019	0.457	n/a	0	0	0.85	94.2	35.6	58.050	58.669	0.240
4	10:42 AM	0.53	n/a	n/a	1.040	0.270	n/a	0	3.4	6.82	94.1	38.1	58.730	58.582	0.240
5	10:43 AM	0.53	n/a	n/a	0.248	0.204	n/a	0	0.85	3.4	94	40.6	58.050	58.669	0.241
6	10:44 AM	0.53	n/a	n/a	0.245	0.375	n/a	0	0	2.55	94.1	44.4	58.050	58.712	0.242
7	10:45 AM	0.53	n/a	n/a	0.257	0.247	n/a	0	0	0	94.1	48.1	58.730	58.798	0.243
8	10:46 AM	0.53	n/a	n/a	0.143	0.165	n/a	0	0	0	94	50.6	58.730	58.885	0.245
9	10:47 AM	0.53	n/a	n/a	0.271	2.035	n/a	0.01	0	0	94.1	53.1	58.730	58.928	0.245
10	10:48 AM	0.53	n/a	n/a	0.289	0.552	n/a	0	0	2.55	94.1	54.4	58.730	58.885	0.245
11	10:49 AM	0.53	n/a	n/a	0.276	0.427	n/a	0	0	2.55	94.1	56.9	58.730	58.842	0.245
12	10:50 AM	0.53	n/a	n/a	0.284	0.532	n/a	0	0.85	5.1	94.1	56.9	58.730	58.971	0.244
13	10:51 AM	0.53	n/a	n/a	0.287	0.401	n/a	0	0	0	94	53.1	58.730	59.014	0.244
14	10:52 AM	0.53	n/a	n/a	0.294	0.299	n/a	0	0.85	3.4	94.1	45.6	58.730	58.928	0.243
15	10:53 AM	0.53	n/a	n/a	0.307	0.417	n/a	0.01	1.7	5.95	93.9	39.4	58.730	58.885	0.243
16	10:54 AM	0.53	n/a	n/a	0.312	0.306	n/a	0	0	0	93.9	38.1	58.730	58.971	0.243
17	10:55 AM	0.53	n/a	n/a	0.303	0.207	n/a	0	0.85	3.4	93.9	41.9	58.730	58.928	0.242
18	10:56 AM	0.53	n/a	n/a	0.322	0.293	n/a	0	0.85	3.4	93.9	44.4	58.730	58.885	0.242
19	10:57 AM	0.53	n/a	n/a	0.329	0.191	n/a	0	0.85	5.1	93.8	46.9	58.730	58.842	0.242
20	10:58 AM	0.53	n/a	n/a	0.332	0.381	n/a	0	2.55	5.1	93.5	45.6	58.730	58.798	0.242
21	10:59 AM	0.54	n/a	n/a	0.341	0.237	n/a	0.01	2.55	5.95	93.4	45.6	58.730	58.842	0.242
22	11:00 AM	0.54	n/a	n/a	0.337	0.158	n/a	0	1.7	4.25	93.5	45.6	58.730	58.885	0.243
23	11:01 AM	0.54	n/a	n/a	0.329	0.355	n/a	0	0.85	3.4	93.4	45.6	58.730	58.842	0.243
24	11:02 AM	0.54	n/a	n/a	0.337	0.355	n/a	0	0	0	93.4	45.6	58.730	58.971	0.243
25	11:03 AM	0.54	n/a	n/a	0.340	0.693	n/a	0.01	1.7	3.4	93	43.1	58.730	58.755	0.243
26	11:04 AM	0.54	n/a	n/a	0.349	0.539	n/a	0	0	1.7	93	45.6	58.730	58.798	0.244
27	11:05 AM	0.54	n/a	n/a	0.338	0.424	n/a	0	0	0	93.1	48.1	58.730	58.798	0.245
28	11:06 AM	0.54	n/a	n/a	0.342	0.519	n/a	0	0	5.1	93.2	44.4	58.730	58.755	0.246
29	11:07 AM	0.54	n/a	n/a	0.340	0.401	n/a	0	0.85	4.25	93.3	35.6	58.730	58.798	0.247
30	11:08 AM	0.54	n/a	n/a	0.571	0.302	n/a	0	0	2.55	93.3	29.4	58.730	58.712	0.248
31	11:09 AM	0.54	n/a	n/a	0.563	0.401	n/a	0	0	0.85	93.4	36.9	58.730	58.755	0.248
32	11:10 AM	0.54	n/a	n/a	0.565	0.299	n/a	0	0	0	93.4	53.1	58.730	58.712	0.248
33	11:11 AM	0.52	n/a	n/a	0.559	0.207	n/a	0	0	0.85	93.5	65.6	58.730	58.755	0.246
34	11:12 AM	0.52	n/a	n/a	0.565	0.273	n/a	0	0	0.85	93.6	71.9	58.730	58.842	0.245
35	11:13 AM	0.52	n/a	n/a	0.556	0.181	n/a	0	0.85	4.25	93.5	76.9	58.730	58.842	0.244
36	11:14 AM	0.52	n/a	n/a	0.559	0.342	n/a	0	1.7	5.1	93.4	80.6	58.730	58.798	0.243
37	11:15 AM	0.52	n/a	n/a	0.556	0.217	n/a	0	1.7	5.95	93.3	88.1	58.730	58.842	0.241
38	11:16 AM	0.52	n/a	n/a	0.557	0.142	n/a	0	4.25	8.52	93	93.1	58.730	58.798	0.241
39	11:17 AM	0.51	n/a	n/a	0.551	0.142	n/a	0	2.55	5.1	92.7	96.9	58.730	58.885	0.240
40	11:18 AM	0.51	n/a	n/a	0.571	0.421	n/a	0	0	2.55	92.6	101.9	58.730	59.014	0.240
41	11:19 AM	0.51	n/a	n/a	0.563	0.503	n/a	0.01	0.85	3.4	92.8	106.9	58.730	59.272	0.240
42	11:20 AM	0.51	n/a	n/a	0.558	0.381	n/a	0	0.85	5.95	92.7	115.6	58.730	59.014	0.240
43	11:21 AM	0.51	n/a	n/a	0.562	0.467	n/a	0	0.85	5.95	92.7	114.4	58.730	59.099	0.240
44	11:22 AM	0.5	n/a	n/a	0.560	0.332	n/a	0	0	0	92.9	116.9	58.730	59.445	0.239
45	11:23 AM	0.5	n/a	n/a	0.557	0.617	n/a	0	0	0	93	123.1	58.730	59.445	0.239
46	11:24 AM	0.5	n/a	n/a	0.553	0.348	n/a	0	1.7	4.25	93.1	118.1	58.730	59.445	0.238

Table B2. November 10, 2009 (10:39 am- 12:09 pm) monitoring station report cont.

Nov. 10 Tuesday 10:39 am - 12:09 am

	Time	Observed, ft.	Radar, ft.	Ultrasonic, ft.	Pressure, ft.	Bubbler, ft.	Turbidity Meter, NTU/FNU	Rain, in.	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m2	Water Temp, °F	Air Temp, °F	Water Content, m3/m3
47	11:25 AM	0.5	n/a	n/a	0.551	0.243	n/a	0	0	1.7	93	109.4	58.730	59.401	0.237
48	11:26 AM	0.5	n/a	n/a	0.545	0.486	n/a	0	1.7	6.82	92.9	100.6	58.730	59.185	0.237
49	11:27 AM	0.5	n/a	n/a	0.545	0.270	n/a	0	0.85	3.4	92.8	96.9	58.730	59.272	0.235
50	11:28 AM	0.5	n/a	n/a	0.535	0.184	n/a	0	4.25	6.82	92.5	95.6	58.730	59.099	0.235
51	11:29 AM	0.5	n/a	n/a	0.542	0.414	n/a	0	0.85	3.4	92.3	91.9	58.730	59.272	0.234
52	11:30 AM	0.5	n/a	n/a	0.540	0.224	n/a	0	0	0	92.4	85.6	58.730	59.272	0.233
53	11:31 AM	0.5	n/a	n/a	0.538	0.142	n/a	0	0	0.85	92.6	85.6	58.730	59.272	0.232
54	11:32 AM	0.49	n/a	n/a	0.534	0.145	n/a	0	0	1.7	92.8	94.4	58.730	59.315	0.232
55	11:33 AM	0.49	n/a	n/a	0.539	0.509	n/a	0	0.85	4.25	92.8	88.1	58.730	59.272	0.230
56	11:34 AM	0.49	n/a	n/a	0.524	0.388	n/a	0	0	0	92.8	81.9	58.730	59.315	0.230
57	11:35 AM	0.49	n/a	n/a	0.527	0.434	n/a	0	0	0	93	75.6	58.730	59.272	0.229
58	11:36 AM	0.49	n/a	n/a	0.525	0.325	n/a	0	0	0	93.1	71.9	58.730	59.272	0.227
59	11:37 AM	0.48	n/a	n/a	0.523	0.401	n/a	0	0	4.25	93.4	80.6	58.730	59.486	0.226
60	11:38 AM	0.48	n/a	n/a	0.520	0.276	n/a	0.01	0	0	93.4	81.9	58.730	59.572	0.225
61	11:39 AM	0.48	n/a	n/a	0.529	0.493	n/a	0	0	0	93.4	81.9	58.730	59.572	0.225
62	11:40 AM	0.48	n/a	n/a	0.525	0.299	n/a	0	0	0	93.4	86.9	58.730	59.401	0.223
63	11:41 AM	0.48	n/a	n/a	0.517	0.198	n/a	0	0	2.55	93.4	95.6	58.730	59.445	0.223
64	11:42 AM	0.48	n/a	n/a	0.516	0.424	n/a	0	0	0	93.4	103.1	58.730	59.788	0.222
65	11:43 AM	0.48	n/a	n/a	0.523	0.234	n/a	0	0	2.55	93.4	106.9	58.730	59.529	0.221
66	11:44 AM	0.48	n/a	n/a	0.514	0.152	n/a	0	0	2.55	93.2	105.6	58.730	59.616	0.220
67	11:45 AM	0.47	n/a	n/a	0.516	0.348	n/a	0	0	0	93.2	96.9	58.730	59.616	0.219
68	11:46 AM	0.47	n/a	n/a	0.517	0.204	n/a	0	0	0	93.3	83.1	58.730	59.659	0.218
69	11:47 AM	0.47	n/a	n/a	0.508	0.204	n/a	0	1.7	5.95	92.9	73.1	58.730	59.445	0.218
70	11:48 AM	0.47	n/a	n/a	0.520	0.585	n/a	0	1.7	5.95	92.3	69.4	58.730	59.272	0.217
71	11:49 AM	0.47	n/a	n/a	0.501	0.437	n/a	0	0	0	92.5	66.9	58.730	59.486	0.217
72	11:50 AM	0.47	n/a	n/a	0.506	0.706	n/a	0	0	2.55	92.5	60.6	58.730	59.358	0.217
73	11:51 AM	0.47	n/a	n/a	0.495	0.394	n/a	0	0	0.85	92.9	45.6	58.730	59.445	0.217
74	11:52 AM	0.47	n/a	n/a	0.504	0.276	n/a	0	0	0	93	55.6	58.730	59.358	0.217
75	11:53 AM	0.47	n/a	n/a	0.495	0.358	n/a	0.01	0	0.85	93	63.1	58.730	59.315	0.217
76	11:54 AM	0.47	n/a	n/a	0.508	0.240	n/a	0	0	0	93.1	64.4	58.730	59.315	0.217
77	11:55 AM	0.46	n/a	n/a	0.515	0.355	n/a	0	0	3.4	92.9	74.4	58.730	59.272	0.217
78	11:56 AM	0.46	n/a	n/a	0.506	0.250	n/a	0	0.85	2.55	92.7	93.1	58.730	59.272	0.217
79	11:57 AM	0.46	n/a	n/a	0.501	0.161	n/a	0	0	0	92.9	106.9	58.730	59.358	0.218
80	11:58 AM	0.47	n/a	n/a	0.496	0.302	n/a	0.01	0	0	93.1	110.6	58.730	59.572	0.217
81	11:59 AM	0.46	n/a	n/a	0.497	0.204	n/a	0	2.55	9.37	92.9	116.9	58.730	59.272	0.217
82	12:00 PM	0.46	n/a	n/a	0.503	0.220	n/a	0	3.4	10.22	92.6	114.4	58.730	59.142	0.216
83	12:01 PM	0.46	n/a	n/a	0.492	0.217	n/a	0	2.55	5.95	92.4	106.9	58.730	59.358	0.216
84	12:02 PM	0.45	n/a	n/a	0.498	0.594	n/a	0	0	1.7	92.8	99.4	58.730	59.616	0.216
85	12:03 PM	0.46	n/a	n/a	0.495	0.460	n/a	0	0	0	92.8	91.9	58.730	59.616	0.215
86	12:04 PM	0.46	n/a	n/a	0.504	0.362	n/a	0	0	1.7	92.7	84.4	58.730	59.445	0.217
87	12:05 PM	0.46	n/a	n/a	0.496	0.457	n/a	0	1.7	5.95	92.6	78.1	58.730	59.315	0.215
88	12:06 PM	0.46	n/a	n/a	0.487	0.325	n/a	0.01	1.7	5.1	92.7	73.1	58.730	59.272	0.216
89	12:07 PM	0.46	n/a	n/a	0.494	0.230	n/a	0	0	2.55	92.7	74.4	58.730	59.272	0.216
90	12:08 PM	0.46	n/a	n/a	0.485	0.299	n/a	0	0	0	92.9	79.4	58.730	59.445	0.216
91	12:09 PM	0.46	n/a	n/a	0.485	0.201	n/a	0	0.85	5.95	92.9	81.9	58.730	59.229	0.216

Table B3. November 10, 2009 (1:39 pm- 3:09pm) monitoring station report.

Nov. 10 Tuesday 1:39 pm - 3:09 pm

Time	Observed, ft.	Radar, ft.	Ultrasonic, ft.	Pressure, ft.	Bubbler, ft.	Turbidity Meter, NTU/FNU	Rain, in.	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m2	Water Temp, °F	Air Temp, °F	Water Content, m3/m3
1:39 PM	0.46	N/A	N/A	0.495	0.309	n/a	0.01	0	0	93.7	23.1	58.73	58.541	0.246
1:40 PM	0.46	N/A	N/A	0.498	0.207	n/a	0	0.85	4.25	93.6	28.1	58.73	58.498	0.246
1:41 PM	0.46	N/A	N/A	0.503	0.329	n/a	0	0	3.4	93.6	34.4	58.73	58.455	0.247
1:42 PM	0.46	N/A	N/A	0.507	0.24	n/a	0	0	1.7	93.7	40.6	58.73	58.541	0.245
1:43 PM	0.46	N/A	N/A	0.508	0.165	n/a	0	0	0	93.6	39.4	58.73	58.582	0.245
1:44 PM	0.46	N/A	N/A	0.509	0.355	n/a	0	0	0.85	93.9	40.6	58.73	58.755	0.244
1:45 PM	0.46	N/A	N/A	0.507	0.211	n/a	0	0	0	94	43.1	58.73	58.712	0.244
1:46 PM	0.46	N/A	N/A	0.504	0.125	n/a	0.01	0.85	5.1	94	44.4	58.73	58.798	0.244
1:47 PM	0.46	N/A	N/A	0.513	0.125	n/a	0	0	0	94	46.9	58.73	58.755	0.243
1:48 PM	0.46	N/A	N/A	0.513	0.555	n/a	0	0	0	94	51.9	58.73	58.712	0.243
1:49 PM	0.46	N/A	N/A	0.506	0.417	n/a	0	1.7	5.95	94.1	56.9	58.73	58.712	0.243
1:50 PM	0.47	N/A	N/A	0.522	0.542	n/a	0.01	0	2.55	94.1	63.1	58.73	58.798	0.243
1:51 PM	0.47	N/A	N/A	0.517	0.407	n/a	0	0	3.4	94	68.1	58.73	58.798	0.242
1:52 PM	0.48	N/A	N/A	0.518	0.296	n/a	0	0.85	5.1	94	73.1	58.73	58.755	0.242
1:53 PM	0.48	N/A	N/A	0.516	0.421	n/a	0	0	1.7	93.9	81.9	58.73	58.755	0.244
1:54 PM	0.48	N/A	N/A	0.524	0.316	n/a	0	0	0	94	90.6	58.73	58.928	0.246
1:55 PM	0.48	N/A	N/A	0.518	0.211	n/a	0.01	0	0	94	96.9	58.73	58.928	0.248
1:56 PM	0.48	N/A	N/A	0.522	0.342	n/a	0	0	0.85	94	100.6	58.73	59.014	0.249
1:57 PM	0.48	N/A	N/A	0.522	0.26	n/a	0	0	2.55	94	96.9	58.73	58.971	0.250
1:58 PM	0.48	N/A	N/A	0.518	0.171	n/a	0	0	0	94.1	93.1	58.73	59.014	0.251
1:59 PM	0.48	N/A	N/A	0.516	0.329	n/a	0	0	0.85	94.1	86.9	58.73	58.885	0.250
2:00 PM	0.48	N/A	N/A	0.522	0.214	n/a	0.01	0	1.7	94.1	76.9	58.73	58.885	0.250
2:01 PM	0.49	N/A	N/A	0.524	0.125	n/a	0	0	1.7	94.1	70.6	58.73	58.928	0.250
2:02 PM	0.49	N/A	N/A	0.522	0.125	n/a	0	0	2.55	94.2	73.1	58.73	59.014	0.250
2:03 PM	0.49	N/A	N/A	0.531	0.565	n/a	0	0.85	4.25	94.2	80.6	58.73	59.014	0.249
2:04 PM	0.49	N/A	N/A	0.520	0.43	n/a	0	0	1.7	94.1	86.9	58.73	59.099	0.248
2:05 PM	0.49	N/A	N/A	0.526	0.542	n/a	0	0	1.7	94.1	89.4	58.73	59.014	0.246
2:06 PM	0.49	N/A	N/A	0.530	0.421	n/a	0	0	0.85	94.1	88.1	58.73	59.272	0.245
2:07 PM	0.49	N/A	N/A	0.529	0.312	n/a	0	0.85	4.25	94.2	81.9	58.73	59.142	0.244
2:08 PM	0.5	N/A	N/A	0.525	0.44	n/a	0	0	1.7	94	73.1	58.73	59.099	0.243
2:09 PM	0.5	N/A	N/A	0.534	0.332	n/a	0	0	0.85	94	64.4	58.73	59.099	0.242
2:10 PM	0.5	N/A	N/A	0.521	0.234	n/a	0.01	0	0	94.1	59.4	58.73	58.971	0.240
2:11 PM	0.51	N/A	N/A	0.539	0.368	n/a	0	0	0.85	94.1	61.9	58.73	58.928	0.239
2:12 PM	0.51	N/A	N/A	0.536	0.28	n/a	0	0	2.55	94.1	71.9	58.73	58.928	0.239
2:13 PM	0.51	N/A	N/A	0.536	0.194	n/a	0	0	0.85	94	76.9	58.73	58.928	0.237
2:14 PM	0.52	N/A	N/A	0.553	0.388	n/a	0	0	0.85	94	76.9	58.73	58.885	0.237
2:15 PM	0.52	N/A	N/A	0.542	0.237	n/a	0	0	2.55	94	71.9	58.73	59.014	0.236
2:16 PM	0.52	N/A	N/A	0.547	0.165	n/a	0	0	0	93.8	70.6	58.73	58.798	0.235
2:17 PM	0.52	N/A	N/A	0.556	0.165	n/a	0	0	1.7	93.8	70.6	58.73	58.842	0.234
2:18 PM	0.52	N/A	N/A	0.551	0.575	n/a	0	2.55	9.37	93.8	74.4	58.73	58.798	0.233
2:19 PM	0.53	N/A	N/A	0.556	0.453	n/a	0	0	3.4	93.6	80.6	58.73	58.885	0.233
2:20 PM	0.53	N/A	N/A	0.548	0.598	n/a	0	1.7	6.82	93.7	96.9	58.73	58.885	0.232
2:21 PM	0.53	N/A	N/A	0.545	0.424	n/a	0	3.4	7.67	93.4	94.4	59.41	58.842	0.231

Table B3. November 10, 2009 (1:39 pm- 3:09pm) monitoring station report cont.

Nov. 10 Tuesday 1:39 pm - 3:09 pm

Time	Observed, ft.	Radar, ft.	Ultrasonic, ft.	Pressure, ft.	Bubbler, ft.	Turbidity Meter, NTU/FNU	Rain, in.	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m2	Water Temp, °F	Air Temp, °F	Water Content, m3/m3
2:22 PM	0.53	N/A	N/A	0.563	0.316	n/a	0	0	3.4	93.4	99.4	59.41	58.928	0.230
2:23 PM	0.53	N/A	N/A	0.543	0.476	n/a	0	0	1.7	93.4	99.4	59.41	59.014	0.229
2:24 PM	0.53	N/A	N/A	0.539	0.335	n/a	0	4.25	8.52	93	84.4	59.41	58.755	0.226
2:25 PM	0.53	N/A	N/A	0.551	0.25	n/a	0	0.85	7.67	93	79.4	59.41	58.885	0.225
2:26 PM	0.53	N/A	N/A	0.560	0.385	n/a	0	0	1.7	93.2	78.1	59.41	59.014	0.225
2:27 PM	0.53	N/A	N/A	0.560	0.26	n/a	0	0.85	3.4	93.3	74.4	59.41	59.014	0.225
2:28 PM	0.53	N/A	N/A	0.555	0.181	n/a	0.01	1.7	4.25	93.3	73.1	59.41	58.971	0.224
2:29 PM	0.53	N/A	N/A	0.555	0.329	n/a	0	0.85	3.4	93.3	71.9	59.41	58.842	0.224
2:30 PM	0.53	N/A	N/A	0.551	0.217	n/a	0	0	1.7	93.3	63.1	59.41	58.885	0.222
2:31 PM	0.52	N/A	N/A	0.536	0.145	n/a	0	0	4.25	93.4	55.6	59.41	58.842	0.222
2:32 PM	0.52	N/A	N/A	0.543	0.148	n/a	0	0	0.85	93.4	50.6	59.41	58.842	0.222
2:33 PM	0.52	N/A	N/A	0.545	0.558	n/a	0	0	0.85	93.5	45.6	59.41	58.712	0.222
2:34 PM	0.52	N/A	N/A	0.536	0.43	n/a	0	0	3.4	93.5	43.1	59.41	58.755	0.221
2:35 PM	0.52	N/A	N/A	0.552	0.604	n/a	0	0	2.55	93.6	40.6	59.41	58.669	0.221
2:36 PM	0.51	N/A	N/A	0.543	0.421	n/a	0	0.85	2.55	93.6	43.1	59.41	58.582	0.220
2:37 PM	0.51	N/A	N/A	0.544	0.322	n/a	0	0	2.55	93.5	40.6	59.41	58.582	0.220
2:38 PM	0.51	N/A	N/A	0.545	0.467	n/a	0	0	2.55	93.5	40.6	59.41	58.498	0.219
2:39 PM	0.51	N/A	N/A	0.549	0.329	n/a	0	0	0.85	93.5	41.9	59.41	58.541	0.219
2:40 PM	0.51	N/A	N/A	0.542	0.24	n/a	0	0.85	3.4	93.6	45.6	59.41	58.455	0.218
2:41 PM	0.51	N/A	N/A	0.542	0.335	n/a	0	0	1.7	93.4	44.4	59.41	58.455	0.218
2:42 PM	0.5	N/A	N/A	0.534	0.227	n/a	0	0	1.7	93.6	45.6	59.41	58.498	0.217
2:43 PM	0.5	N/A	N/A	0.532	0.539	n/a	0	0	4.25	93.6	68.1	59.41	58.669	0.217
2:44 PM	0.5	N/A	N/A	0.536	0.266	n/a	0	0	2.55	93.7	68.1	59.41	58.755	0.216
2:45 PM	0.5	N/A	N/A	0.533	0.181	n/a	0	0	2.55	93.6	65.6	59.41	58.712	0.216
2:46 PM	0.5	N/A	N/A	0.529	0.437	n/a	0	0	2.55	93.5	74.4	59.41	58.669	0.215
2:47 PM	0.5	N/A	N/A	0.532	0.437	n/a	0	0	1.7	93.5	76.9	59.41	58.755	0.215
2:48 PM	0.5	N/A	N/A	0.534	0.614	n/a	0	0	3.4	93.7	74.4	59.41	58.885	0.215
2:49 PM	0.5	N/A	N/A	0.530	0.483	n/a	0	0	3.4	93.7	80.6	59.41	58.842	0.214
2:50 PM	0.5	N/A	N/A	0.533	0.516	n/a	0	0	1.7	93.7	74.4	59.41	58.928	0.214
2:51 PM	0.5	N/A	N/A	0.529	0.394	n/a	0	0	1.7	93.9	63.1	59.41	59.014	0.214
2:52 PM	0.5	N/A	N/A	0.532	0.506	n/a	0	0	3.4	93.7	60.6	59.41	58.842	0.213
2:53 PM	0.5	N/A	N/A	0.525	0.388	n/a	0	0	1.7	93.8	55.6	59.41	58.755	0.213
2:54 PM	0.5	N/A	N/A	0.529	0.283	n/a	0	0	2.55	93.8	55.6	59.41	58.842	0.212
2:55 PM	0.49	N/A	N/A	0.532	0.424	n/a	0	0	2.55	93.6	64.4	59.41	58.755	0.212
2:56 PM	0.49	N/A	N/A	0.526	0.296	n/a	0	0	1.7	93.5	88.1	59.41	58.842	0.212
2:57 PM	0.49	N/A	N/A	0.523	0.204	n/a	0	0	0	93.5	94.4	59.41	58.842	0.212
2:58 PM	0.48	N/A	N/A	0.513	0.352	n/a	0	0	0	93.8	109.4	59.41	59.099	0.212
2:59 PM	0.48	N/A	N/A	0.521	0.234	n/a	0	0	2.55	93.7	125.6	59.41	59.099	0.211
3:00 PM	0.49	N/A	N/A	0.508	0.152	n/a	0	0	1.7	93.8	119.4	59.41	59.099	0.211
3:01 PM	0.48	N/A	N/A	0.514	0.289	n/a	0	0.85	5.95	93.7	115.6	59.41	59.099	0.211
3:02 PM	0.48	N/A	N/A	0.512	0.289	n/a	0	0	1.7	93.7	100.6	59.41	59.142	0.211
3:03 PM	0.48	N/A	N/A	0.511	0.66	n/a	0	0.85	5.1	93.7	91.9	59.41	59.056	0.210
3:04 PM	0.48	N/A	N/A	0.512	0.512	n/a	0	0	1.7	93.5	88.1	59.41	59.056	0.197
3:05 PM	0.48	N/A	N/A	0.511	0.391	n/a	0	0	1.7	93.7	90.6	59.41	59.315	0.151
3:06 PM	0.47	N/A	N/A	0.507	0.44	n/a	0	0	0.85	93.6	89.4	59.41	59.272	0.149
3:07 PM	0.47	N/A	N/A	0.506	0.329	n/a	0	1.7	5.1	93.7	96.9	59.41	59.185	0.148
3:08 PM	0.47	N/A	N/A	0.509	0.463	n/a	0	0	0	93.6	95.6	59.41	59.185	0.145
3:09 PM	0.47	N/A	N/A	0.497	0.322	n/a	0	0	2.55	93.6	95.6	59.41	59.185	0.144

Table B4. November 10, 2009 (5:32 pm-6:15 pm) monitoring station report.

	Nov. 10 Tuesday 5:32pm-6:15pm													
	Observed, (ft)	Radar, ft	Ultrasonic, ft	Pressure, ft	Bubbler, ft	Turbidity Meter, NTU/FNU	Rain, in	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m^2	Water Temp, °F	Air Temp, °F	Water Content, m^3/m^3
1	0.39	0.523	0.602	0.492	0.44	41.26	0	0	2.55	93.7	0.6	58.73	57.117	0.13525
2	0.39	0.524	0.595	0.492	0.319	40.38	0.01	0	1.7	93.8	0.6	58.73	57.074	0.13483
3	0.39	0.521	0.595	0.487	0.371	41.26	0	0	0.85	93.8	0.6	58.73	57.117	0.13525
4	0.39	0.530	0.591	0.490	0.263	41.69	0	0.85	6.82	93.8	0.6	58.73	57.074	0.13441
5	0.39	0.520	0.594	0.491	0.165	41.26	0	0	1.7	93.9	0.6	58.73	57.074	0.1361
6	0.39	0.525	0.600	0.493	0.227	42.13	0	1.7	5.1	93.9	0.6	58.73	57.117	0.1378
7	0.39	0.530	0.597	0.496	0.135	41.69	0	0.85	3.4	93.9	0.6	58.73	57.117	0.13822
8	0.39	0.528	0.597	0.496	0.237	41.69	0	0	0.85	93.8	0.6	58.73	57.074	0.1378
9	0.39	0.525	0.566	0.492	0.119	41.26	0.01	0	1.7	93.9	0.6	58.73	57.074	0.13822
10	0.39	0.524	0.605	0.490	0.309	42.56	0	0	2.55	93.8	0.6	58.73	57.031	0.1395
11	0.39	0.530	0.598	0.493	0.119	42.13	0	0	3.4	93.8	0.6	58.73	57.031	0.13822
12	0.4	0.530	0.602	0.496	0.043	41.69	0	3.4	8.52	93.8	0.6	58.73	57.117	0.13738
13	0.4	0.536	0.598	0.504	0.181	41.26	0	0	2.55	93.7	0.6	58.73	57.074	0.13653
14	0.4	0.535	0.606	0.502	0.093	41.69	0	0	1.7	93.8	0.6	58.73	57.031	0.1361
15	0.4	0.536	0.617	0.523	0.093	42.13	0	0	1.7	93.8	0.6	58.73	57.117	0.1361
16	0.4	0.534	0.614	0.500	0.483	43	0.01	0	1.7	93.8	0.6	58.73	57.074	0.13568
17	0.41	0.542	0.620	0.512	0.368	43.44	0	3.4	7.67	93.8	0.6	58.73	57.117	0.1361
18	0.41	0.529	0.613	0.515	0.26	43.44	0	0.85	3.4	93.8	0.6	58.73	57.117	0.13441
19	0.41	0.550	0.606	0.507	0.355	43.87	0	0	0.85	93.8	0.6	58.73	57.117	0.13441
20	0.42	0.545	0.619	0.534	0.25	44.31	0	0	1.7	93.8	0.6	58.73	57.074	0.13568
21	0.42	0.537	0.634	0.516	0.988	43.44	0	0	0.85	93.9	0.6	58.73	57.074	0.1361
22	0.42	0.539	0.619	0.514	0.27	46.49	0	0	0	93.8	0.6	58.73	57.074	0.1395
23	0.42	0.547	0.620	0.514	0.178	45.18	0.01	0	1.7	93.9	0.6	58.73	57.074	0.1395
24	0.42	0.534	0.633	0.523	0.765	45.18	0	0.85	3.4	93.9	0.6	58.73	57.117	0.14035
25	0.42	0.551	0.630	0.519	0.214	44.31	0	1.7	5.95	93.9	0.6	58.73	57.117	0.13992
26	0.43	0.552	0.603	0.499	0.135	46.49	0	0	1.7	93.9	0.6	58.73	57.074	0.14119
27	0.43	0.561	0.634	0.530	0.473	44.31	0.01	0	0	93.9	0.6	58.73	57.074	0.14331
28	0.43	0.547	0.638	0.528	0.138	45.62	0	0	2.55	94	0.6	58.73	57.074	0.16834
29	0.43	0.555	0.641	0.528	0.063	46.92	0	1.7	8.52	93.9	0.6	58.73	57.117	0.20228
30	0.44	0.562	0.639	0.517	0.063	46.05	0	0	0.85	93.8	0.6	58.73	57.074	0.21585
31	0.44	0.550	0.648	0.535	0.496	47.36	0.01	0	1.7	93.9	0.6	58.73	57.117	0.22009
32	0.44	0.566	0.655	0.534	0.365	46.92	0	0	1.7	93.9	0.6	58.73	57.16	0.22264
33	0.45	0.562	0.648	0.540	0.667	46.92	0	0.85	3.4	93.9	0.6	58.73	57.204	0.22561
34	0.45	0.558	0.650	0.539	0.368	48.23	0.01	0.85	3.4	93.9	0.6	58.73	57.16	0.23324
35	0.45	0.578	0.666	0.545	0.266	47.8	0	1.7	6.82	93.9	0.6	58.73	57.16	0.23876
36	0.45	0.569	0.656	0.546	0.404	49.1	0	3.4	7.67	93.6	0.6	58.73	57.204	0.24342
37	0.45	0.572	0.669	0.552	0.23	49.98	0.01	0	2.55	93.5	0.6	58.73	57.16	0.24639
38	0.45	0.577	0.667	0.556	0.161	51.28	0	0.85	4.25	93.4	0.6	58.73	57.204	0.24979
39	0.45	0.581	0.669	0.556	0.237	48.23	0	0	0.85	93.2	0.6	58.73	57.204	0.25064
40	0.46	0.563	0.670	0.554	0.152	48.23	0.01	0.85	2.55	93.4	0.6	58.73	57.204	0.25064
41	0.46	0.572	0.683	0.546	0.237	49.98	0	0	0.85	93.4	0.6	58.73	57.204	0.25021
42	0.46	0.609	0.680	0.569	0.152	49.1	0	3.4	9.37	93.4	0.6	58.73	57.204	0.25064
43	0.46	0.622	0.688	0.559	0.601	49.98	0.01	3.4	8.52	93.2	0.6	58.73	57.204	0.25064
44	0.46	0.587	0.688	0.569	0.171	50.41	0.01	3.4	8.52	93	0.6	58.73	57.204	0.25148

Table B5. November 18, 2009 monitoring station report.

Nov. 18 Wednesday 9:34am-11:04am

	Time	Observed, ft	Radar, ft	Ultrasonic, ft	Pressure, ft	Bubbler, ft	Turbidity Meter, NTU/FNU	Rain, in	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m²	Water Temp, °F	Air Temp, °F	Water Content, m³/m³
1	9:34 AM	0.29	0.4363	0.4281	0.520825632	0.246	34.28	0	0	0	92.6	14.4	58.05	52.686	0.2027
2	9:35 AM	0.29	0.41165	0.4547	0.419254467	0.279	37.33	0.01	0	0	92.9	14.4	58.05	52.729	0.20652
3	9:36 AM	0.3	0.417825	0.4453	0.4508626	0.453	36.46	0	0	0	92.9	14.4	58.05	52.686	0.20949
4	9:37 AM	0.3	0.427675	0.4609	0.568237831	0.24	28.61	0.01	0	0	93	14.4	58.05	52.772	0.21246
5	9:38 AM	0.3	0.39565	0.4609	0.593006778	0.308	410.54	0	0	0	93	14.4	58.05	52.686	0.21585
6	9:39 AM	0.3	0.42645	0.4578	0.583949476	0.213	28.61	0.01	0	0	93	13.1	58.05	52.686	0.2184
7	9:40 AM	0.3	0.420275	0.4609	0.617868145	0.276	270.15	0	0	0	93.2	11.9	58.05	52.729	0.22009
8	9:41 AM	0.3	0.42645	0.475	0.597535428	0.203	73.52	0	0	0	93.1	10.6	58.05	52.597	0.22179
9	9:42 AM	0.3	0.442475	0.4766	0.576093654	0.269	44.31	0.01	0	0	93.1	13.1	58.05	52.554	0.22646
10	9:43 AM	0.31	0.438775	0.4859	0.616666667	0.197	33.41	0.01	0	0	93.2	14.4	58.05	52.597	0.23282
11	9:44 AM	0.32	0.4326	0.4797	0.615557609	0.233	34.72	0.01	0	0	93.4	15.6	58.05	52.641	0.23621
12	9:45 AM	0.32	0.43385	0.4984	0.611028959	0.187	37.77	0.01	0	0	93.4	18.1	58.05	52.641	0.2413
13	9:46 AM	0.33	0.4548	0.4937	0.651694393	1.342	39.51	0	0	0	93.4	20.6	58.05	52.597	0.243
14	9:47 AM	0.33	0.467125	0.5141	0.595317314	0.361	56.52	0.01	0	0	93.5	24.4	58.05	52.686	0.24385
15	9:48 AM	0.35	0.456025	0.5188	0.583949476	0.39	75.7	0	0	0	93.6	23.1	58.05	52.686	0.243
16	9:49 AM	0.36	0.483125	0.5312	0.616666667	0.308	84.42	0	0	0	93.7	21.9	58.05	52.597	0.24215
17	9:50 AM	0.36	0.458475	0.5344	0.621195317	0.341	88.34	0.01	0	1.7	93.8	20.6	58.05	52.772	0.24046
18	9:51 AM	0.36	0.47575	0.5531	0.629143561	0.269	101.42	0	0	1.7	93.9	20.6	58.05	52.86	0.23876
19	9:52 AM	0.37	0.49175	0.5516	0.625723968	0.308	104.04	0	0	0.85	93.8	18.1	58.05	52.772	0.23536
20	9:53 AM	0.38	0.4708	0.5625	0.643746149	0.44	99.24	0	0	0	93.8	16.9	58.05	52.729	0.23324
21	9:54 AM	0.37	0.501625	0.5703	0.638108441	0.282	97.5	0	0	0	93.8	16.9	58.05	52.817	0.23155
22	9:55 AM	0.38	0.500375	0.5687	0.636999384	0.348	89.65	0	0	0	93.8	18.1	58.05	52.772	0.23027
23	9:56 AM	0.38	0.504075	0.5828	0.623505853	0.272	93.58	0	0	0	93.9	20.6	58.05	52.903	0.22985
24	9:57 AM	0.39	0.5349	0.5859	0.633672212	0.331	96.19	0	0	0	94.1	20.6	58.05	52.992	0.22858
25	9:58 AM	0.4	0.522575	0.5969	0.626833025	0.276	94.01	0	0	0	94.1	21.9	58.05	53.078	0.22858
26	9:59 AM	0.42	0.5386	0.6125	0.702433765	0.361	90.96	0	0	0	94	23.1	58.05	53.121	0.22815
27	10:00 AM	0.43	0.53365	0.6391	0.628034504	0.295	94.45	0	0	0	94.1	24.4	58.05	53.121	0.2273
28	10:01 AM	0.45	0.574325	0.6609	0.647165742	0.302	97.06	0.01	0	0	94.1	24.4	58.05	53.253	0.22688
29	10:02 AM	0.47	0.58295	0.6797	0.642637092	0.492	91.4	0	0	0	94.1	24.4	58.05	53.121	0.22646
30	10:03 AM	0.49	0.59405	0.6937	0.646056685	0.509	99.68	0	0	0	94.1	23.1	58.05	53.121	0.22646
31	10:04 AM	0.51	0.62115	0.7328	0.636999384	0.522	104.91	0	0	0	93.9	23.1	58.73	52.947	0.22603
32	10:05 AM	0.53	0.62485	0.7578	0.643746149	0.558	103.17	0	0	0	94	23.1	58.73	53.078	0.22603
33	10:06 AM	0.54	0.6606	0.7562	0.642637092	0.482	104.91	0	0	0	93.8	28.1	58.73	53.035	0.22561
34	10:07 AM	0.54	0.669225	0.7672	0.644947628	0.522	92.27	0	0	0	93.8	31.9	58.73	53.078	0.22561
35	10:08 AM	0.55	0.67045	0.7797	0.62008626	0.446	90.52	0	0	1.7	93.8	25.6	58.73	53.078	0.22518
36	10:09 AM	0.54	0.669225	0.7703	0.631361676	0.495	93.58	0	0	0	93.9	18.1	58.73	53.209	0.22434
37	10:10 AM	0.55	0.665525	0.7812	0.609919901	0.761	86.6	0	0	0	93.9	11.9	58.73	53.253	0.22264
38	10:11 AM	0.53	0.655675	0.7453	0.635890327	0.446	79.62	0	0	0	93.8	6.9	58.73	53.166	0.21797
39	10:12 AM	0.52	0.6384	0.7391	0.613339495	0.499	83.11	0	0	0	93.7	5.6	58.73	53.035	0.21755
40	10:13 AM	0.5	0.6113	0.7375	0.631361676	0.41	75.26	0	0	0	93.6	6.9	58.73	52.903	0.21755
41	10:14 AM	0.49	0.640875	0.7297	0.633672212	0.446	69.16	0	0	0	93.6	14.4	58.73	52.772	0.21755
42	10:15 AM	0.49	0.616225	0.7	0.611028959	0.381	68.72	0.01	0	1.7	93.4	20.6	58.73	52.772	0.21755
43	10:16 AM	0.47	0.591575	0.7	0.594115835	0.965	63.93	0.01	0	0	93.3	25.6	58.73	52.729	0.22179
44	10:17 AM	0.45	0.598975	0.6875	0.635890327	0.505	62.18	0.01	0	0	93.4	24.4	58.73	52.86	0.229
45	10:18 AM	0.45	0.592825	0.6781	0.608810844	0.512	59.13	0.01	0	0	93.5	15.6	58.73	52.947	0.23197
46	10:19 AM	0.45	0.581725	0.6438	0.617868145	0.42	56.95	0	0	0	93.5	15.6	58.73	52.903	0.23579
47	10:20 AM	0.44	0.55585	0.6531	0.614448552	0.436	57.82	0.01	0	0	93.7	18.1	58.73	52.86	0.23664
48	10:21 AM	0.46	0.574325	0.6578	0.546796057	0.499	58.7	0	0	0	93.7	18.1	58.73	52.86	0.23918
49	10:22 AM	0.46	0.59035	0.6594	0.523043746	0.39	57.82	0	0	0	93.8	19.4	58.73	52.947	0.23918
50	10:23 AM	0.46	0.557075	0.6547	0.516296981	0.453	55.21	0	0	5.95	94.1	28.1	58.73	53.078	0.2413

Table B3. November 18, 2009 monitoring station report continued.

Nov. 18 Wednesday 9:34am-11:04am

	Time	Observed, ft	Radar, ft	Ultrasonic, ft	Pressure, ft	Bubbler, ft	Turbidity Meter, NTU/FNU	Rain, in	Wind Speed, mph	Gust Speed, mph	RH, %	Solar Radiation, W/m²	Water Temp, °F	Air Temp, °F	Water Content, m³/m³
51	10:24 AM	0.44	0.5583	0.6203	0.505021565	0.354	61.75	0	0	0	94.1	33.1	58.73	53.121	0.2413
52	10:25 AM	0.44	0.55215	0.6422	0.517406038	0.377	58.26	0.01	0	0	94.1	33.1	58.05	53.253	0.2413
53	10:26 AM	0.44	0.557075	0.6562	0.50723968	0.318	63.93	0	0	0	94.1	26.9	58.05	53.209	0.24088
54	10:27 AM	0.44	0.55585	0.6453	0.47008626	0.364	63.93	0	0	0	94.1	26.9	58.05	53.121	0.24003
55	10:28 AM	0.45	0.562	0.6438	0.508441158	0.659	66.98	0	0	0	94.1	33.1	58.05	53.253	0.23876
56	10:29 AM	0.44	0.55215	0.6406	0.483579791	0.341	66.98	0	0	0	94.1	39.4	58.05	53.298	0.23664
57	10:30 AM	0.44	0.560775	0.6219	0.485797905	0.43	60.88	0.01	0	0	94.1	38.1	58.05	53.298	0.23621
58	10:31 AM	0.43	0.550925	0.6469	0.501601972	0.43	58.26	0	0	0	94.1	44.4	58.05	53.253	0.23536
59	10:32 AM	0.44	0.5657	0.65	0.564818238	0.548	60	0	0	0	94.1	48.1	58.05	53.209	0.23452
60	10:33 AM	0.45	0.578025	0.6672	0.51176833	0.646	60.88	0	0	0	94.1	40.6	58.05	53.384	0.23409
61	10:34 AM	0.46	0.602675	0.6812	0.515187924	0.489	62.18	0	0	2.55	94.1	36.9	58.05	53.298	0.23324
62	10:35 AM	0.5	0.6224	0.7281	0.4982748	0.545	62.62	0	0	1.7	94	30.6	58.05	53.121	0.23282
63	10:36 AM	0.52	0.610075	0.7328	0.50280345	0.466	64.36	0	0	0.85	94.1	29.4	58.05	53.341	0.2324
64	10:37 AM	0.54	0.66305	0.7719	0.515187924	0.554	73.08	0	0	0.85	94.1	34.4	58.05	53.384	0.23155
65	10:38 AM	0.57	0.6951	0.8187	0.53099199	0.489	71.78	0	0	0.85	94.2	34.4	58.05	53.515	0.23112
66	10:39 AM	0.6	0.709875	0.8219	0.536629698	0.558	73.96	0	0	0	94.2	40.6	58.05	53.559	0.23027
67	10:40 AM	0.63	0.75795	0.8969	0.53099199	0.512	72.21	0	0	0	94.2	49.4	58.05	53.645	0.22943
68	10:41 AM	0.64	0.7641	0.8969	0.519716574	0.577	69.6	0	0	0	94.2	44.4	58.05	53.645	0.22815
69	10:42 AM	0.65	0.773975	0.9094	0.500492914	0.509	65.24	0	0	0	94.1	35.6	58.05	53.645	0.2273
70	10:43 AM	0.67	0.773975	0.9187	0.512877388	0.541	66.54	0	0	0	94.2	29.4	57.36	53.559	0.22688
71	10:44 AM	0.67	0.781375	0.9312	0.516296981	0.584	68.72	0	0	0	94.2	33.1	57.36	53.559	0.22688
72	10:45 AM	0.66	0.776425	0.9125	0.534319162	0.62	73.52	0	0	0	94.2	36.9	57.36	53.645	0.22646
73	10:46 AM	0.66	0.770275	0.9094	0.525354282	0.617	79.62	0.01	0	0	94.2	43.1	57.36	53.69	0.2273
74	10:47 AM	0.66	0.76905	0.9094	0.505021565	0.928	85.73	0	0	0	94.1	41.9	57.36	53.645	0.22688
75	10:48 AM	0.66	0.770275	0.9297	0.526463339	0.673	93.58	0	0	0	94.1	46.9	57.36	53.559	0.22688
76	10:49 AM	0.66	0.78505	0.9109	0.53099199	0.689	97.06	0	0	0	94	51.9	57.36	53.515	0.22646
77	10:50 AM	0.66	0.770275	0.9	0.47905114	0.597	97.06	0	0.85	4.25	93.9	41.9	57.36	53.341	0.22603
78	10:51 AM	0.66	0.766575	0.9125	0.481361676	0.627	98.81	0	0	1.7	94	26.9	57.36	53.559	0.22518
79	10:52 AM	0.66	0.751775	0.9031	0.477942083	0.696	99.24	0	0	3.4	93.8	21.9	57.36	53.384	0.22052
80	10:53 AM	0.65	0.745625	0.8891	0.464448552	0.568	100.12	0	0	0	93.9	35.6	57.36	53.472	0.21882
81	10:54 AM	0.64	0.75425	0.8812	0.462138016	0.617	98.81	0	0	0	93.9	40.6	57.36	53.515	0.21797
82	10:55 AM	0.64	0.7444	0.8953	0.453080715	0.531	105.35	0	0	0	93.9	31.9	57.36	53.515	0.21755
83	10:56 AM	0.62	0.755475	0.8781	0.4508626	0.6	97.94	0	0	0.85	93.7	25.6	57.36	53.472	0.21755
84	10:57 AM	0.62	0.718525	0.8812	0.446333949	0.512	100.12	0	0	0.85	93.8	21.9	57.36	53.559	0.21712
85	10:58 AM	0.61	0.734525	0.8656	0.435058534	0.568	103.6	0	0	0	93.9	23.1	57.36	53.559	0.21712
86	10:59 AM	0.61	0.75425	0.8609	0.525354282	0.476	110.58	0	0	0	93.9	29.4	57.36	53.645	0.2167
87	11:00 AM	0.61	0.734525	0.8531	0.508441158	0.531	112.76	0	0	0.85	94	40.6	57.36	53.733	0.21628
88	11:01 AM	0.61	0.74315	0.8781	0.489217498	0.535	121.04	0	0	0	94	38.1	57.36	53.776	0.215
89	11:02 AM	0.61	0.7259	0.8641	0.454282193	0.653	132.38	0	0	0	93.9	35.6	57.36	53.733	0.215
90	11:03 AM	0.6	0.739475	0.8734	0.439587184	0.676	140.23	0	0	0	93.9	35.6	57.36	53.733	0.215
91	11:04 AM	0.6	0.74685	0.8281	0.444115835	0.591	146.33	0	0	0.85	94	35.6	57.36	53.776	0.215

APPENDIX C

SAS 9.2 Outputs

SAS 9.2 Program:

```
PROC IMPORT OUT= WORK.ONE

            DATAFILE= "E:\SAS_Depths.xls"
            DBMS=EXCEL REPLACE;
     RANGE="Up$";
     GETNAMES=YES;
     MIXED=NO;
     SCANTEXT=YES;
     USEDATE=YES;
     SCANTIME=YES;
RUN;
data all;
set ONE;
run=_n_;
drop f5 down;
goptions colors=(black);
symbol1 v=circle i=rl;
symbol2 v=square i=rl;
symbol3 v=diamond i=rl;
symbol4 v=triangle i=rl;

proc print;
proc gplot;
 plot (Radar Ultrasonic Pressure bubbler)* Actual / overlay;
data radar;
set all;
reading=radar;
drop ultrasonic pressure radar bubbler;
type='Radar     ';
data ultrasonic;
set all;
reading=ultrasonic;
drop radar pressure ultrasonic bubbler;
type='Ultrasonic';
data pressure;
set all;
reading=pressure;
drop Ultrasonic radar pressure bubbler;
type='Pressure';
data bubbler;
set all;
reading=bubbler;
drop ultrasonic radar pressure bubbler;
type='Bubbler';
data two;
set radar ultrasonic pressure bubbler;
```

Program Continued:

```
proc mixed;
class run type;
model reading= type Actual*type / solution noint;
random run;
lsmeans type;
estimate 'int b vs p' type 1 -1;
estimate 'int b vs r' type 1 0 -1;
estimate 'int b vs u' type 1 0 0 -1;
estimate 'int p vs r' type 0 1 -1;
estimate 'int p vs u' type 0 1 0 -1;
estimate 'int r vs u' type 0 0 1 -1;
estimate 'slope b vs p' type*actual 1 -1;
estimate 'slope b vs r' type*actual 1 0 -1;
estimate 'slope b vs u' type*actual 1 0 0 -1;
estimate 'slope p vs r' type*Actual 0 1 -1;
estimate 'slope p vs u' type*Actual 0 1 0 -1;
estimate 'slope r vs u' type*Actual 0 0 1 -1;
 run;quit;
```

SAS 9.2 output for laboratory analysis:

```
                    The SAS System       16:12 Monday, November 23, 2009  86

                                 The Mixed Procedure

                              Convergence criteria met.


                                Covariance Parameter
                                      Estimates

                                Cov Parm     Estimate

                                run                 0
                                Residual       3.1043


                                   Fit Statistics

                        -2 Res Log Likelihood         50468.7
                        AIC (smaller is better)       50470.7
                        AICC (smaller is better)      50470.7
                        BIC (smaller is better)       50476.9


                              Solution for Fixed Effects

                                             Standard
         Effect         type        Estimate        Error      DF    t Value    Pr > |t|

         type           Bubbler      -3.7650      0.06078    9037     -61.95      <.0001
         type           Pressure     0.04193      0.03966    9037       1.06      0.2904
         type           Radar         0.4187      0.03966    9037      10.56      <.0001
         type           Ultrason      0.7705      0.03966    9037      19.43      <.0001
         Actual*type    Bubbler       1.0216     0.003130    9037     326.43      <.0001
         Actual*type    Pressure      1.0030     0.002157    9037     465.03      <.0001
         Actual*type    Radar         0.9819     0.002157    9037     455.24      <.0001
         Actual*type    Ultrason      1.1515     0.002157    9037     533.84      <.0001


                             Type 3 Tests of Fixed Effects

                                      Num     Den
                        Effect         DF      DF    F Value    Pr > F

                        type            4    9037    1081.82    <.0001
                        Actual*type     4    9037     203759    <.0001




                                 The Mixed Procedure

                                      Estimates

                                       Standard
              Label          Estimate       Error      DF    t Value    Pr > |t|

              int b vs p       -3.8070     0.07257    9037     -52.46      <.0001
              int b vs r       -4.1837     0.07257    9037     -57.65      <.0001
               int b vs u       -4.5355     0.07257    9037     -62.49      <.0001
              int p vs r       -0.3768     0.05609    9037      -6.72      <.0001
```

```
   int p vs u       -0.7285     0.05609    9037     -12.99      <.0001
   int r vs u       -0.3518     0.05609    9037      -6.27      <.0001
   slope b vs p     0.01854    0.003801    9037       4.88      <.0001
   slope b vs r     0.03966    0.003801    9037      10.43      <.0001
   slope b vs u     -0.1299    0.003801    9037     -34.17      <.0001
   slope p vs r     0.02112    0.003050    9037       6.92      <.0001
   slope p vs u     -0.1484    0.003050    9037     -48.66      <.0001
   slope r vs u     -0.1695    0.003050    9037     -55.58      <.0001


                           Least Squares Means

                                          Standard
Effect    type         Estimate          Error       DF    t Value    Pr > |t|

type      Bubbler        9.1801        0.04249     9037     216.07      <.0001
type      Pressure      12.7521        0.02915     9037     437.46      <.0001
type      Radar         12.8613        0.02915     9037     441.21      <.0001
type      Ultrason      15.3615        0.02915     9037     526.98      <.0001
```

SAS 9.2 output for field analysis:

```
                  The SAS System        09:16 Friday, December 4, 2009 159

                                   The Mixed Procedure

                                  Covariance Parameter
                                        Estimates

                                  Cov Parm     Estimate

                                  run           0.02951
                                  Residual       0.4555


                                     Fit Statistics

                          -2 Res Log Likelihood          2880.9
                          AIC (smaller is better)        2884.9
                          AICC (smaller is better)       2884.9
                          BIC (smaller is better)        2893.2


                                Solution for Fixed Effects

                                                     Standard
          Effect         type         Estimate          Error      DF    t Value    Pr > |t|

          type           Bubbler       0.07095         0.2652     884       0.27      0.7891
          type           Pressure       0.4693         0.1470     884       3.19      0.0015
          type           Radar          2.0453         0.1613     884      12.68      <.0001
          type           Ultrason       0.5767         0.1613     884       3.58      0.0004
          Actual*type    Bubbler        0.6465         0.5422     884       1.19      0.2335
          Actual*type    Pressure      0.09112         0.3305     884       0.28      0.7828
          Actual*type    Radar         -2.5101         0.3967     884      -6.33      <.0001
          Actual*type    Ultrason       0.3394         0.3967     884       0.86      0.3925
```

SAS 9.2 output for field analysis continued:

```
                              Type 3 Tests of Fixed Effects

                                   Num      Den
                    Effect          DF       DF    F Value    Pr > F

                    type             4      884      43.61    <.0001
                    Actual*type      4      884      10.92    <.0001


                                        Estimates

                                      Standard
          Label           Estimate       Error      DF    t Value    Pr > |t|

          int b vs p       -0.3984      0.2988     884      -1.33      0.1828
          int b vs r       -1.9743      0.3059     884      -6.45      <.0001
          int b vs u       -0.5057      0.3059     884      -1.65      0.0986
          int p vs r       -1.5759      0.2121     884      -7.43      <.0001
          int p vs u       -0.1073      0.2121     884      -0.51      0.6129
          int r vs u        1.4686      0.2211     884       6.64      <.0001
          slope b vs p      0.5554      0.6245     884       0.89      0.3740
          slope b vs r      3.1566      0.6610     884       4.78      <.0001
          slope b vs u      0.3071      0.6610     884       0.46      0.6423
          slope p vs r      2.6012      0.5033     884       5.17      <.0001
          slope p vs u     -0.2482      0.5033     884      -0.49      0.6220
          slope r vs u     -2.8494      0.5442     884      -5.24      <.0001


                                   Least Squares Means

                                         Standard
       Effect    type        Estimate       Error      DF    t Value    Pr > |t|

       type      Bubbler       0.3478     0.04932     884       7.05      <.0001
       type      Pressure      0.5084     0.03221     884      15.78      <.0001
       type      Radar         0.9703     0.04337     884      22.37      <.0001
        type      Ultrason      0.7220     0.04337     884       16.65      <.0001
```

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