WOODVILLE KARST PLAIN
HYDROLOGIC RESEARCH PROGRAM

REPORT ON TASKS PERFORMED IN 2008
UNDER FGS CONTRACT GW272

Prepared for:

Rodney DeHan, Ph.D.
Florida Geological Survey
Gunter Building MS #720
903 W. Tennessee St.
Tallahassee, FL 32304-7700

Prepared by:

Todd R. Kincaid, Ph.D.
H2H Associates, LLC
Specialized Geological Modeling Group
27 Keystone Ave.
Reno, NV 89503

Overview

H2H Associates, LLC (H2H) was contracted by the Florida Geological Survey (FGS) to coordinate and administer the FY2008 objectives of the FGS' Woodville Karst Plain (WKP) hydrologic research program and synthesize the results into this report. The FY2008 program included the five following tasks.

- Task-1: Continuation of Statistical Analysis
- Task-2: Field Program Management and Supervision
- Task-3: Telemetry System Installation & Metering Network Maintenance
- Task-4: Database and Data Portal Development and Maintenance
- Task-5: Spring Creek Groundwater Tracer Testing

The Principal Investigator for Task-1 was Dr. David Loper, Professor Emeritus at Florida State University (FSU). Task-2 was subcontracted to Gareth Davies of Cambrian Groundwater Company. Tasks 3-5 were preformed and/or managed by H2H. A copy of the contract that includes the formal scope of work (SOW) is provided as Appendix I. As has been customary with this ongoing research project, specific objectives (tasks) were modified during the course of the investigations to conform to evolving goals of the overall project and logistical and weather constraints.

The contract was executed on January 14, 2008 for a period of performance of January 14, 2008 – May 31, 2008. Due to the delayed execution date, an extension to December 31, 2008 was granted for the submittal of contract deliverables. This report provides a summary of the performance and results of each task, includes or references the specific deliverables as appendices, and constitutes the final deliverable for this project.

Task 1: Continuation of Statistical Analysis

Task-1 was performed by Dr. David Loper (Principal Investigator) and Dr. Eric Chicken of FSU. The primary objectives of Task-1 as identified in the SOW were as follows. 1) Develop statistical analyses of the hydrologic data being collected by the various meters managed by the FGS, and eventually, data available from other agencies as a means of estimating conduit sizes in regions where they are known to be present but cannot be directly measured. 2) Develop a comparative analysis of temporal variations in water level measured at the coast (i.e., tidal variations) and at various inland locations. 3) Quantify both the amplitude ratios and the phase speeds of the primary tidal components (diurnal and semi-diurnal) between the coast and various inland locations. 4) Analyze the existing records of discharge at Wakulla Springs in an attempt to identify and quantify salt-water-plug events.

Due in part to problems with the water level meter deployments and apparent malfunction in two of the existing hydraulic meters, both of which will be discussed in a subsequent section, the Task-1 objectives were modified to focus primarily on conduit area estimation, temperature trends in the malfunctioning hydraulic meters deployed at K-Tunnel and AK-Tunnel in Wakulla Cave, and a statistical analysis of microgravity signals that were collected and reported on by Technos in 2007. A summary of these projects, prepared by Chicken and Loper, is presented in Appendix II. They also published results and conclusions from their work in two papers for the 11th annual ASCE sinkhole conference that was held in Tallahassee in September 2008 (Loper and Chicken, 2008; Chicken et al, 2008).

Two of their conclusions are immediately relevant to the use of the hydraulic meter data and planning for future deployments and will thus be briefly summarized here. First, their conclusions about conduit cross-sectional areas based on flow balances are relevant to our calculation of flow from all of the meters currently deployed in Wakulla Cave. Table 1 presents their estimates from the stations they were able to address relative to the estimates developed from the radial measurements collected by the Woodville Karst Plain Project (WKPP) divers for the same stations and the percent error assuming that the estimates based on the measured radials are more correct. The statistically estimated cross-sectional area for AD-Tunnel compares most favorably to the measured value with a percent error of 24%. The comparison at the other three tunnels however is significantly less favorable. However, this work is ongoing and the figures obtained from flow analysis cannot yet be deemed reliable.

Figure 1 shows the meter placements at each of the conduit stations relative to the measured radials and cross-sectional profiles calculated from the radials. From those diagrams, it is reasonable to conclude that the velocity measurements collected by the hydraulic meters are not characteristic of the average velocity through the conduits and that the discrepancies between the statistically estimated and measured areas arise from those inadequate velocity measurements. If this is true, our future analyses should focus on determining if the error in velocity measurements is sufficiently consistent between stations to allow for a meaningful comparison of relative flows if the actual magnitudes cannot be measured.

The second important conclusion that they were able to develop addresses the apparent malfunction in the temperature readings recorded by the K-Tunnel and AK-Tunnel hydraulic meters. In their analysis that is presented in Appendix II, they show that the decline in temperature at those stations is most likely due to a drift in the measurement readings. More importantly, they were able to back the drift out of the temperature signals yielding a trend in temperature that is reflective of the actual water temperature at the respective stations. Their corrected data will fill a significant gap in temperature readings at those stations that we currently have because that data was omitted from the database.

Table 1. Comparison of conduit cross-sectional area estimates from four stations in Wakulla Cave

Conduit / Meter	Chicken/ Loper Est. (ft^2)	WKPP Est. (ft^2)	Percent Error (%)
B-Tunnel	774	129	500
C-Tunnel	27	886	-97
D-Tunnel	97	504	-81
AD-Tunnel	2969	2404	24

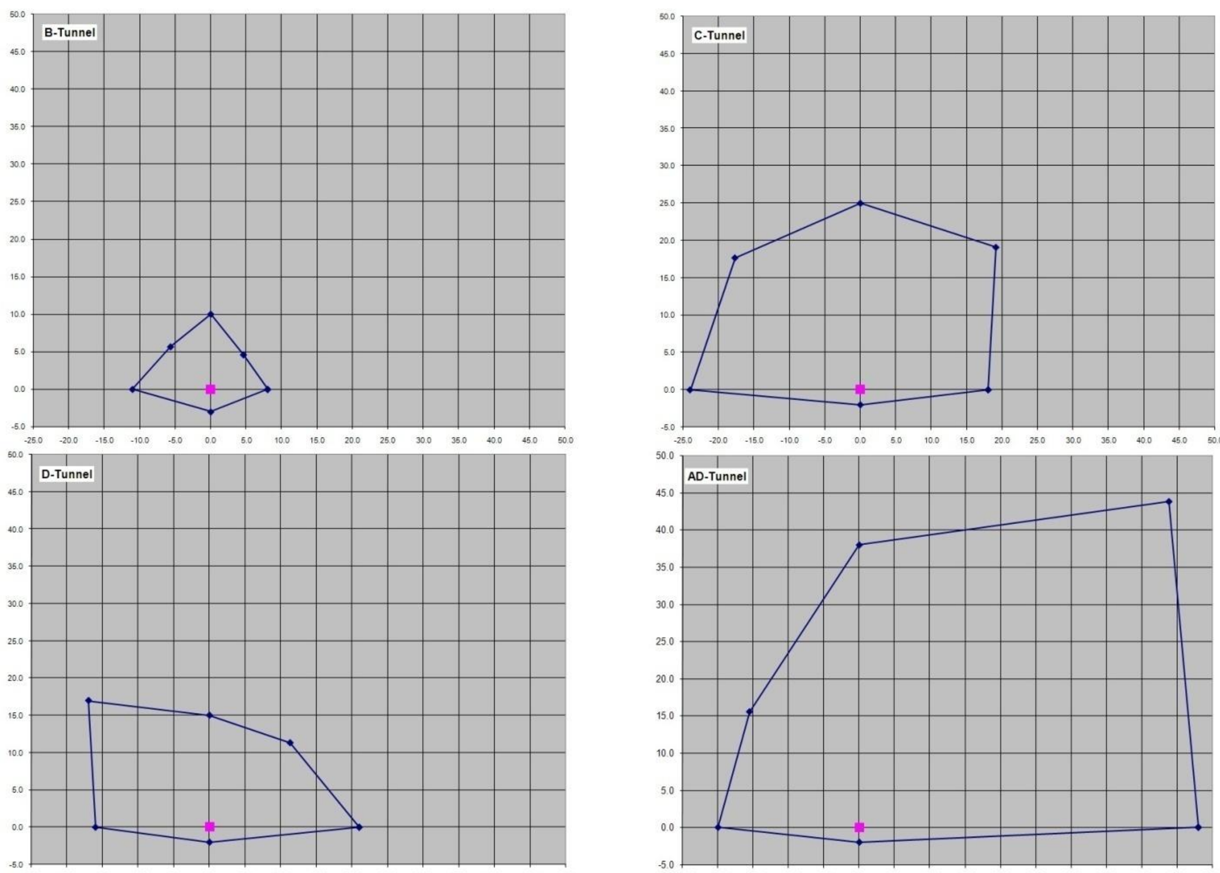


Figure 1. Cross-sectional areas for four of the primary tunnels in Wakulla Cave as calculated from radial measurements taken from the meter location (pink dot) to the cave walls along 90 degree, 45 degree, and vertical azimuths from the meters.

Task-2: Field Program Management and Supervision

Task-2 was performed by Gareth Davies. The primary objectives were 1) to organize, coordinate, and participate in fieldwork aimed at installing telemetry systems and deploying and maintaining the WKP metering network; 2) develop a QA/QC program for the Falmouth and transducer data; 3) interface with manufactures as necessary to troubleshoot instrumentation problems; and 4) interface with H2H to facilitate data transmission and the development of the telemetry system data server and database.

Some of Davies' time allocated to this task was shifted to Task-5 (Spring Creek Trace) to perform sample analysis that was necessary due to malfunctioning fluorometers and problems with fluorometer deployments at Spring Creek. Davies has submitted two drafts of a QA/QC / Field Procedures manual and prepared a summary of his work on these tasks. His summary is included as Appendix III. The QA/QC manual is still being reviewed and modified. A completed draft that will be sent to the FGS for review is anticipated in early 2009.

Task-3: Telemetry System Installation & Metering Network Maintenance

Task-3 was performed by H2H. Kevin Day of H2H was the primary geologist/technician working on the design and installation of the telemetry system. The metering network maintenance was primarily performed by Scott Dyer of the FGS with assistance from Gareth Davies and oversight and guidance provided by Todd Kincaid of H2H.

Significant problems were encountered with both the telemetry system installation and the maintenance of the metering network. Details of both are discussed below. The basic conclusions from this task are as follows.

- The telemetry system as it was originally designed has failed.
- The system components cannot reliably work together under field conditions to continuously transmit data signals from the Falmouth Hydraulic meters to a data server that has been set up at the Wakulla Springs State Park (WSSP) Administration building.
- A new design and new components will be required to bring the telemetry system online.
- A preliminary design for such a system has been developed and the required equipment has been identified.
- The Falmouth hydraulic meters are being deployed for periods that exceed the manufacturer recommendations.
- The K-Tunnel, AK-Tunnel, and Vent meters have all been offline or malfunctioning for a significant portion of the last 18 months.
- The K-Tunnel and AK-Tunnel meters have been replaced and are now producing reliable data.
- The Vent meter was temporarily replaced but has been offline again since March 2008.

Telemetry System

H2H collaborated with the telemetry system designers from the FSU Geophysical Fluid Dynamics Institute (GFDI) in 2007 to establish a working benchtop version of the telemetry system for the Falmouth hydraulic meters. That system consisted of a radio transmitter constructed by GFDI that transmitted data directly from the Falmouth meter to a receiver attached to a desktop computer. It was determined, at the time, that through the use of a signal splitter, the system might be adaptable for use with multiple devices for each radio (the Falmouth meter and a level logger or twp Falmouth meters) though one radio would most likely be needed for every Falmouth meter.

The primary objective for 2008 was to set up a central data server at the WSSP Administration building that would receive data from field deployed radios and automatically send that data to the project data server once per day for upload to the project database. The design called for two radios at each well that would transmit data from two Falmouth meters and possibly a water level recorder. The data server at WSSP was to be set up as a Micro Soft Windows server to receive data from the devices via the Falmouth interface software and transmit that data to the project server located in the H2H Reno, NV office.

To follow through on the 2008 objectives, Kevin Day and Todd Kincaid traveled to Tallahassee in March and April 2008 to work with Scott Dyer and Gareth Davies on the deployment of the radios and the data server and to thereby bring the telemetry system online. Day's report on the deployment effort is attached as Appendix IV. Several problems were encountered that precluded satisfactory system operation, some of which were overcome but others could not be solved with the existing system design.

The first problem stemmed from an inability to access WSSP's T-1 line due to DEP security regulations. As a result, we were forced to set up the server to use a dial-up connection and an Earthlink ISP account. The transmission rate turned out to be sufficient but poor phone line reliability resulted in repeated but irregular breaks in service and consequently dropped data transmissions. A stop-gap solution was implemented in which the system was forced to repeat communications with the meters whenever a data transmission was interrupted. If and when the telemetry system becomes operational, this stop-gap measure needs to be supplanted with a more reliable internet connection for the data server at WSSP.

Incomplete or corrupt data transmissions persisted after the internet connection problem was solved. Investigations into the problem ultimately revealed a problem with the standard baud rate settings on the meters and the radios. For distant and prolonged communications between the radios and the meters and the radios and the data server, which could not be created for the laboratory tests, we determined that the baud rate on the radio must be set to a faster speed than the rate on the Falmouth meters.

After that issue was solved, successful communications between the meter, radio, and server were achieved at the K-Tunnel Station though we soon learned that they could not be sustained. Research into that problem revealed that the K-Tunnel and AK-Tunnel meters were likely malfunctioning as manual communications with the meters could not be established during the problem periods. Since the only way to resolve a malfunctioning meter is to have the WKPP divers replace it, we moved our focus to the D-Tunnel and the AD-Tunnel meters, which had been configured with telemetry radios in 2007. Our first attempts to establish communications there failed as well. Through a meticulous trial and error investigation, we determined that the coaxial cables installed at the D/AD Station were not functioning. After they were replaced, we established the requisite communications only to discover the last and fatal problem with the system.

After successfully establishing communications between the server and the D-Tunnel meter, we tried to initiate a connection to a second meter only to realize that the Falmouth meters are not designed to communicate as a network of devices. Instead they are designed to have an independent connection to a data receiving device. Since the telemetry system was designed as a network of data collecting nodes connected to a single central server, any transmission from the server, say to the D-Tunnel meter would initiate the same command to all the Falmouth meters on the network. This initially prohibited automated communications through a hyperterminal because the individual Falmouth meters do recognize themselves by a unique name. Focus was then shifted to establishing remote manual connections via the Falmouth interface software but we quickly determined that the interface software has no functionality for choosing a meter to which to connect from a list of meters on a network. Communications with Falmouth technical staff revealed that their devices and systems are not designed for such network communications.

Status

As it stands, the telemetry system cannot work with the Falmouth meters but is likely suitable for remote and automatic communications with the Insitu water level recorders because those devices are designed to be recognized on a network by a unique device name. In order to set up a telemetry system for the Falmouth meters, we will need to purchase and install intermediary data loggers at each station that can physically connect with the individual meters on unique communications lines. The existing radio network could then be used to establish communications with those loggers. Davies researched this option and determined that Campbell Scientific makes a data logger that is designed for this task and that Falmouth typically uses those loggers in the manner described above when they need to set up remote communications networks.

Recommendations

- Option 1: No action
  The existing telemetry equipment should be removed from the field and stored until such time that there is sufficient time and budget to upgrade the system and re-deploy it for use with the Falmouth and water level logging devices simultaneously.
- Option 2: Upgrade the system
  Purchase one Campbell Scientific data logger for each data station. The logger should be configured to communicate with each device at the station over a unique hard-wired channel. Initially, these would include multiple Falmouth meters and a water level logger. That configuration could be expanded to include the filter fluorometers as well. Secure a reliable internet connection for the data server at WSSP. Bring the system online and initiate connection to the main server through the data interface software that has already been developed.

- Option 3: Move system to water level logger stations
  The telemetry system, as it is currently designed, appears to be suitable for use with the Insitu water level loggers. In order to capitalize on the time and funding that has been invested in the system without significant additional costs would be to shift the telemetry stations to locations where the Insitu loggers are deployed independently. Independent deployment locations are emphasized because the value of the remote access would be significantly diminished if the stations must be visited to download data from other instruments such as the Falmouth meters. The required investments would entail the breakdown and reassembly of the telemetry stations at other locations and potentially the installation of antenna poles long enough to clear the canopy. The most logical stations for such deployments include: Sullivan Sink, Turner Sink, Tobacco Sink, and Revel Sink.

Metering Network

Table 2 lists the location and status of all instruments comprising the metering network as of July 2008. A copy of the equipment inventory list is attached as Appendix V. Plots of the available data from the period are provided below as Figures 2-5.

Table 2. Instrument status in the WKP metering network

Station	Device	Status	Days Online
Wakulla-Vent	Falmouth	off line	105
B-Tunnel	Falmouth	on line	365
C-Tunnel	Falmouth	on line	365
D-Tunnel	Falmouth	on line	188
AD-Tunnel	Falmouth	on line	329
K-Tunnel	Falmouth	on line	323
AK-Tunnel	Falmouth	on line	337
B-Tunnel	Level Logger	on line	365
D-Tunnel	Level Logger	on line	322
K-Tunnel	Level Logger	on line	345

The most significant issues stemmed from equipment malfunctions at the Vent, K-Tunnel, and AK-Tunnel Stations. The Vent meter had gone off line in 2006 due to a collapse of the pole holding it and the Northwest Florida Water Management District's S-4 meter in place at the cave entrance. The WKPP divers replaced the meter in December 2007 with a new one that was positioned on a 3-ft stand on the floor near the north side of the cave. Due to a cable problem that occurred coincidently with the collapse of the pole, the new meter was set up to run on an internal battery. The meter ran continuously until April 2008 when the battery died. It was removed and downloaded but has not been successfully re-deployed.

The K-Tunnel and AK-Tunnel meters were both presenting erratic problems with communications, which hampered the March/April efforts to bring the telemetry system on line. Additionally, both displayed consistently declining temperature signals that were difficult to explain. Eventually, it was determined that the temperature probes on those meters was most likely malfunctioning. Chicken and Loper were able to statistically process the signals to remove the downward drift (See discussion of Task-1) but it was decided to replace the meters. The WKPP divers replaced both meters in May 2008. An abrupt change in temperature is recorded in the data from both those meters when they were exchanged (Figure 4).

Upon advancing into the FY2009 agenda, additional water level meters have been scheduled for deployment and survey at seven new locations throughout the WKP: Wakulla Springs boat dock, St. Marks River Rise, Sullivan Sink, Tobacco Sink, Revel Sink, Turner Sink, and Mc Brides #4. Additionally, problems were encountered with the water level meter placement at the K-Tunnel well that have been corrected via redeployment. At present, the most significant limitation is the lack of survey data placement data for the three water level meters that have been operating since 2007.

Recommendations

- Obtain survey and placement data for the B-Tunnel, D-Tunnel and K-Tunnel water level meters and submit that data to Kevin Day for inclusion in the database and date querry routines in the Data Portal.
- Move the K-Tunnel Falmouth Meter south into the main A-tunnel passage such that it records water conditions indicative of both K and AK Tunnels.
- Remove the AD-Tunnel and AK-Tunnel Falmouth meters.

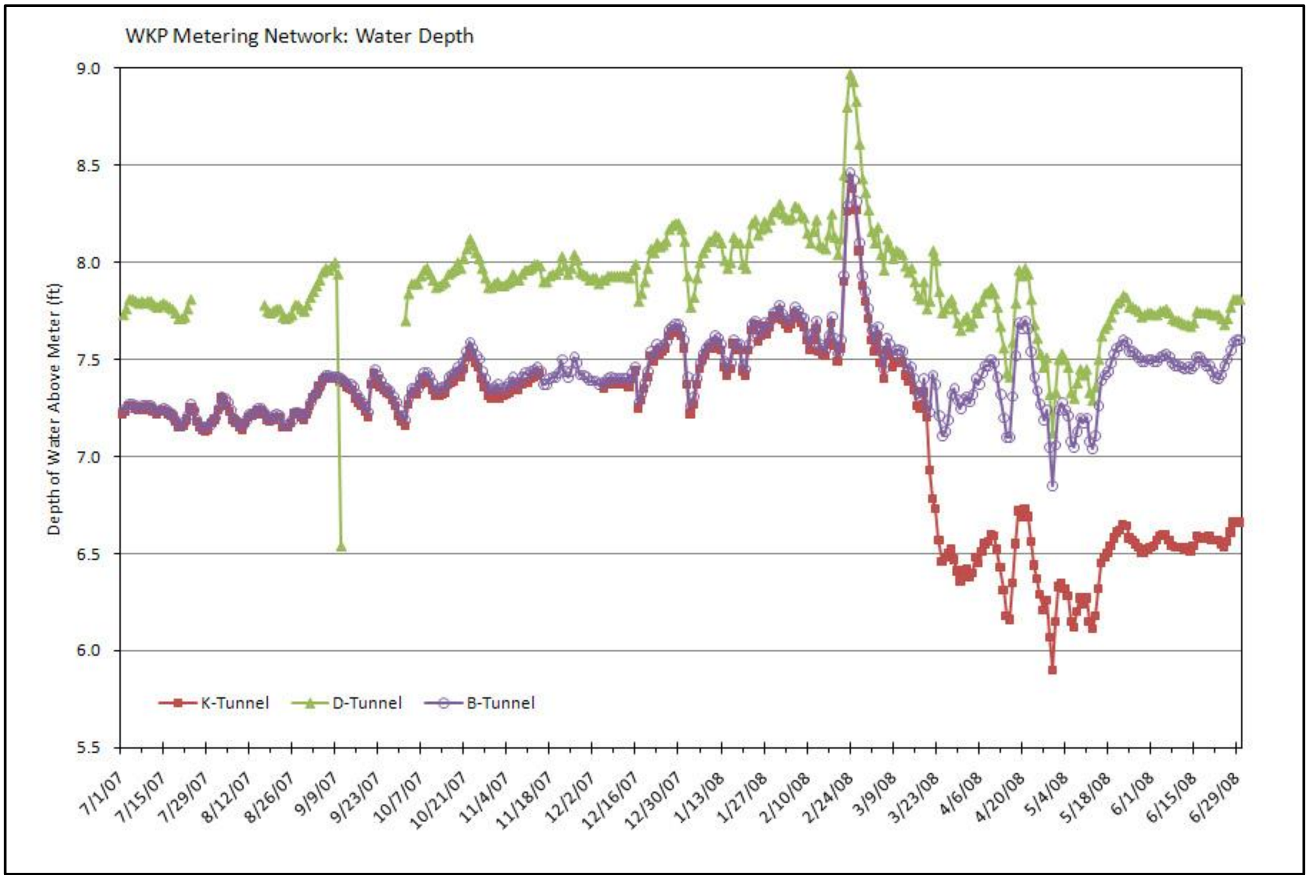


Figure 2. Depth of water column above the water level meter at the B-, D-, and K-Tunnel stations. Only the relative change at each station has relevance. In order to calculate water table elevations, the depth of placement below the top of casing and the top of casing elevations must be determined.

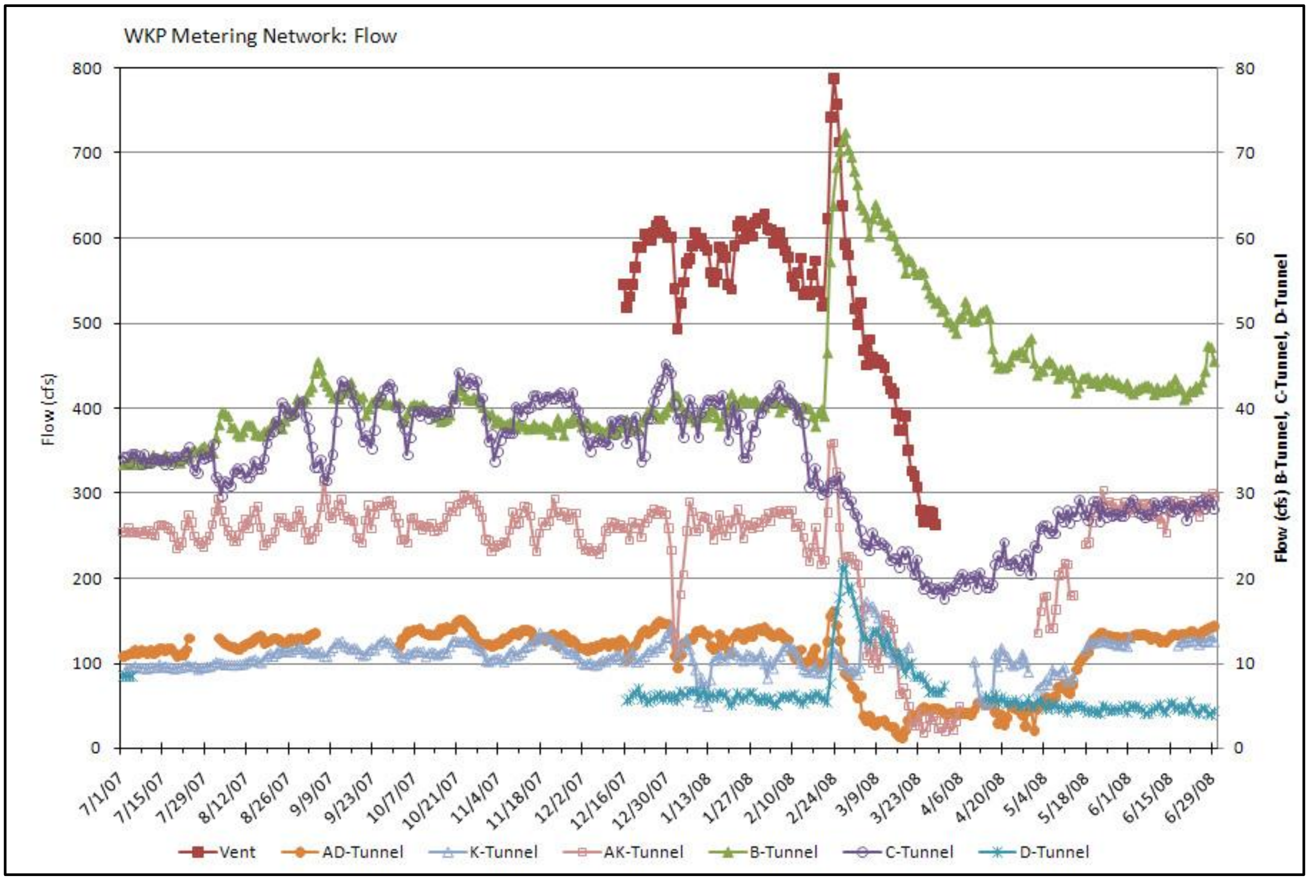


Figure 3. Water flow at each of the seven Wakulla Cave measuring stations recorded during the contract period. Gaps indicate periods when the meters were off line. Note that B-, C-, and D-Tunnel are plotted on the secondary y-axis.

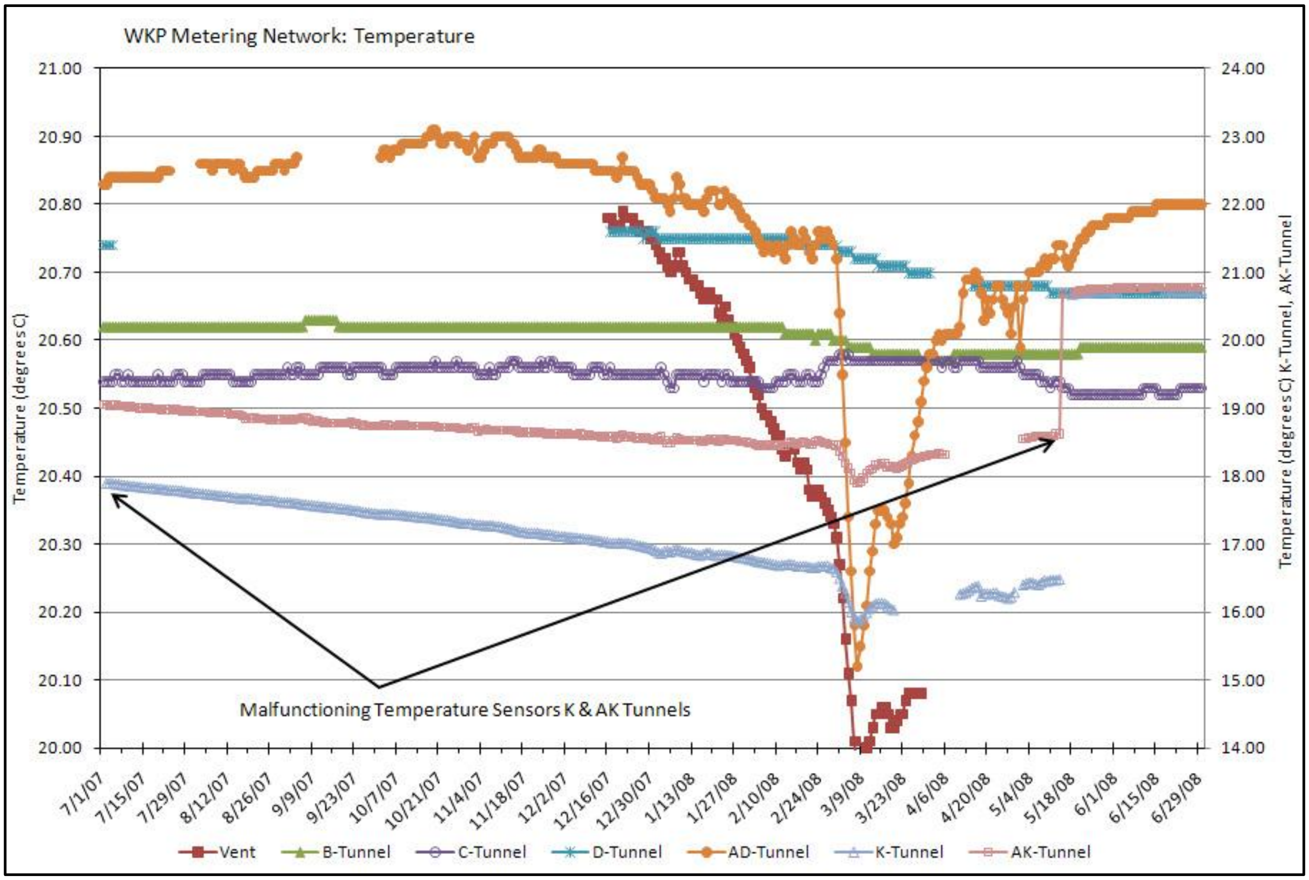


Figure 4. Water temperature at each of the seven Wakulla Cave measuring stations recorded during the contract period. Gaps indicate periods when the meters were off line. Note that the K- and AK-Tunnel data are plotted on the secondary y-axis due to the declining trend in temperature that marked the period between early 2007 and May 2008 when they were replaced.

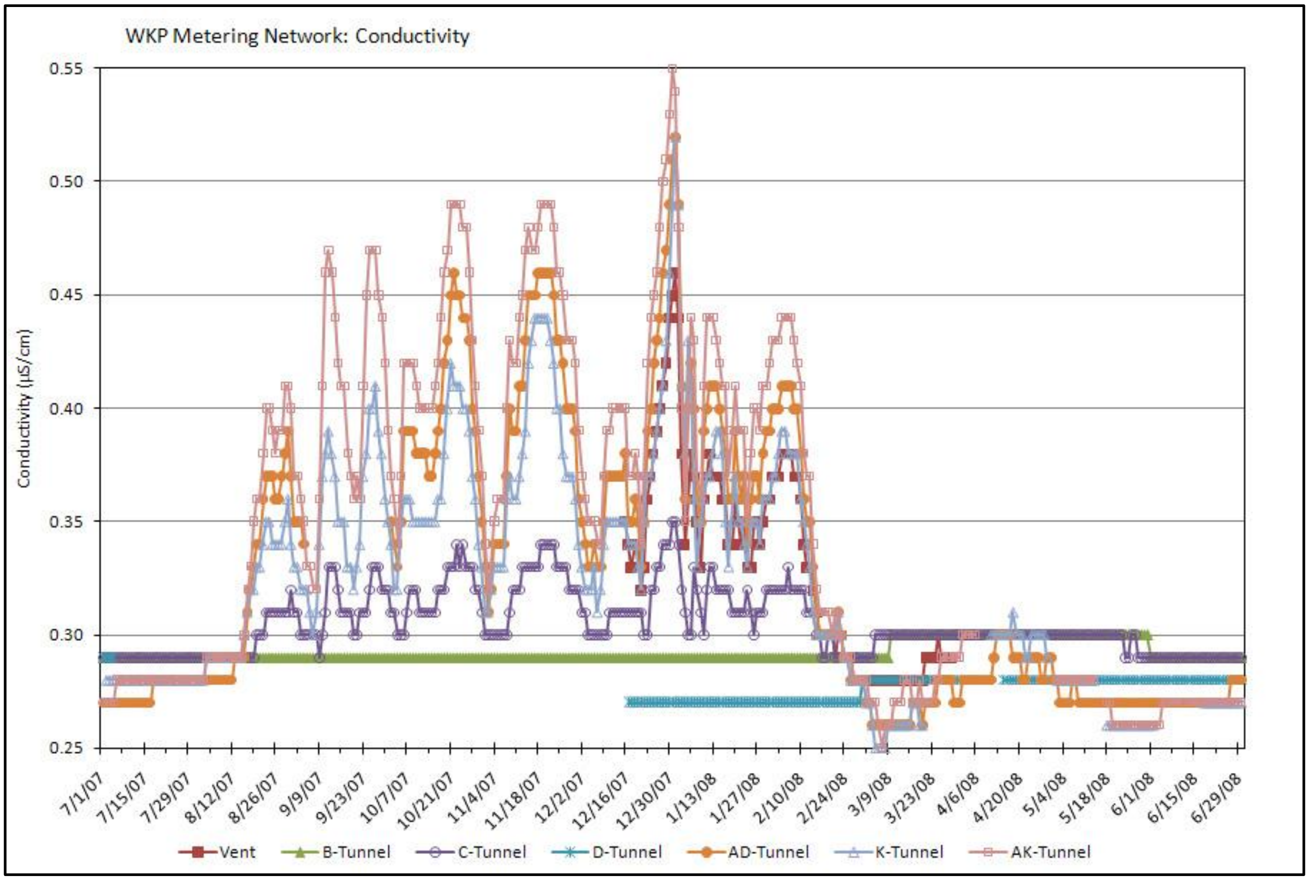


Figure 5. Conductivity at each of the seven Wakulla Cave measuring stations recorded during the contract period. Gaps indicate periods when the meters were off line.

TASK-4: DATABASE AND DATA PORTAL DEVELOPMENT AND MAINTENANCE

The work for Task-4 was performed by H2H and is a continuation of an effort that began in 2005 to develop a database to manage collected data from the WKP instrumentation network and a web-based Data Portal through which the project data and other relevant data for the WKP can be accessed and viewed by any interested party. The purpose of the data management component of the monitoring effort continues to be the provision of reliable and redundant storage of the data in a scalable platform and the ability of the stakeholders and the public to access the data on demand. This is an on-going effort wherein each year the database is revised to accommodate data from new devices and stations and the Data Portal functionality is advanced to better serve the project and outside users. The activities reported on in this section were initiated under the FY2008 (GW272) contract and completed under the FY2009 (GW275) contract.

The original database and web based interface was developed by H2H (HKI) in 2005, and was built on a PHP – MYSQL platform using open source tools such as Gnuplot to render graphs on-the-fly. Each time data was collected in the field, it was compiled and submitted to a set of server-scripts to ensure quality control and filter problem data points, and appended to the database tables. The structure of the management system and interface was designed to facilitate addition of new meters and to be readily adaptable to new data types.

CURRENT PROJECT STATUS

The main objectives for this period were to upgrade the database and web interface to accommodate the water level meters and to upgrade the plotting tools and Data Portal interface to accommodate the new data and advancements made in the web server software. A number of issues pertaining to the design and functionality of the original system have been addressed. Although the overall theme of the layout and general database structure are consistent with the original design, H2H has focused on streamlining the QC routines, upgrading the web interface to be compliant with the most recent code standards, increasing the performance and functionality of the graphing utility, and modifying the database to contain multiple types of data (depth logger data has been added) and station information.

The most obvious feature of the new web interface (Figure 6) is that an Adobe Flash graphing utility has been designed to render query results. The interface renders the query results more quickly than the original Gnuplot-based system, has sharper resolution, and features an optional cursor that enables the viewer to mouse-over the plot and dynamically view the reported values at any point within the query range (Figure 7). The Cursor Trace becomes available when the Cursor button is toggled. Additionally, an export feature can be executed by toggling the Export button which gives the user an option to save a snapshot of the flash query results to their local hard drive. The multiple parameters interface previously offered pre-configured comparisons of two parameters at a single meter. This has been upgraded to offer the user a choice of multiple parameters and multiple meters (Figure 8).

The updates and upgrades to the interface required that the database server be upgraded to the current versions of PHP, MySQL and Apache. All software used in the data management system and interface is open source with the exception of the addition of the Flash component.

The current status of the Data Portal and Metering Data Website can be viewed at: http://www.h2hmodeling.com/FGS/Meters/index.htm.

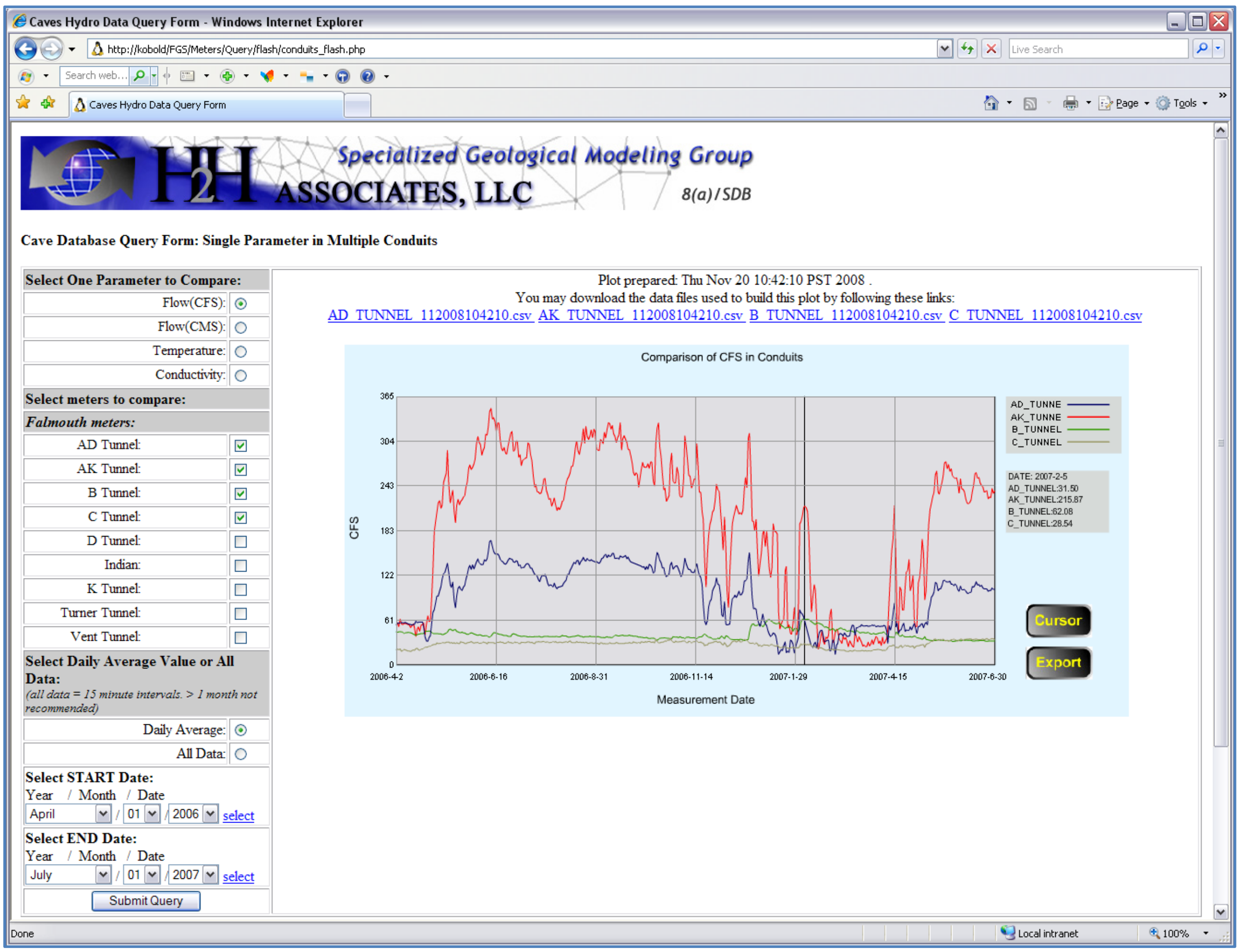


Figure 6. New Data Portal interface providing queries for a single parameter in multiple stations for the Falmouth data.

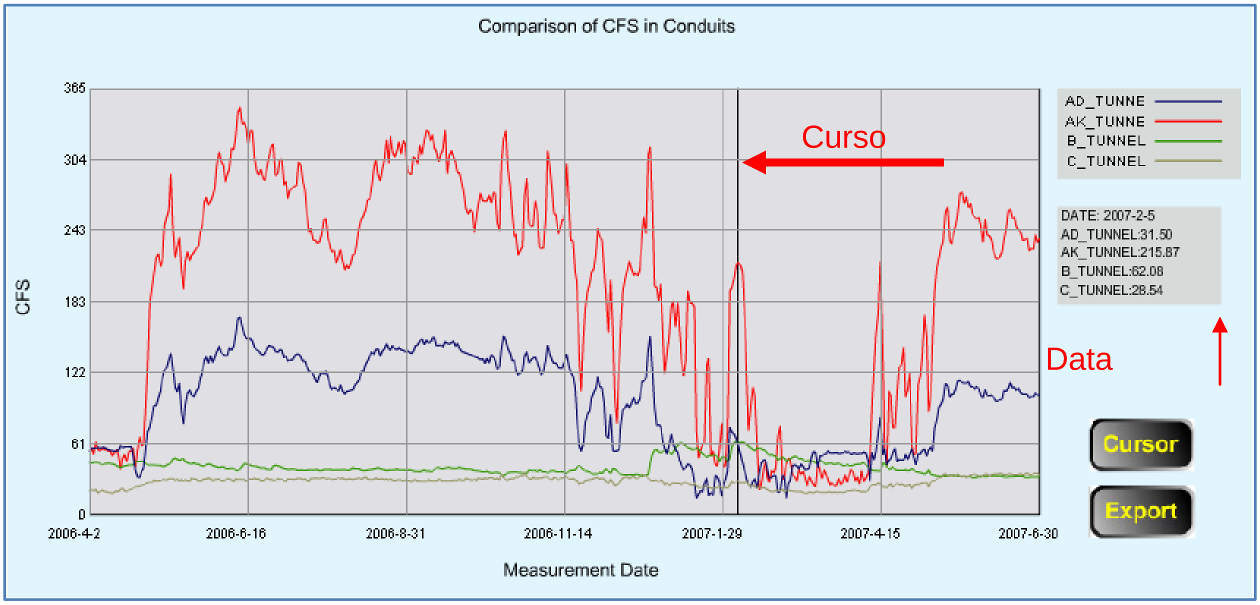


Figure7. Updated graphing interface included in the Data Portal with Flash component dynamic cursor.

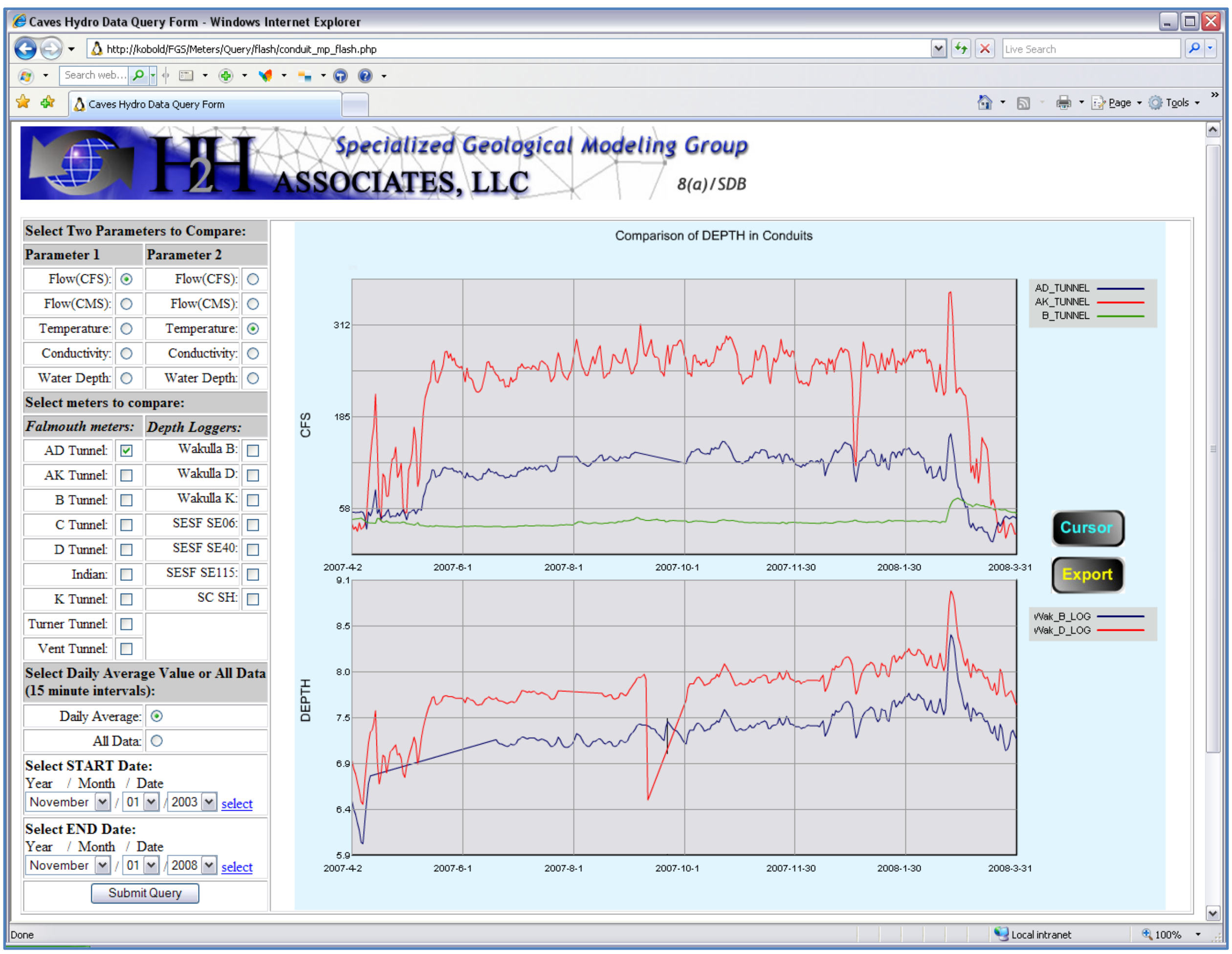


Figure8. New Data Portal interface providing queries for multiple parameters at multiple stations for the Falmouth and water level meter data.

Summary of Upgrades

The following features have been added and changed during the 2008 and 2009 contract periods:

- Replace Gnuplot / Imagemagick plot rendering engine with Flash / XML graphing application
- Redesign query menu to provide query persistence (selections no longer reset when plot is rendered)
- New graphing functionality of multiple meters *and* multiple parameters in a stacked plot
- Update PHP 4.3.11 to PHP 5.2.6
- Update Apache 2.0 to 2.2.28
- Update MySQL 4.1.11 to MySQL 5.0.5
- Upgrade server operating system from Redhat Linux 9 to Suse 11.0
- Redesign database to accommodate Depth Loggers data and Station metadata

Recommendations

- Meta Data establishing the source and Q/C records for all data streams should be included in the Data Portal interface.
- A maps feature should be added so that users can see the location of all the meter stations.
- The data download feature should be revised such that all data streams are consolidated into one file with a single consistent date field and such that the original velocity data is included with all flow exports.
- The Data Portal interface should be revised to reflect the current status and objectives of the project, to include all the project description material currently available via the root project website, and to reflect the future goals of establishing a Wakulla Springs Observatory. This should become the new home page for the project.
- Develop an interface to allow authorized users to upload data directly to the database.
- The Data Portal should be ported to the Hydrogeology Consortium website.

TASK-5: SPRING CREEK GROUNDWATER TRACER TESTING

Initial objectives for Task-5 included the installation of five (5) insitu fluorometers in selected Spring Creek spring vents; performance of a repeated dye injection at Turner Sink under higher water level conditions than those encountered in the 2007 test; and performance of a dye injection at Lost Creek when Lost Creek is flowing. Low water level conditions persisted throughout much of the contract period. Those and consideration of potential flow to both Spring Creek and Wakulla Spring from Lost Creek led us to focus our objectives for this period on the design and performance of one tracer test with a single injection at Lost Creek and an evaluation of ways to reduce turbidity masking of fluorescence signals recorded by the insitu filter fluoreters (IFF). The tracer test design was performed by Kincaid and Davies, sampling was conducted by Dyer, sample analysis was performed by Davies, and data analysis and reporting was performed by Kincaid.

The tracer injection was performed on May 29, 2008 between 9:49 AM and 12:30 PM Immediately following a rainstorm that established flowing water in Lost Creek that had been dry for a prolonged period prior to the injection. Approximately 33 lbs (3 5-gallon pales) of uranine dye were pumped into the Lost Creek swallet, which was receiving flow from Lost Creek, via tubing set at ~50 feet below the water surface. The tracer was pumped from three pails until all three were emptied. The pails were then filled with water from the basin and the rinse water was also pumped into the swallet.

Prior to the injection, sampling stations were set up at Spring Creek vents #1, #2, and #10, Revel Sink, Wakulla K-Tunnel, and the Wakulla Spring vent. Grab sampling was planned for Spring Creek vents #8 and #11 and shepherd Spring. Immediately prior to the injection, a problem manifested at the Spring Creek sampling station servicing vents #8, #10, and #11. It was learned that the low marsh island on which the sampling platform was established is private property and the property owner dismantled our station and refused access. The storm resulting in flowing water in Lost Creek occurred immediately after we learned about the problem. As water levels associated with the storm were subsiding, Kincaid made the decision to inject the tracer due to concerns that the window created by the storm might have been the only opportunity in FY2008 to inject.

Immediately after the injection, the Dyer and the FGS project manager, Rodney DeHan, were able to negotiate access with the property owner and Dyer was able to re-establish the sampling station on the marsh island. The station came on-line on June 3 and the first water sample was collected from Spring Creek vent #10 at midnight June 4, 2008. All other stations came on line prior to the injection.

The initial sampling plan called for the deployment of IFFs and automatic water samplers at each of the six sampling stations. Evaluation of tracer recoveries was to be based primarily on the IFF signals with water sampling used only to confirm interpretations of positive detections from the fluorescence curves. Problems encountered with the fluorometers, including systemic malfunctions, malfunctions associated with exposure to salt water, potential erroneous signals related to high turbidity signals indicative of Spring Creek waters, and logistical problems with deployments at Spring Creek, however prevented us from being able to confidently depend on the IFFs as the primary tool for tracer detection. Consequently, significantly more water samples were collected and used as the primary basis for determining tracer detections and plotting breakthrough curves. To accommodate this, part of the Davies' time originally dedicated to Task-2 was redirected to tracer test sample analysis.

The tracer was detected in the first sample collected from Spring Creek vent #10 and subsequent 59 samples spanning approximately 20 days marked the tailing edge of a breakthrough curve for which we apparently missed the peak. The last detection at #10 was recorded on June 23 at 8:00 AM. Sporadic weak tracer detections were obtained at Spring Creek vent #2 during that period but the tracer was not detected at vents #1, or #11. Figure 9 shows the distribution of detections at the Spring Creek spring vents. Figure 10 shows the breakthrough curve obtained at vent #2 relative to green fluorescence measured by the IFFs at vent #2.

Two IFFs were deployed at Spring Creek vent #2. One was covered with a filter sock intended to remove or mitigate the potential masking effect of turbidity on the fluorescence signals. It appears from a comparison of the fluorescence data that the sock successfully filtered a significant amount of turbidity, that turbidity has a significant effect on fluorescence, and that the filtered fluorescence is a better record of fluorescence changes. Figures 11 shows the fluorescence and turbidity curves measured by the filtered and unfiltered IFFs at Spring Creek vent #2. Figures 12-16 show the regression of filtered vs non-filtered response for each the IFF measured parameters.

The tracer was subsequently detected in water samples collected from Revel Sink and by the IFF deployed at that station beginning at about 28 days after the injection and peaking at about 41 days after the injection. The tailing edge of a well-formed breakthrough curve finished at about 48 days after the injection. The tracer continued to be detected at that station at erratic concentrations in water samples through to about 77 days after the injection when water sampling was stopped due to budget constraints. A potential second peak was recorded by the insitu fluorometer that came through between 80 and 90 days after the injection at which time it was taken off line due to budget constraints. Figure 17 shows the green and green-blue fluorescence curves relative to the uranine concentrations measured from the water samples for the Wakulla K-Tunnel and the Wakulla Vent stations respectively.

The tracer was also detected at Wakulla K-Tunnel and the Wakulla Spring vent. A breakthrough curve at K-Tunnel determined by water sample concentrations began at about 44 days after the injection. It contained two apparent peaks at increasing concentrations at 56 and 71 days after the injection. A corresponding curve was recorded by the IFF in terms of both green and green-blue fluorescence. Those curves showed two small bumps on a generally rising trend in fluorescence corresponding to the two water sample peaks and a subsequent significantly larger peak in fluorescence levels that occurred at about 93 days after the injection and roughly 22 days after water sampling at the K-Tunnel station stopped. Figure 18 contains two plots showing the green and green-blue fluorescence curves relative to the uranine concentrations measured from the water samples for the Wakulla K-Tunnel. The green-blue fluorescence curve shows two small rises and a decline that correspond to the uranine detections from the water samples and a later significantly larger rise that likely marks a second higher concentration plume of uranine passing the K-Tunnel station. Figure 19 shows the uranine recovery curve obtained from the water samples collected at the Wakulla Spring vent. No IFF was deployed at the Wakulla Spring vent. Figure 20 provides a map showing the location of tracer detections and the resulting tracer-defined groundwater flow paths.

Hypotheses

The southern conduits in the Wakulla-Leon Sinks Cave System extend south to the Spring Creek spring vents. When Lost Creek was flowing, water traveled rapidly via conduits to Spring Creek vent #10 but not the others due to a wedge of higher salinity water flowing into the deeper conduits that connect to vents #2 and

#1. When Lost Creek stopped flowing, USGS water level gauge at spring Creek indicated that stage rose. The rising stage caused reversed flow conditions at all of the Spring Creek vents (salt water flowing into caves). The tracer that was in the conduit system but that had not made it to Spring Creek stalled in the conduits and as stage continued to drop, the hydraulic gradient reversed and the tracer flowed to Wakulla Cave past Revel Sink.

Recommendations

- The Lost Creek trace should be repeated under similar hydraulic conditions wherein sampling at all of the Spring Creek vents should be initiated at least one week prior to the tracer injection to confidently establish a baseline from which tracer breakthrough curves can be evaluated.
- IFFs should be deployed at Spring Creek vents #2, #3, and #10.
- Flow, stage and/or conductivity should be measured at the vents in tandem with fluorescence such that the fluorescence curves obtained from those stations can be related to hydraulic conditions.
- Stage recorders should be deployed and operated at Revel Sink and Wakulla K-Tunnel during the trace such that fluorescence measured at those stations can also be related to hydraulic conditions.

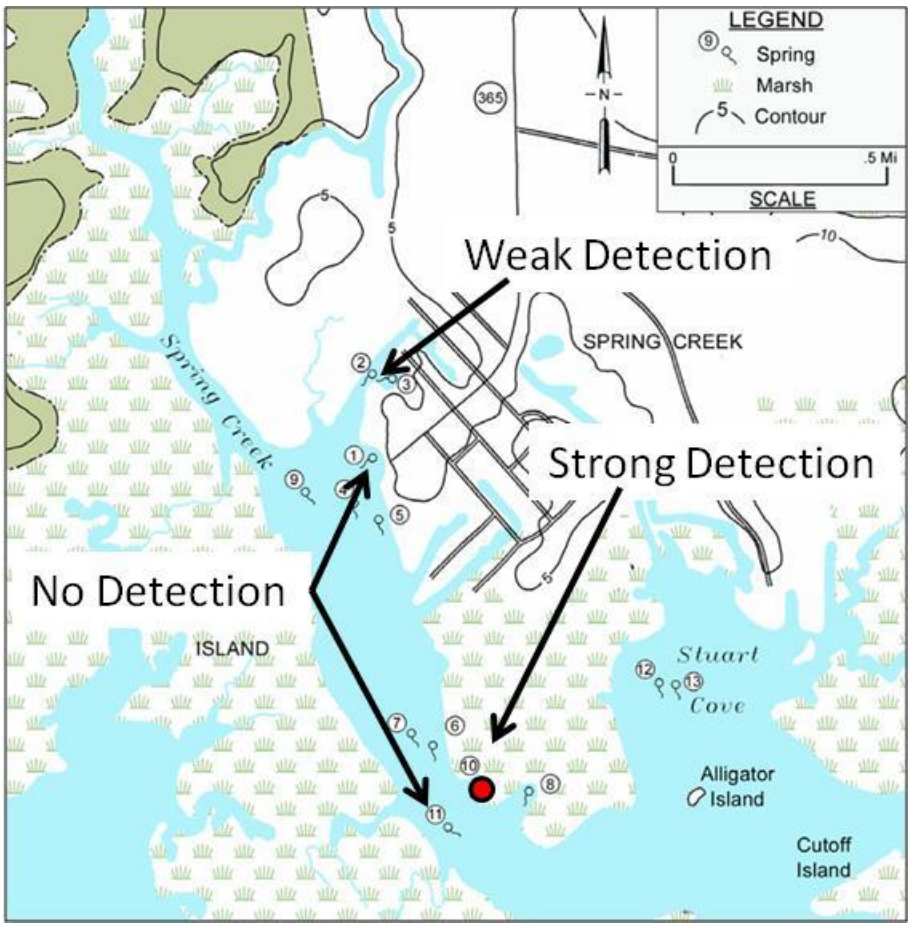


Figure 9. Location of the major Spring Creek spring vents and the distribution of tracer detections obtained from the 2008 Lost Creek groundwater tracer test. Basemap is from Lane (????).

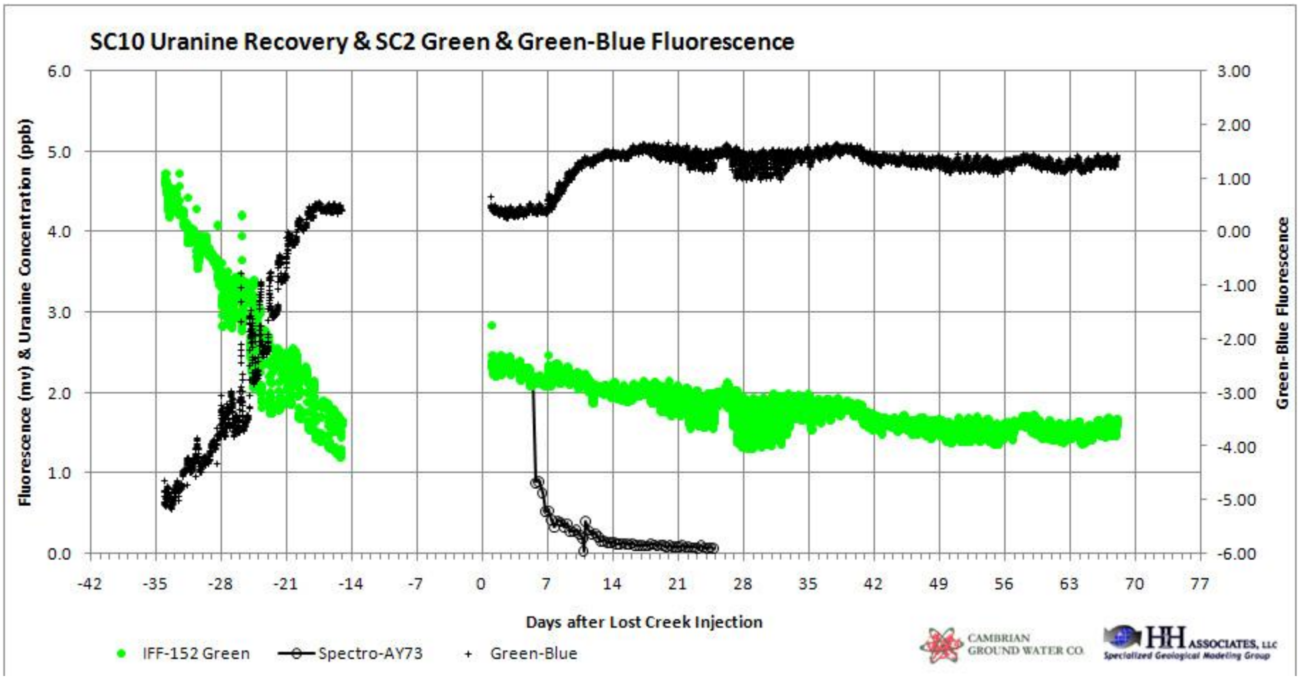
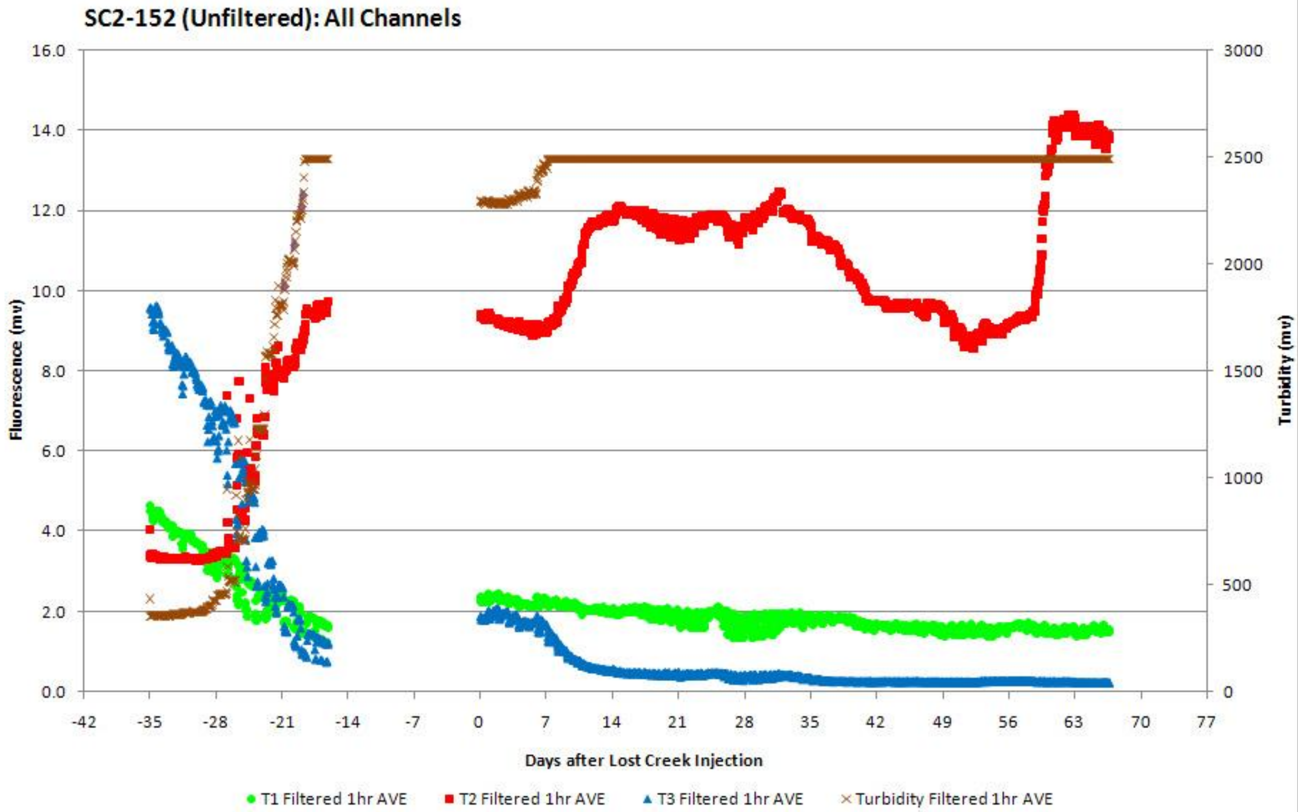


Figure 10. Tailing edge of a uranine breakthrough curve measured at Spring Creek vent #10 relative to green and green-blue fluorescence measured by the filtered (IFF-192) IFF during the 2008 Lost Creek tracer test. The early time data from the IFF records background fluorescence that was measured as part of a QA/QC test of the IFFs prior to initiating the tracer test. The inverse correlation between green and green-blue fluorescence during the early time period indicates that the initial high green fluorescence levels are from natural tannins rather than uranine. The later time fluorescence data indicates that the tracer did not travel to Spring Creek vent #2.



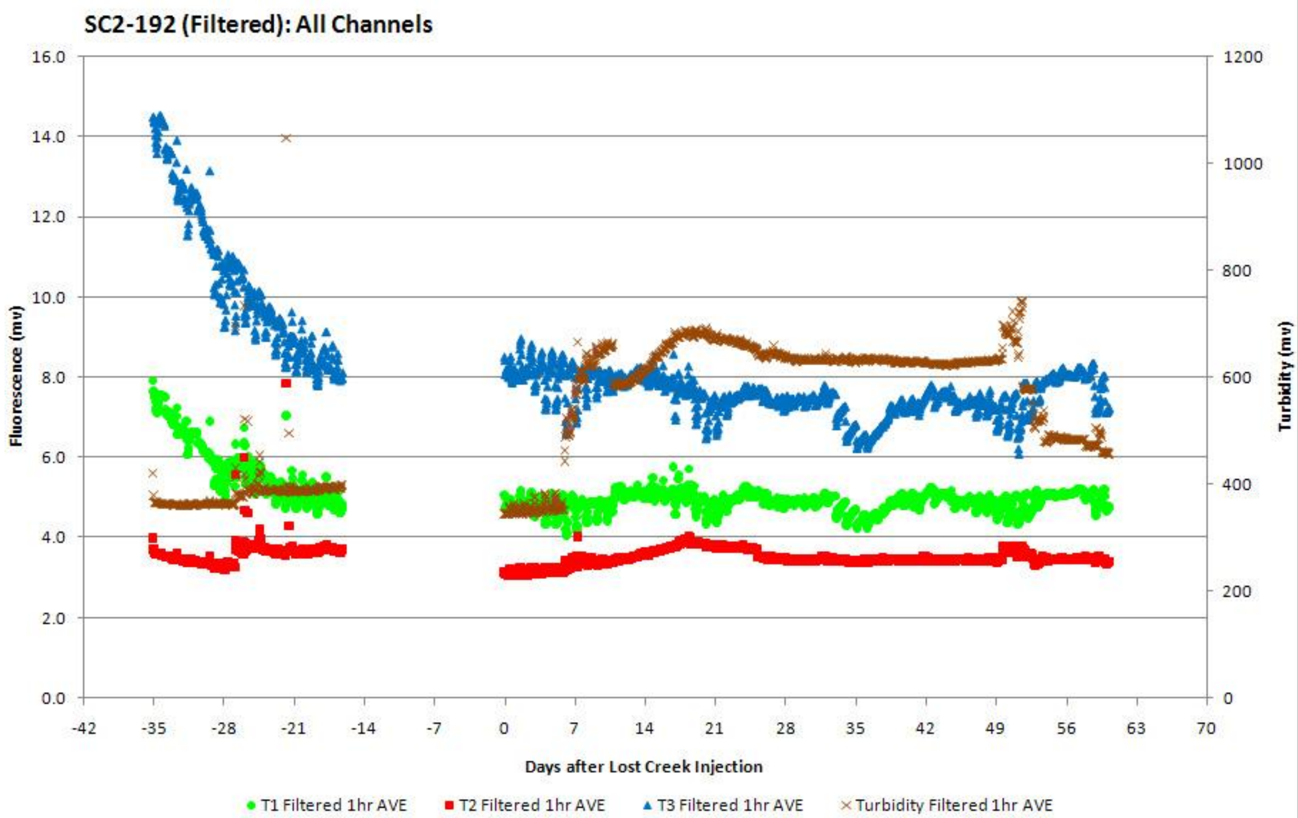


Figure 11. Fluorescence and turbidity curves recorded in the unfiltered and filtered fluorometers at Spring Creek vent #2 during the 2008 Lost Creek tracer test. The early time data from the IFFs record background fluorescence that was measured as part of a QA/QC test of the IFFs prior to initiating the tracer test.

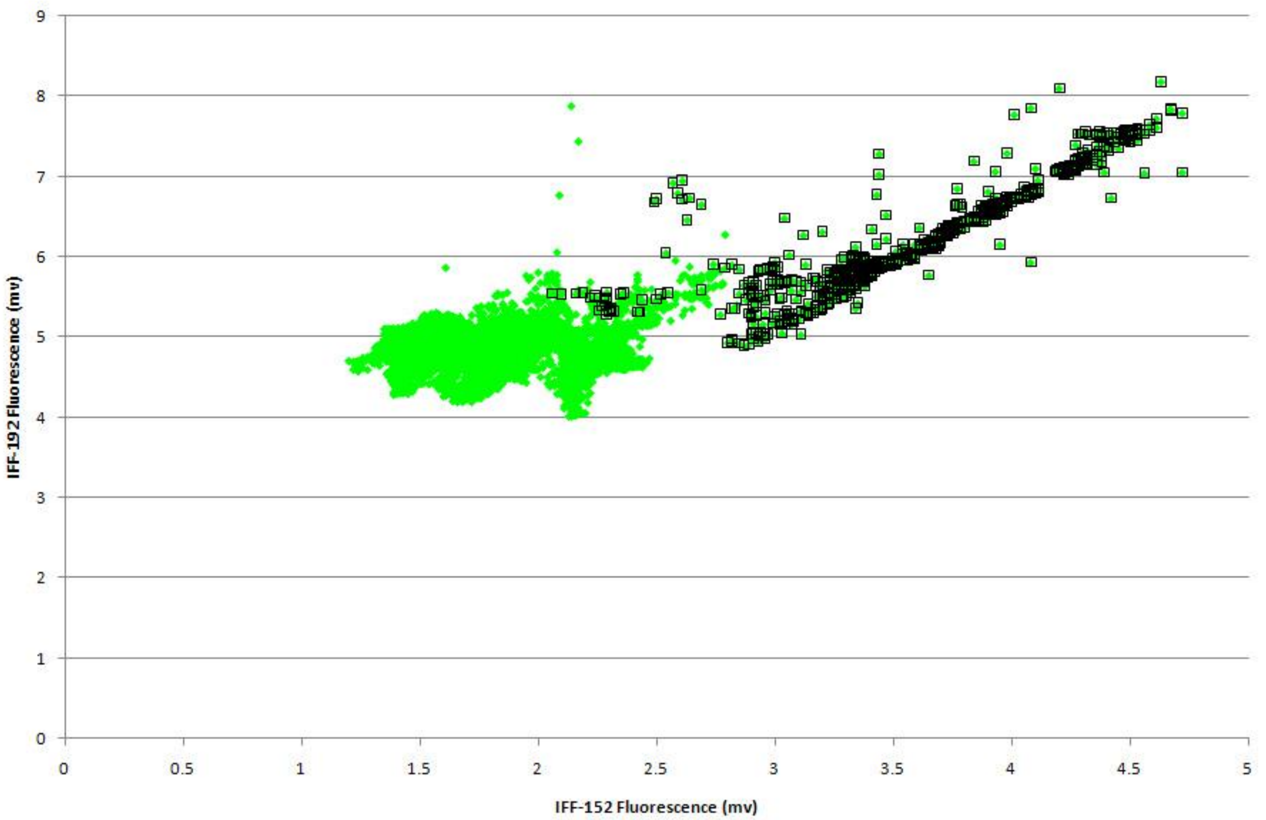


Figure 12. Regression of unfiltered (IFF-152) vs filtered (IFF-192) green fluorescence measurements recorded at Spring Creek vent #2 during the 2008 Lost Creek groundwater tracing test. The boxes mark the early time data, which record a declining trend in fluorescence at the start of sampling (see Figure 11). There is a strong correlation between the filtered and unfiltered values for the early-time data (higher fluorescence values), which breaks down in the later-time data (lower fluorescence levels). This indicates that the influence of turbidity on green fluorescence, which marks our uranine tracer, is only significant to green fluorescence measurements at low levels.

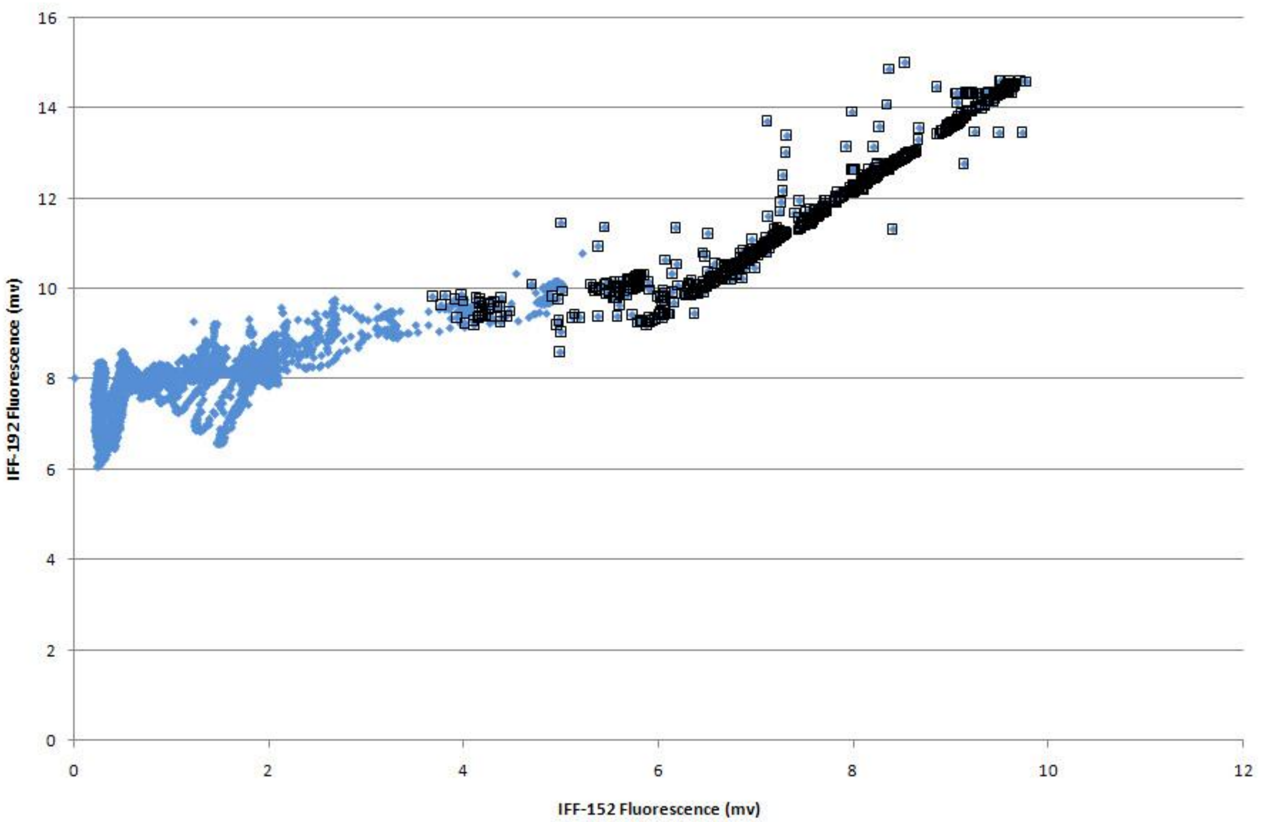


Figure 13. Regression of unfiltered (IFF-152) vs filtered (IFF-192) blue fluorescence measurements recorded at Spring Creek vent #2 during the 2008 Lost Creek groundwater tracing test. The boxes mark the early time data, which record a declining trend in fluorescence at the start of sampling (see Figure 11). There is a strong correlation between the filtered and unfiltered values for the early-time data (higher fluorescence values), which breaks down in the later-time data (lower fluorescence levels). This indicates that the influence of turbidity on blue fluorescence, typically derived from natural tannins, is only significant to blue fluorescence measurements at low levels.

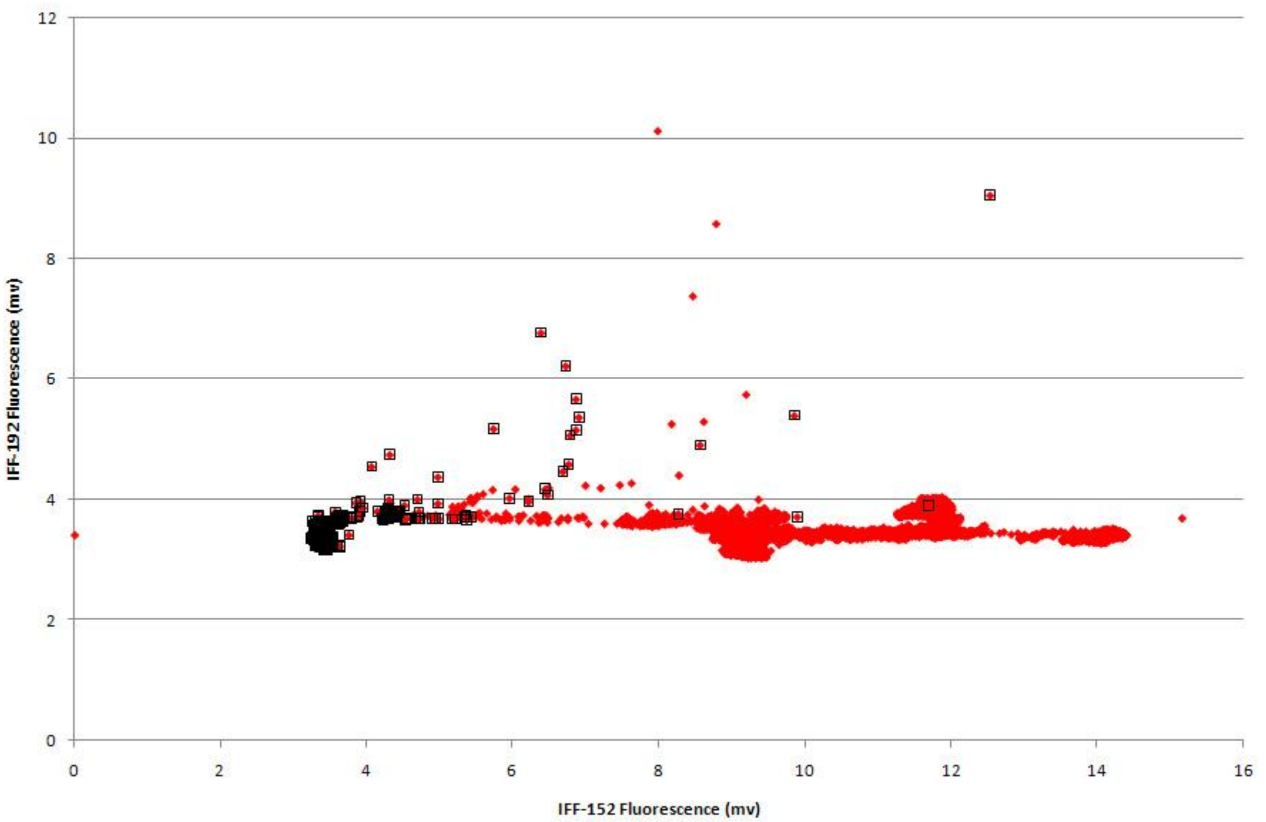


Figure 14. Regression of unfiltered (IFF-152) vs filtered (IFF-192) red fluorescence measurements recorded at Spring Creek vent #2 during the 2008 Lost Creek groundwater tracing test. The boxes mark the early time data noted for the green and blue fluorescence curves. In this case however, there was no initial decline from elevated levels in the red fluorescence curve (see Figure 11). There is no significant correlation between the filtered and unfiltered values for any period of the data record indicating that turbidity had a significant effect on red fluorescence levels throughout the duration of the sampling period. Since there was no recorded rise in red fluorescence however, it is impossible to determine from these data how higher red fluorescence levels, which would mark the passage of our phloxine-B tracer if injected, would be affected by turbidity.

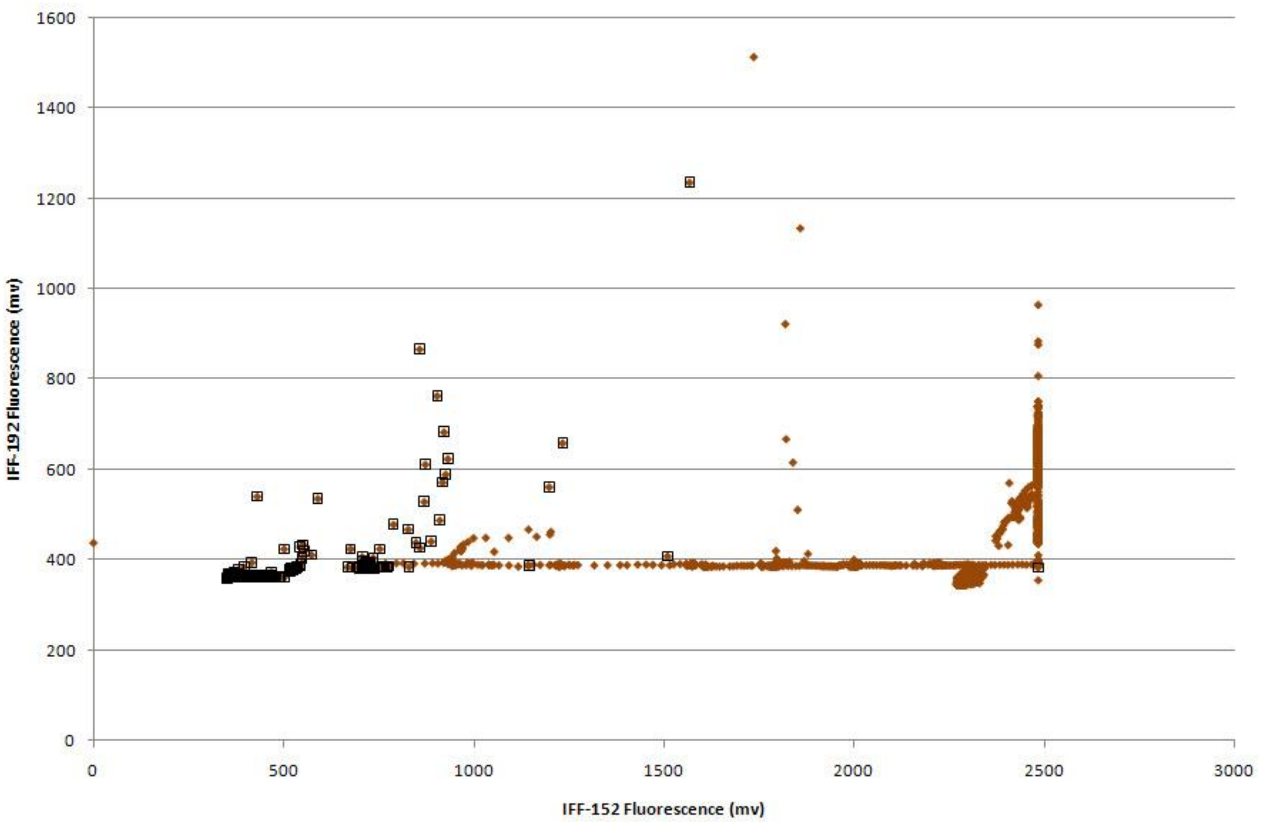


Figure 15. Regression of unfiltered (IFF-152) vs filtered (IFF-192) turbidity measurements recorded at Spring Creek vent #2 during the 2008 Lost Creek groundwater tracing test. The boxes mark the early time data noted for the green and blue fluorescence curves. There is no significant correlation between the filtered and unfiltered values for any period of the data record. From Figure 11, it can be seen that the unfiltered values rose to a plateau level (probably an instrument maxima) early in the sampling period but that the filtered values displayed some fluctuations. It is likely therefore that the filter reduced turbidity values sufficiently to be within the instrument measurement range and therefore the fluctuations in the filtered curve reflect natural variation.

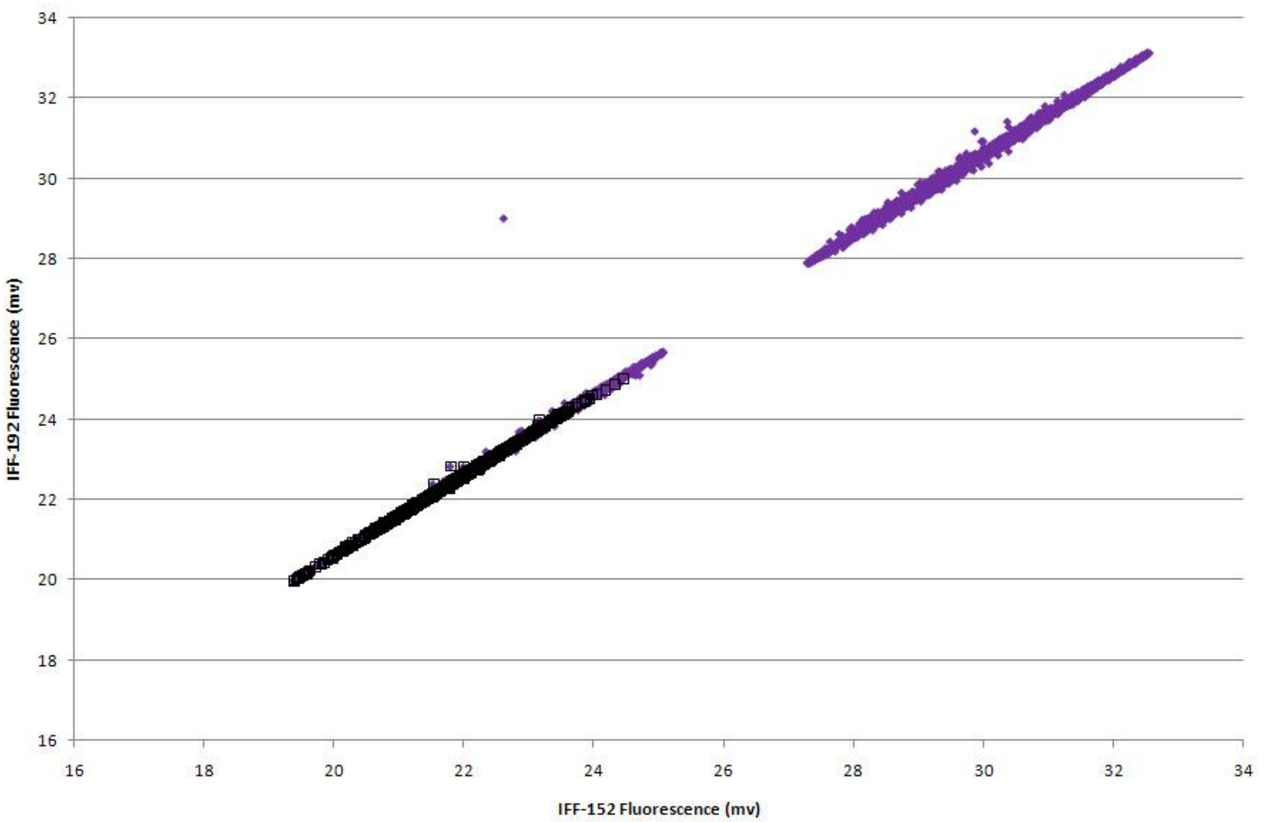


Figure 16. Regression of unfiltered (IFF-152) vs filtered (IFF-192) temperature measurements recorded at Spring Creek vent #2 during the 2008 Lost Creek groundwater tracing test. The boxes mark the early time data noted for the green and blue fluorescence curves. As expected, the filter exerted no apparent effect on the temperature measurements.

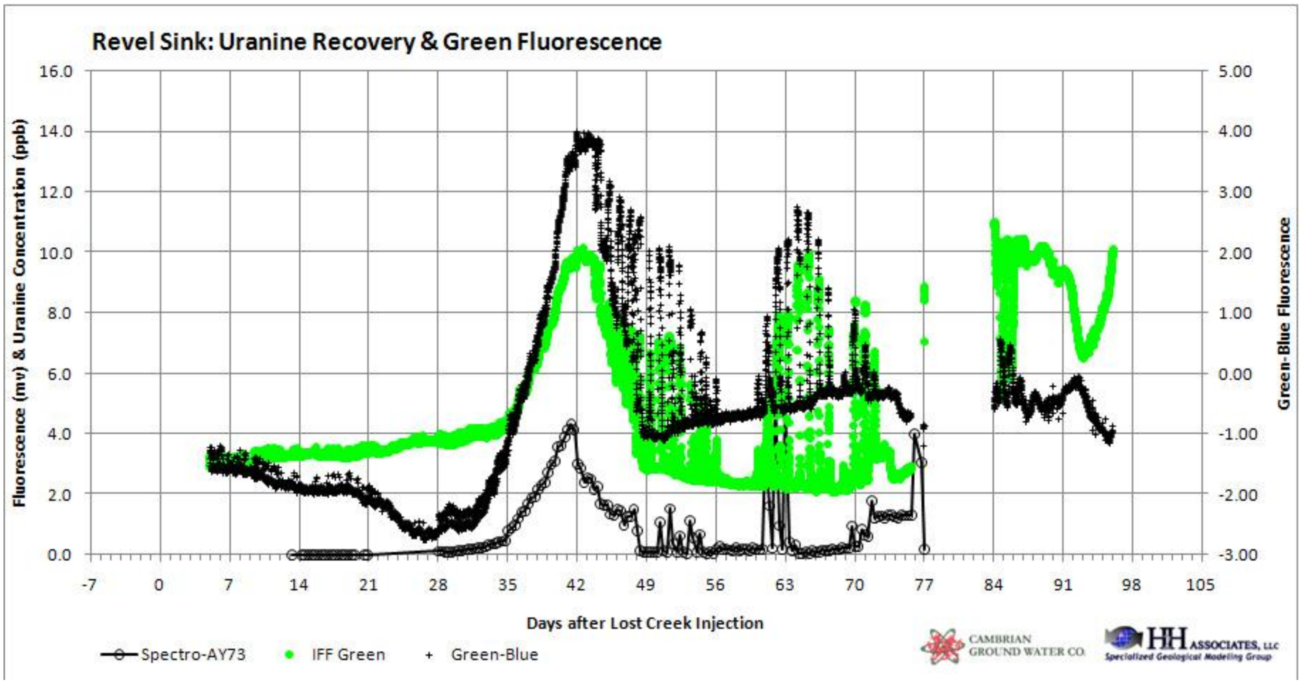


Figure 17. Green and Green-Blue fluorescence and uranine concentrations measured from water samples collected at Revel Sink marking a distinct uranine breakthrough curve that passed the sampling station between 28 and 47 days after the injection at Lost Creek. The curves indicate that some portion of the tracer plume was retained somewhere between the injection and sampling points and traveled to the sampling station in surges of lower concentrations after the main body of the tracer plume passed. The green fluorescence curve obtained from the IFF data, which was collected for a longer period than the water samples, indicates that a second larger concentration plume might have passed through Revel Sink at between 84 and 98 days after the injection.

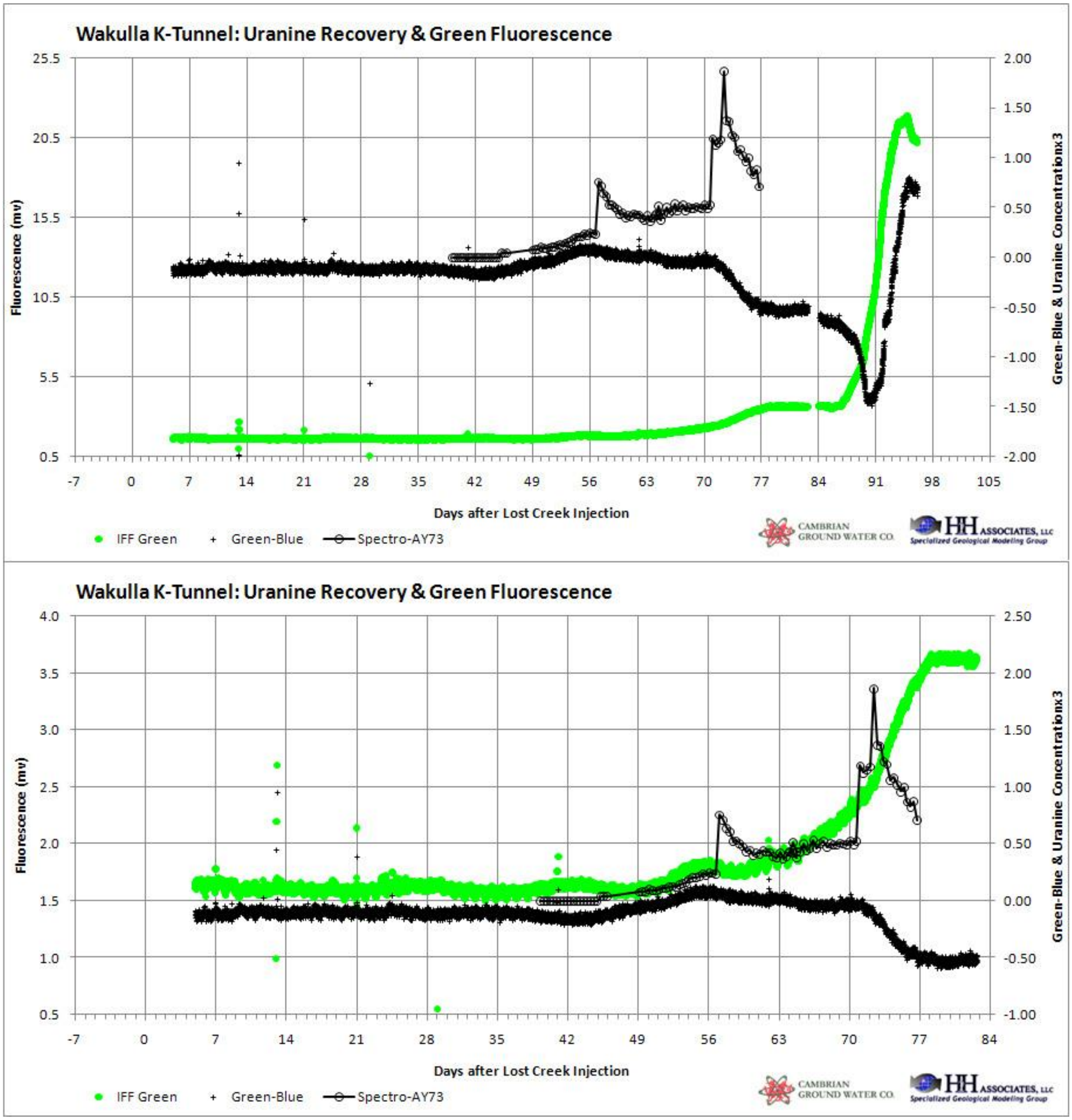


Figure 18. Plots of green and green-blue fluorescence and uranine concentrations measured from water samples collected at Wakulla K-Tunnel across the full range of the combined data (top) and a range limited to the duration of water sampling (bottom). The water sample data marks an uranine breakthrough curve with two small peaks that passed the sampling station between 44 and 77 days after the injection at Lost Creek. These peaks are reflected in the green-blue fluorescence and can be seen in the green fluorescence data when the range is lowered to show only the range corresponding to the water sampling period (bottom). Water sampling was stopped at K-Tunnel prior to recording the full tailing edge of the breakthrough curve due to budget constraints. A subsequent significant rise in green fluorescence that began at about 87 days after the injection (after water sampling was stopped) and supported by a similar distinct rise in green-blue fluorescence indicates that a second higher-concentration plume of uranine passed the K-Tunnel sampling station during that time period. One explanation for the multiple plumes is surges of northward flow from the Lost Creek and potentially Spring Creek regions responding to water table fluctuations that push parts of inject dye plume north to Wakulla Spring.

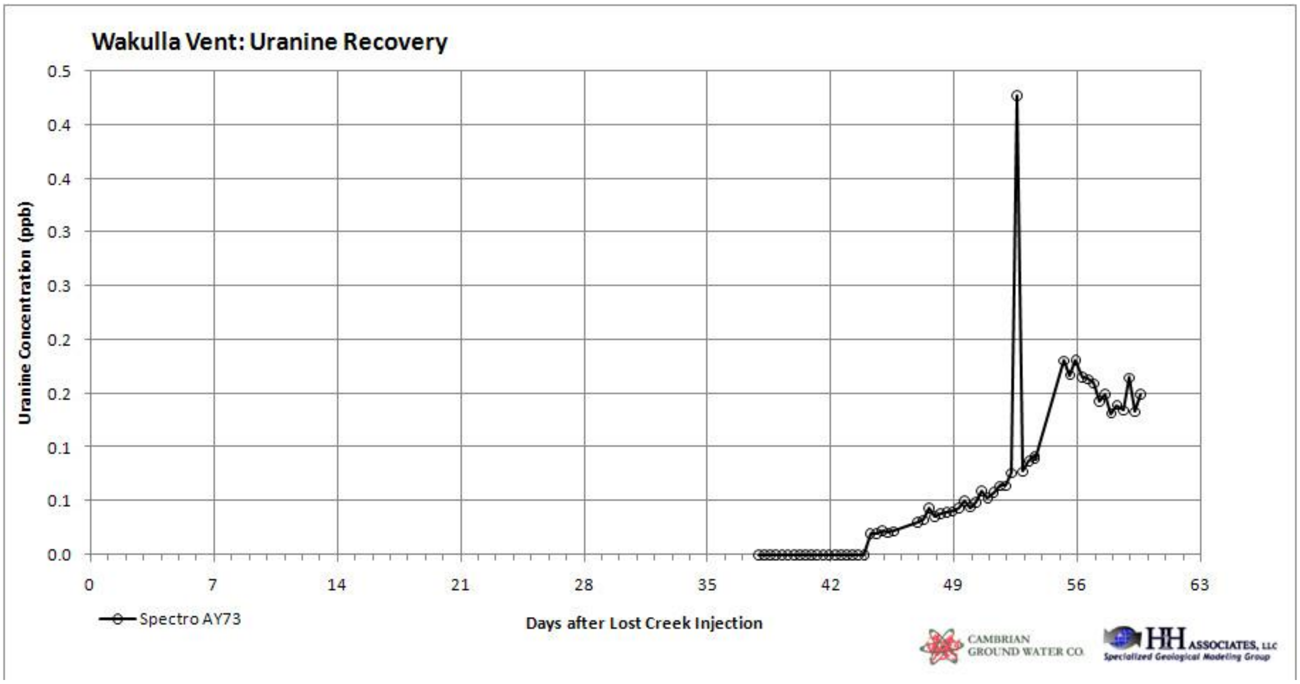


Figure 19. Plot of uranine concentrations measured from water samples collected at the Wakulla Vent showing a partial uranine breakthrough curve that passed the sampling station between 45 and 61 days after the injection at Lost Creek. Water sampling at the Wakulla Spring Vent was stopped at 61 days due to budget constraints.

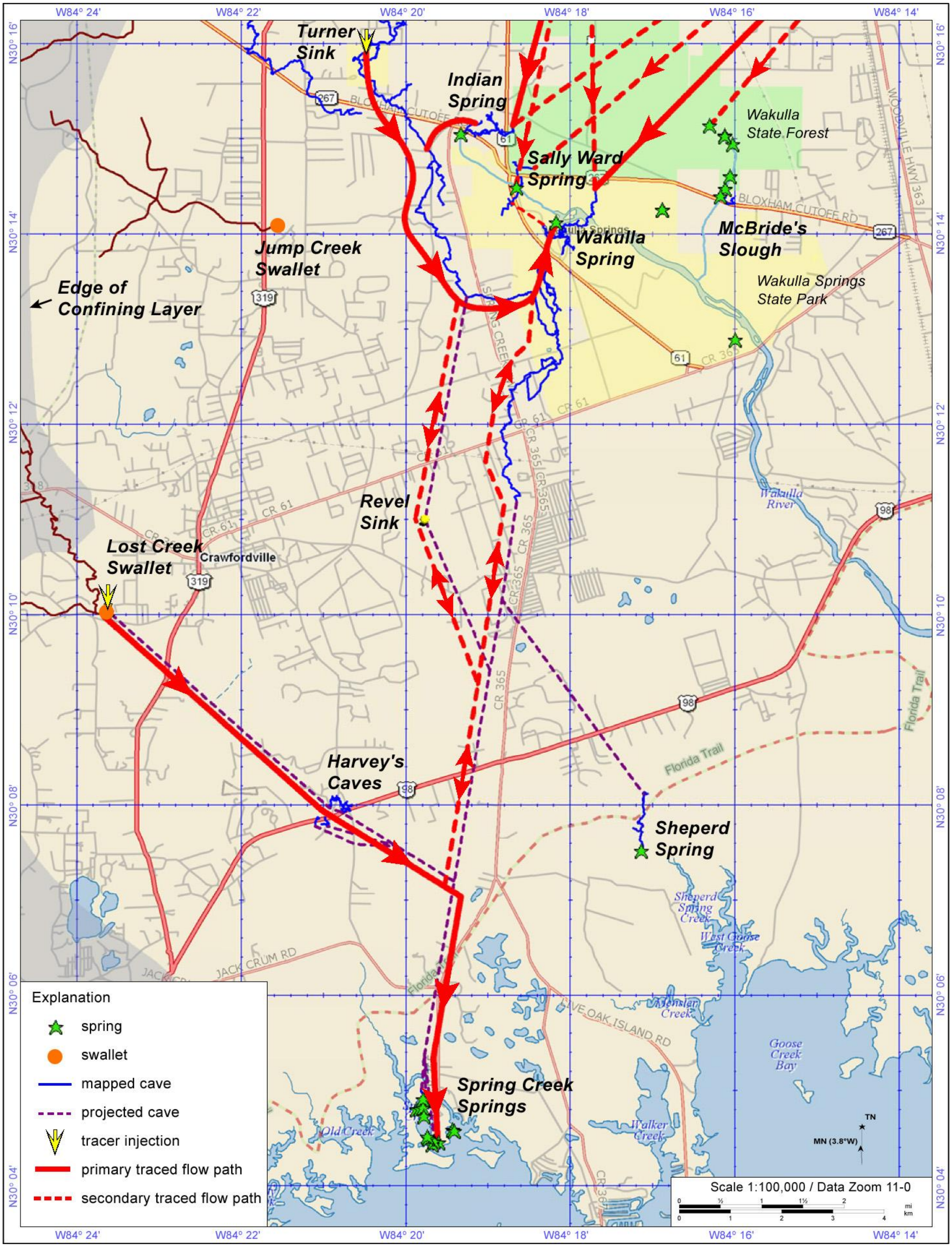


Figure 20. Map of the southwestern part of the WKP showing the tracer defined groundwater pathways as of the 2008 Lost Creek groundwater tracer test.

APPENDIX I: SCOPE OF WORK

ATTACHMENT A

SCOPE OF SERVICES

Characterization of the Woodville Karst Plain for the purpose of Numerical Modeling

Task-1: Continuation of Statistical Analysis

The purpose of this task is to develop statistical analyses of the hydrologic data being collected by the various meters managed by the FGS, and eventually, data available from other agencies as a means of estimating conduit sizes in regions where they are known to be present but cannot be directly measured.

The FGS meters, both those that are presently in operation (e.g., flow meters and tide gauges) and those that will soon become operational (water-level loggers), provide a plethora of data – far more than can be systematically analyzed given the current level of funding available. Consequently relatively few of the many interesting avenues of investigation, identified by visual inspection of graphs of the data, can be explored and analyzed in the coming year. While the level of data gathering and analysis will be dictated by funding and other priorities, it is safe to say that one statistical issue, which is currently under investigation, will continue to have priority in the coming year. This involves the comparative analysis of temporal variations in water level measured at the coast (i.e., tidal variations) and at various inland-locations. The goal of the comparative analysis is to quantify both the amplitude ratios and the phase speeds of the primary tidal components (diurnal and semi-diurnal) between the coast and various inland locations. This information, when coupled to a model of flow in conduits that was developed during the past fiscal year, will provide estimates of the sizes of the conduits connecting the coastal and in-land locations. Reliable estimates of conduit sizes are very important, particularly in regions which have not yet been explored by divers, as these conduits dominate regional flow and transport.

In addition, the existing records of discharge at Wakulla Springs will be analyzed in an attempt to identify and quantify *salt-water-plug* events. These are events (described in more detail in the proposed modeling task) during which the discharge at Wakulla Springs is elevated significantly for periods of weeks or months, unrelated to rainfall and recharge.

Task 1 Timeline

Task 1 shall be completed no later than 12 months from the date of Contract execution.

Task 1 Total Cost = $20,000.

Task 1 Deliverables

The deliverables for this task will include periodic reports of progress, summaries and highlights of any unusual events recorded by the meters, files of both raw and processed data and descriptions of statistical procedures employed to process the raw data. A digital or hard copy task summary report shall also be submitted.

Task-2: Field Program Management and Supervision

The Contractor shall provide a qualified person to provide part-time field program management and supervision. Responsibilities shall include:

- Organizing, coordinating, and participating in fieldwork aimed at installing telemetry systems and deploying and maintaining the WKP metering network.
- Developing a QA/QC program for the Falmouth meters and transducer data.

- Interfacing with manufactures as necessary to troubleshoot frequent instrument operation and maintenance problems.
- Interfacing with other Contractor personnel to facilitate data transmission and the development of the telemetry system data server and database.

<u>Task 2 Timeline</u>

Task 2 shall be completed no later than 12 months from the date of Contract execution.

<u>Task 2 Total Cost</u> = $50,500.

<u>Task 2 Deliverable</u>

The Contractor shall submit data from all competed field experiments in the form of a task summary report.

<u>Task-3: Telemetry System & Metering Network</u>

The purpose of this task is to complete the design, installation, and setup of the telemetry system for the seven (7) Falmouth meter stations currently operating at Wakulla Springs State Park, service and calibrate those and service and calibrate new meters recently purchased totaling twelve (12) meters. Deploy five (5) additional Falmouth Meters at Spring Creek, and regularly visit the field stations to check the performance of the units and download data as necessary. Specific subtasks may be revised as necessary, through written documentation between Contract Managers, through the course of the year, but the following shall be completed under this task:

- Complete construction of instrument boxes for all seven (7) Wakulla Falmouth meter stations.
- Determine actual pressure sensitivity on all deployed Falmouth meters (total of 12) compare sensitivity to transducer sensitivity; determine if available resolution is acceptable.
- If transducers are needed, debug the problem with dual signal transmission.
- Deploy telemetry systems at all seven (7) of the Wakulla meter stations.
- Setúp and install server at Wakulla State Park for data communications.
- Resolve a current problem with temperature signal from the control Falmouth meter.
- Cycle out meters from cave (schedule is dependent on Woodville Karst Program's (WKP) divers agenda and availability).
- Verify/Calibrate meters extracted from caves.
- Fix any problematic meters.
- Deploy all but one (1) (control unit) of the new meters (schedule is dependent on WKP agenda and availability).
- Develop program for regular meter calibration using the control meter kept at FGS.
- The Contractor shall serve as the liaison between the Department and the Woodville Karst Plain Program, who will perform the diving activities.

<u>Task 3 Timeline</u>

Task 3 shall be completed no later than 12 months from the date of Contract execution.

<u>Task 3 Total Cost</u> = $15,000.

<u>Task 3 Deliverable</u>

The Contractor shall provide an operating telemetry system that can convey data directly to the researchers' computers.

<u>Task-4: Database & Data Portal</u>

The purpose of this task is to continue the development of the WKP database and web interface tool (*Data Portal*). The database will be expanded such that it is fully capable of storing, archiving, and providing remote access to both the Falmouth meter and transducer data streams currently being managed by the FGS-WKP team. The Data Portal will be expanded to: 1) provides a fully functional web-based tool for accessing the team data; 2) provides a complete description of the metering and database project that will serve as a surrogate for the evolving WKP Observatory project; and 3) provides interactive access to data being managed by partnering agencies to be identified (USGS and NWFWMD at a minimum). Specific subtasks will include the following.

- Revise database to handle transducer data.
- Advance Data Portal to handle all Falmouth and Transducer data, describe project objectives, supporters, and provide access to collaborators data streams.
- Develop demonstration-level interactive web-based application to provide access and analytical tools for comparing real-time or near real-time data accessed through collaborators' servers and project website.

<u>Task 4 Timeline</u>

Task 4 shall be completed no later than 12 months from the date of Contract execution.

<u>Task 4 Total Cost</u> =$25,000

<u>Task 4 Deliverable</u>

The Contractor shall submit a tested and operative Web-based data portal.

Task-5: Spring Creek Tracing

The purpose of this task is to continue the groundwater tracing program that has been initiated to identify and map the sources of water to Spring Creek and determine the relationship between the Spring Creek and Wakulla Spring systems. This work is significant to the modeling effort since Spring Creek represents the southern boundary of the WKP. Budget constraints will necessitate that this effort be a scaled-down version of our typical tracer studies as it will not be quantitative in nature. Tracer detection will depend primarily on the insitu fluorometers with the use of sporadic water sampling only as a conformation measure. Specific subtasks will be dictated by hydrologic conditions, but will accomplish the following.

- Install five (5) insitu fluorometers in selected Spring Creek spring vents.
- Perform a repeated dye injection at Turner Sink under higher water level conditions than those encountered in the 2007 test.
- Perform a dye injection at Lost Creek under high water level conditions (i.e. Lost Creek must be flowing).
- Regularly visit the Spring Creek sampling stations to service the fluorometers and download data.
- Compile and evaluate the data and produce a report on the tracer test results.

Task 5 Timeline

Task 5 shall be completed no later than 12 months from the date of Contract execution.

Task 5 Total Cost = $9,500.

Task 5 Deliverable

The Contractor shall submit a final report documenting the completed dye tracing experiment and all data. The report shall be submitted in both digital and hard copy.

REMAINDER OF PAGE INTENTIONALLY LEFT BLANK

Appendix II: Letter Report on Task-1 from Loper and Chicken

Annual Report 2007-2008
Last update 081223

This is an annual report on activities performed by David Loper and Eric Chicken as Task 1 of FGS contract GW272 for the fiscal year from July 1, 2007 to June 30, 2008. The text of this task is presented in Appendix A.

The overall goal of the research project is to develop an accurate model of flow and transport in karstic aquifers, such as the Floridan Aquifer, that can be used to better manage and protect Florida's springs and ground water. An important aspect of this project is the statistical analysis of relevant data sets, including velocity, temperature and electrical conductivity measured by the seven Falmouth meters installed in the tunnels leading to Wakulla Spring, velocity measured in the main vent by the S4 meter operated by the Northwest Florida Water Management District, river flow and stage measured by the US Geological Survey, tides and water levels measured by our water-level loggers and rainfall near and north of Wakulla Spring (available from NOAA). The goals of the statistical analyses are

- to gain a better understanding of the nature of the system,
- to motivate model development,
- to quantify specific aspects of the system and
- to calibrate and test various flow models.

During the 07-08 fiscal year, a number of data issues were addressed, including

1. Identification of the location, depth and size of conduits from micro-gravity data
2. Recovery of temperature data from malfunctioning instruments
3. Estimates of conduit areas from flow data
4. Investigation of sources and pathways of water from flow and temperature data
5. Possible identification of flow regimes from flow data
6. Determination of properties of conduit waves from water-level data
7. Development of a linear theory of conduit waves

These issues are discussed in the following sections

1. Analysis of Microgravity Signals.

The presence of subterranean conduits within the Woodville Karst Plain was inferred from statistical analysis of several sets of microgravity measurements. In addition to determining the locations of such conduits, their approximate relative depths and sizes were estimated as well. An iterated non-linear least squares method was used to fit observed gravity data to a proposed theoretical model for the conduit- gravity relation. The spatial density of the conduits was examined with respect to their relative cross-sectional areas. For details, see: Chicken, E., Chalise, P. and Loper, D. (2008). Conduit prevalence in the Woodville Karst Plain. *Proc., 11th Multidisciplinary Conference*, ASCE, Tallahassee, 303-312.

2. Temperature Drift.

After the Falmouth meters at K and A/K were changed in late 2006, the temperature readings of both meters showed a marked decline with time, see Figure 2.1. The data gap seen in the first half of the time period occurred between the removal of one meter and the activation of the next. Once the new meters were installed, the temperatures measured by the two meters appear to decline nearly linearly with time, though at differing rates.

The decline in temperature after meter replacement is shown more clearly in Figure 2.2. The data from each meter was fit by a linear regression model of the form:

$$y = \beta_0 + \beta_1 x + \varepsilon \tag{2.1}$$

where y is temperature, x is time, β_0 and β_1 are constant parameters and ε is random error,. The slope for the K data shown in Figure 2.2, is –0.00271 (which translates to decrease of –0.00271 degrees per day). For AK, the slope is –0.00198.

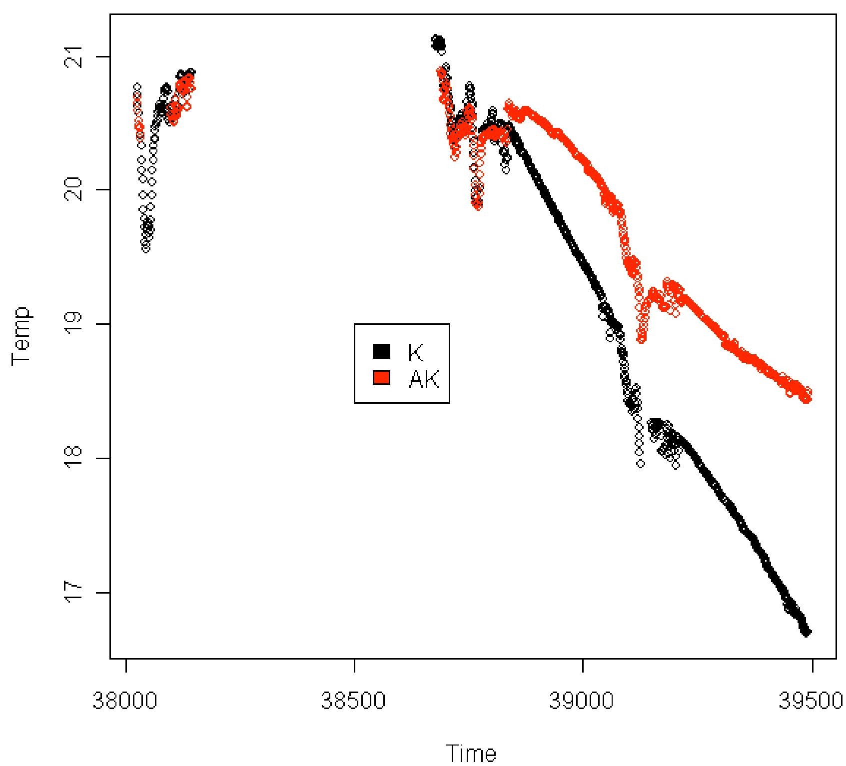


Figure 2.1. Temperatures measured by Falmouth meters at K and A/K, prior to and following the change-out in late 2006.

It is apparent that the variable data at the beginning of each signal is affecting the estimates of each line's slope and intercept. This can be remedied, perhaps, by a careful selection of the time frame for the model. Figure 2.3 shows a linear fit applied to a reduced set of data. The corresponding slopes for Figure 2.3 are –0.00566 and –0.00370. These are significant changes, and are directly a result of "handpicking" the data. Intuitively, it seems that the results from the data used in Figure 2.3 are more reasonable.

To control for the data window selection, we applied a search algorithm to fit the best line to each data set. This uses the entire window, and minimizes (maximizes) the error (correlation) between the temperatures at K and AK and the correctly functioning temperature meter and tunnel AD. The water temperature from one meter to the next should be closely related. Each of the temperature signals K and AK is detrended with a linear model, then compared with the AD temperature signal.

Figure 2.4 shows the results of such an algorithm for AK. The upper panel displays the AD temperature (red), AK temperature (black) and the best fit line (green) through AK. The lower panel shows AD temperature (red) and the linearly corrected AK temperature. Figure 2.5 shows the equivalent for AD and K temperatures.

Initially, AD with AK, and AD with K, have a near zero correlation: no relation between the data sets. After the algorithm, AD and AK have a positive correlation of 0.89 (a value of 1 is maximum and implies the two signals are perfectly linearly correlated) and the correlation between AD and K is 0.90. This implies that after an appropriate linear trend is removed, the temperature signals at AK and K align strongly with that of AD.

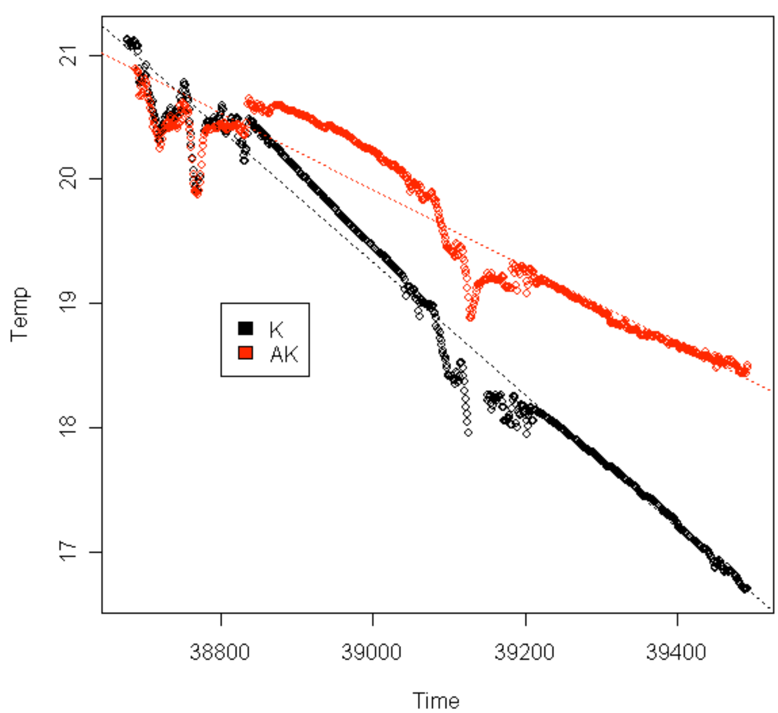


Figure 2.2. Temperatures measured by Falmouth meters at K and A/K following the change-out in late 2006.

The estimated slopes using this algorithm are –0.00572 degrees per day for AK (compared to –0.00566 when subjectively selecting a data window) and –0.00349 for K (compared to –0.00370). They using the two approaches agree quite well.

The slopes of the two trend lines are not statistically equivalent. A hypothesis test of equality of the two lines is soundly rejected with a p-value of essentially 0.

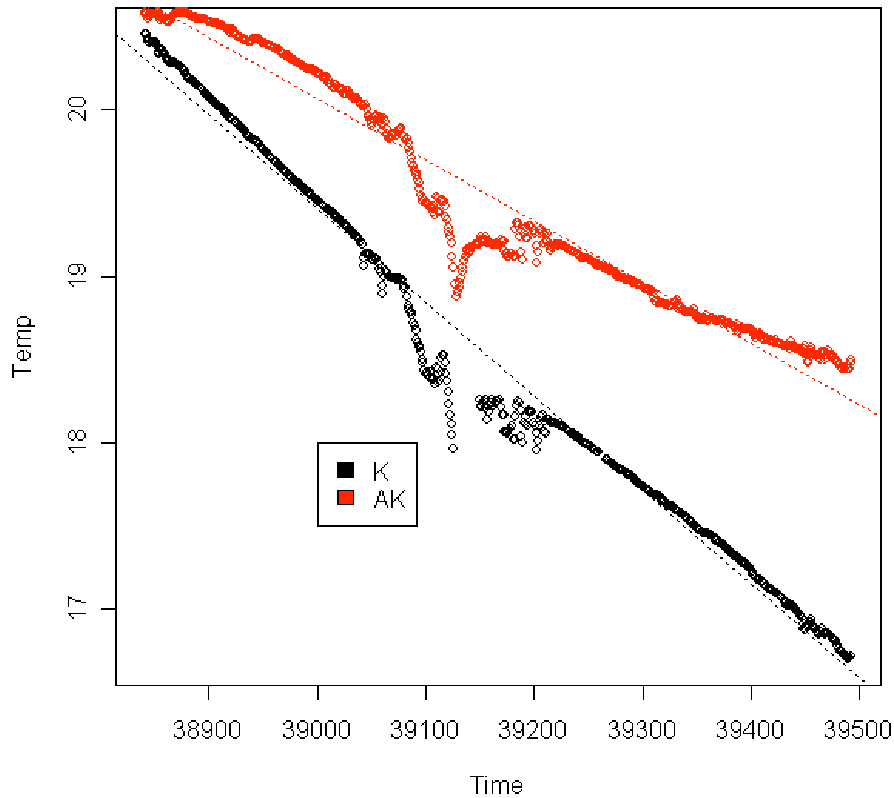


Figure 2.3. Temperatures measured by Falmouth meters at K and A/K following the change-out in late 2006.

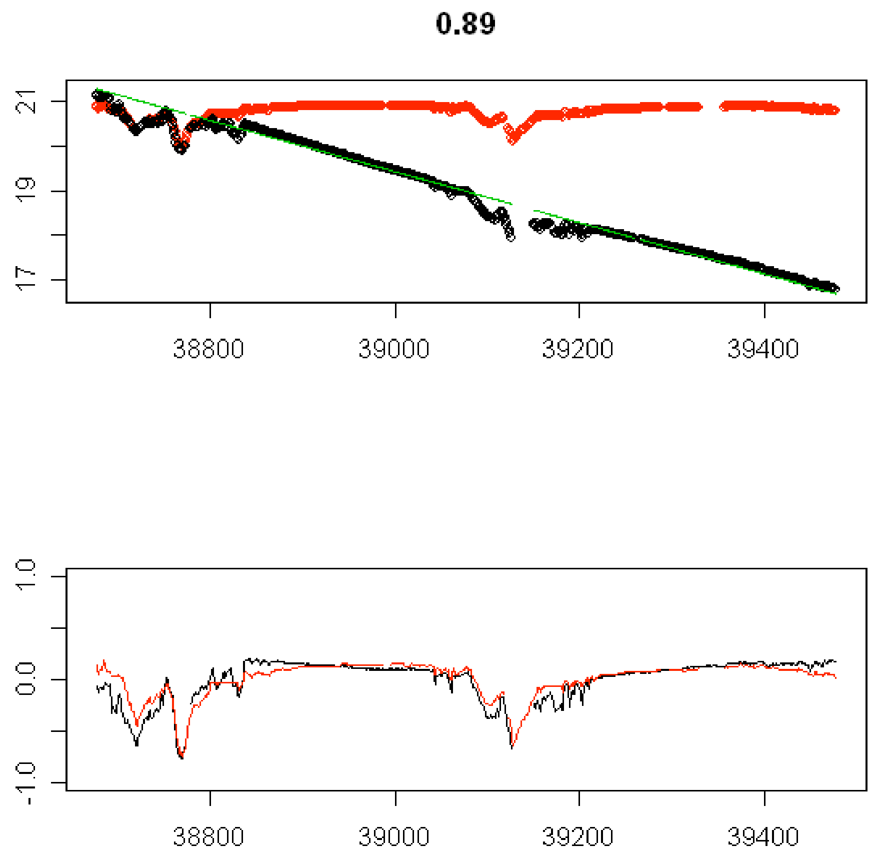

0.89
21
19
17
38800
39000
39200
39400
1.0
0.0
-1.0
38800
39000
39200
39400

Figure 2.4.

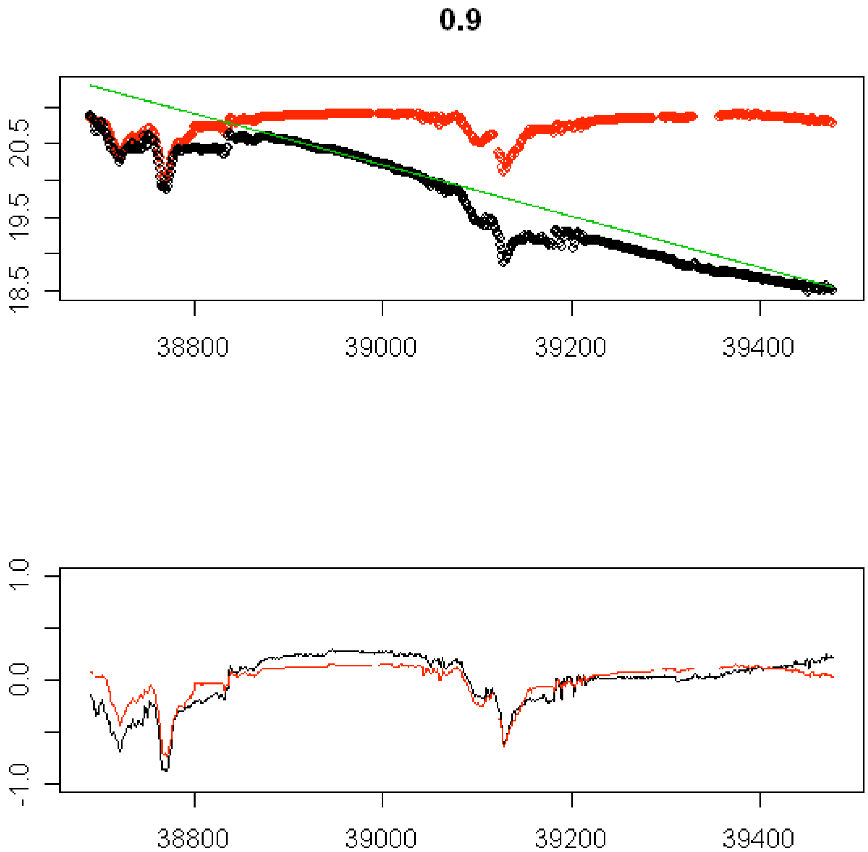


Figure 2.5.

3. **Cross-sectional area estimates of tunnels.**

The goal of the analysis reported in this section is to estimate the cross sections of various tunnels by correlating the temporal variations in flow into and out of two control volumes. One control volume (near the vent) has inflow from B, C, D and A/D and outflow at the vent, while the second has inflow at A/K and K and outflow at D.; see Figure 3.1.

The flux of water into and out of each control volume must be conserved, with the water flux at a given location being the product of the cross-sectional area of the tunnel times the mean flow speed. That is,

$$Q_v = Q_1 + Q_{AD} + Q_B + Q_C + Q_D + \varepsilon_1 \tag{3.1}$$

and

$$Q_D = Q_2 + Q_{AK} + Q_K + \varepsilon_2 \tag{3.2}$$

where Q_1 and Q_2 represent flow into or out of each control volume that is not sampled by the meters, ε_1 and ε_2 are random measurement errors and, in a simple formulation, the fluxes at the meter locations are given by

$$Q_M = \beta_M S_M \tag{3.3}$$

where β is the cross-sectional area and S is the mean speed of flow normal to that area. Here M stands for one of the seven meter locations: v (vent), A/D, B, C, D, A/K and K.

Each meter measures horizontal velocity at a point, resolved into northward and eastward components. In order to employ the simple formulation, this velocity must be projected in an unknown direction to obtain the flow speed. An alternate formulation that avoids this step is to represent the flow past each meter as a sum of eastward and northward flows.

$$Q_M = \beta_M^N S_M^N + \beta_M^E S_M^E \tag{3.4}$$

where β_M^N and β_M^E are the projections of the cross sectional area sat meter M in the northerly and easterly directions, respectively, and S_M^N and S_M^E are the measured northward and eastward flow speeds, respectively.

Since the velocity measured by the meter may not be the mean velocity, each β should be interpreted as an effective area, given the specific location of the meter. If the meter is moved to a new location, the effective areas may well be different.

The angle of flow at the vent does not vary much and the magnitude of flow is calibrated with measurements of flow in the Wakulla River (see Figure B4), so that the effective areas of the vent, β_v^N and β_v^N, are known.

The model consisting of (3.1) or (3.2) and (3.4) may used to determine the effective areas and mean flow directions at the various meter locations. The procedure is entails using multiple linear regression to find the best correlation between variations

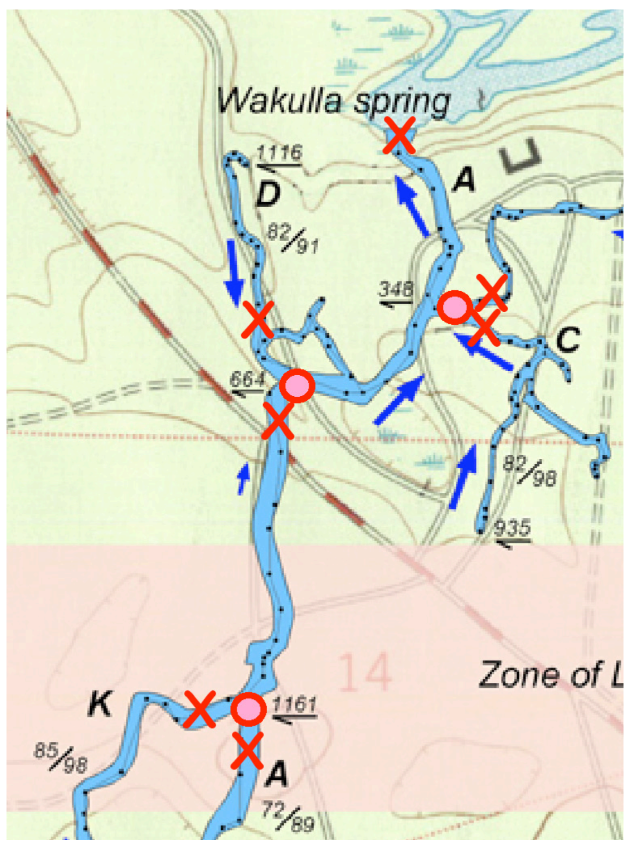


Figure 3.1 Map showing the locations of the seven Falmouth meters.

in the inflow and outflow for the two control volumes, using a fairly large set of measurements taken over an interval of time. In the following the data are for the 70-day interval from June 1 to August 10, 2006.

Consider first the model consisting of (3.1) and (3.4). In practice, for diagnostic purposes, tunnels were added one at a time on the right-hand side of (3.1) tunnel was added at a time to the flow equation. The AD flow is most highly correlated with the vent in terms of flow magnitude, so the test began with three terms on the right-hand side of (3.1): AD.N, AD.E, and a constant base flow. Figure 3.2 shows the relation between the vent and the directional components of AD.

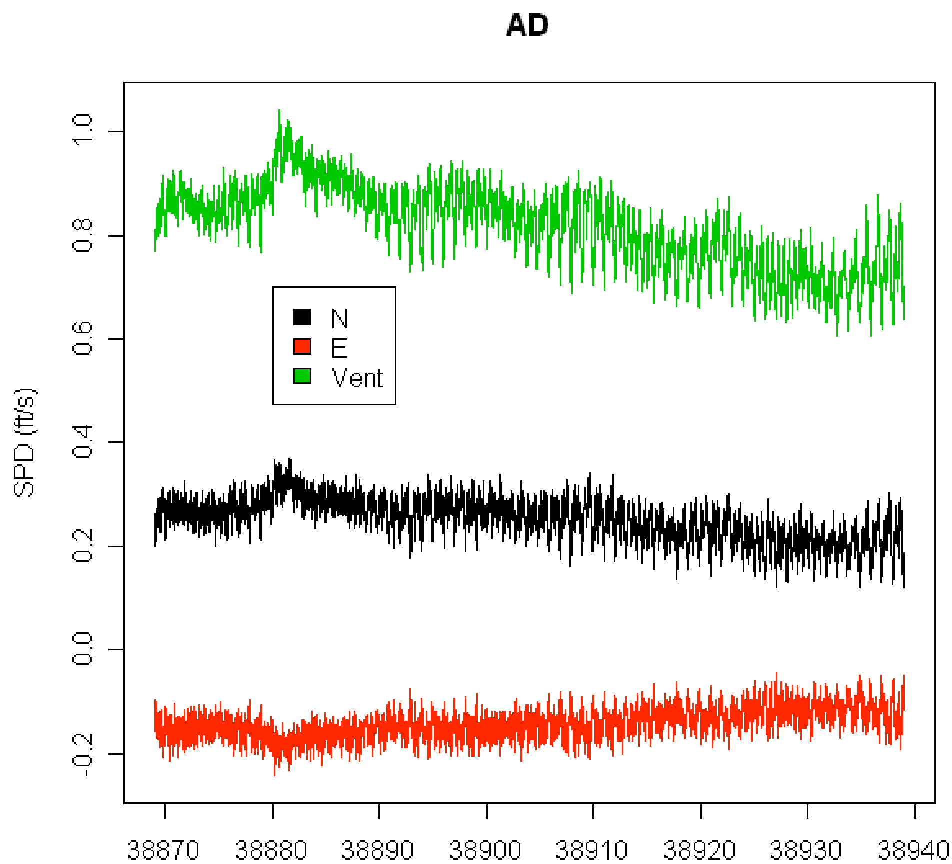


Figure 3.2. Variations with time of northward (black) and eastward (red) flow at A/D and vent (green) from June 1 to August 10, 2006.

Figure 3.3 shows the results. The fit is accurate, the base flow is modeling all flow not from AD. The estimate for cross-sectional area (in square feet), determined geometrically based on the estimates of flow in each direction is

```
                  AD
Base         199.1461787
N           2651.9461068
E           1842.0334276
Area        3228.9170479
```

Angle	55.2162777

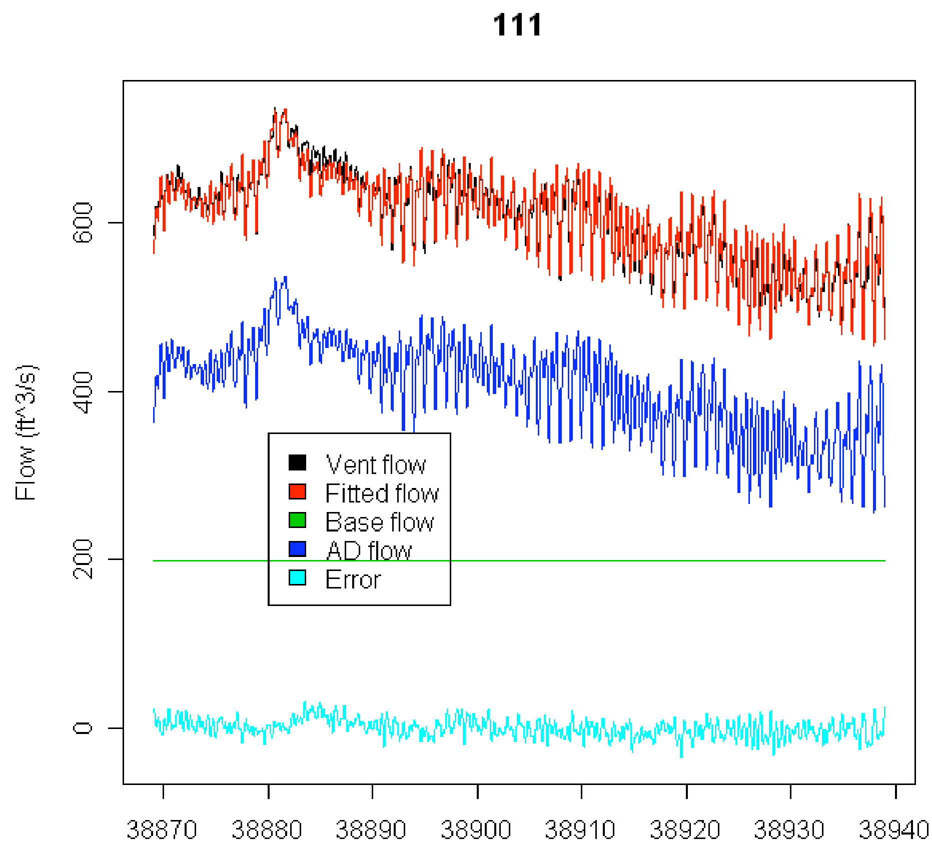


Figure 3.3. Fitted vent flow (red), based on the components of the AD flow (blue), compared with the vent flow (black), and the residual error (cyan).

The next terms added are for B tunnel. The fit of base flow, AD and B to the vent flow is shown in Figure 3.4. The area estimates are

	AD	B
Base	52.2093898	NA
N	2491.0794814	225.6079985
E	1625.9292855	-712.6385775
Area	2974.7475564	747.4976328
Angle	56.8674878	-17.5668097

The base flow is reduced since it is no longer attempting to account for B flow.

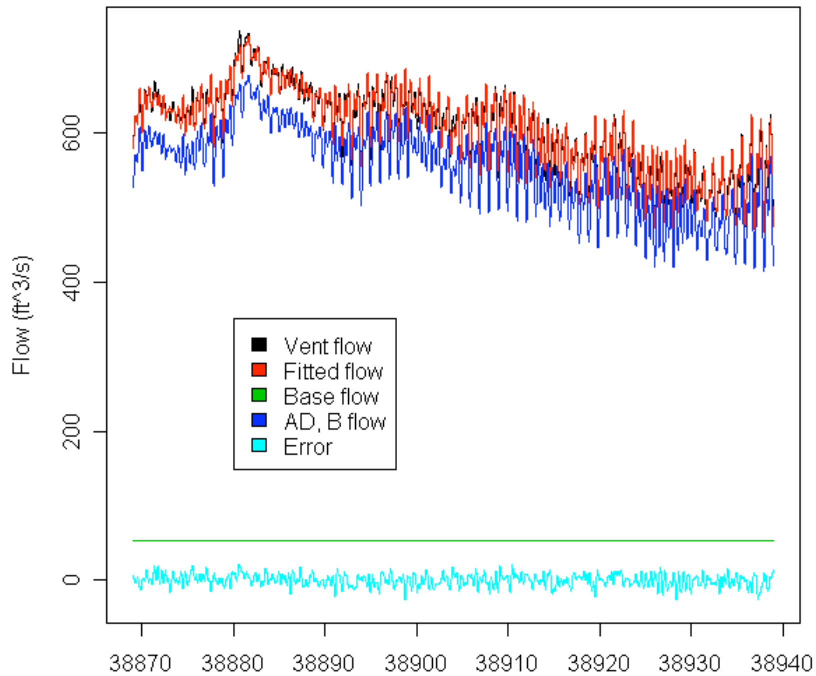


Figure 3.4

Continuing in this fashion, the estimates for all 5 components are

	AD	B	C	D
Base	47.5707188			
N	2485.9152477	234.3950212	13.576199211	39.36371354
E	1622.8743337	-738.0271244	-22.997197591	-88.36504149
Area	2968.7532268	774.3546102	26.705510332	96.73614888
Angle	56.8623848	-17.6196793	-30.555115136	-24.01139645

Statistically, C and D areas could be 0.

On examining these results, a problem became apparent. The regression method applies signs to the estimated parameters based on mathematical fit, not physical reasoning, and the good fit obtained is not physically reasonable. In particular, some components (E, N) of tunnel flow were being overestimated, and then the corresponding components in the other directions were given opposite signs to compensate.

To correct for this, constraints need to be applied to the model. Using physical locations and directions for the tunnels, the component flows were forced to be in certain directions. This required abandoning multiple linear regression in favor of a nonlinear least squares method. This method gives equivalent results to regression when it is run without constraints. The estimates obtained (not area estimates, but values needed to calculate areas) are:

```
       Estimate
base   210.738
NS.AD 1246.232
EW.AD    0.000
NS.B     0.000
EW.B  -323.022
NS.C    55.393
EW.C     0.000
NS.D    77.667
EW.D     0.000
```

An unintended consequence here is that the constraints imposed on the physical problem forced several estimates to be 0. This is not accurate, either. For example, the AD component flow estimate for east-west is 0 implying only north-south flow. At this point, the next step is to try a new method, such as projecting the combined directional flows for each tunnel into a specified direction, then fitting a model analogous to (3.3) using these unconstrained, projected flows. This has not yet been implemented.

In a similar fashion, the model consisting of (3.2) and (3.4) will be considered, assuming that the area at AD is known. So, this estimation problem will proceed after estimates for AD are considered reasonable. If the area of AD is not known, then fitting the data to this model will only give relative results, i.e. the areas of AD, AK and K will be in the correct proportion with respect to each other, but the absolute values for the areas will remain unknown.

Work on this issue has not been completed.

4. Investigation of sources and pathways of water close to the vent

According to the divers four tunnels (named A, B, C and D) feed water directly to the main vent at Wakulla Spring. Relying on this information, flow meters were installed in the entries of each of these vents. As can be seen by the Kincaid map (Figure 3.1), these tunnels and monitoring points are quite close (within 1 km as the crow flies) to the main vent. The meters measure velocity at a point, and it is a simple matter to convert speeds to volume fluxes by multiplying by the cross-sectional areas of the tunnels, estimated by the divers. But, as discussed in Appendix B, the fluxes don't add up correctly. On average, the volume flux of water provided by the four tunnels is less than half that discharging from the main vent. Part of the problem may be that the area estimates are not valid. For example, a meter (A/D?) might consistently record a low speed, perhaps because it is located within an eddy.

However, this cannot be the whole story. The temperature recorded at the main vent (blue in the graph shown in Figure 4.1) cannot be explained by summing any combinations of inputs from the four meters supposedly supplying all the water. In particular, the abrupt decrease of the temperature of water flowing in A tunnel near D is not reflected in the temperature of the vent water; it appears that the warm water is continuing to reach the main vent, but by a different route. Further, the multi-day variations in vent temperature are not seen in any of the four inputs.

At this point, the conclusion about a hidden source of water is only qualitative; no quantitative analysis of this behavior has yet been performed, due to a lack of manpower and funding. A mass-balance calculation using data for both temperature and conductivity should be able to quantify the relative contributions of water to the main vent from the know sources and from the hidden source. Such calculations could be further refined by additional mass balance calculations using specific chemicals, elements or isotopes, but the relevant data has not yet been collected.

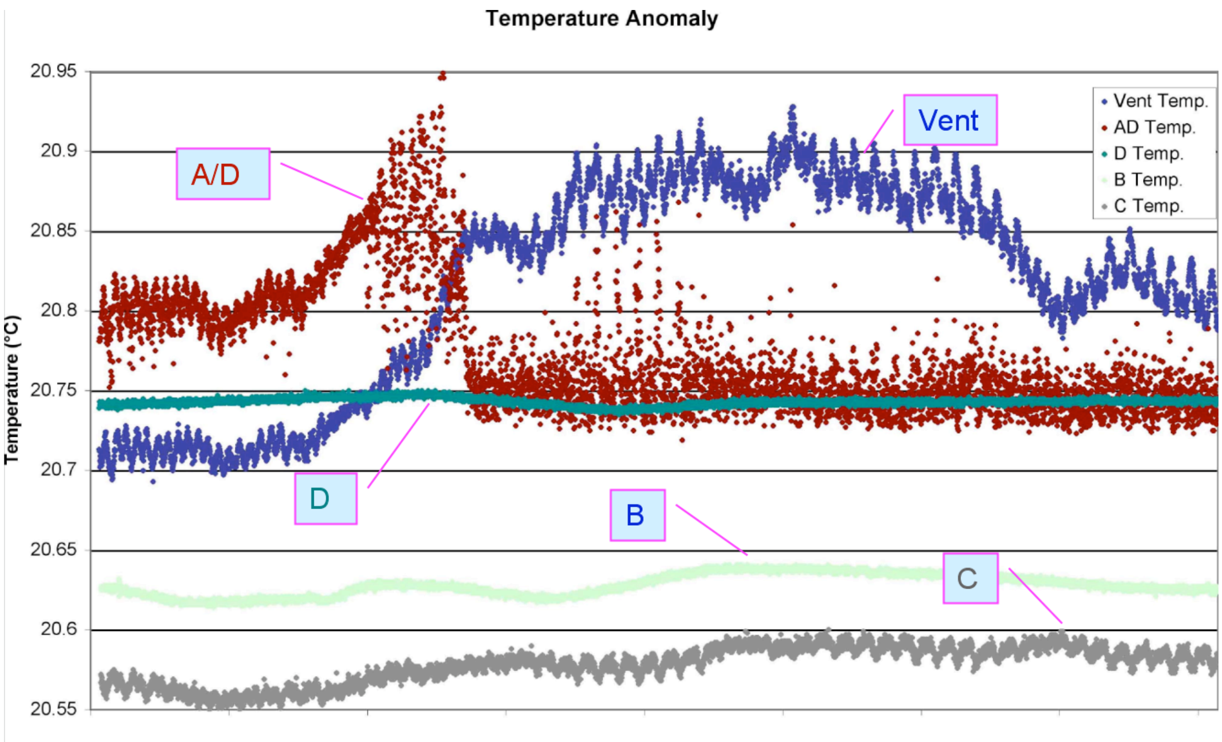


Figure 4.1. Temperatures in the vent and tunnels A/D, B, C and D, June 4– July 31, 04.

5. Hydrologic connections and flow regimes

An important issue is whether and how Wakulla Spring is connected to other springs in the region, particularly Spring Creek Springs. Strong evidence of a direct link (i.e., a tunnel or a system of tunnels) between Spring Creek and Wakulla Spring comes from the observed correlation between water levels at the coast and both water level and discharge at Wakulla Spring; see Figures 5.1 and 5.2. This correlation is seen in both the regular luni-solar tides and episodic storm events. Somewhat more indirect evidence of a connection is the anecdotal anti-correlation of discharge from Wakulla Spring and Spring Creek Springs that occurs over timescales of months.

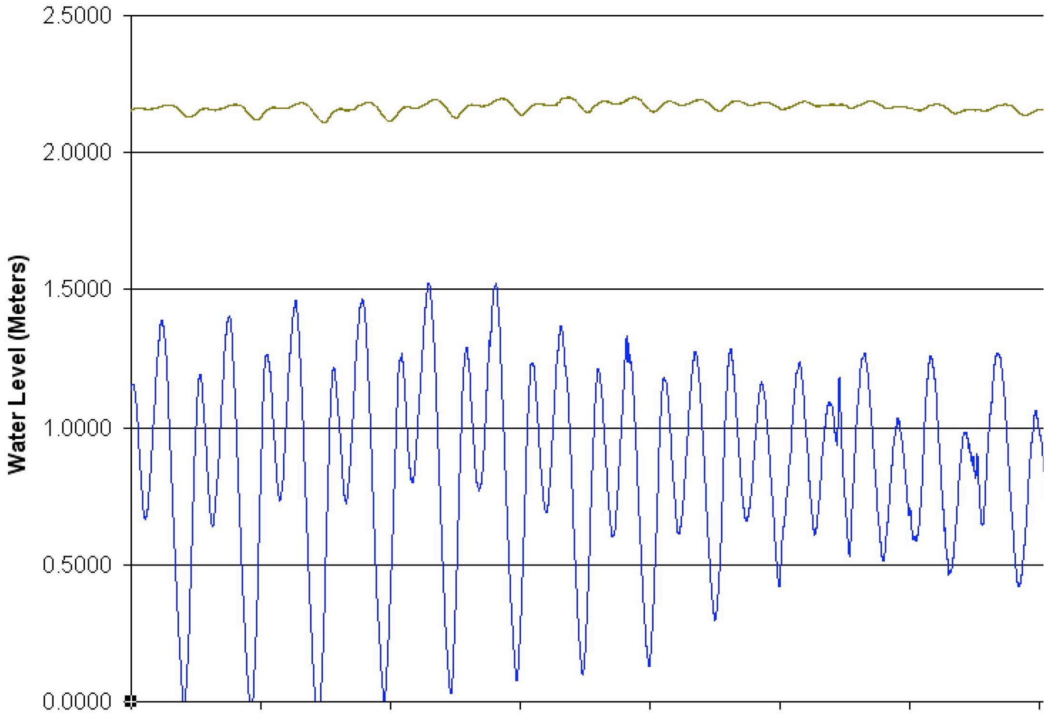


Figure 5.1. Water levels measured at Spring Creek springs at the coast (lower curve) and at a location 16 km inland (upper curve) for the two-week period June 22 – July 6, 2006.

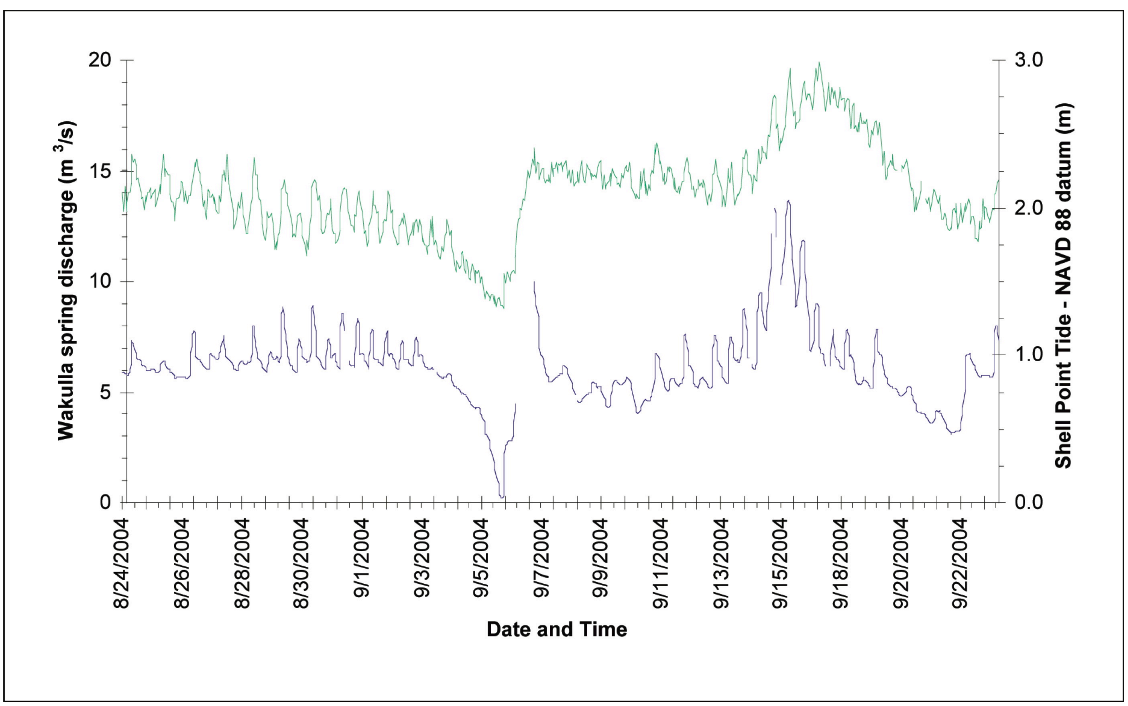


Figure 5.2. Discharge at Wakulla spring (blue; scale at left) and tide at Shell Point (green; scale at right) from 24 August to 23 September, 2004.

Measurements of flow by the Falmouth meters at A/D, A/K and K reveal that the flow system appears operates in three distinct regimes with transitions between regimes being fairly abrupt; as illustrated in Figure 5.3. Since flow in the vents at Spring Creek is not being monitored yet, these regimes cannot yet be fully characterized. A rough characterization of the three regimes is given in the following table.

	Regime 1		**Regime 2**		**Regime 3**	
Location	**strength**	**variability**	**strength**	**variability**	**strength**	**variability**
A/D	mod	mod	low/mod	strong	low	weak
A/K	high	strong	mod	very strong	low	weak
K	mod	weak	mod	mod	low	weak
B	mod	weak/mod	strong	strong	falling	mod
C	mod	weak	mod	weak	low/mod	weak
D	very low	weak	mod	not consistent	very low	weak

A possible explanation for these regimes, in terms of a salt-water plug, is given in §4.5 of the final report for contract GW258 for July 1, 2006 through September 30, 2007.

We have begun an attempt to develop a statistical procedure to objectively identify and quantitatively characterize the flow regimes as well as the times of transition. The current state of these efforts is described in §4.4 of the final report for contract GW258 for July 1, 2006 through September 30, 2007. Once we have flow data for the vents at Spring Creek, we will be in a much better position to characterize and quantify these regimes.

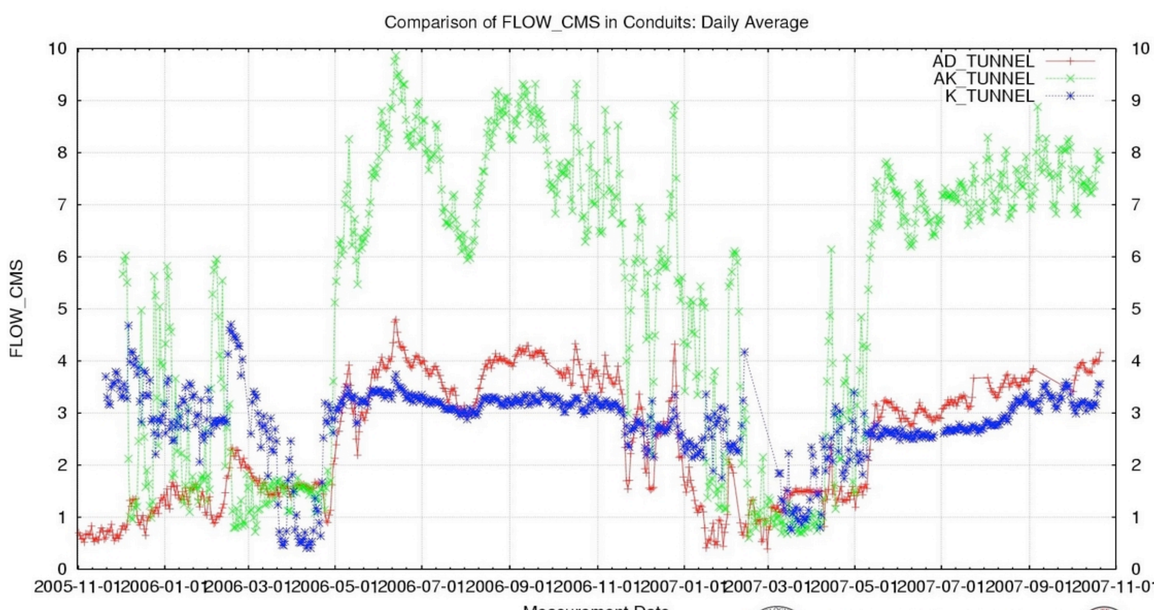


Figure 5.3. Flow measured in A.D, A/K and K tunnel, Nov 05 – Oct 07.

6. Determination of properties of conduit waves from water-level data

The theory of conduit waves described in the following section provides mechanism to estimate key properties of the conduit system, particularly the effective conduit radius, from observations of water levels made at the surface. The two key links between observation and theory are the rate of decay of amplitude (with distance from the coast) and the phase speed of a given wave mode. With observations taken at two fixed locations (as illustrated in Figure 5.1), the equivalent observations are the amplitude ratio and the phase lag. Water level data of sufficient accuracy and frequency for statistical analysis are available at Marker 35 close to Spring Creek springs and at the K-tunnel borehole.

According to the theory, the observed properties of conduit waves depend on the frequency. The luni-solar tides are composed of 12 components: four nearly semi-diurnal (periods close to 12 hours), four nearly diurnal (periods close to 24 hours) and four having periods of two weeks or longer. The seemingly straightforward task of determining amplitude ratios and phase lags is in fact surprisingly challenging due to a combination of factors, including (1) several of the tidal modes have nearly identical frequencies, (2) very small errors in frequency estimation can accumulate to confound estimation of phase, (3) extraneous inputs to water level (from rainfall and weather systems) introduce errors into the water-level data and (4) the relative strength of the modes may vary with the seasons.

Given the relatively short duration (less than five months, from March 19 through August 10, 2006) of un-interrupted simultaneous water level measurements available at present, it is not possible to model all 12 tidal components separately using a parametric model. Consequently, this ‘scientific’ approach was abandoned in favor of an ‘engineering’ method, focusing on obtaining estimates of amplitude ratio and phase lag for two tidal periods: nearly diurnal and nearly semi-diurnal, and using only the more dominant modes at these periods.

A Fourier analysis of the power spectrum reveals that the tides are dominated by two nearly diurnal (K1, O1) and two nearly semi-diurnal modes (M2 and S2). The amplitude ratios and phase speeds of these dominant modes can be determined reasonably accurately, but those for the remaining four nearly diurnal and nearly semi-diurnal modes (P1, Q1, K2, N2) are too inaccurate to be of use. This gives two estimates of the amplitude ratio and phase lag of conduit waves at each of the two periods (nearly diurnal and nearly semi-diurnal). A weighting scheme (based on the amplitudes of these wave modes at Marker 35) was used to obtain best estimates of the phase lag $\Delta\Phi = \Phi_M - \Phi_K$ and amplitude ratio (A_K/A_M) as follows.

Period	Frequency (day^{-1})	Phase lag	Amplitude ratio
Nearly diurnal	0.97	1.37	0.065
Nearly semi-diurnal	1.95	1.22	0.039

7. A linear theory of unsteady conduit waves

The purpose of this section is to summarize the manuscript "A Linear Model of Conduit Waves in Karstic Aquifers" by David E Loper & Carol M Wicks. The model aquifer, illustrated in Figure 7.1, has a horizontal conduit of circular cross-section being imbedded within an otherwise homogeneous porous matrix. The top boundary is free, while the sidewalls are at sufficient distance that they do not affect the flow. A regional hydraulic gradient is imposed on the system (parallel to the conduit). The mathematical problem is linearized by assuming that the head gradients associated with the conduit waves are small compared with this regional gradient.

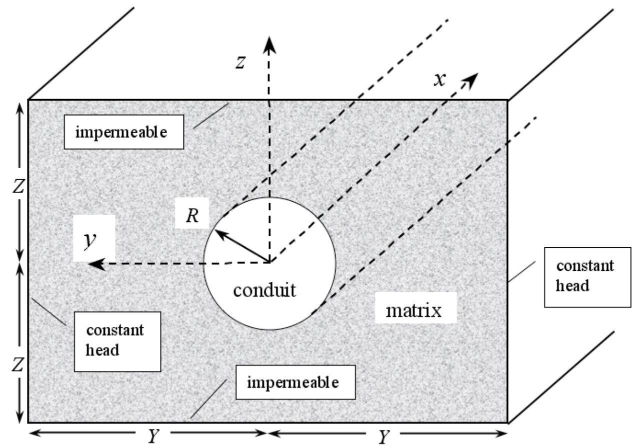


Figure 7.1. An illustration of the y-z cross section of the aquifer, showing a conduit of radius R imbedded in a porous matrix having horizontal extent 2Y and a vertical extent 2Z. The top and bottom boundaries are impermeable and the sidewalls are held at constant head.

The solution procedure relies on the presence of a large length scale in the direction of the conduit, to separate the problem into a two-dimensional problem for head within the matrix and a one-dimensional problem for head within the conduit. Flow within the porous matrix is driven by the head specified at the conduit boundary, while variations in flow within the conduit are driven by the radial gradient of head at that boundary. Water can be stored at the top of the saturated aquifer, introducing a time-delay in the problem that has two consequences: one physical and one mathematical. The physical consequence is that wave-like solutions are permitted. The mathematical consequence is that the representation for head in the matrix must include a convolution integral. In spite of this complication, an analytic solution for the head within the matrix has been obtained. The matrix-head solution provides a relation between the head and radial gradient at the conduit boundary, leading to a linear integro-differential problem for head within the conduit. This problem has been solved for the case of harmonic forcing, leading to the following theoretical relations for the decay rate and phase speed of the wave.

The decay scale X and phase speed V are given by $X = \gamma_+ L$ and $V = \gamma_- \omega L$ where ω is the prescribed frequency,

$$L^2 = \sqrt{\frac{gR}{f\Gamma}}\frac{R^2}{2K}$$

is a large length scale and

$$\gamma_{\pm} = \sqrt{\frac{\sigma^2+1}{\sqrt{\sigma^2+1} \pm 1}}$$

where

$$\sigma = \frac{I_s}{\bar{F} + I_c},$$

$$\bar{F} \approx 2\ln\left(2Z / R\right) + 0.483129$$

and

$$\left\{I_c,\, I_s\right\} = 4\int_0^{\infty} \frac{\left\{\alpha \tanh\left(2\alpha\right),\, \omega n Z K^{-1}\right\} \cosh^2\left(\alpha\right)}{\alpha^2 \sinh^2\left(2\alpha\right) + \omega^2 n^2 Z^2 K^{-2} \cosh^2\left(2\alpha\right)}\, d\alpha\,.$$

Here f is the friction factor, g is the acceleration of gravity, K is the permeability n is the porosity, R is conduit radius, Z is conduit depth and Γ is the regional hydraulic gradient.

This manuscript will be submitted to *Water Resources Research*, once the values for the decay rates and phase speeds for the diurnal and semi-diurnal components of the luni-solar tides are incorporated into the manuscript.

Appendix A: Task-1: Continuation of Statistical Analysis

The purpose of this task is to develop statistical analyses of the hydrologic data being collected by the various meters managed by the FGS, and eventually, data available from other agencies as a means of estimating conduit sizes in regions where they are known to be present but cannot be directly measured.

The FGS meters, both those that are presently in operation (e.g., flow meters and tide gauges) and those that will soon become operational (water-level loggers), provide a plethora of data – far more than can be systematically analyzed given the current level of funding available. Consequently relatively few of the many interesting avenues of investigation, identified by visual inspection of graphs of the data, can be explored and analyzed in the coming year. While the level of data gathering and analysis will be dictated by funding and other priorities, it is safe to say that one statistical issue, which is currently under investigation, will continue to have priority in the coming year. This involves the comparative analysis of temporal variations in water level measured at the coast (i.e., tidal variations) and at various inland-locations. The goal of the comparative analysis is to quantify both the amplitude ratios and the phase speeds of the primary tidal components (diurnal and semi-diurnal) between the coast and various inland locations. This information, when coupled to a model of flow in conduits that was developed during the past fiscal year, will provide estimates of the sizes of the conduits connecting the coastal and in-land locations. Reliable estimates of conduit sizes are very important, particularly in regions which have not yet been explored by divers, as these conduits dominate regional flow and transport.

In addition, the existing records of discharge at Wakulla Springs will be analyzed in an attempt to identify and quantify *salt-water-plug* events. These are events (described in more detail in the proposed modeling task) during which the discharge at Wakulla Springs is elevated significantly for periods of weeks or months, unrelated to rainfall and recharge.

The deliverables for this task will include periodic reports of progress, summaries and highlights of any unusual events recorded by the meters, files of both raw and processed data and descriptions of statistical procedures employed to process the raw data.

Budget:

- Dr. Eric Chicken: $8,000.00
- Dr. David Loper: $11,500.00
- Overhead: $500.00
- *Total: $20,000.00*

Appendix B. Problems with flow balance

The seven Falmouth flow meters installed in the Wakulla Spring tunnel system form two apparently closed systems: (1) V = A/D + B + C + D and (2) A/D = A/K + K. Each meter measures the horizontal velocity at a point every 15 minutes (when operating), with each measurement being a five-minute average. Each velocity measurement is converted to a volume flux by first projecting the velocity onto the along-tunnel direction then multiplying by the cross-sectional area as measured by the divers. This procedure assumes that the flow meter is measuring a representative velocity. This is generally the case if the flow is turbulent, provided the meter is not located in the laminar sub-layer near the wall.

It would seem a simple matter to verify equations (3.1) and (3.2). However, these checks, based on cross-sectional areas provided by the divers, are seriously out of balance. For example, checks of these equations for the period 20060601 to 20061020 are shown Figures B1 and B2. This time interval was chosen because the flow from K tunnel had very small variation.

In Figure B1, the vent flow (top curve) should be the sum of the four flows measured at A/D, B, C and D. However, the vent flow appears to be more than 200% of the sum of these four. In Figure B2, the flow at A/D (middle brown curve) should be the sum of the other two. Here the discrepancy is even greater; the flow at A/D would have to be increased by about a factor of 4 to achieve balance.

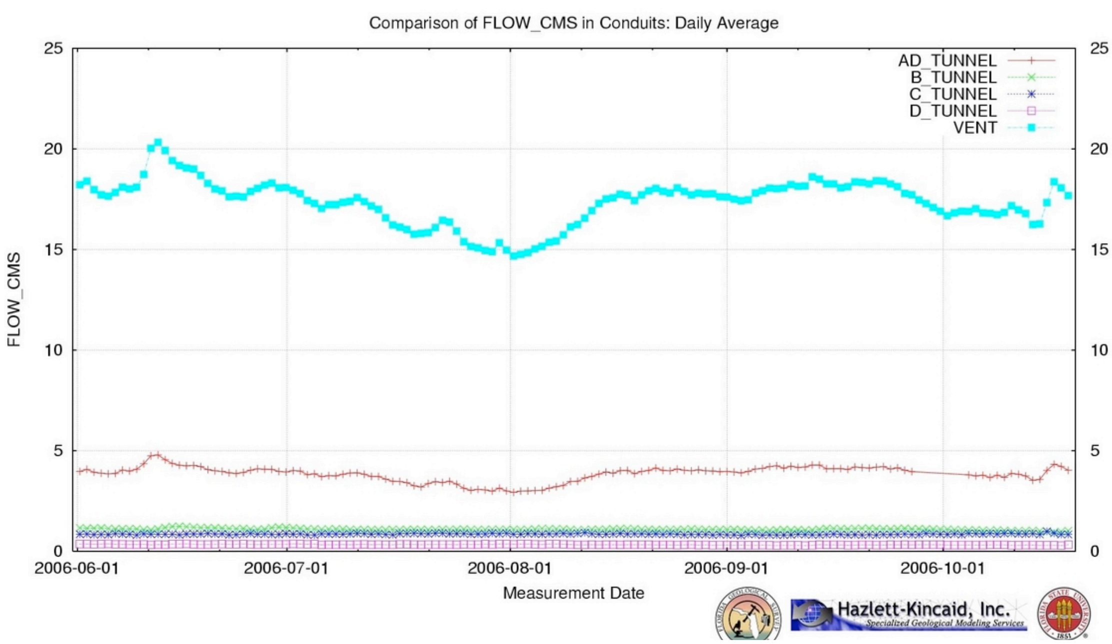


Figure B1. Flows measured at the vent and in tunnels A/D, B, C and D for June 1 through October 20, 2006.

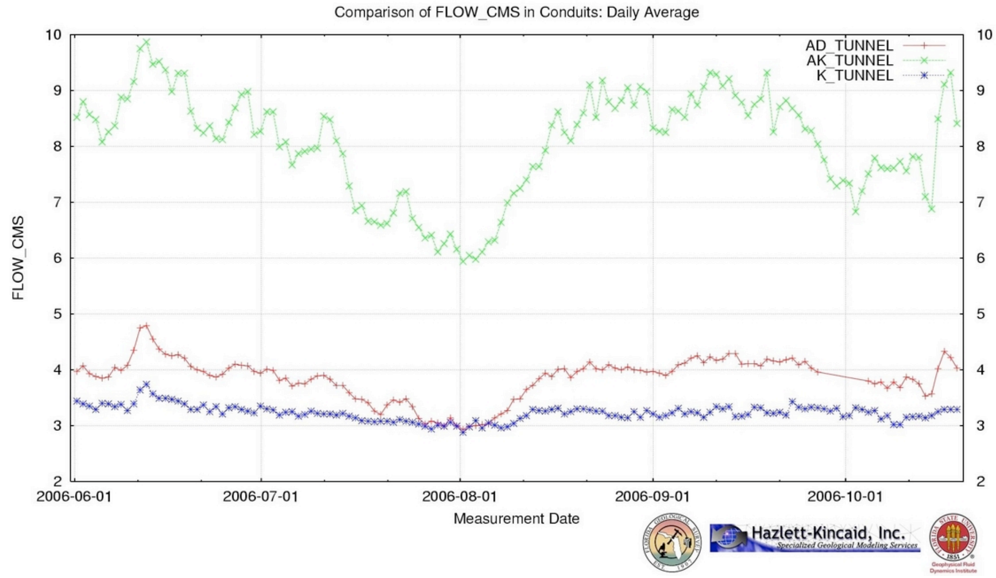


Figure B2. Flows measured in tunnels A/D, A/K and K for June 1 through October 20, 2006.

Possible sources of error include:

\> projecting the velocity along an incorrect azimuth. The rose diagrams (e.g., see Figure B3) shows that there is significant variation in flow directions measured at A/K and especially K, even after the 5-minute average. This variation may be due to long-period turbulence or to variations in flow regime.

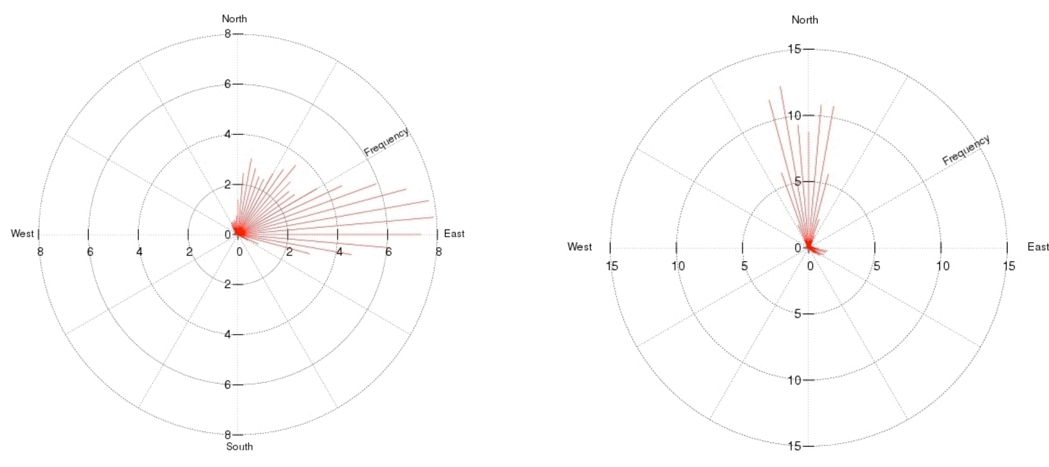


Figure B3. Cumulative rose diagrams for meters at K (left) and A/K (right) for the duration of deployment: Feb 7, 2004 through Feb 15, 2008.

\> incorrectly estimating the cross-sectional area.

\> having the meter located at an inauspicious point, so that the meter measurement is either greater or – more likely – less than the mean flow. The latter might occur, for example, if the meter is located in the 'flow shadow' of a rock or projection upstream of the meter or if the Reynolds number of the flow is sufficiently low that the measurement point, located about 1 meter from the floor, is within the boundary layer.

> having additional significant inputs to the flow, other than via the known tunnels – perhaps by unmapped tunnels (not likely) or by seepage through the walls or floors.

Possible errors in the flow measured at the vent can be checked by comparison with measurements of flow in the Wakulla River at the upper bridge, located about 5 km downstream from the vent. As can be seen from figure B4 the discharge measured by the Falmouth meter is slightly lower than measured by other meters or means, but the error is both too small and of the wrong sign to account for the discrepancy; if our vent discharge were corrected upward, it would make the discrepancy with flows measured at A/D and A/K worse, not better.

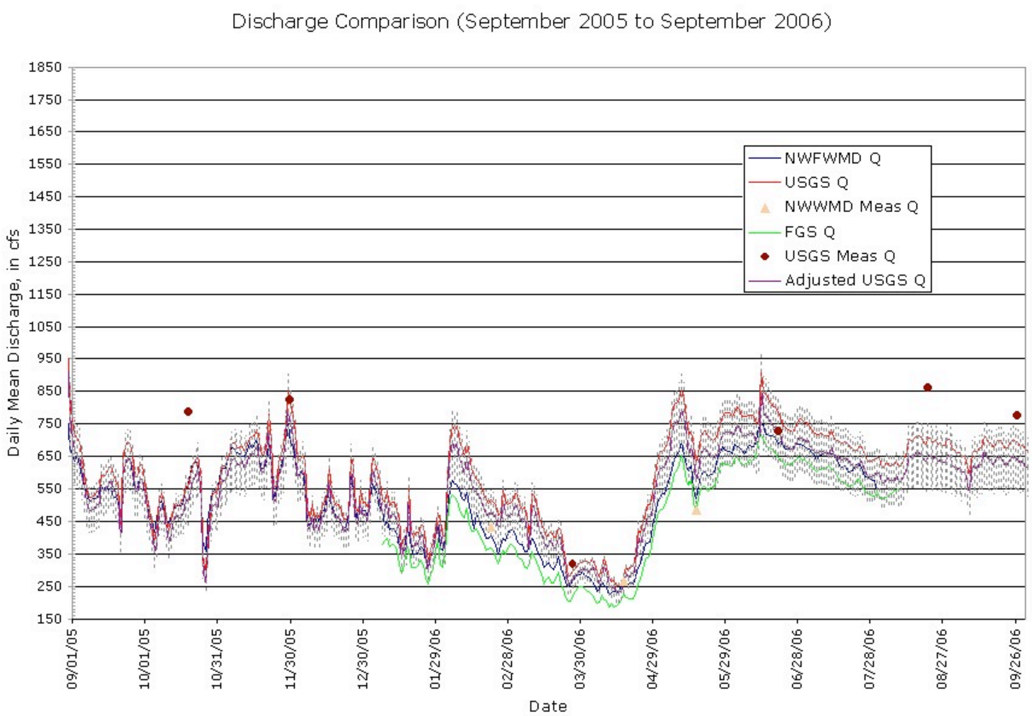


Figure B4. Comparison of Wakulla-Spring discharge measured by various instruments and agencies from September 2005 to September 2006. Discharge measured by the Falmouth meter in the main vent is shown in green. Courtesy of Richard Verdi, USGS.

For the chosen time interval (June 1 to October 20, 2006), most of the variability in flow is confined to three meters: vent, A/D and A/K. This affords the opportunity to correlate the variations in flow to obtain a better estimate of the effective areas.

The variations in discharge seen in Figure B5 are strongly correlated. In order to make these variation the same size, we would need to increase the effective area at A/D by a factor of about 4 and that at A/K by a factor of about 2. It is doubtful that the divers' estimates are this far off. It is likely that the meters at A/D and A/K are consistently measuring low velocities.

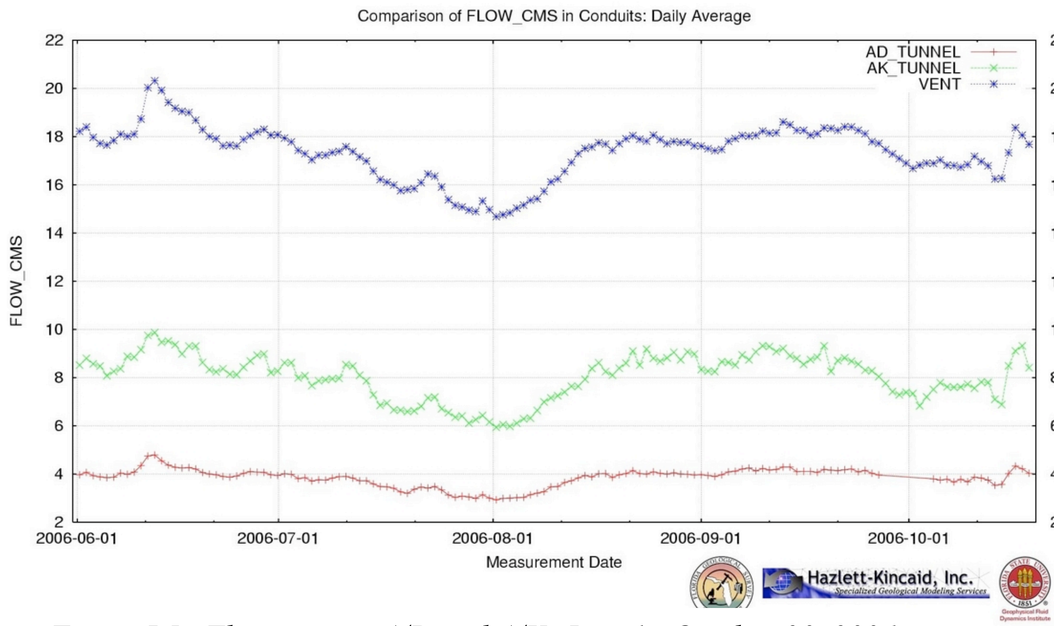


Figure B5. Flow at vent, A/D and A/K, June 1– October 20, 2006.

APPENDIX III: LETTER REPORT ON TASK-2 FROM DAVIES

Memorandum

Date: December 17, 2008

To: Todd R. Kincaid

From: Gareth J. Davies

Re: Accomplishments in contract GW272, Task 2 in 2008

Falmouth Meter Data Collection and Telemetry

- The data collection and telemetry system design comprised of Falmouth Scientific Inc. meters and cables (to physiaclly link the meters to the suface, Integra radios (to transmit via RF the data stream to the server that was to be installed at the Wakulla Springs State Park Administration Building), In-Situ and Global brand transducers and a custom-built server running Windows XP.
- The radios, transducers and Falmouth meters are controlled and manipulated by software that runs on a laptop computer. This computer interface is also necessary to download data from the memory in each meter or logger.
- After extensive field and laboratory tests problems were found between the radios and the software components running various meters or loggers, also pieces of hardware, such as a multiplexer plug and null mode
- It was determined that the proposed telemetry system components were more difficult to interface than envisaged. One problem was related to connecting both the transducers and Falmouth meters together using a multiplexer plug. This was necessary for the telemetry but could be bypassed if merely downloading the data to the laptop. This problem could not be resolved and was related to the hardware (plug) which would not allow a dual connection.
- It was also determined that the Falmouth meter software would not allow connection with more than one meter at a time and the Falmouth software had not provision to allow switching between more than one meter.
- The server designed to process the telemetry data running Windows XP had problems with a bug in the software package designed to connect with the internet (Earthlink connection). This caused a hang up where the server would need a manual reboot to continue running.
- It was determined that a possible solution to these problems was to connect a Campbell Scientific data logger so that it could acquire the separate data streams from all

devices and transmit them to the server. Campbell also provides software that can be installed onto the server that can process the data and stream it to the web.

QA/QC Protocols for the Falmouth Data

- The Falmouth meters are located in extremely remote locations and this complicates the maintenance of them.
- The remoteness causes the QA/QC to be done remotely unless there is a hard failure of any component.
- Obviously the only way to hands-on maintain the meters is to do it with the help of divers, but this is controlled by diving conditions in the cave.
- If problems were seen with the Falmouth meters and there was no diver support, they were discussed within the group and with Falmouth Scientific technicians.
- The Falmouth Technicians suggested that any continuous deployment of a meter beyond one year was a long deployment and since some of our meters had been in use continuously for nearly three years this was unprecedented.
- The only way to check a meter without changing it for a new or refurbished meter is install an additional meter alongside the suspected malfunctioning meter.
- A problem with the K and AK meters was resolved by the divers replacing the both the meters.
- In the process of checking the health of new meters that it was thought had possibly been damaged during delivery, a set of tests was completed at the Wakulla dock that tested both the precision and accuracy of the meters. This technique can be used to assess the general health of other meters if required.

QA/QC Protocols for the Transducer Data

- Pressure transducers have been used in the Falmouth locations because the accuracy and precision of the Falmouth Scientific built-in pressure transducer was not deemed sufficient for the project.
- In 2008 an additional network of tranducers has been installed to monitor water level variations at sinks and the Wakulla Spring vent.
- Prior to installation of the 2008 set of pressure transducers several transducers (manfactured by In-Situ Inc.) had been purchased but not installed. When the 2008 program started it was found that (1) several had been tested in the laboratory, but had

been left running, so they had accumulated data in the memory, and (2) the software for some was not the correct version (this was discovered after conversations with the manufacturer).

- The water level data that are being and will be collected will be referenced to vertical and horizontal survey data collected independently.

Notes

The transducers in use at every location are all the non-vented type and therefore do not correct for changes in atmospheric pressure.

This means that local atmospheric pressure must be measured separately and corrections applied to the pressure data calculated, this provision is usually included in the software supplied with the transducer.

It is recommended that an atmospheric pressure reading is obtained within 10 miles (16 kilometers) of each transducer in the entire area to be monitored. There may be enough weather measuring stations in the vicinity of the Woodville Karst Plain to accommodate this. There are continuous pressure data measured at the municipal airport, and there are NOAA stations on the coast at Shell Point.

Situation as of December 2008

The Falmouth Meters are in place and functioning with the exception of that meter at the Wakulla vent. This meter initially had a problem with the meter and the cable from the surface. The original meter and cable plug connection corroded so the meter was replaced, which was operated on internal battery for the time period that would last.

The telemetry system as designed cannot function but with the addition of Campbell Data Loggers it has a high probability of being operational. There is currently no funding for such an operation.

Appendix IV: Letter Report on Task-3 from Day

May 1, 2008

Dr. Rodney DeHan
Florida Geological Survey
Gunter Building MS #720
903 W. Tennessee St.
Tallahassee, FL 32304-7700

Subject: Woodville Karst Plain (WKP) Telemetry System Update

Dear Dr. DeHan:

The following is a brief synopsis of the results of my trip to Florida on March 24-26, 2008 and my subsequent work from Reno with Scott Dyer, Todd Kincaid, and Gareth Davies working in the field on April 6-11 that focused on bringing the telemetry systems for the Falmouth meters on line. Details of the previous visit were outlined in an earlier letter, attached for reference.

Background Understanding

To facilitate the data collection and processing, telemetry systems have been partially developed that, if brought into to operational status, will provide near real-time access to the hydrologic data being collected.

The Florida State University – Geophysical Fluid Dynamics Institute assumed responsibility for the design and construction of the telemetry system in 2005 but had not been able to produce a working system. H2H Associates, LLC, took control of the project in 2008 with the purpose of activating the telemetry system. The most recent effort focused on the following system components:

1. Data Collection
    a. Falmouth Scientific 3D ACM Current Meter measuring Flow Direction, Velocity, Temperature and Conductivity
2. Telemetry
    a. Data Radio Integra-TR150 Integrated VHF Wireless Modem
    b. Antenna, antenna wiring
    c. Server to retrieve data from remote stations and make available via www.

A trial system was installed at the K-Tunnel and A-D Tunnel monitoring wells. Prior to this visit, the trial system had not been brought into operational status.

Results of and Comment on March 2008 Field Effort

I was able to establish a connection between the server situated in the Wakulla Springs Park Headquarters and the Falmouth meter at K-Tunnel through the Integra-TR Data Radios. The data that was transmitted to the server was partially corrupted, likely due to inconsistencies between the data transmission rates of the meter and the radios.

After the first transmission of data from the K-Tunnel meter, we were unable to conclusively connect to any more Falmouth meters. It is unclear whether this problem is attributable to stability issues with the meters, as they have been deployed beyond their expected service intervals, or if it is an issue that needs to be addressed by adjusting baud rates and buffer intervals on the Data Radios. It is also currently unclear whether the Falmouth meter baud rate needs to match the Data Radio transmission rate, or if it only needs to be matched to the baud rate of the Data Radio COM port. Discussion with Integra Data Radio technical support suggested that all baud rates should be matched, while Falmouth Scientific provided documentation indicating that the 2DACM baud rates should be lower than that of the telemetry network. As baud rates and data buffering parameters are changed in the remote radio and instrument, the rates also need to be adjusted in the master station. This was a logistical problem because with one person in the field, a 30 minute round trip was required to synchronize radios for each 10 second test in addition to the issue of the Falmouth becoming unstable after repetitive changes of the settings.

Part of the Field Effort included configuration of server software to automate modem dial-up testing of server connectivity with the Data Radios. During this portion of the work, it became apparent through testing of the Falmouth software and discussion with Falmouth technical support that there is no built-in utility to select from a list of meters. This means that it may not be possible to access multiple meters through the Falmouth ACM-Pro software.

One additional problem that was encountered was a faulty wire installed in an antenna connection at A-D Tunnel. That set back our work schedule because we had assumed that the problem resided in the radio or the meter. We have now added a check of the radio-antenna connectivity to the troubleshooting process.

Our conclusions after several coordinated attempts to bring the system on line are as follows:

1) The reliability of the currently designed telemetry system with the Falmouth meters is suboptimal. This may stem from the fact that the meters have been over deployed and are in need of service - in particular the older meters need to have firmware upgrades. However, it is currently unclear whether the Falmouth meters had any role in the degradation of the communications system after the initial connection. The meter reliability variable can be removed from the equation by using two new (taken from FGS inventory) in the proposed control test and network setup effort.

2) Falmouth Scientific's -Pro software used to retrieve data from the 2DACM meters is not set up to distinguish between multiple meters accessed through the same connection. Discussion of this issue with Integra Data Radio technical support revealed that there is no control over, or splitting of the communications stream through the modems. This means that the meter/device management software (ACM-Pro) needs to be able to choose from a list of simultaneously connected devices. Theoretically, the data streams could be separated and alternate ports could be emulated, but this would likely entail a moderate to substantial effort beyond the practical scope of this project.

3) The complexities detailed in the two previous conclusions suggest that if the issues are overcome in the existing setup, it would likely still not be practical to run both the In-Situ and Falmouth devices through a single radio using the Telebyte Port Miser (RS-232 Serial Port Multiplexor).

4) The Server situated in the Park Headquarters has exhibited some minor problems maintaining an internet connection through the dial-up account. With the exception of periodic loss and reconnection to the Internet Service Provider (ISP), the connection speed was adequate for transmitting data files in the anticipated size range of several megabytes at a time. The Server is not currently configured to automatically retrieve data from the remote stations. The first problem can be (and has partially been) addressed by adding some error checking routines to restart services on detection of system errors. The second task is dependent on which software is being used to retrieve data. The Server has been configured as a dual-boot computer with both Windows XP and Linux. During my recent visit, I briefly reviewed the Linux configuration, but there was an issue with the modem driver. I did not pursue bringing the Linux system on line due to time constraints, but would like to consider this option as Linux is more robust and appropriate for a server performing autonomous tasks.

Work Projection

We propose a final effort to produce a working telemetry system in a better-controlled environment and with a hardware enhancement to the system. In order to have the best chance of success, all necessary equipment should be shipped to the H2H Reno Office to provide ample time to test, configure and complete a working multi-metered system. This effort would be considered a complete success if we can establish a functioning network of 2 2DACM meters, 2 InSitu level meters, 3 Data Radios, 2 Data Loggers and 1 master station / server that work autonomously.

The Data Loggers produced by Campbell Scientific, Inc. were identified by Gareth Davies as a potential solution to all of the major problems outlined previously in conclusions 1, 2 and 3. Follow up discussions with a technical representative from Campbell indicate that their Data Loggers and software are a good solution to these issues for the following reasons:

- CR800 series data loggers can connect to up to 3 separate instruments and a radio / modem, which will enable transmission of both In-Situ and Falmouth meter data.
- CR1000 series data loggers can connect to 4 separate instruments, which would enable K/A-K and D/A-D instrumentation to all be brought on-line through a single radio and data logger.
- Installed Data Logger will resolve the baud rate / buffering issue between the Falmouth meters and the radios. Campbell loggers are programmed to communicate individually with each device.
- ampbell Scientific ogger et soft are installed on either a inu or Windo s server is easily programmable to schedule data retrieval from multiple remote Data Loggers. This completely cuts out the Falmouth and In-Situ software and any associated issues. Falmouth and In-Situ software would only be used for initial deployment and re-setting of meters by field personnel as needed.

In addition to identifying a solution in the Data Loggers, Gareth has located several of the Campbell Data Loggers that can potentially be taken on loan from the Dept. of Atmospheric Sciences at FSU for the duration of the configuration phase of this project. Once the system has been successfully brought online, tested, then transplanted to K & D tunnels and proven in the field, a purchasing contract can be discussed for the Campbell devices.

We anticipate approximately 6-8 days of work to establish a test network, program the Campbell software and the data loggers, configure the server for autonomous operation and test the system under a set of scenarios (power loss, unresponsive meter, lost connection, etc). If the system performs satisfactorily under controlled conditions, we believe there is a high probability that it can be successfully setup in the field. Once the tests are completed, I will compile a report on the outcome and prepare a time, cost, and needs estimate for the field deployment.

Sincerely,

Kevin E. Day, P.G.
Geologic Modeler

CC: T. Kincaid
G. Davies
File

APPENDIX V: EQUIPMENT INVENTORY LIST

Autosamplers - Instrument Tracking Sheet ***Sheet last updated:***

Technical Info: http://www.isco.com/products/products2.asp?PL=20110&image=Samplercollage.jpg
Technical Info: http://www.cee.vt.edu/ewr/environmental/teach/smprimer/isco/isco.html
Manufacturer Contact: Who is the Person?
Manufacturer Contact Phone #: What's their phone number?

Sampler #	DEP Property #	Type	Purchase Date	Current Deployment Location	Date of Current Deployment	Device Status	Data Collection Frequency	Tubing Status	Responsible Project Manager	Field Service Technician	Last House Inspection Date	Last Manuf. Service Date
1	?	Unknown	Unknown	FGS	NA	Unknown	NA	Unknown	Rodney DeHan	Scott Dyer	Unknown	None
2	?	Unknown	Unknown	FGS	NA	Unknown	NA	Unknown	Rodney DeHan	Scott Dyer	Unknown	None
3	?	Unknown	Unknown	FGS	NA	Unknown	NA	Unknown	Rodney DeHan	Scott Dyer	Unknown	None
4	?	Unknown	Unknown	FGS	NA	Unknown	NA	Unknown	Rodney DeHan	Scott Dyer	Unknown	None
5	?	Unknown	Unknown	FGS	NA	Unknown	NA	Unknown	Rodney DeHan	Scott Dyer	Unknown	None

Notes

	Marks "Prior to" Dates
NA	*Not Applicable*

Autosamplers - Instrume

Sampler #	DEP Property #	Date of Last Tubing Change	Maintenance Required	Previous Deployment Location	Date of Last Deployment	Date of Retreival	Other / Comments	Deployment History
1	?	Unknown	Unknown	Unknown	Unknown	Unknown		
2	?	Unknown	Unknown	Unknown	Unknown	Unknown		
3	?	Unknown	Unknown	Unknown	Unknown	Unknown		
4	?	Unknown	Unknown	Unknown	Unknown	Unknown		
5	?	Unknown	Unknown	Unknown	Unknown	Unknown		

Batteries - Tracking Sheet

Sheet last updated:

	Totals
Excellent	*0*
Good	*0*
Fair	*0*
Poor	*0*
Dead	*0*

Battery Retailer: http://corporate.interstatebatteries.com/www/distributors/tallahassee/default.asp
Battery Info: http://www.helioselectric.com/sales/index.php?main_page=product_info&cPath=101_136&products_id=291
Manufacturer Contact: Interstate Batteries of Tallahassee
Manufacturer Contact Phone #: 850-580-5545

Batteries

Battery #	DEP Property #	Type	Purchase Date	Status	Max Volts	Last House Inspection Date	Current Deployment Location	Date of Current Deployment	Responsible Project Manager	Field Service Technician	Other / Comments
1	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
2	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
3	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
4	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
5	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
6	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
7	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
8	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
9	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
10	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
11	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
12	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
13	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
14	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
15	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
16	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
17	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
18	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
19	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
20	?	DCM0100	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	

Notes

	Marks "Prior to" Dates
NA	*Not Applicable*

Battery Chargers - Tracking Sheet ***Sheet last updated:***

Charger #	DEP Property #	Type	Purchase Date	Status	Last House Inspection Date	Current Location	Responsible Project Manager	Field Service Technician	Other / Comments
1	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
2	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
3	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
4	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
5	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
6	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
7	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
8	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
9	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	
10	?	Unknown	Unknown	Unknown	Unknown	FGS	Rodney DeHan	Scott Dyer	

Notes

	Marks "Prior to" Dates
NA	*Not Applicable*

Falmouth Flow Meters - Instrument Tracking Sheet ***Sheet last updated:***

Technical Info: http://www.falmouth.com/DataSheets/2ACMRev3.pdf
Manufacturer Contact: Who is the Person?
Manufacturer Contact Phone #: What's their phone number?

Serial #	DEP Property #	Purchase Date	Current Deployment Location	Date of Current Deployment	Status	Data Collection Frequency	Responsible Project Manager	Field Service Technician	Last House Inspection Date	Last Manuf. Service Date	Maintenance Required
1889	132314	Unknown	Wakulla D-Tunnel	12/15/2007	Working	15-min	Rodney DeHan	Scott Dyer	Unknown	None	None
1890	132316	Unknown	FGS	NA	Working	NA	Rodney DeHan	Scott Dyer	Unknown	None	None
1891	132315	Unknown	Wakulla AK-Tunnel	5/17/2008	Working	15-min	Rodney DeHan	Scott Dyer	Unknown	None	None
1892	132311	Unknown	Unknown	NA	Unknown	NA	Rodney DeHan	Scott Dyer	Unknown	None	None
1893	132312	Unknown	Wakulla K-Tunnel	5/17/2008	Working	15-min	Rodney DeHan	Scott Dyer	Unknown	None	None
1894	132313	Unknown	FGS	NA	Working	NA	Rodney DeHan	Scott Dyer	Unknown	None	None
1665	117526	Unknown	Wakulla AD-Tunnel	10/1/2006	Working	15-min	Rodney DeHan	Scott Dyer	Unknown	None	None
1669/1453	118896	Unknown	FGS	NA	Working	NA	Rodney DeHan	Scott Dyer	Unknown	None	None
1674/1437	117525	Unknown	FGS	NA	Not Responding	NA	Rodney DeHan	Scott Dyer	Unknown	12/11/2008	House Inspection
1677/1454	118895	Unknown	lmouth, disposed of, not repairal	NA	Dead	NA	Rodney DeHan	Scott Dyer	Unknown	2/29/08 abandonne	Unknown
1678/1455	118897	Unknown	FGS	NA	Working	NA	Rodney DeHan	Scott Dyer	Summer 08	12/11/2008	None
1687	118892	Unknown	Wakulla B-Tunnel	10/1/2006	Working	15-min	Rodney DeHan	Scott Dyer	Unknown	None	None
1688	118893	Unknown	Wakulla C-Tunnel	10/1/2006	Working	15-min	Rodney DeHan	Scott Dyer	Unknown	None	None
1788	122232	Unknown	FGS	NA	Working	NA	Rodney DeHan	Scott Dyer	Summer 08	12/11/2008	None
1789	122231	Unknown	FGS	NA	Working	NA	Rodney DeHan	Scott Dyer	Summer 08	12/11/2008	None
Below machines are on the DEP Inventory but NOT in our posession. Theses are being used by Suwanne River Water Management District											
1657	118894	Unknown	Manatee Main Tunnel	Unknown	Unknown	Unknown	Tom Greenhalgh	SRWMD	Unknown	Unknown	Unknown
1673	117524	Unknown	Manatee Sewer Tunnel	Unknown	Unknown	Unknown	Tom Greenhalgh	SRWMD	Unknown	Unknown	Unknown
1686	118891	Unknown	Manatee Bluewater Tunnel	Unknown	Unknown	Unknown	Tom Greenhalgh	SRWMD	Unknown	Unknown	Unknown

Notes

	Marks "Prior to" Dates
NA	*Not Applicable*

Falmouth Flow Meters - I

Serial #	DEP Property #	Previous Deployment Location	Date of Last Deployment	Date of Retreival	Other / Comments	Deployment History
1889	132314	None	NA	NA		Purchased ??/??/??, Deployed AD-Tunnel 12/15/07
1890	132316	Wakulla Vent	Unknown	12/15/2007		Purchased ????, Deployed Wakulla Vent ??/??/??, Retreived 12/15/07, Stored FGS 12/15/07
1891	132315	None	NA	NA		Purchased ??/??/??, Deployed AK-Tunnel 5/17/08
1892	132311	None	NA	NA	Believed to be in Wakulla Vent - Not Responding	Purchased ????, Unknown
1893	132312	None	NA	NA		Purchased ??/??/??, Deployed K-Tunnel 5/17/08
1894	132313	None	NA	NA		Purchased ??/??/??, Stored FGS
1665	117526	Unknown	Unknown	Unknown		Purchased ??/??/??, Deployed AD-Tunnel.
1669/1453	118896	Wakulla Dock Control Unit	8/23/2007	8/23/2007		Purchased ??/??/??, Deployed Wakulla Dock 8/23/07, Retreived 8/23/07, Stored FGS
1674/1437	117525	Wakulla Vent	Unknown	12/15/2007	Awaiting test following refurbishing	Purchased ??/??/??, Deployed Wakulla Vent ??/??/??, Retreived 12/15/07, Serviced by Falmouth 12/11/08, Stored FGS
1677/1454	118895	Unknown	Unknown	Unknown	Unrepairable, too costly	Purchased ??/??/??, Unknown Deployement, Shipped to Falmouth, abandoned with them 12/08, they will dispose of properly.
1678/1455	118897	Wakulla D-Tunnel	Unknown	12/15/2007	Refurbished by Falmouth, awaiting deployment	Purchased ??/??/??, Deployed D-Tunnel ??/??/??, Retreived 12/15/07, Serviced by Falmouth 12/11/08, Stored FGS
1687	118892	Unknown	Unknown	Unknown		Purchased ??/??/??, Deployed B-Tunnel
1688	118893	Unknown	Unknown	Unknown		Purchased ??/??/??, Deployed C-Tunnel ??/??/??
1788	122232	Wakulla K-Tunnel	Unknown	5/17/2008	Refurbished by Falmouth, awaiting deployment	Purchased ??/??/??, Deployed K-Tunnel ??/??/??, Retreived 5/17/08, Serviced by Falmouth 12/11/08, Stored FGS
1789	122231	Wakulla AK-Tunnel	Unknown	5/17/2008	Refurbished by Falmouth, awaiting deployment	Purchased ??/??/??, Deployed AK-Tunnel ??/??/??, Retreived 5/17/08, Serviced by Falmouth 12/11/08, Stored FGS
Below machines are on t						
1657	118894	Unknown	Unknown	Unknown		Unknown
1673	117524	Unknown	Unknown	Unknown		Unknown
1686	118891	Unknown	Unknown	Unknown		Unknown

Falmouth Flow Meters - I

Serial #	DEP Property #	Data Download Dates - - - - - - - - - -										
1889	132314	01/07/09	02/05/09									
1890	132316											
1891	132315	01/07/09	02/05/09									
1892	132311											
1893	132312	01/07/09	02/05/09									
1894	132313											
1665	117526	01/07/09	02/05/09									
1669/1453	118896											
1674/1437	117525											
1677/1454	118895											
1678/1455	118897											
1687	118892	01/07/09	02/05/09									
1688	118893	01/07/09	02/05/09									
1788	122232											
1789	122231											
Below machines are on t												
1657	118894											
1673	117524											
1686	118891											

Insitu Filter Fluorometer - Instrument Tracking Sheet ***Sheet last updated:***

Technical Info: http://www-geol.unine.ch/GEOMAGNETISME/tract.html
Manufacturer Contact: Who is the Person?
Manufacturer Contact Phone #: What's their phone number?

Serial #	DEP Property #	Type	Purchase Date	Current Deployment Location	Date of Current Deployment	Data Collection Frequency	Working Status	Logger Dry Plug Status	Cable Dry Plug Status	Sonde Wet Plug Status	Cable Wet Plug Status	Cable Status
193	None	Schnegg New	Unknown	FGS	NA	NA	Working	Good	Good	Good	Good	Good
192	None	Schnegg New	Unknown	FGS	NA	NA	Working	Good	Good	Corroded	Corroded	Good
191	None	Schnegg New	Unknown	FGS	NA	NA	Unknown	Good	Good	Good	Good	Cut
190	None	Schnegg New	Unknown	FGS	NA	NA	Unknown	Good	Good	Corroded	Corroded	Abraded
152	124571	Schnegg Old	Unknown	FGS	NA	NA	Working	Good	Damp	Damp	Damp	Good-Stained
148	124569	Schnegg Old	Unknown	FGS	NA	NA	Unknown	Good	Good	Corroded	Corroded	Good-Stained
149	124570	Schnegg Old	Unknown	FGS	NA	NA	Working	Unknown	Unknown	Unknown	Unknown	Unknown

Notes

Marks "Prior to" Dates
NA *Not Applicable*

Insitu Filter Fluorometer

Serial #	DEP Property #	Desecant Status	Responsible Project Manager	Field Service Technician	Last House Inspection Date	Last Manuf. Service Date	Maintenance Required	Previous Deployment Location	Date of Last Deployment	Date of Retreival
193	None	Needs Baking	Rodney DeHan	Scott Dyer	Unknown	None	None	Unknown	NA	NA
192	None	Needs Baking	Rodney DeHan	Scott Dyer	Unknown	None	None	Spring Creek #2	4/25/2008	8/5/2008
191	None	Needs Baking	Rodney DeHan	Scott Dyer	Unknown	None	None	Revel Sink	6/3/2008	9/2/2008
190	None	Needs Baking	Rodney DeHan	Scott Dyer	Unknown	None	Fix Connectors	Unknown	NA	NA
152	124571	None	Rodney DeHan	Scott Dyer	Unknown	None	None	Spring Creek #2	4/25/2008	8/5/2008
148	124569	Needs Baking	Rodney DeHan	Scott Dyer	Unknown	None	None	Wakulla K-Tunnel	6/3/2008	9/2/2008
149	124570	Unknown	Rodney DeHan	Scott Dyer	Unknown	None	Unknown	Unknown	NA	NA

Insitu Filter Fluorometer

Serial #	DEP Property #	Other / Comments	Deployment History	Data Download Dates - - - - - - - - - -				
193	None							
192	None							
191	None							
190	None							
152	124571	missing tool box						
148	124569	missing tool box						
149	124570							

Water Level Meters
Instrument Tracking Sheet

Sheet last updated: **2/5/2009**

Technical Info In-Situ: http://www.in-situ.com/In-Situ/Products/LevelTROLL/LevelTROLL500.html
In-Situ Contact: John In-Situ Contact Phone #: 800 4INSITU (446-7488)
Technical Info Global Water: http://www.globalw.com/products/wl16.html
Global Contact: Jesse, Rob, Ben Global Water Contact Phone #: 800 876 1172

Serial #	DEP Property #	Type	Purchase Date	Current Deployment Location	Date of Current Deployment	Status	Data Collection Frequency	Responsible Project Manager	Field Service Technician	Last House Inspection Date	Last Manuf. Service Date	Maintenance Required
107893	128662	In-Situ	Unknown	Turner Sink	8/20/2008	Working	Monthly	Rodney DeHan	Scott Dyer	Fall 08	None	None
107898	128661	In-Situ	Unknown	Sullivan Sink	9/9/2008	Working	Monthly	Rodney DeHan	Scott Dyer	Fall 08	None	None
107904	128664	In-Situ	Unknown	St. Marks River Rise	10/20/2008	Working	Monthly	Rodney DeHan	Scott Dyer	Fall 08	None	None
107905	128665	In-Situ	Unknown	FGS	Unknown	Dead	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	Manuf. Repair
107906	128666	In-Situ	Unknown	Tobacco Sink	8/19/2008	Working	Monthly	Rodney DeHan	Scott Dyer	Fall 08	None	None
107917	128667	In-Situ	Unknown	FGS	Unknown	Working	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	None
107927	128669	In-Situ	Unknown	Lost Creek	12/17/2008	Working	Monthly	Rodney DeHan	Scott Dyer	Fall 08	None	None
107922	128663	In-Situ	Unknown	Revel Sink	8/18/2008	Working	Monthly	Rodney DeHan	Scott Dyer	Fall 08	None	None
107924	128668	In-Situ	Unknown	Wakulla T-Dock	8/14/2008	Working	Monthly	Rodney DeHan	Scott Dyer	Fall 08	None	None
41453	124864	Global	Unknown	FGS	NA	Damaged Working	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	Manuf. Repair
41454	None	Global	Unknown	Smokehouse Sink	Unknown	Not Responding	Unknown	Rodney DeHan	Scott Dyer	Unknown	None	Manuf. Repair
41455	124865	Global	Unknown	Wakulla B/C Well	Unknown	Working	2 weeks	Rodney DeHan	Scott Dyer	Unknown	None	Manuf. Repair
41456	124866	Global	Unknown	FGS	NA	Working	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	None
41457	None	Global	Unknown	FGS	NA	Damaged Working	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	Manuf. Repair
41458	124869	Global	Unknown	FGS, sending to Global for upgrade	NA	Dead	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	Manuf. Repair
41459	124868	Global	Unknown	FGS, sending to Global for upgrade	NA	Dead	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	Manuf. Repair
41461	124867	Global	Unknown	Wakulla D/AD Well	Unknown	Working	2 weeks	Rodney DeHan	Scott Dyer	Unknown	None	Manuf. Repair
41462	None	Global	Unknown	FGS	NA	Damaged Working	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	Manuf. Repair
41463	124860	Global	Unknown	FGS, sending to Global for upgrade	NA	Dead	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	Manuf. Repair
41464	None	Global	Unknown	FGS	NA	Working	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	None
41465	124859	Global	Unknown	FGS, sending to Global for upgrade	NA	Dead	Unknown	Rodney DeHan	Scott Dyer	Fall 08	None	Manuf. Repair

Notes

Marks "Prior to" Dates
NA *Not Applicable*

Water Level Meters
Instrument Tracking Sheet

Sheet last updated: **2/5/2009**

Serial #	DEP Property #	Type	Previous Deployment Location	Date of Last Deployment	Date of Retreival	Other / Comments	Deployment History
107893	128662	In-Situ	None	NA	NA		
107898	128661	In-Situ	None	NA	NA		
107904	128664	In-Situ	None	NA	NA		
107905	128665	In-Situ	Wakulla K-Tunnel	Unknown	Fall 08	bad battery or memory full	
107906	128666	In-Situ	None	NA	NA		
107917	128667	In-Situ	H2H Reno	Unknown	Unknown		
107927	128669	In-Situ	H2H Reno	Unknown	Unknown		
107922	128663	In-Situ	None	NA	NA		
107924	128668	In-Situ	None	NA	NA		
41453	124864	Global	Unknown	Unknown	Unknown	cracked cable housing	
41454	None	Global	Unknown	Unknown	Unknown	on’t calibrate	
41455	124865	Global	None	NA	NA	cracked cable housing	
41456	124866	Global	None	NA	NA		
41457	None	Global	Unknown	Unknown	Unknown	cracked cable housing	
41458	124869	Global	Wakulla K/AK Well	Unknown	Unknown	SentTo Global for upgrade	
41459	124868	Global	Unknown	Unknown	Unknown	SentTo Global for upgrade	
41461	124867	Global	None	NA	NA	cracked cable housing	
41462	None	Global	Unknown	Unknown	Unknown	cracked cable housing	
41463	124860	Global	Unknown	Unknown	Unknown	SentTo Global for upgrade	
41464	None	Global	Unknown	Unknown	Unknown		
41465	124859	Global	Unknown	Unknown	Unknown	SentTo Global for upgrade	

Notes

NA

Water Level Meters
Instrument Tracking Sheet

Sheet last updated: **2/5/2009**

Serial #	DEP Property #	Type	Data Download Dates - - - - - - - - - -										
107893	128662	In-Situ		01/29/09									
107898	128661	In-Situ		01/29/09									
107904	128664	In-Situ		01/29/09									
107905	128665	In-Situ											
107906	128666	In-Situ		01/29/09									
107917	128667	In-Situ											
107927	128669	In-Situ		01/29/09									
107922	128663	In-Situ		01/29/09									
107924	128668	In-Situ		01/29/09									
41453	124864	Global											
41454	None	Global											
41455	124865	Global	01/07/09	02/05/09									
41456	124866	Global											
41457	None	Global											
41458	124869	Global											
41459	124868	Global											
41461	124867	Global		02/05/09									
41462	None	Global											
41463	124860	Global											
41464	None	Global											
41465	124859	Global											

Notes

NA

Water Pumps - Tracking Sheet

Sheet last updated:

	Totals
Excellent	*0*
Good	*0*
Fair	*0*
Poor	*0*
Dead	*0*

Peristaltic Pump Info: http://www.geotechenv.com/newfiles/geotechperistaltic.html
FlowJet Pump Info: http://www.flojet.com/products/rvcaravan/water_system_pumps/quad_water_system_pumps_4xx5_series/iid_2507/index.htm
Global Water Submersible Info: http://www.globalw.com/products/subpump.html
Global Water Inline Info: http://www.globalw.com/products/inpump.html

Pump #	DEP Property #	Type	Purchase Date	Status	Max Lift (ft)	Last House Inspection Date	Current Deployment Location	Date of Current Deployment	Responsible Project Manager	Field Service Technician	Other / Comments
1	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
2	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
3	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
4	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
5	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
6	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
7	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
8	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
9	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
10	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
11	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
12	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
13	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
14	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
15	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
16	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
17	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
18	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
19	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	
20	?	Unknown	Unknown	Unknown		Unknown	FGS	NA	Rodney DeHan	Scott Dyer	

Notes

	Marks "Prior to" Dates
NA	*Not Applicable*

Water Pumps - Tracking

Pump #	DEP Property #	Service/Repair Dates - - - - - - - - - -										
1	?											
2	?											
3	?											
4	?											
5	?											
6	?											
7	?											
8	?											
9	?											
10	?											
11	?											
12	?											
13	?											
14	?											
15	?											
16	?											
17	?											
18	?											
19	?											
20	?											