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SUBMERGED SPRINGS SITE DOCUMENTATION: AUGUST AND SEPTEMBER 2007

Submerged Springs Site Documentation: August and September 2007

For:

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Submerged Springs Site Documentation: August and September 2007

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to assist in ground-truth investigations and the site documentation of various submerged springs and other undocumented sites that were identified as possible groundwater discharge locations by aerial thermography. KES also provided assistance to the SJRWMD and USGS with water sample collection for water quality analysis, and conducted discharge measurements as part of the Silver Springs Characterization Project.

PURPOSE and SCOPE OF WORK

The purpose and objective of this work was to:

1. Collect additional water quality samples, perform discharge measurements, and document measurement point conditions at 5 submerged spring vents of the Silver Springs Group and in the Silver River as part of the Silver Springs Characterization Project.

2. Provide submerged spring point documentation of groundwater discharges at one location in Blue Spring Run (Volusia County), three areas in the Silver River, and as many sites that could be visited for locations identified in the Wekiva River, Crescent Beach Spring, Shands Bridge Spring, the Rodman Reservoir and Ocklawaha River, Lake Harris and near Driggers Island in the St. Johns River.

The following tasks were to be performed at numerous locations within the District:

1. Spring Point Documentation at all located spring vents.

2. Water Quality Sampling at selected springs.

3. Spring Flow Measurements and Spring Flow Measurement Point Documentation at selected previously measured springs, and at un-measured springs investigated during this study that were suitable for the application of KES underwater measurement techniques.

PERSONNEL

Fieldwork was conducted by Peter Butt, Project Manager, Tom Morris, Biologist, and Mark Long, Field Technician. Videography was performed by Mark Long. Data management and report preparation was performed by Peter Butt and Tom Morris. Video was processed, edited and annotated by Georgia Shemitz.

METHODS

The fieldwork for this study was carried out during the months of August and September, 2007.

GPS positions were taken from GIS imagery, and confirmed or corrected in the field. The latitude and longitude presented herein is in WGS84, and the UTM Easting and Northing data is in meters, and in UTM Zone 17, NAD 1983 HARN.

Physical measurements of the springs were taken using fiberglass tape and underwater compass, with data recorded on plastic slates.

Underwater video was taken at each site where spring vents were present.

At selected Silver Springs Group sites and at Shands Bridge Spring, KES divers assisted SJRWMD and USGS personnel in collecting water samples from individual spring vents. Samples were collected by divers running tubing connected to pumps on watercraft directly into spring vents. Water was analyzed on-site for field parameters and collected samples were sent by SJRWMD and USGS to labs for further analysis.

Discharge measurements were taken at selected spring vents. These measurements were taken using an electronic flowmeter adapted for underwater use. Three of the springs were measured using the standard cross-section method used by KES. Three springs (discharging through soft bottom sediments and algae) that did not lend themselves to this method were measured using a Vent Discharge Capture Device specially designed for this purpose. Data was processed using Golden Surfer 8 software. The results and summary of these measurements are presented under separate cover.

A brief narrative description of each of the various springs or spring groups is presented herein.

SITE DESCRIPTIONS

Rodman Reservoir/Ocklawaha River Springs

These following Rodman Reservoir/Ocklawaha River spring sites were all visited on August 29, 2007 by Pete Butt, Tom Morris and Mark Long, accompanied by Jeff Davis of the SJRWMD.

Blue Spring (Marion County)
Marion County
N 29.514404°, W 81.856850°
UTM 416958 E, 3265285 N
Description:
This is the most downstream of the spring vents visited in Rodman Reservoir. This spring lies within a basin with a steeply sloping north (and shoreward) side. Strands of aquatic vegetation extending from the bottom to the surface were present. No boil was visible on the surface during the August 29 and September 27, 2007 visits, but a thermocline was present. The spring has two distinct vents discharging from bedrock, both too small for a diver to enter. The upper vent is an elongated irregular opening, with a horizontal cross-section about 1.5 feet wide by about 5.5 feet long, and begins at a depth of 29 feet. The lower vent is located directly below the upper vent, in about 33 feet of depth. This vent has a vertical cross-section of about 3 feet wide by 2 feet high, and is roughly triangular in shape. A large timber was lying above the vents. Silt around the vents was easily disturbed.

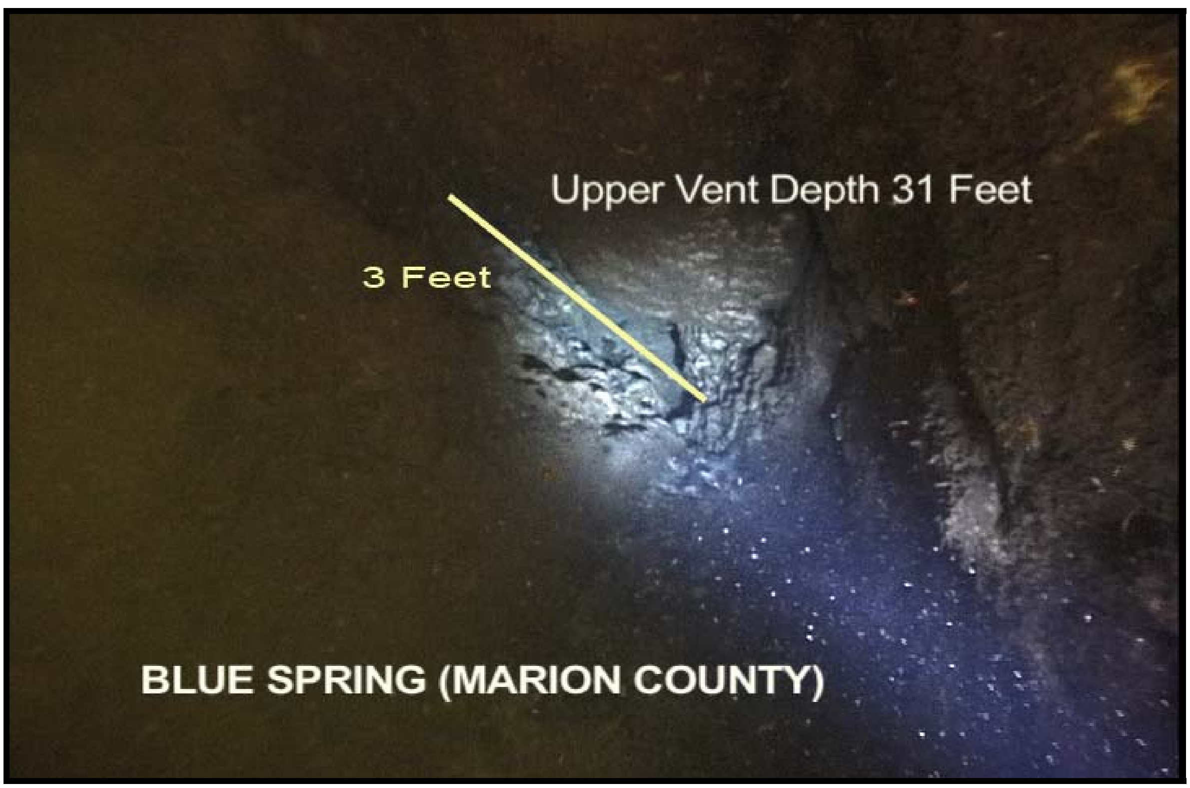

Figure 1. Underwater video still of Blue Spring (Marion County). View of the upper vent measurement cross-section.

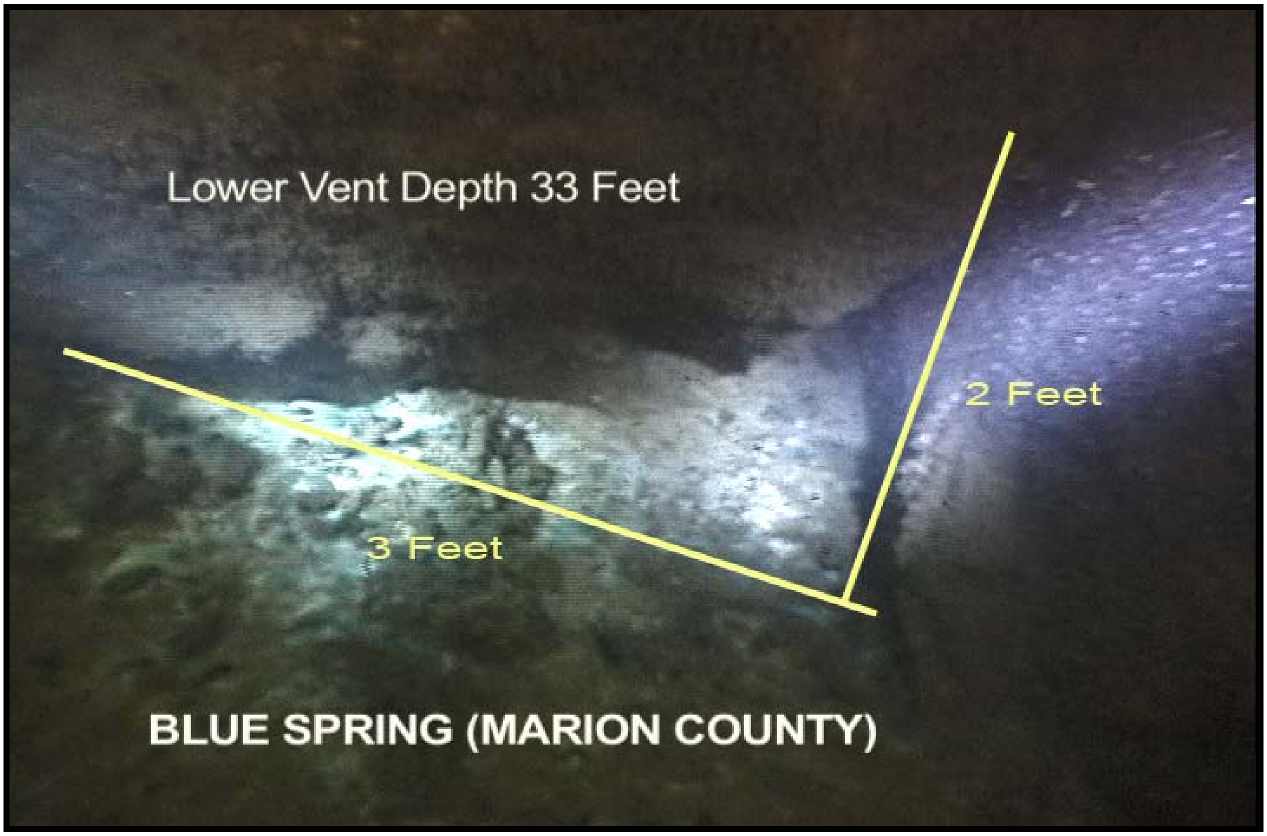

Figure 2. Underwater video still of Blue Spring (Marion County). View of the lower vent.

Bright Angel Spring
Marion County
N 29.516572°, W 81.862090°
UTM 416452 E, 3265529 N
Description:
This spring lies within a large basin about 30 feet in diameter about 560 meters northwest of Blue Spring. Timbers of various sizes are scattered about the bottom. No boil was visible on the surface during the August 29 and September 27, 2007 visits. A thermocline was present, at about 9 to 10 feet deep, with clear water below. The spring has one long vent discharging south to north from bedrock, and is too small for a diver to enter. The vent is at least 10 feet wide, with a horizontal cross-section about 1.5 feet high at its eastern side, and tapering down to a few inches high at its west end. The top of the vent is at about 24 feet of depth, and the bottom is at 26 feet deep. The bottom of the vent is composed of loose rock, rubble and silt. Silt around the vent was easily disturbed.

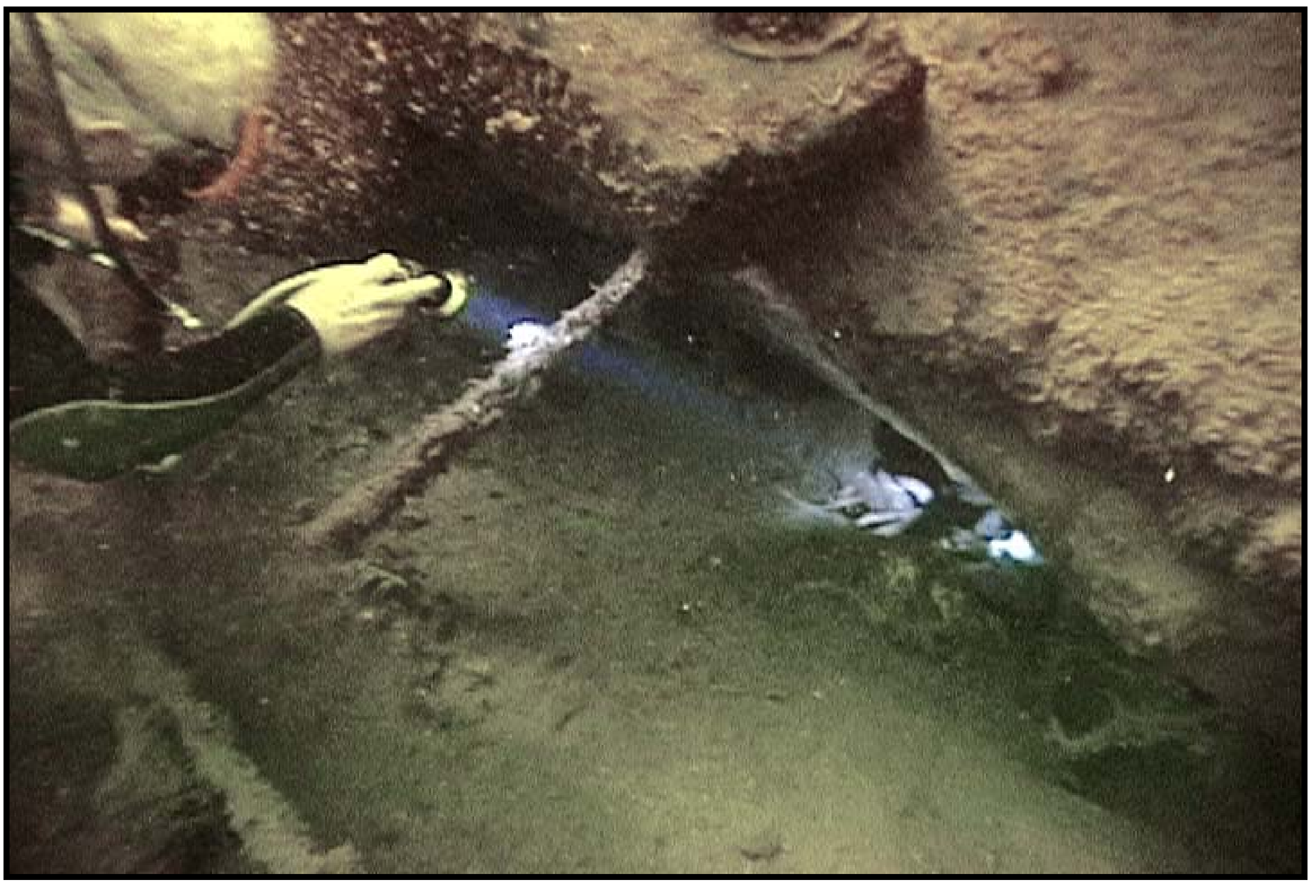

Figure 3. Underwater video still of Bright Angel Spring, Marion County, Florida. The diver is illuminating the higher eastern side of the vent.

Catfish Spring
Marion County
N 29.515419°, W 81.861750°
UTM 416484 E, 3265401 N
Description:
This spring lies in an area of heavy aquatic vegetation about 132 meters south of Bright Angel Spring and about 485 meters west-northwest of Blue Spring. No boil was visible on the surface during the August 29 visit. The spring has one vent discharging from bedrock, too small for a diver to enter. The vent was at about 18 to 20 feet of depth. Discharge from this vent was very weak.

Figure 4. Underwater video still of Catfish Spring, Marion County, Florida.

Bamboo Spring
Marion County
N 29.515847°, W 81.866716°
UTM 416003 E, 3265452 N
Description:
This spring lies in an area of heavy aquatic vegetation about 450 meters west of Bright Angel Spring. The vent was located in an area marked by bamboo poles stuck into the bottom, apparently as markers for fisherman. No boil was visible on the surface during the August 29 visit. This spring had a cluster of small vents discharging from vegetated soft sediments. The vent area is at about 8 feet of depth. Discharge from this spring was very weak.

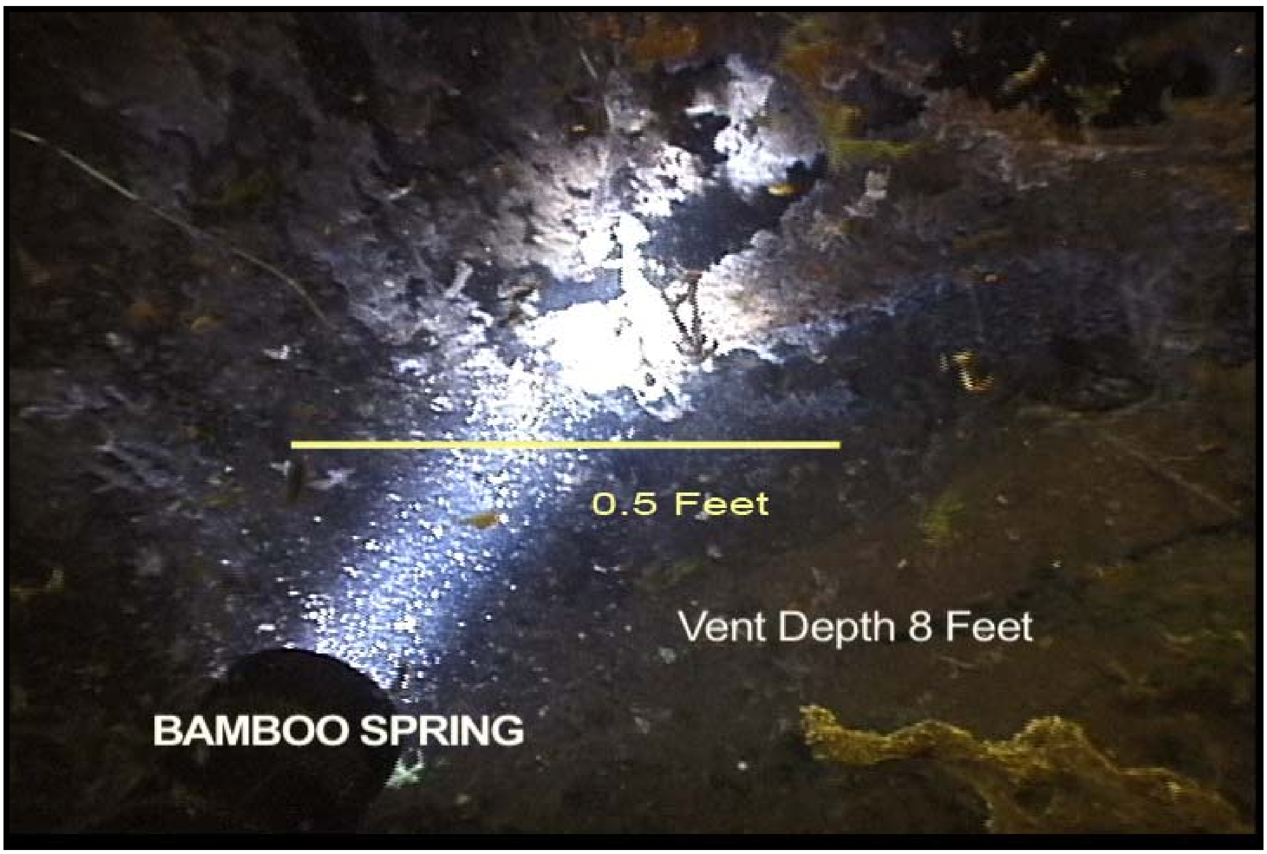

Figure 5. Underwater video still of Bamboo Spring, Marion County, Florida.

Trench Seep
Marion County
N 29.516670°, W 81.868330°
UTM 415842 E, 3265531 N
Description:
This seep area is located in an area of heavy aquatic vegetation northwest of Bamboo Spring. The clear, cooler water that identifies the seep area was located in channels between areas of thick aquatic vegetation. No actual vents were visible during the August 29, 2007 visit. This seep apparently discharges through vegetated soft sediments. The seep area is at about 10 feet deep.

Figure 6. Underwater video still of Trench Seep, Marion County, Florida. This view is typical of bottom conditions in the cool water areas.

Sim’s Spring
Marion County
N 29.508108°, W 81.892010°
UTM 413545 E, 3264613 N
Description:
Sim’s Spring is identified by its surrounding man-made concrete structure, which apparently contained the spring and functioned as a control structure. A walkway leads up the shore slope to a small building that appears to have been a pump house. The pool within the concrete structure was searched, and although bedrock could be seen, there was no apparent discharge. Water depth was about 4 feet deep during the August 29, 2007 visit.

Figure 7. Video still of Sim's Spring, Marion County, Florida. The apparent vent is under the concrete wall on the left. The vertical slot behind the diver on the right is a discharge control structure.

Fish Hook Spring #1
Marion County
N 29.509479°, W 81.901514°
UTM 412625 E, 3264772 N
Description:
This spring lies in an area of heavy aquatic vegetation along the south shore of the reservoir, and about 91 meters east of Fish Hook Spring #2. No boil was visible on the surface during the August 29 visit. This spring has one vent of less than 2 feet in diameter discharging from bedrock and loose rock through soft sediments. The vent is about 8 feet deep. Discharge from this vent was very weak.

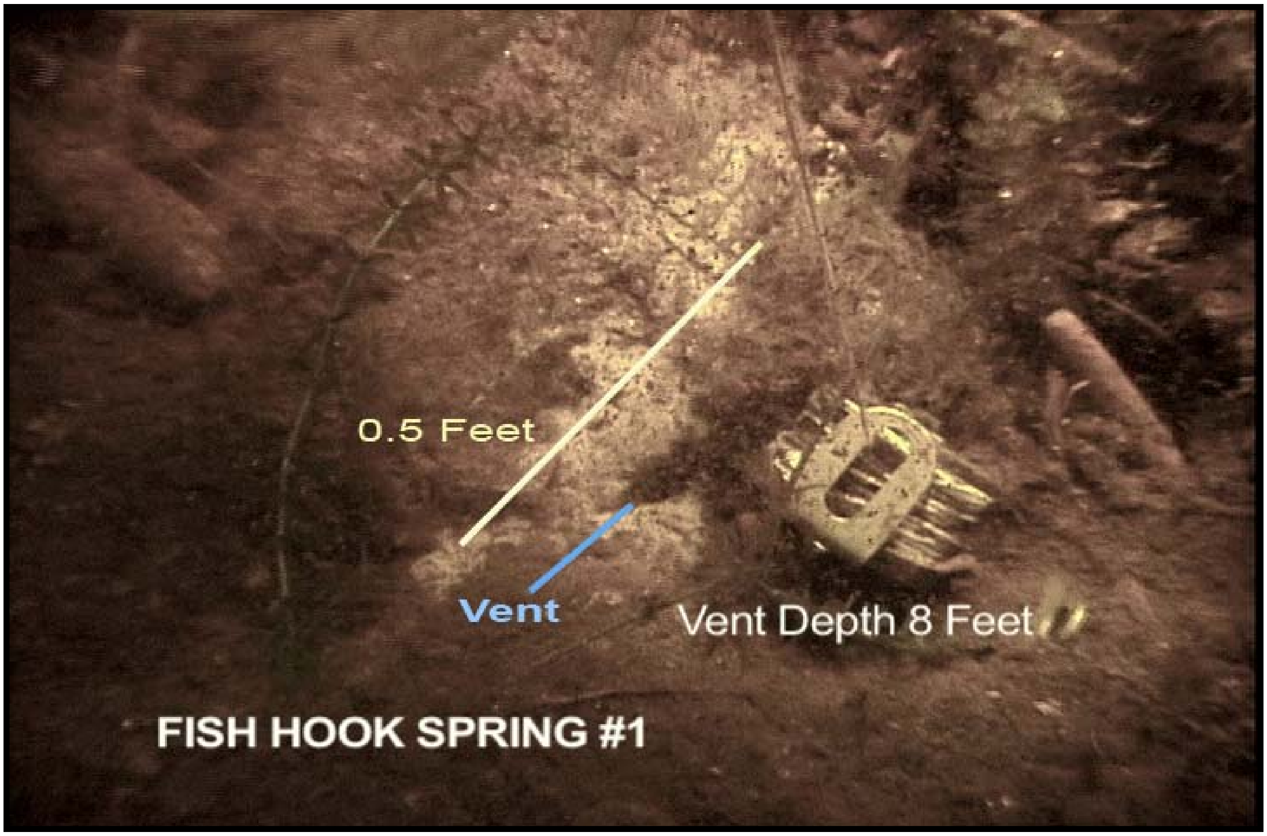

Figure 8. Underwater video still of Fish Hook Spring #1, Marion County, Florida.

Fish Hook Spring #2
Marion County
N 29.509041°, W 81.902304°
UTM 412548 E, 3264724 N
Description:
This spring lies in an area of heavy aquatic vegetation along the south shore of the reservoir, and about 91 meters west of Fish Hook Spring #1. No boil was visible on the surface during the August 29 visit. This spring has a vent area of about 10 feet in diameter discharging from bedrock through a jumble of loose rock and timbers. The vent is about 8 feet deep. Discharge from this vent was weak.

Figure 9. Underwater video still of Fish Hook Spring #2, Marion County, Florida. Shown is one of several vents discharging through a jumble of loose rock and timbers

Floating Dock Anomaly
Marion County
N 29.512660°, W 81.868350°
UTM 415842 E, 3265100 N
Description:
The area searched lies within a bay along the south shore, and near some docks and piers. The bay is in an area of heavy aquatic vegetation. No obvious spring vents, seeps or areas of cooler water were located after extensive snorkeling of the area.

These following Rodman Reservoir/Ocklawaha River spring sites were all visited on August 30, 2007 by Pete Butt, Tom Morris and Mark Long, accompanied by Jeff Davis of the SJRWMD.

No-Name Seep #2
Marion County
N 29.501785°, W 81.912804°
UTM 411524 E, 3263928 N
Description:
This seep area lies in an area of heavy aquatic vegetation. The clear, cooler water that identifies the seep area was located in open areas surrounded by thick aquatic vegetation. The seep formed a cool water layer about a foot thick over the bottom, and no actual vents were visible during the August 30, 2007 visit. This seep apparently discharges through vegetated soft sediments. The seep area is at about 6 feet deep.

No-Name Seep #3
Marion County
N 29.506118°, W 81.910047°
UTM 411795 E, 3264406 N
Description:
This seep area lies in an area of heavy aquatic vegetation. The clear, cooler water that identifies the seep area was located in open areas surrounded by thick aquatic vegetation. The seep formed a cool water layer about a foot thick over the bottom, and no actual vents were visible during the August 30, 2007 visit. This seep apparently discharges through vegetated soft sediments. The seep area is at about 5 feet deep.

Lake Harris Springs

These following Lake Harris spring sites were all visited on September 12, 2007 by Tom Morris and Mark Long, accompanied by Jeff Davis of the SJRWMD.

Site 1 Spring Pool and Outfall
Lake County
N 28.746550°, W 81.798470°
UTM 422039 E, 3180167 N
Description:
The Site 1 Spring Pool and Outfall is located along the southern shoreline of Lake Harris. The assumed spring pool is several hundred feet from the lake, in a mature forested wetland (bayhead). The circular pool was about six feet across and six feet deep and contained cool and slightly tannic water, but no vents were found. Discharge from the pool appears to flow down a small heavily vegetated channel excavated during the construction of a small causeway through the wetland. No discharge was apparent from the pool on September 12, 2007. However, farther downstream, water was flowing fairly vigorously from the bayhead into the littoral zone of the lake. This suggests that the site may be an area of general groundwater seepage, or that undetected vents are hidden in the vegetation of the drainageway.

Figure 10. Video still of Lake Harris Site 1 Spring Pool, Lake County, Florida.

Dock Spring
Lake County
N 28.748366°, W 81.802416°
UTM 421655 E, 3180371 N
Description:
Dock Spring is located along the southern shoreline of Lake Harris, within the littoral zone. The cool water of the spring discharges into a metal casement, about four feet in diameter and five feet tall, that has been placed over the spring. The pipe, which is attached to a dock, acts as a reservoir for a small watering system. The water surface in Lake Harris was low at the time of the visit, and the pipe was just at the waterline. Nonetheless, the water level in the pipe was about three feet above the water level in the lake.

Figure 11. Video still of Lake Harris Dock Spring, Lake County, Florida. Spring is encased in large diameter steel casing below pumps on right side of picture.

Twin Sand Boils Spring
Lake County
N 28.747431°, W 81.804908°
UTM 421411 E, 3180269 N
Description:
Twin Sand Boils Spring is located in the littoral zone of the southern shoreline of Lake Harris. This feature consists of two small sand boils, each several inches in diameter and about a foot apart, in an area of very shallow water (less than 0.5 feet) and somewhat sparse emergent vegetation. The cool temperature of the discharge relative to the warm lake water suggests a groundwater source.

Figure 12. Video still of Lake Harris Twin Sand Boils Spring, Lake County, Florida.

Cypress Tree Seep
Lake County
N 28.748069°, W 81.803837°
UTM 421516 E, 3180339 N
Description:
Cypress Tree Seep is located in the littoral zone of the southern shoreline of Lake Harris. This feature is an area of notably cool water, no more than several inches deep, and about ten feet in diameter. No vent was found, but the relatively cool temperature of the seep area, when compared with the surrounding warm water of the lake, indicates discharge of groundwater. The shallow water in and around the seep supports emergent vegetation, and the feature is named after a nearby cypress tree.

Figure 13. Video still of Lake Harris Cypress Tree Seep, Lake County, Florida.

Sandy's Spring
Lake County
N 28.745080°, W 81.810154°
UTM 420897 E, 3180012 N
Description:
Sandy's Spring is located at the head of a small run about 200 feet from the southern shoreline of Lake Harris. The spring run discharges into the littoral zone of the lake after flowing through a small culvert under Lakeshore Drive. The spring vent is located in a roughly circular pool, which is about ten feet in diameter, and about six feet deep. Groundwater gently discharges from a linear vent about two feet long at the deepest part of the spring pool. The vent was partially covered by soft sediments. The spring pool and run are maintained by the owner and are free of aquatic vegetation.

Figure 14. Video still of Sandy's Spring pool, Lake County, Florida.

Figure 15. Underwater video still of Sandy's Spring, Lake County, Florida. The vent at the deepest part of the pool is shown.

Crescent Beach Spring

St. Johns County
N 29.768295°, W 81.207945°
UTM 479898 E, 3293129 N
Description:
Crescent Beach Spring was visited on August 30, 2007 by Peter Butt, Tom Morris and Mark Long. Jeff Davis of the SJRWMD arranged for a District work boat and crew, and provided surface support. A video of the dive here was made.

Upon arrival at the site, a prominent and very cloudy boil, or slick, was present on the ocean surface. The boat was anchored in the depression, and the divers descended down the anchor line to the bottom. Upon reaching the bottom, visibility was extremely limited, and a guideline reel was affixed to the anchor line and a sweep was made of the bottom, at depths reaching 130 feet. The water here was very agitated and filled with suspended sediments. The search of the bottom was by feel, and only soft and clay-like sediments and bivalve shells were found. No direct contact was made with any identifiable vents, either visually or by feel.

After exploring the bottom of the depression, the divers ascended the anchor line to about 65 feet deep and then ran a guideline laterally until making contact with the bottom. The divers swam radially, exploring the sloping sides of the depression at 60 to 70 feet of depth. The bottom consisted of soft sediments. No natural bottom structure was encountered that would allow for support of an underwater discharge measurement, and visibility was problematic.

Shands Bridge Spring

St. Johns County
N 29.988461°, W 81.623216°
UTM 439885 E, 3317670 N
Description:
Shands Bridge Spring was visited on August 31, 2007 by Peter Butt, Tom Morris and Mark Long. Jeff Davis of the SJRWMD arranged for a District work boat and crew, and provided surface support. A video of the dive here was made.

Shands Bridge Spring is located in depression in the approximate middle of the St. John's River, downstream of Shands Bridge. No boil or slick was visible during this visit. The general location of the site was located using a depth finder, and then divers found the vent by following water temperature, bottom topography and debris. The spring vent was located beneath a derelict wire crab trap, and discharged up through the trap, at about 28 feet deep. A thick layer of soft organic sediments containing considerable man-made debris surrounded the vent (and crab trap) at the bottom of the depression. The vent could only be viewed by looking down through the upper end of the crab trap, and even then, the vent below was obscured by debris and sediment.

A water sample was collected by divers placing the end of an intake tube through the top of the crab trap and into the clear water directly above the vent.

Figure 16. Underwater video still of Shands Bridge Spring, St. Johns County, Florida. Beam of light is shining down through the crab trap to the debris choked vent below.

Driggers Island Hole, St. Johns River

Volusia County
N 28.998834°, W 81.377810°
UTM 463201 E, 3207915 N
Description:
Driggers Island Hole is a large depression, over sixty feet deep, in the bottom of the St. Johns River, downstream of the Hwy 44 bridge. This feature had been previously located by KES personnel with a depth finder, and its unusual depth suggested the possibility of groundwater discharge. Morris and Long explored the area with SCUBA on September 12, 2007. Jeff Davis of the SJRWMD provided surface support. The divers entered the water from a boat about fifty feet from the east bank and, with the aid of an underwater guideline, explored the river bottom almost over to the west bank, looking for relatively cool and clear groundwater. The maximum depth of the feature was 63 feet deep, and there was no ambient light below about fifteen feet deep. The bottom was composed of soft organic sediments. No groundwater discharge was found. As no groundwater discharges were located here, no photographs or video was taken at the site.

Wekiva River Upstream of Highway 46 Bridge

A section of the Wekiva River upstream of Highway 46 Bridge was visited on August 9, 2007 by Peter Butt, Tom Morris and Mark Long. Jeff Davis and Stan Williams of the SJRWMD provided surface support and watercraft. The only video of activity made here was of a large fossil bone that was forwarded to state park personnel.

Numerous anomaly sites that were identified by aerial thermography as potential spring sites were thoroughly investigated using snorkeling gear. No springs or areas of identifiable groundwater discharge were found. This included the search of main and side channel areas. The only vent-like features observed were those created near the “old trestle” area in the clay bottom sediments by exotic armored catfish.

Blue Spring State Park; Recon of Main Spring and Spring Run/St. Johns River Confluence

The headspring, run and St. Johns River confluence of Blue Spring at Blue Springs State Park area was visited on August 8, 2007 by Peter Butt, Tom Morris and Mark Long. Jeff Davis and Stan Williams of the SJRWMD provided surface support and watercraft. A video of the dive activities in the cavern, run and confluence was made.

The Blue Spring cavern was dived to the bottom by Tom Morris and Mark Long. A maximum depth of 130 feet was reached at the high flow restriction. As the divers ascended, they investigated the sides of the cavern for additional incoming flow of groundwater, including a small side tunnel at about 25 feet deep; no additional flows were found. The high flow restriction at 130 feet deep is the only location through which water enters the cavern. The divers took compass azimuths of the joint alignments of the cavern. These were directly reported to SJRWMD staff.

All three divers investigated the entire length of the spring run, with special attention paid to areas identified by aerial thermography as potential spring vents; none were found.

The prominent anomaly signature area identified by aerial thermography as a potential spring site in the run/river confluence was thoroughly investigated using SCUBA gear. No depressional features, springs or areas of identifiable groundwater discharge were found. Several sweeps were made independently by all three divers, including moving along the river/spring run water interface. The sand/silt bottom was relatively featureless, with widely scattered man-made debris, shell and rubble. Bottom relief was gentle, with a maximum depth of about 17 feet. The water near the bottom in the search area had very good visibility due to the spring water discharging from the run.

Silver River Below the Silver Springs Group

The section of the Silver River downstream of the Silver Springs Group and the 1200 meter gauging station was visited on August 10, 2007 by Peter Butt and Tom Morris. Jeff Davis and Stan Williams of the SJRWMD provided surface support and watercraft. No video of activity here was made.

Numerous anomaly sites that were identified by aerial thermography as potential spring sites were thoroughly investigated using SCUBA and/or snorkeling gear. No springs or areas of identifiable groundwater discharge were found. This included the search of a channel and pond area on the south side of the river. The only vent-like features observed were those created in the clay bottom sediments by exotic armored catfish.

Silver Springs Group Channel and Boat House Vents

Gang of 5 Vent #1
Marion County
N 29.213593°, W 82.052945°
UTM 397652 E, 3232109 N
Description:
The Gang of Five Vent Group lies within a boat channel about 100 meters northeast of the boat house area, and about 60 meters south of a tourist boat dock located on one of the park's islands. All of these vents are approximately 10 feet deep. All discharge directly from bedrock, with varying amounts of loose rock, shells, sand, and dead wood (branches) in them. Vent #5 was the smallest, and the most difficult to collect water samples from.

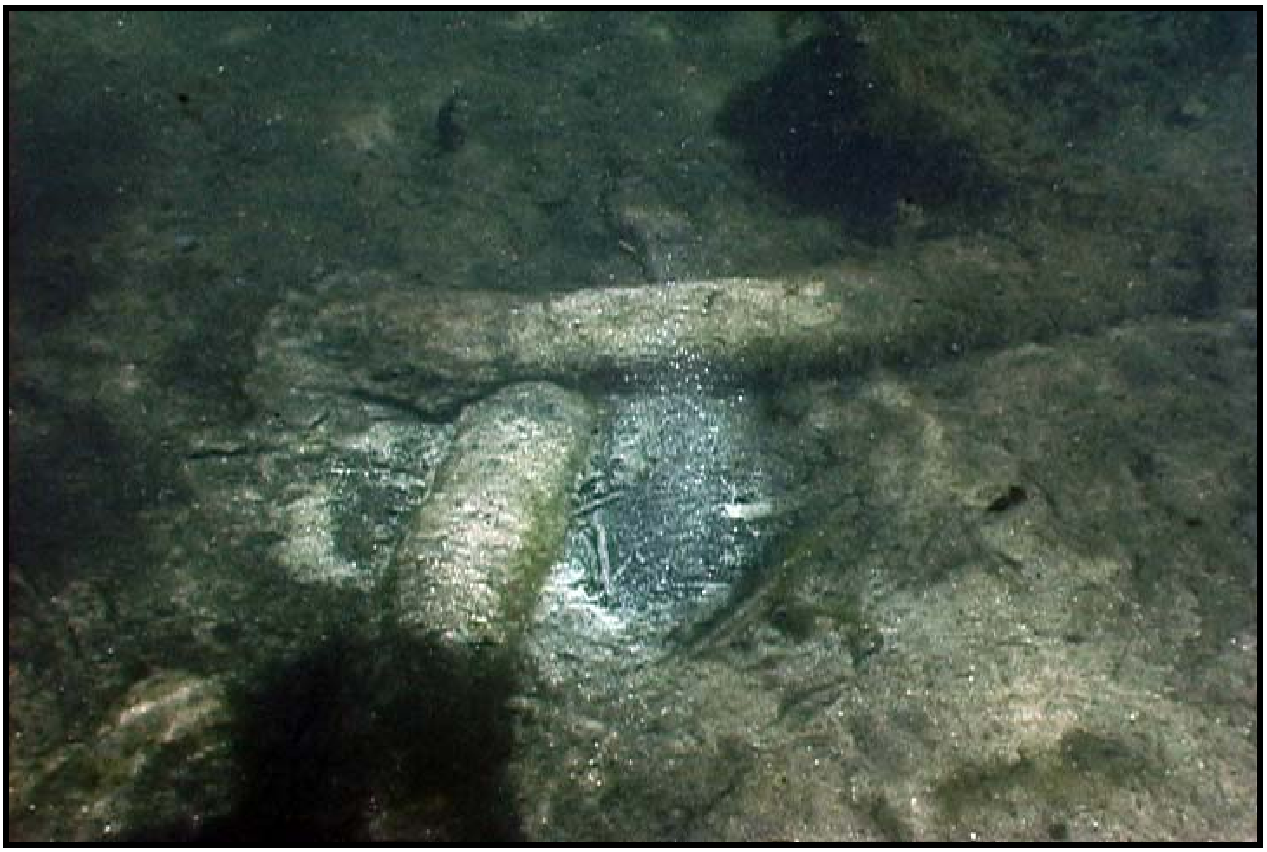

Figure 17. Underwater video still of Gang of 5 Vent #1, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

Gang of 5 Vent #2
Marion County
N 29.213592°, W 82.053058°
UTM 397641 E, 3232109 N

Figure 18. Underwater video still of Gang of 5 Vent #2, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

Gang of 5 Vent #3
Marion County
N 29.213646°, W 82.053058°
UTM 397641 E, 3232115 N

Figure 19. Underwater video still of Gang of 5 Vent #3, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

Gang of 5 Vent #4
Marion County
N 29.213691°, W 82.053079°
UTM 397639 E, 3232120 N

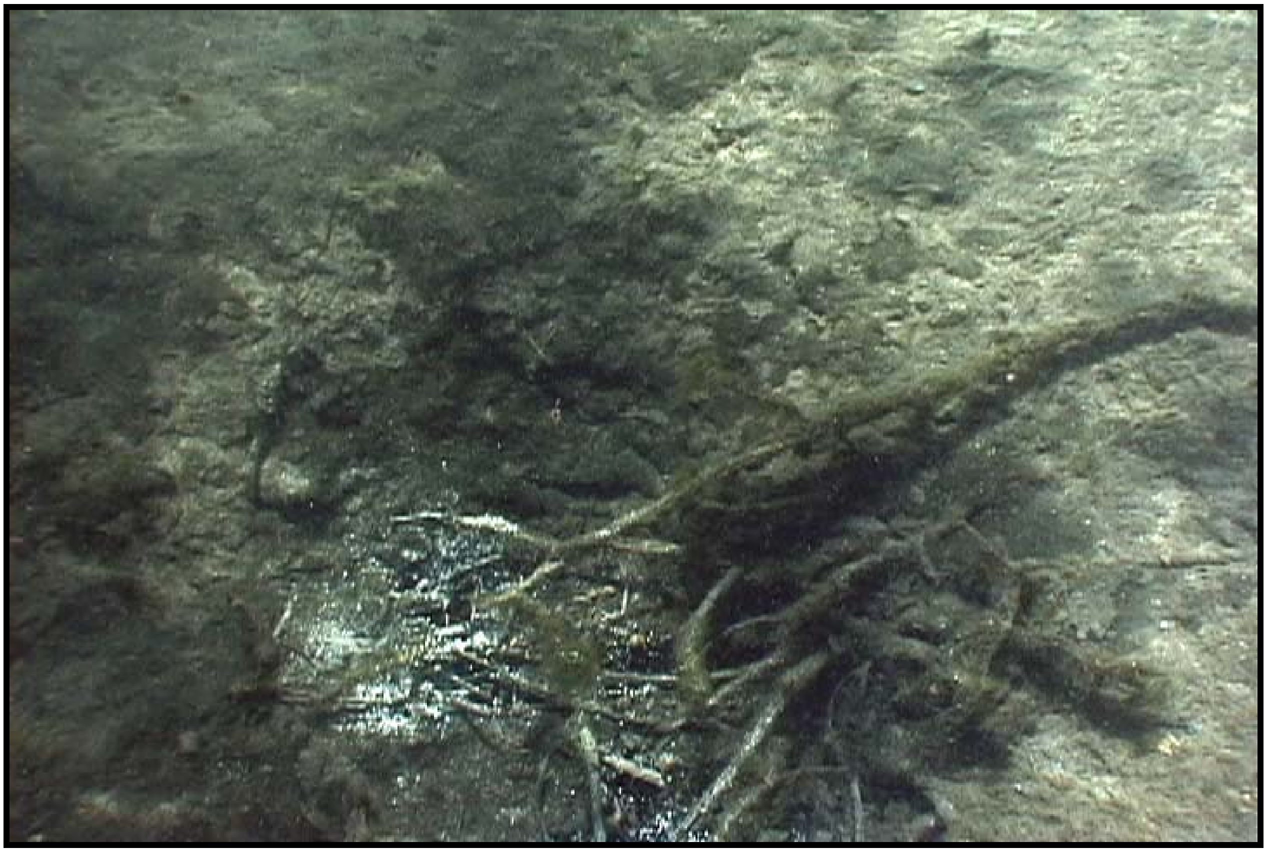

Figure 20. Underwater video still of Gang of 5 Vent #4, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

Gang of 5 Vent #5
Marion County
N 29.213637°, W 82.053079°
UTM 397639 E, 3232114 N

Figure 21. Underwater video still of Gang of 5 Vent #5, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

Sandboil Vent
Marion County
N 29.214100°, W 82.051520°
UTM 397791 E, 3232164 N
Description:
This spring is a small sand boil located on the bottom of the channel, about 225 meters downstream of the boat house. It discharges through sand and soft bottom sediments about 10 feet deep.

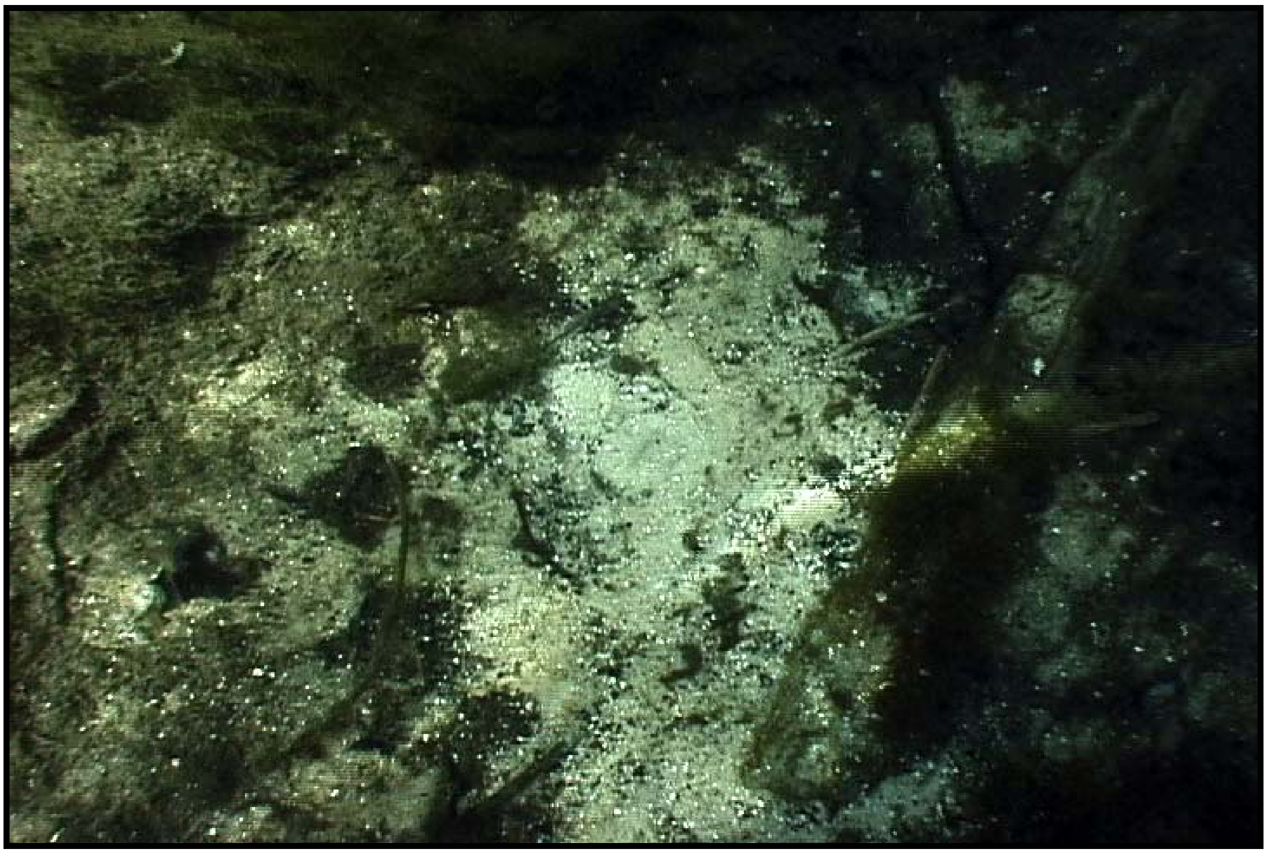

Figure 22. Underwater video still of Sandboil Vent, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

Silver Springs Landing Vent #1
Marion County
N 29.215121°, W 82.046767°
UTM 398254 E, 3232273 N
Description:
These vents form a group, or cluster, in a deeper portion of the channel about 750 meters downstream of the boat house. They are located in front of a park re-creation of an old time Florida river trading post and river boats. They all discharge through sand, soft bottom sediments and heavy detritus at about 13 feet of depth. Vent #1 is the most northern of the vents, Vent #2 is mid-channel, and Vent #3 lies closest to the south bank. Vent #3 has the most aquatic vegetation around it.

Figure 23. Underwater video still of Silver Springs Landing Vent #1, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

Silver Springs Landing Vent #2
Marion County
N 29.215058°, W 82.046746°
UTM 398256 E, 3232266 N

Figure 24. Underwater video still of Silver Springs Landing Vent #2, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

Silver Springs Landing Vent #3
Marion County
N 29.215013°, W 82.046745°
UTM 398256 E, 3232261 N

Figure 25. Underwater video still of Silver Springs Landing Vent #3, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

South Boat House/Christmas Boat Vent
Marion County
N 29.212856°, W 82.053709°
UTM 397577 E, 3232028 N
Description:
This vent has two openings in the rocky bottom in front of the eastern side of the south (main) boathouse. Flow was vigorous from both openings. Aquatic vegetation surrounds the vent, which is 8 feet deep. The name references a glass-bottomed boat berthed nearby that has been outfitted with Christmas lighting.

Figure 26. Underwater video still of South Boat House/Christmas Boat Vent, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

South Boat House Vent #2
Marion County
N 29.212856°, W 82.053688°
UTM 397579 E, 3232028 N
Description:
This vent is located under the roof of the south (main) boathouse in 8 feet of water, just southwest of the Christmas boat vent. The spring discharges from a bedrock vent obscured by sand, and is littered with debris.

Figure 27. Underwater video still of South Boat House Vent #2, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

South Boat House Vent #3
Marion County
N 29.212856°, W 82.053678°
UTM 397580 E, 3232028 N
Description:
This vent is located under the roof of the south (main) boathouse in 8 feet of water, just west of Vent #2. The vent discharges from bedrock mantled by sand, and is littered with debris.

Figure 28. Underwater video still of South Boat House Vent #3, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

North Boat House/Rubber Mask Vent
Marion County
N 29.212982°, W 82.053741°
UTM 397574 E, 3232042 N
Description:
This vent has multiple openings in the rocky bottom in front of (south of) the north boathouse. Flow was vigorous from all openings. Aquatic vegetation surrounds the vent openings, which are 8 feet deep. The name makes reference to a piece of man-made litter that was found during the investigation

Figure 29. Underwater video still of North Boat House/Rubber Mask Vent, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

North Boat House/Silver Queen IV Vent
Marion County
N 29.213054°, W 82.053762°
UTM 397572 E, 3232050 N
Description:
This vent is located under the roof of the north boathouse in 8 feet of water. The vent discharges from bedrock mantled with sand and debris. The name makes reference to an old river boat berthed above it.

Figure 30. Underwater video still of North Boat House/Silver Queen IV Vent, Silver Springs Group Channel and Boat House Vents, Marion County, Florida.

APPENDIX I

Main Silver Springs Group Water Quality Sampling and Discharge Measurements

The following are spring descriptions and maps excerpted from “Silver Springs Spring Vent Documentation, Marion County, Florida; September, 2006”, a report prepared by Karst Environmental Services, Inc. for SJRWMD in 2006 and 2007. These have been edited and are presented as support information relative to the Main Silver Springs Group Water Quality Sampling and Discharge Measurements made during September of 2007 by SJRWMD and USGS. All springs included below were sampled by a SJRWMD contactor on September 4, 2007 for specific parameters. Mammoth East and West, Catfish Hotel, Catfish Convention Hall and Lost River Springs were sampled by USGS personnel on September 5 and 6, 2007. Underwater discharge measurements were made at Mammoth, Catfish Convention Hall and Lost River Springs by KES personnel on September 10 and 11, 2007.

Mammoth Spring
Marion County
N 29.216167°, W 82.052667°
UTM 397670 E, 3232394 N
Description:
This is the largest and most upstream of the spring vents. It discharges horizontally into a large basin just east of the glass-bottom boat loading area. The vent is a horizontal, oval-shaped opening 2 to 6 feet high and about 65 feet wide at the base of a limestone wall. The bottom of the vent’s mouth is composed largely of breakdown boulders and rubble. The depth of water measured in front of the vent opening is about 34 feet. Water from at least two distinct sources (Mammoth East and Mammoth West) discharge from the cave opening. These sources differ in temperature and chemistry. The spring basin measures about 300 feet north to south and 200 feet east to west.

Figure 31. Mammoth Spring, Silver Springs Group, Marion County, Florida. Viewed from inside the cavern looking out. Discharge measurement supports are in place.

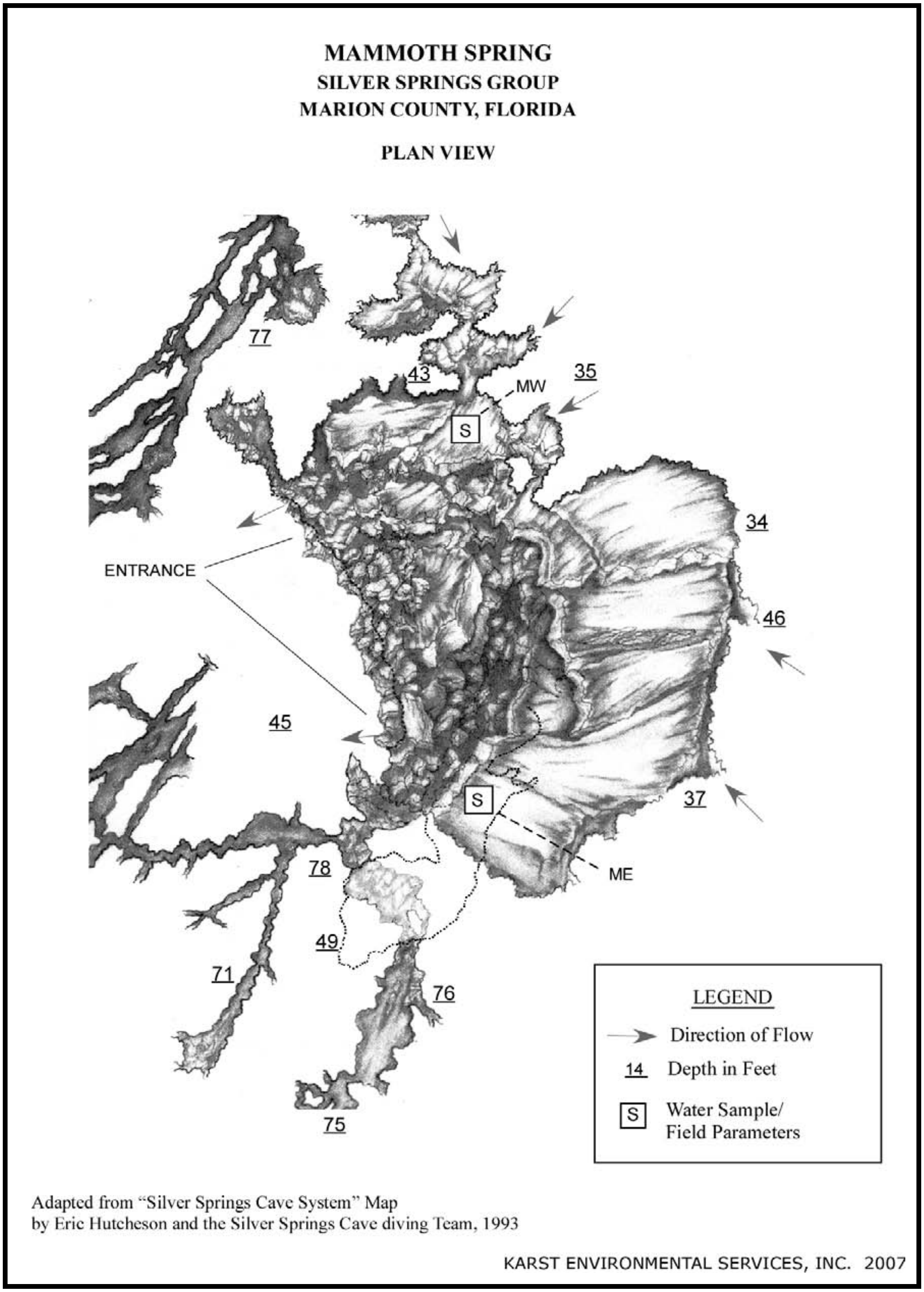

Figure 32. Map of Mammoth Spring, Silver Springs Group, Marion County, Florida.

Oscar Spring
Marion County
N 29.215283°, W 82.051533°
UTM 397791 E, 3232294 N
Description:
Oscar Spring is a group of spring vents in a shallow depression on the north side of the center of the river channel, about 140 feet northeast of Jacob’s Well Spring. There are three small vents in the depression, one of which discharges from a marl ledge, and a line of vents about 8 feet long about ten feet to the southwest of the marl ledge. The deepest part of the depression is about 17 feet deep.

Figure 33. Underwater photograph of Oscar Spring, Silver Springs Group, Marion County, Florida.

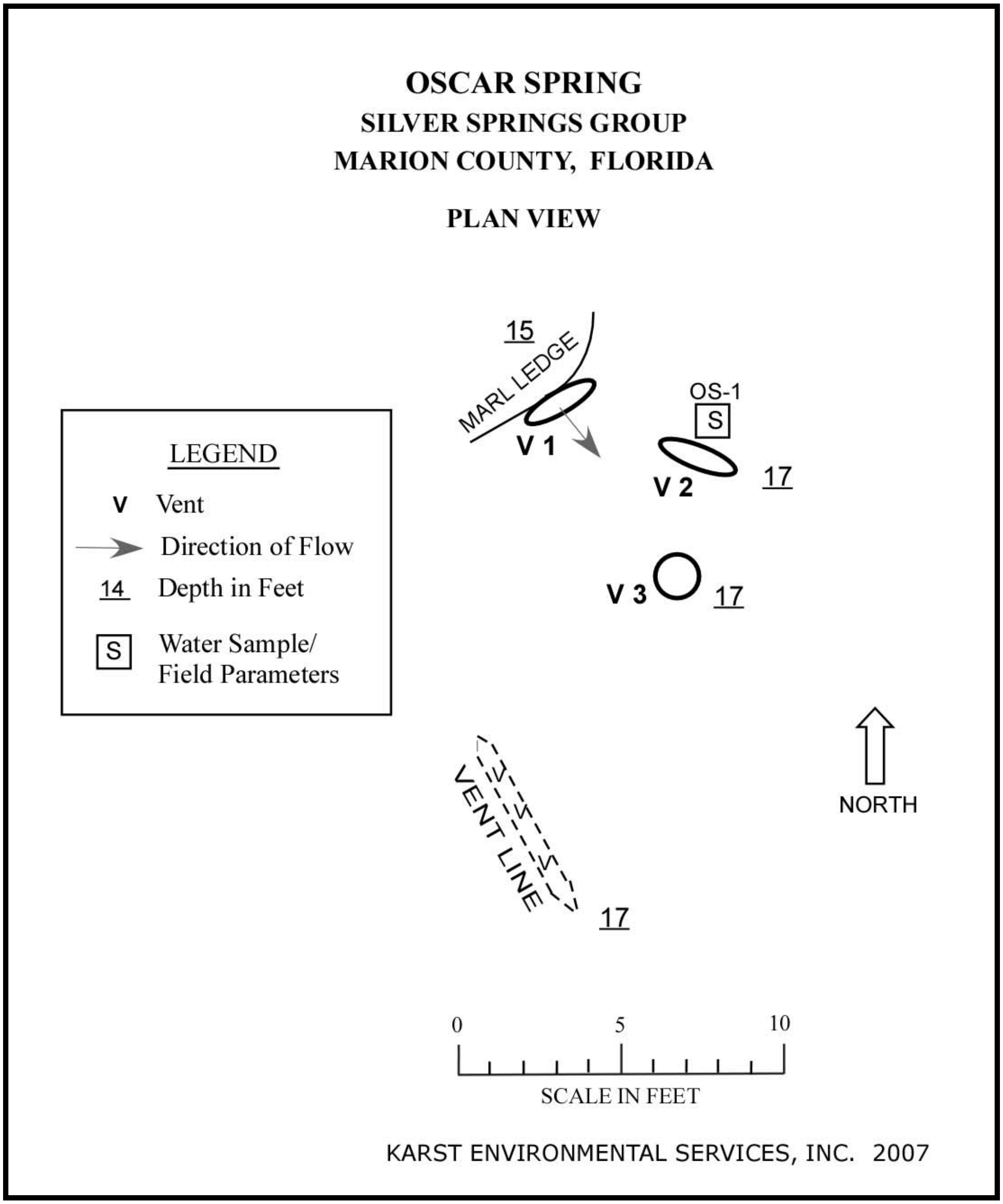

Figure 34. Map of Oscar Spring, Silver Springs Group, Marion County, Florida.

Garden of Eden Spring Group
Description:
The Garden of Eden Spring Group is located in a cove about 240 feet east of Christmas Tree Spring. Garden of Eden is in the same cove as the jungle boat docks. A linear depression about 24 feet long and 15 feet deep contains a line of vents. This vent line accounts for most of the discharge from this group, and contains debris. About 30 feet west of this vent line, there is a roughly circular vent about 4 feet in diameter and 14 feet deep.

Another line of vents, about 17 feet long and 15 feet deep, lies 110 feet southwest of the main vent line. This vent line lies within a depression at the edge of the strong flow of the Silver River. The vents discharge through sand and gravel sediments.

Lost River Spring and Log Spring
Marion County
N 29.216267°, W 82.048200°
Description:
Two additional vents were discovered during this study east of the vent line, in a shallow swampy extension of the cove. The nearest of these, named Lost River Spring, is about 70 feet to the east, and is about two feet in diameter and about 8 feet deep. The second vent, named Log Spring, is 110 feet to the east of the vent line, and is about 3 feet in diameter and 5 feet deep. The vents of both of these springs gently discharge through detrital sediments and are beneath fallen tree limbs.

Figure 35. Underwater photograph of Lost River Spring, Silver Springs Group, Marion County, Florida.

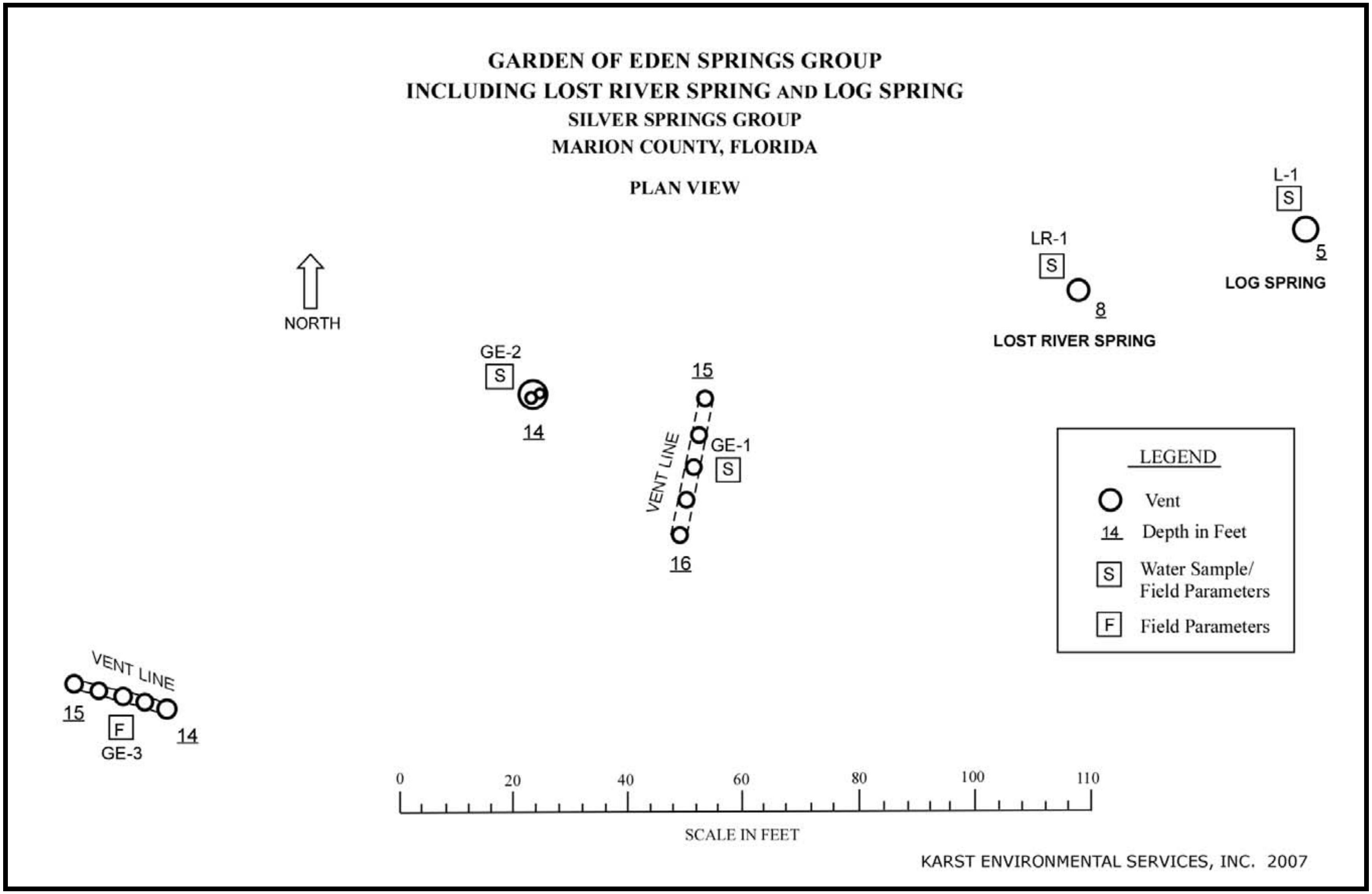

Figure 36. Map of Garden of Eden Springs Group, including Lost River Spring, Silver Springs Group, Marion County, Florida.

No Name Cove Spring
Marion County
N 29.215617°, W 82.046300°
UTM 398298 E, 3232326 N
Description:
No Name Cove Spring is a line of six vents spread along the bottom of linear depression located in a small cove along the south side of the Silver River, about 450 feet east of First Fisherman's Paradise. The vents discharge vertically through soft bottom sediments, from between 10 to 14 feet deep.

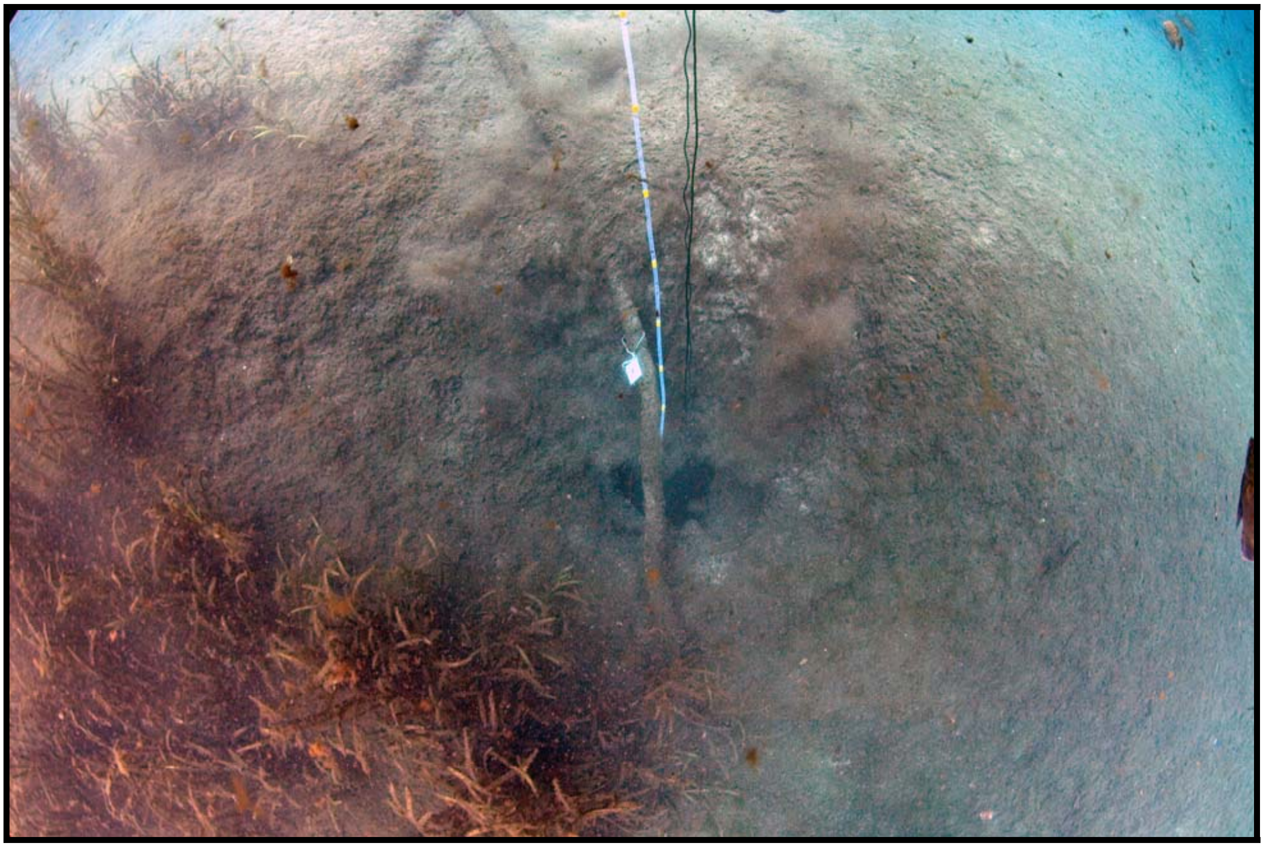

Figure 37. Underwater photograph of No Name Cove Spring, Silver Springs Group, Marion County, Florida.

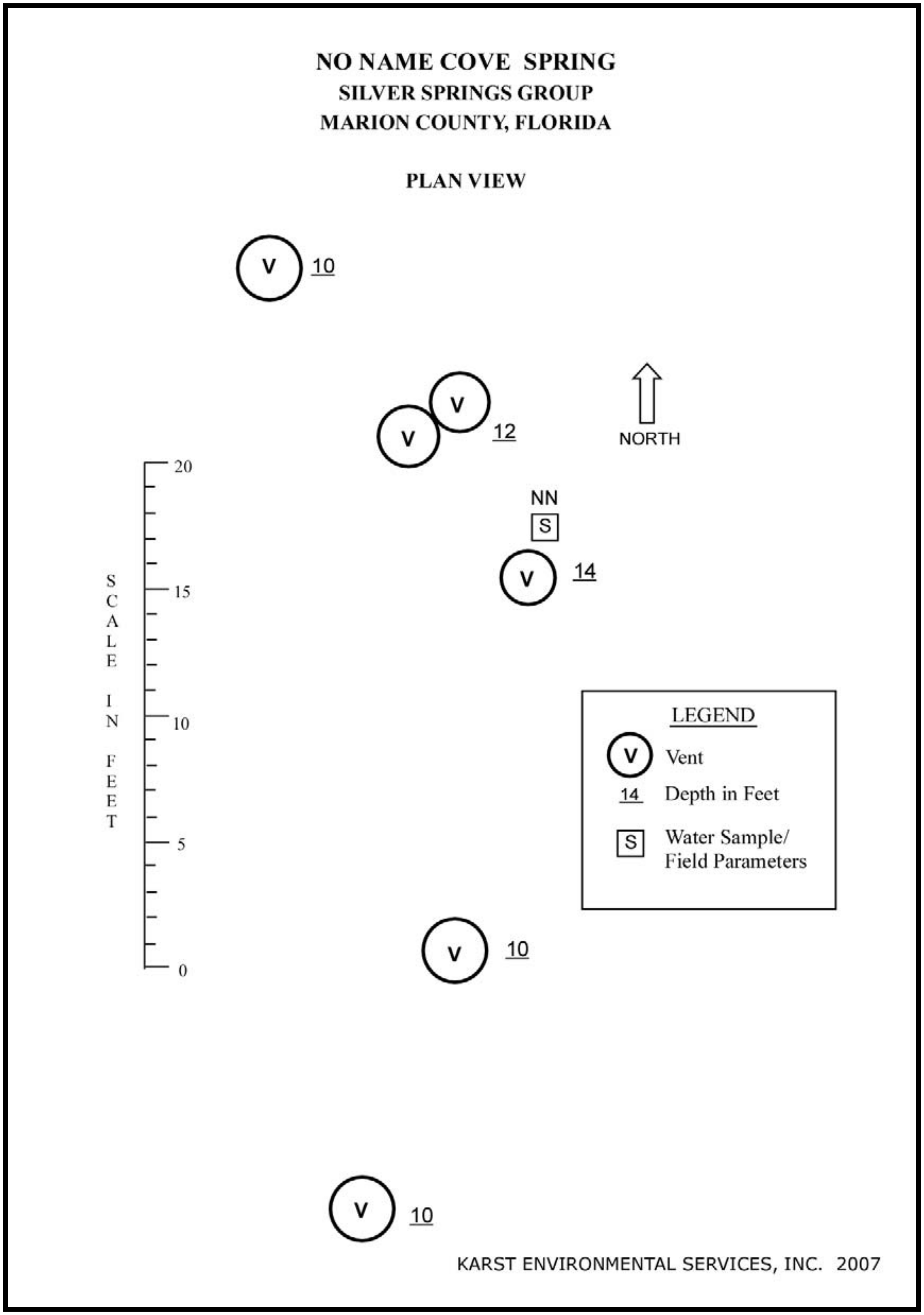

Figure 38. Map of No Name Cove Spring, Silver Springs Group, Marion County, Florida.

Catfish Hotel Spring
Marion County
N 29.215383°, W 82.0545050°
UTM 398415 E, 3232301 N
Description:
Catfish Hotel Spring is located in the main channel approximately 100 feet southeast of Second Fisherman's Paradise Spring. This spring has a deep basin that is bordered on the east by a limestone ledge. West of this ledge is a large and complex area of angular boulders and slabs. Discharge was strong from the numerous vents scattered among the boulders and ledges. Void spaces below the rocks extend down past depths of 25 feet. The physical structure and complexity of this spring did not lend itself to the application of the underwater discharge measurement methods used at the other springs.

Figure 39. Underwater photograph of Catfish Hotel Spring, Silver Springs Group, Marion County, Florida.

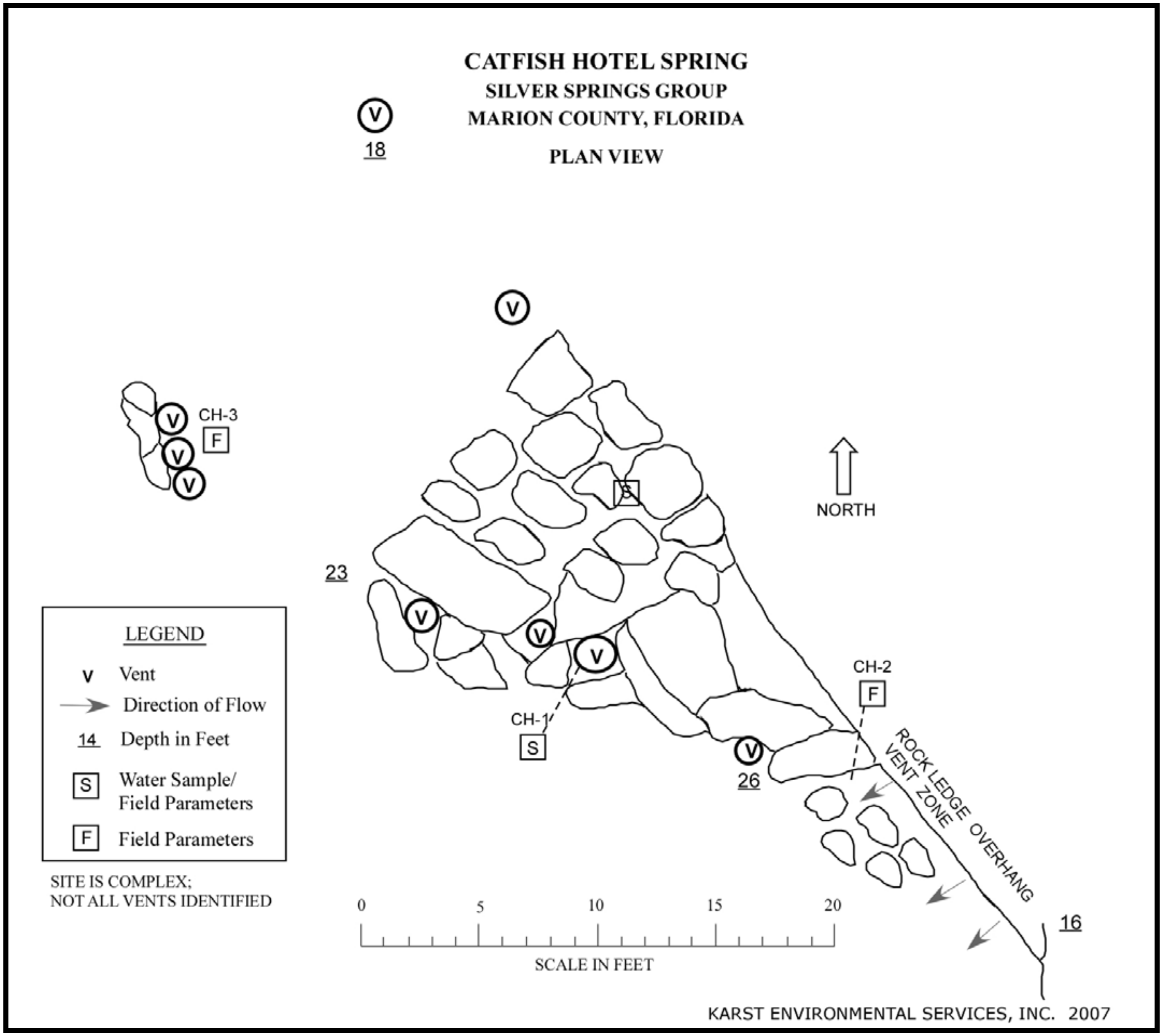

Figure 40. Map of Catfish Hotel Spring, Silver Springs Group, Marion County, Florida.

Shipwreck Springs Group

Shipwreck Spring

Description:
The main vent of the Shipwreck Springs Group is located at the bow of a sunken boat on the bottom of a large, 20 foot deep depression north of the main river channel, and east of the eastern tip of a forested island. The main vent discharges from rock through a layer of sediment and algae. Another similar but smaller vent lies about 15 feet to the east. Discharging from the algae-covered bottom of the western side of the basin, and about 20 to 30 feet from the stern section of the sunken boat, are numerous small vents.

Catfish Convention Hall Spring

Marion County
N 29.215450°, W 82.0438667°
UTM 398536 E, 3232306 N
Description:
Catfish Convention Hall Spring is comprised of two clusters of small vents, about 20 feet deep, and located directly downstream from Shipwreck Spring and the bow of the namesake sunken boat. They lie in the eastern end of the basin that is an extension of the Shipwreck Spring basin. The main vent cluster contains about five small vents within an area of about six feet in diameter, all discharging through sediments.

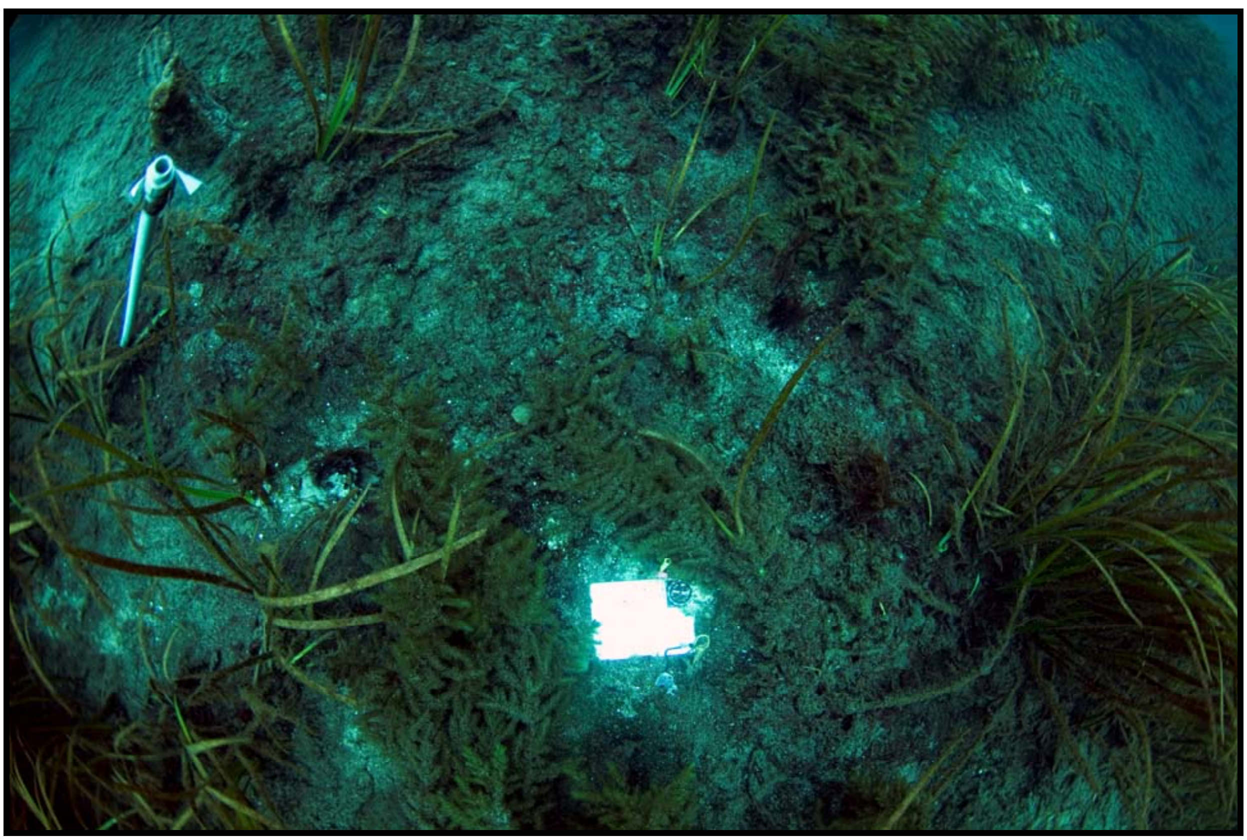

Figure 41. Underwater photograph of Catfish Convention Hall Spring vents, Silver Springs Group, Marion County, Florida. This area contains the main vent cluster.

Figure 42. Underwater photograph of Catfish Convention Hall Spring, Silver Springs Group, Marion County, Florida. Vents that comprise this spring lie in front of the diver.

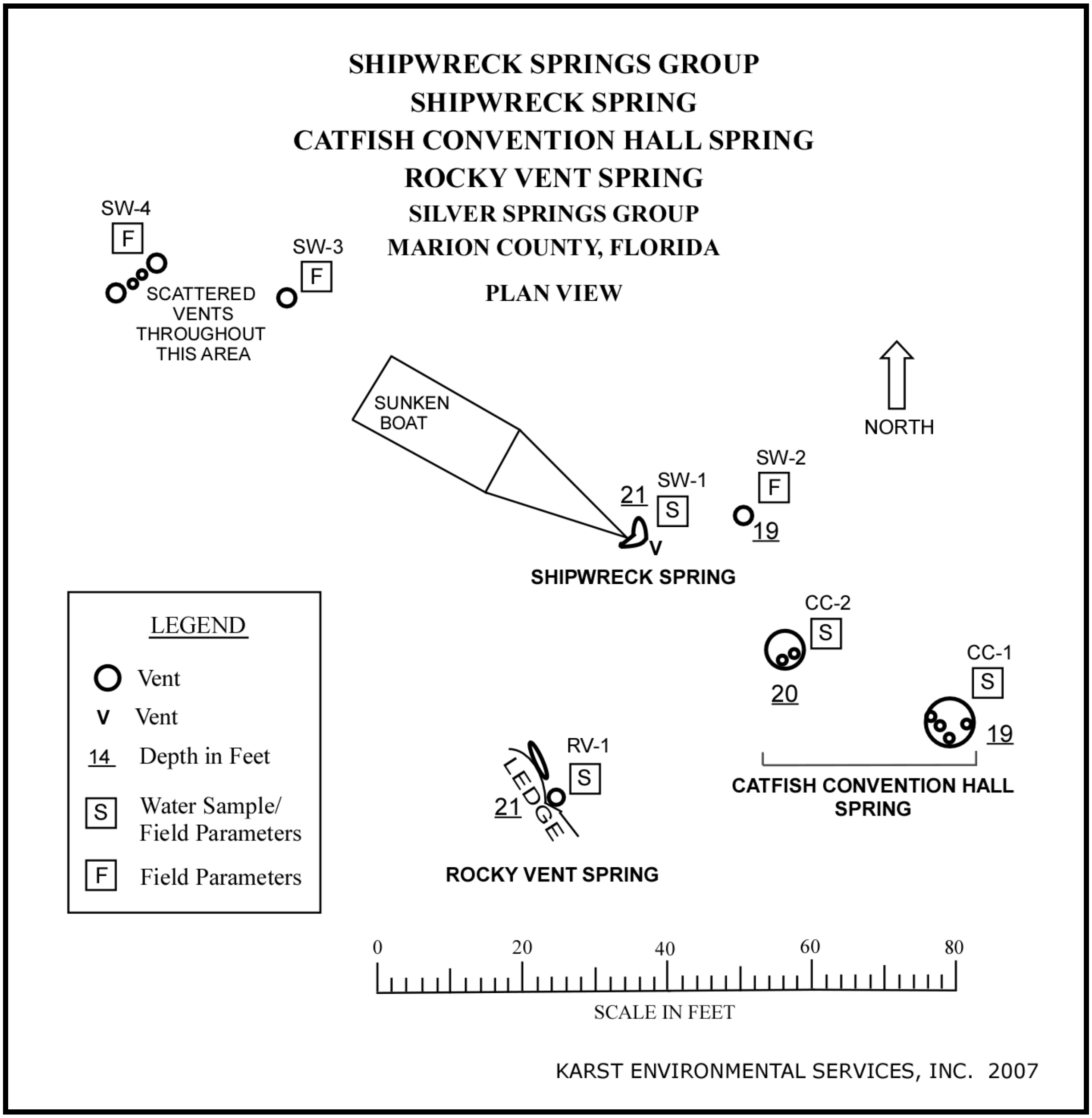

Figure 43. Map of Catfish Convention Hall Spring in the Shipwreck Springs Group, Silver Springs Group, Marion County, Florida.

APPENDIX II

Copy of "Twenty Springs of the Oklawaha.
An Occasional Paper prepared for the
Florida Defenders of the Environment, Inc."
By Elizabeth F. Abbott,
University of Florida Dept. of Geology.
Gainesville, Florida
Summer, 1971

The following 15 page report, "Twenty Springs of the Oklawaha" by Elizabeth F. Abbott, is reproduced herein for historical and reference purposes, and contains narrative descriptions, a list and map of springs, and references. This report was consulted during the Ocklawaha/Rodman Reservoir area fieldwork covered in this report. This copy of the report was provided by the SJRWMD library.

TWENTY SPRINGS OF THE OKLAWAHA

By

Elizabeth F. Abbott

Department of Geology
University of Florida
Gainesville, Florida
Summer, 1971

An Occasional Paper prepared for

Florida Defenders of the Environment, Inc.

TWENTY SPRINGS OF THE OKLAWAHA

An analysis of the hydrology of the Oklawaha River region should include some mention of the numerous springs along the river's course, especially between Eureka Bridge and Rodman Dam. Interviews with the "old-timers" of the region unleash countless stories of the delights of the small springs. Some of these springs can still be found bubbling from limestone orifices rimmed with white sand. Typically there would be a circular pool of gently swirling water drained by a short crystal brook running into the river.

Although there have been a number of investigations of the springs of Florida, there has not been work done specifically on these small beautiful springs of the Oklawaha.

It can be assumed that man has long found a certain fascination in springs. Not only have they served as needed sources of water, they have also been places of rest, worship, and healing. The event of appearing water, usually pristine, surely seemed to be almost magic -- or at least the product of mysterious or miraculous circumstances. There is some evidence that the Indians of Florida utilized the springs as well as did the early settlers. However, remoteness from transportation routes had kept these springs relatively isolated.

The several Oklawaha springs do not serve as examples of springs of the first magnitude -- the "Big Springs" of the United States.

Rather they are quiet pools, reflecting the myriad colors of the sub-tropical environment. The sylvan biome of the Oklawaha is a perfect setting for these crystal pools. The source of the water in these springs is, of course, ground water. Of all the water in the hydrologic cycle the part that sinks into the earth is termed "ground-water". Some is absorbed by the soil, some is used by plants, and some sinks by gravity deeper into the earth or rock. When this gravitational water reaches a fairly impermeable layer of material, it accumulates as a reservoir, the surface of which is called the "water table".

The elevation of the water table in central Florida usually corresponds rather closely with the undulation of the topography, lying in smooth hills, ridges, depressions, and troughs. When the reservoir fills to overflowing, water moves through connected pore spaces, cracks, or other passageways. The flow is from higher to lower levels, down the hydraulic gradient or "slope" of the water table.

In some locations a permeable layer or aquifer is overlain by a less permeable stratum which may be termed an aquitard, or aquiclude. Water thus confined is said to be under artesian pressure and will sometimes flow out onto the surface without pumping. Thus, the ground-water reservoir may be classified as a water-table aquifer, or an artesian aquifer. These conditions give rise to the two kinds of springs found in Florida. Where the water table intersects with the land surface, there will be a seep, or spring. This water originally has fallen as rain and has percolated through the soil to the water table. There it may move down-slope toward an outlet where it may be discharged. The other general type of spring is the flow from a confined aquifer issuing wherever the layer under pressure is exposed. This artesian water may come from great depths where it has been accumulating for many many years. Springs of this kind will yield a fairly steady flow and be only a little affected by variations in precipitation.

Springs of both kinds sometimes discharge directly into stream beds, lakes, or river swamps, thus augmenting the surface waters. In times of flooding or high water, the flow of these springs, as well as that of those located nearby, may be reversed and the intake becomes a recharge for the aquifer. Thus the run-off or surface flow could enter the aquifer through the spring orifice.

The twenty springs along the Oklahawa described here were observed in an area reaching from Eureka Landing to Rodman. (See map.) About half were personally investigated, and the rest were described specifically and were located on air photographs by persons who have known the area well for many years.

In addition to the twenty "confirmed" springs, there are considered to be a number of others in the general area. Reliable sources vouch for their presence along the east or right bank north of Eureka.

The physiography of the area is most marked by the striking right-angle bend in the river near the mouth of Orange Creek.

Analyses of the structure and geology of the underlying rocks show extensive jointing and some major faults. The springs may reflect the exposure by faulting of an older stratum, a portion of the regional aquifer.

In the southernmost section of the part of the river under discussion here, there is a marked difference in the east and west bank topography. To the west lies the Oklawaha Lowlands, an extensive region of flatwoods underlain by clay deposits. This poorly drained land merges into the River Swamp immediately adjacent to the river itself. If springs arise in this swampy terrain, they are not readily discernable even from air photographs. They could more accurately be termed "seeps" for they could mark the areas where the ground level intersects the local water table.

The east, or right bank, is generally higher in elevation than the west and is much more easily studied. This area is designated physiographically as the Mount Dora Ridge, named for its more southerly extent. The region is chiefly comprised of the Fort Preston (or Hawthorn) formation of Miocene Age, which is generally sand hills with lenses of gravel or clay. There are scattered deposits of pinkish-orange sandy clay of the Citronelle, as well as coarse sand and gravel, possibly even Pliocene in age. These highlands are generally quite permeable and there is no major surface drainage other than the Oklawaha River itself. The response of the vegetation to the scarcity of available water is that of a "scrub-complex" with turkey oak in stands alternating with sand pine. The gopher mouse, or "sandy mounder", leaves scattered spots of yellowish sand among the inhospitable scrub.

Close to the river the slope of the ridge is covered with a hamock-type forest of hardwoods merging into the cypress of the river swamp. At many locations, the steep bank is quite close to the channel, offering good firm access to the main stream. Where the slope is of intermediate steepness and of moderate extent seems to be the favored locale of the small springs.

Springs in general may be classified into different types dependent upon their geologic occurrence, temperature, amount of water discharged, or the forces causing the springs. The small Oklawaha springs are limestone springs, mostly cold, possibly salt or sulfur, and usually artesian, but may be gravity-flow. The underlying water table, or the surface of the reservoir of ground water called the aquifer, is the Eocene Limestone exposed by the "levelling" of the structure of the Ocala Arch. As stated before, this water-table surface is seldom, if ever, flat; it undulates gently following the slope of the land. Where the overlying hills contain lenses of clay, there may be small local reservoirs, or "perched" ground water held above an aquitard. Water flowing from this perched stratum would be a gravity-flow spring and would diminish in volume during times of drought. The perennial flow from the Oklawaha indicates that most are powered by hydrostatic pressures built up in the regional aquifer.

Artesian flow-wells exist in the area, some known to carry water several feet above ground level. Also, distinctive limestone rocks can be identified as late Eocene outcrops in several of the springs. So it seems likely that most of the springs of the east bank of the Oklawaha are representative of the Floridian aquifer.

The several springs as numbered on the map are all changed to a greater or lesser degree by the elevation of the waters of the Rodman Pool. The lower locations are flooded and only faint outlines remain as evidence today. The somewhat higher springs are altered but are still present.

Blue Spring, No. 1, is located south of the river and is now inundated by the waters of the Rodman Reservoir. The large outline of the spring pool and run can be seen today. Only the rooftop remains of the spring-house. Tucked close between the high bluff and the river, the spring was perfect for those wishing to "get away from it all". It was privately owned for many years, but was always open for public use -- swimming and fishing, as well as picnicking and camping. The most discriminating of seasoned fishermen marveled at the "quality" of fish of Blue Springs -- not to mention the quantity. Freshwater mullet and catfish swam like giant denizens convoyed by nervous bream, but the large bass was the most sought-after catch.

Roads of "ball-bearing" sand dusted with orange clay lead down and around the bluff to the relict Blue Springs. Tangles of muscadine and a few wild roses mark the way out to the low promontory. The oval outline of the spring-pool is marked by stark dead trees. The run is outlined by cypress skeletons on one side and the hardwood hammock trees on the other. Gone is the blue crystal pool and the jet-mirror stream, replaced by dead vegetation and murky water. The spring run was formerly long enough to merit the name of Indian Creek. Another spring, unnamed and much smaller than Blue Spring, also feeds from the foot of the bluff into Indian Creek. (Shown by X on map.)

Bright Angel Springs, north of the River, had two runs, both about the same size. One emptied into Horseshoe Creek which arched to the north before joining the river. The other was very short and followed a direct route. Because of a huge cypress log in the water, this pool was sometimes called Log Springs. It was a favorite camping site. Between Bright Angel and Cedar Landing was a large turbulent spring walled with cabbage palm logs. This was Catfish Springs, comparable in volume with Blue Spring. Huge fish like black torpedoes would circle the boil. There were also mullet and striped bass in the turbulent water. There was a small spring only about twenty-five feet in circumference at Cedar Landing. It was easily possible to walk all the way around this one, stepping over the narrow run.

Near Agnew's Landing, upriver from Cedar Landing was an unnamed spring, No. 5 on the map. This spring was located almost in the river itself and was often flooded by high water. It was located between two huge cypress trees at the river's edge. When fishermen passed by at night, or during "high water", they could discern its location by its distinctive smell! No. 6 on the map represents a cluster of boils at the confluence of two creeks close to where they emptied into the river. The rocky springs made an unusually wide main trunk of Therman Creek. This stream was the location of a saw mill whose boilers remained at the site until only a few years ago.

Sim's Spring flows out of a cleft in the rocky hillside below high land belonging to George Alcorn. This spring was developed many years ago and water was pumped to the top of the bluff by a steam pump. It was used for irrigation of an orange grove. This spring, protected by a coffer dam, is present today.

No. 8 marks a "large" spring with a circular pool described also as being "between Sim's and Bud Springs". No. 9 is Bud Springs, not too far downstream from the Orange Creek Ferry site. This spring had a large deep pool with the water spilling over a shelf and spreading into a wide shallow run to the river.

Existing today are Mullet Cove Spring, Indian Bluff Spring, and a small spring at Tobacco Patch Landing. Cannon Springs, Numbers 13-18, are found at Couse Landing between Tobacco Patch Landing and Eureka. Signs call them "Sparks Springs", but the old name more often used is Cannon. There are at least six springs of varying sizes remaining. They are arranged in a rough line forming a slough resembling a meander cutoff in the river. Several different kinds of fish can be seen today in the largest pool, as well as a variety of birds. (The nanhinga dries its wings, wet from fishing.) The forest here is perhaps the most beautiful of all that along the river. It is a low-hammock type with a mixture of palms and hardwoods. The cry of the limpkin is a noisy and interesting distraction in the quiet woods.

Several small springs are reported near the farm of Elmer Fiddia, upriver from Cannon Springs. Also there is at least one more spring, nearer Eureka than the rest. This one is called Dudley Spring, named for its most recent owner. It is reported to be near in size to the largest of the Cannon Springs pools.

Not included specifically, but indicated by X's on the map, are some of the springs near Orange Creek. The principal one is Orange Springs itself, a sulfur spring west of the mouth of the Creek. It is a walled-in roughly circular pool about 75 feet across. The boil is about eighteen feet deep; but, except for this area, the water is shallow. The run into Orange Creek is about 500 feet long. The sulfur is said to be organic in origin, the hydrogen sulfide from ancient decayed vegetation. Another "spring" nearby is Seminole Spring, a man-made flow from artesian wells drilled into two small springs near Orange Creek. Among the numerous small springs, some only drinking springs, are Maria Spring and White Spring. Also there is a "drilled" spring in Collin's Slough between the McRae farm and the Oklawaha River. The artesian well nearby has existed for decades and has been used regularly for data-recording by the Geological Survey.

The springs of the middle Oklawaha do certainly contribute to the volume of the river. All together, however, they do not amount to as much as that from Silver Springs Run, a combined flow from fourteen spring complexes. On the average, nevertheless, the river increases in volume by almost one-third when measured between gauges at Conner (just below Eureka) and at Riverside (below Orange Ferry). If the flow of Orange Creek is subtracted, the increase in volume must be from the several springs along the river. Clean, unpolluted water from these springs no doubt also adds to the overall quality of the river water.

Almost all of these springs have been damaged or destroyed by man and are not flowing to their maximum capacity. No doubt some are beyond salvage, but certainly a few could be restored and preserved to contribute to the natural beauty of the National Forest

No.	Name	Location	Approximate Dimensions	Run	Comments	Existing Today
1	Blue Spring	South of river Near Dutchman's Reach	200' N-S 350' E-W 22' deep	5 miles long (Indian Creek) 40' wide 6' deep	Largest of these springs, spring-house, landscaping	No
2	Bright Angel (or Log) Spring	North of river almost opposite Catfish Spring	Round pool 30' diam. 25' deep	2 runs 8' wide 2' deep 1-into river 2-into Horse-shoe creek	Cypress log in water	No
3	Catfish Spring	South of river below Cedar Land-ing	Round pool 50' diam.	100' long 30' wide	Large volume, turbulent flow, once walled with cabbage-palm logs	No
4	Cedar Landing Spring	South of river at Cedar Landing	Round pool 8' diam.	150' long	Small spring	No
5	--	On bank, directly on river near Agnew's Landing	No pool, just ori-fice	No run	Directly on edge of river, sometimes flooded	No
6	-- (cluster)	At confluence of Therman Creek and another stream	Cluster of several boils in rocky con-fluence	No run, creek empties di-rectly into river	Therman Creek parallels river as far as Blue Springs saw mill site	No
7	Sim's Spring	At George Al-corn's out of cleft in rock bluff	No pool, flow di-rectly out of hill face	No data	Protected by coffer dam, once pumped to top of hill	Yes

(Continued)

- 11 -

		Location	D' nsions	Run	Comments	Exis' To..
8	--	Large spring between Sim's and Bud Spring	"Large" pool	No data	Strong flow	No
9	Bud Spring	East of river, nearly opposite mouth of Orange Creek	Round pool 35' diam.	650' long 50' wide 3' deep	Appeared to come straight up, then emptied over shelf into shallow run	No
10	Mullet Cove Spring	East bank, close to Wells Landing	2 small boils	No data	No data	Yes
11	Indian Bluff Spring	East bank, above Tobacco Patch Landing	No data	No data	Clear water flowing out of swamp	Yes
12	--	East bank at Tobacco Patch Landing	No data	No data	Small spring	Yes
13-18	Cannon (or Sparks) Spring	East bank, several pools in a line	Round pool 50' diam.	200', in slough	At least 3 large and 3 small springs	Yes
19	--	East bank, near mouth of Mill Creek	No data	No data	At Elmer Fiddia's	Yes
20	Dudley Spring	East Bank, nearest Eureka.	No data	No data	Dudley, last owner	Yes

- 12 -

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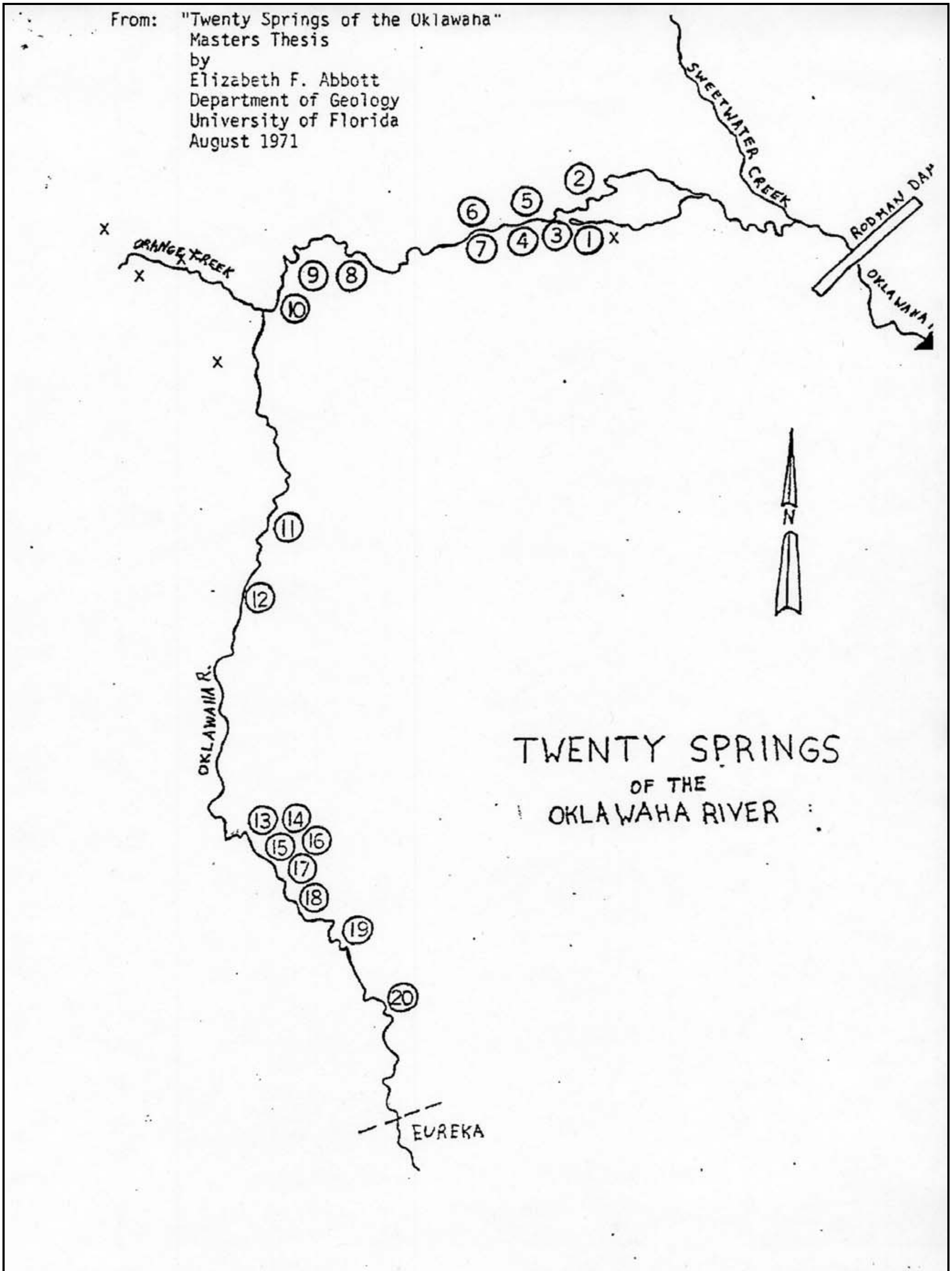
From: "Twenty Springs of the Oklawaha"
Masters Thesis
by
Elizabeth F. Abbott
Department of Geology
University of Florida
August 1971
SWEETWATER CREEK
RODMAN DAM
OKLAWAHA
ORANGE CREEK
OKLAWAHA R.
N
TWENTY SPRINGS
OF THE
OKLAWAHA RIVER
EUREKA

APPENDIX III

Discharge reports

Blue Spring, Marion County, 9-07 Discharge Report
Bright Angel Spring, 9-07 Discharge Report
Fish Hook #1 spring, 9-07 Discharge Report
Catfish Convention Hall Spring, 9-07 Discharge Report
Lost River Spring, 9-07 Discharge Report
Mammoth Spring, 9-07 Discharge Report

Discharge Measurement:
Blue Spring,
Rodman Reservoir/Ocklawaha River,
Marion County, Florida;
September 27, 2007

Prepared for:

St. Johns River Water Management District

4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.

5779 NE County Road 340 High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX
kes@atlantic.net

Discharge Measurement: Blue Spring,
Marion County, Florida; September 27, 2007

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Results of Discharge Measurements of Blue Spring, Marion County, Florida; September 27, 2007

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to perform discharge measurements of selected submerged springs that discharge into the Rodman Reservoir/Ocklawaha River in Marion and Putnam Counties, Florida. This report documents the results of the measurement made at the Blue Spring (Marion County) site on September 27, 2007. A summary of the results and collected data for that measurement are presented on Table 1.

PURPOSE and SCOPE OF WORK

The purpose of this work was to obtain an initial discharge measurement of Blue Spring (Marion County), which is among the many sources of groundwater discharging into the Rodman Reservoir/Ocklawaha River. A program of discharge measurements was to be made of the springs in the Rodman Reservoir/Ocklawaha River during September of 2007.

SITE DESCRIPTION

Blue Spring (Marion County) is located on the south side of the Rodman Reservoir and the Ocklawaha River channel, southeast of the public boat ramp at Kenwood Landing, at 416958 Easting/3265285 Northing (UTM Zone 17, NAD 1983 HARN, meters), or Lat. N29.514404°, Long. W81.856850° (WGS84).

The spring discharges primarily from two vents in bedrock, at the bottom of a large basin. The upper and larger vent was about 31 feet deep (during this measurement), and a lower vent was at about 33 feet deep. The vents are too small to allow for diver entry, and conditions around them during this measurement were very silty. See Figures 1A and 1B. There was considerable aquatic vegetation present in the spring basin area.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, the upper spring vent opening provided a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

PERSONNEL

Fieldwork for this discharge measurement was conducted by KES personnel Peter Butt and Tom Morris. Jeff Davis of the SJRWMD was also on site during the measurement, and provided logistics support. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech of Orlando, Florida.

METHODS

Instrumentation

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 20, 2007. A copy of the Calibration Certificate is included with this report.

A video record of the site was made on August 29, 2007.

Field Operations

Velocity measurements were taken at the upper-most vent. The measurement site was 31 feet deep. Cross-section dimensions were approximately 5 feet long by 2 feet wide. A lower vent was blocked with plastic bubble wrap sheets to eliminate open areas that could not be measured.

Four telescoping aluminum poles with 0.1, 0.25, 0.5 and one-foot interval markings were positioned horizontally to provide a positioning grid for velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a low-profile metal spring clamp. Conduit dimensions around the grid were measured with a collapsible steel tape. See Figure 2.

Peter Butt positioned the sensor and recorded positional data, while Tom Morris took the velocity readings after taking reset cues from Butt. During all measurements, the sensor handler was able to move away from the measurement cross-section, and remove himself from the cross section of the flow. The meter operator was also positioned above and away from the cross-section. This minimized or eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in the "Fixed Point Averaging" mode. Fixed Point Averaging is an average of velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Twenty-one station readings were made.

Data Processing

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 2. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, and anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1. The results of the contour processing are illustrated in Figures 3 and 4.

Discharge and measurement cross-section area are given on the Grid Volume Computations and Gridding Report feature of the software, included in this report on page 1 of Table 2. The total discharge is shown as the "**Net Volume (Cut-Fill)**". The Net Volume value is used because a Surfer 8 "blanking file" operation was used to define the measurement cross-section boundary and eliminate artifacts present in the contouring process that would create inaccuracies in the flow calculations. The software also calculated the total cross-sectional area of the measurement location within the passage, and is shown in square feet as the "**Positive Planar Area (Cut)**".

RESULTS AND DISCUSSION

This measurement is the first one performed at Blue Spring (Marion County) applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Blue Spring (Marion County) on September 27, 2007 was 0.778 CFS (cubic feet per second). This result is also expressed as 349 GPM (gallons per minute) or 0.503 MGD (million gallons per day), see Table 1. Twenty-one (21) readings were made, see Figures 2 and 4. The point velocity readings ranged from 0 to 0.66 feet per second (fps), with an overall average station reading of 0.30 fps. The total cross-sectional area was calculated as 4.42 square feet. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 11:44 hours and were completed by 12:18.

	UNDERWATER DISCHARGE MEASUREMENT				
	Location:	**BLUE SPRING (MARION COUNTY)**		Date:	**September 27, 2007**
		Rodman Reservoir/Ocklawaha River		Time Start:	11:44
		Marion County, Florida		Time End:	12:18
	Personnel:	Peter Butt, Tom Morris			
	Method:	Grid within irregular conduit			
	Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles			
	Analysis Method: Surfer 8 with kriging				
	Blue Spring (Marion County) Total Discharge:				
	CFS	**0.778**			
	MGD	**0.503**			
	GPM	**349**			
	Total Cross-sectional Area:		4.42	square feet	
	Avg. Station Point Velocity:		0.30	feet/second	
	Cross-section Depth:		31	feet deep	
	Msmt. Periods:		60 seconds		
	Velocity Reading by Station:		(All velocity readings in feet per second.)		
	Station #	Point Velocity			
	1	0.23			
	2	0.39			
	3	0.48			
	4	0.31			
	5	0.12			
	6	0.03			
	7	0.02			
	8	0.54			
	9	0.54			
	10	0.06			
	11	0.53			
	12	0.64			
	13	0.38			
	14	0.01			
	15	0.04			
	16	0.01			
	17	0			
	18	0.49			
	19	0.66			
	20	0.62			
	21	0.13			

Table 1. Discharge of Blue Spring, Marion County, Florida on September 27, 2007.
Data record and calculation of discharge measurement.

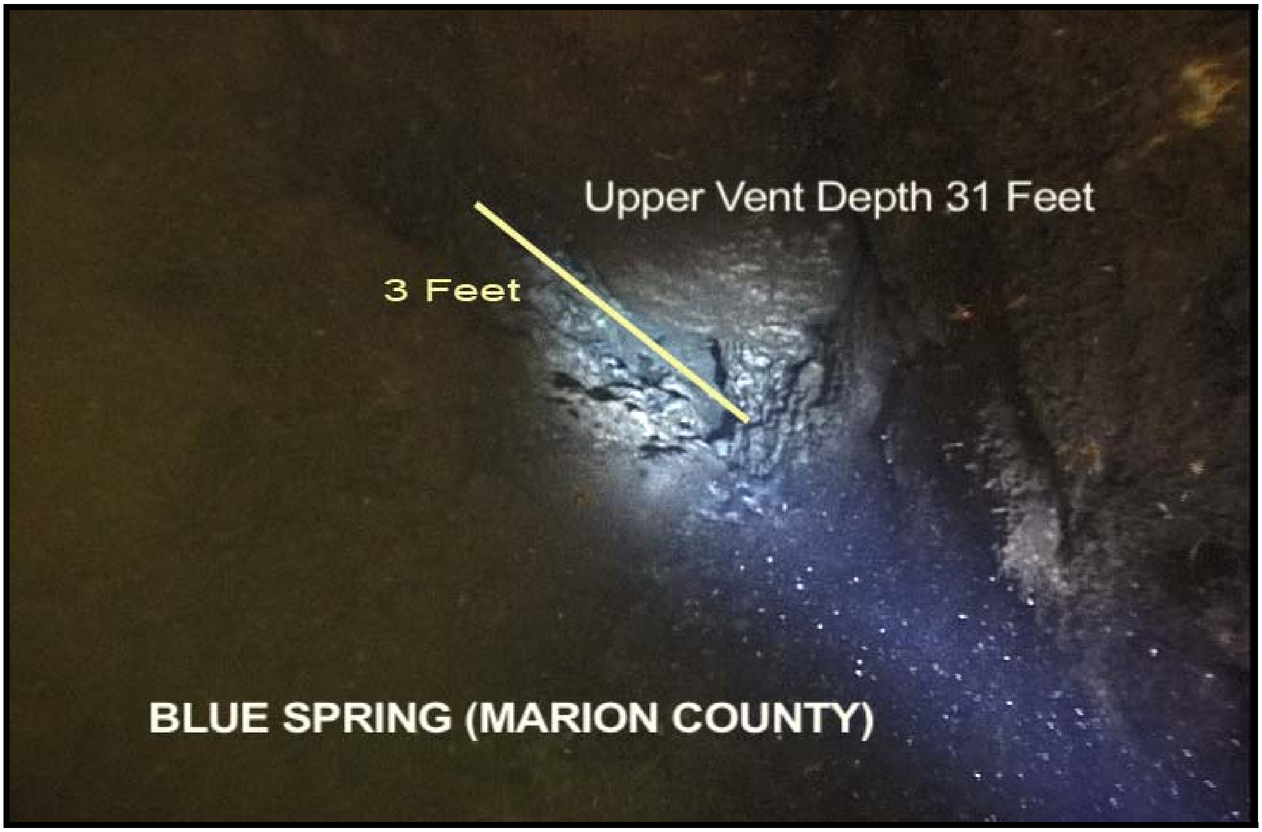

Figure 1A. Underwater video still of Blue Spring (Marion County). View of the upper vent measurement cross-section.

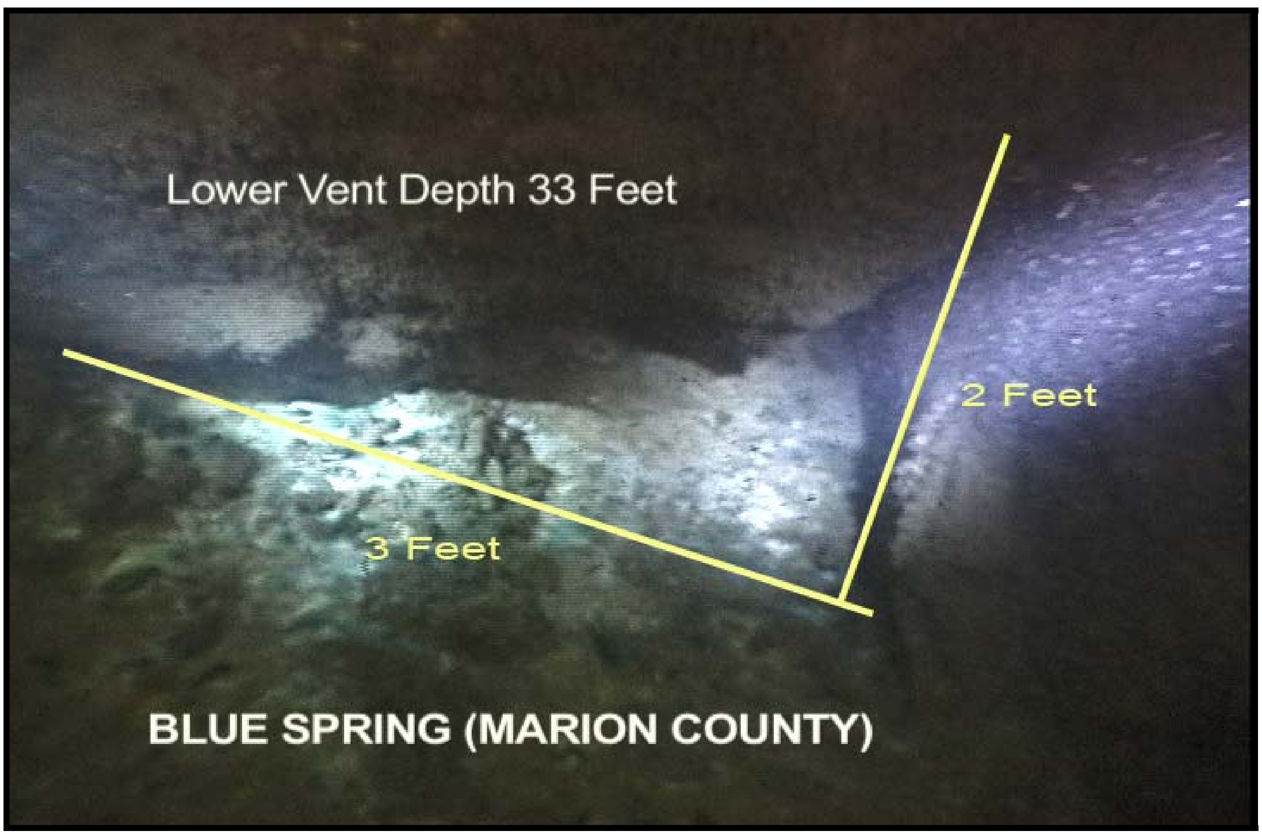

Figure 1B. Underwater video still of Blue Spring (Marion County). View of the lower vent.

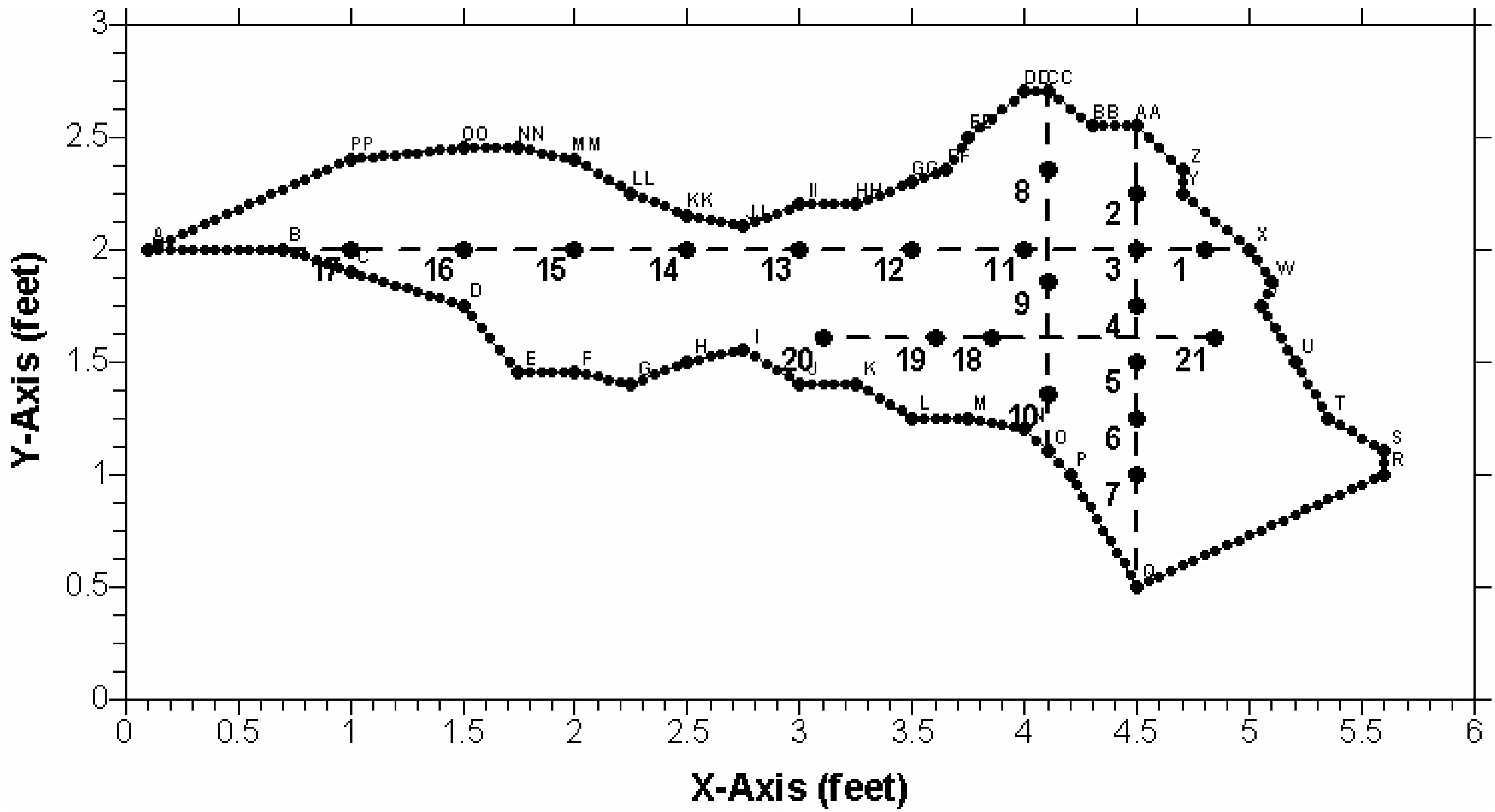

Figure 2. Discharge measurement cross-section; Blue Spring, Marion County, Florida, September 27, 2007 measurement. Cross-section is viewed to the upstream of observer, and is located at the 31-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected, lettered points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

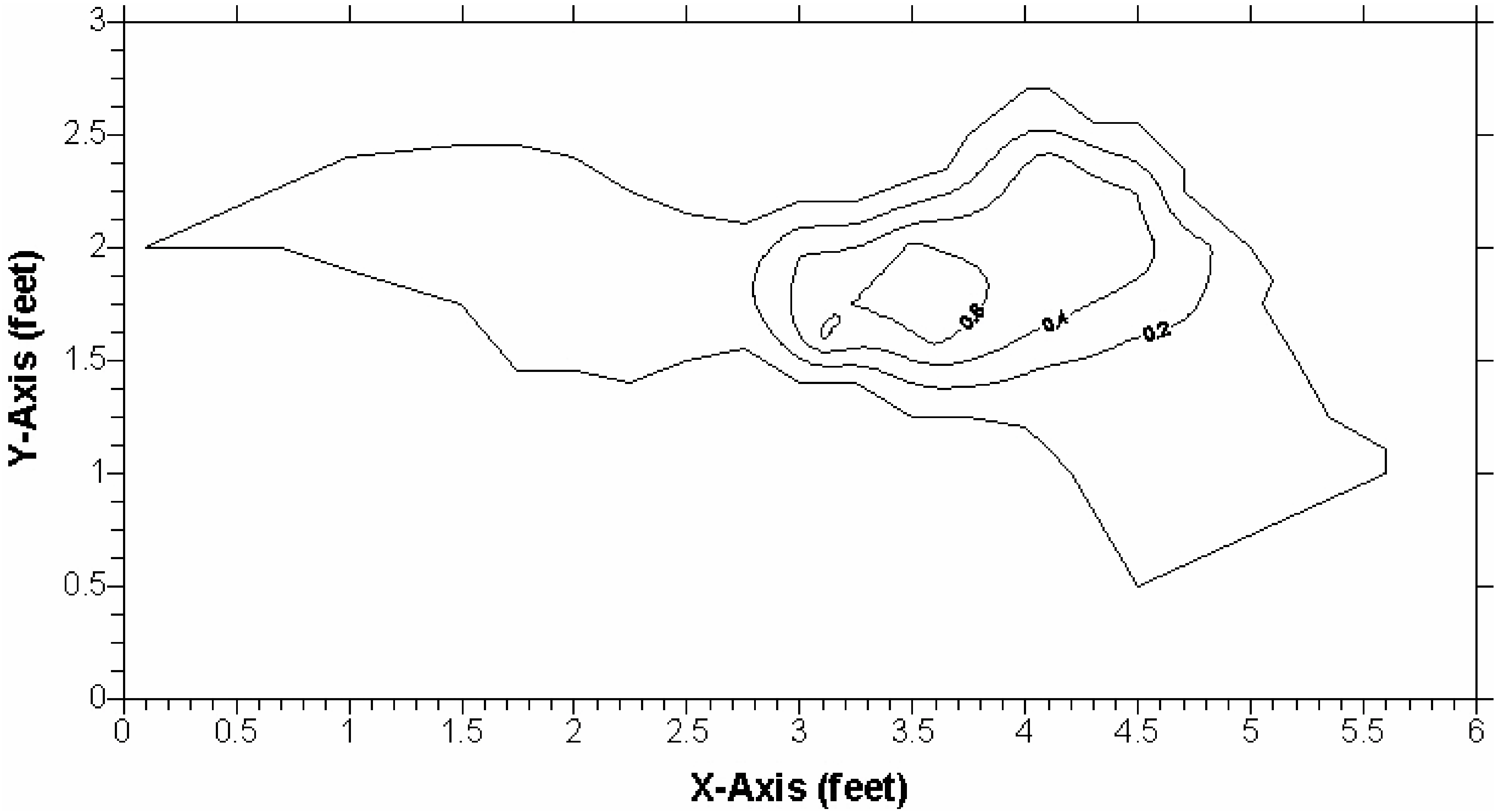

Figure 3. Discharge measurement cross-section; Blue Spring, Marion County, Florida, September 27, 2007 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

TABLE 2. BLUE SPRING, MARION COUNTY, SEPTEMBER 27, 2007.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Rodman\Oklawaha Blue\2007-09\OklawahaBlue_09-2007.bln.grd
Grid Size:	61 rows x 121 columns
X Minimum:	0
X Maximum:	6
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05
Z Minimum:	-1.5712924850142E-009
Z Maximum:	0.68867191012325

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES

Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	0.7776379372613
Simpson's Rule:	0.77745177168607
Simpson's 3/8 Rule:	0.77755008943736

CUT & FILL VOLUMES

Positive Volume [Cut]:	0.77763793728787
Negative Volume [Fill]:	2.6577153317253E-011
Net Volume [Cut-Fill]:	**0.7776379372613<<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the use of a blanking file operation in the calculations. Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas

Positive Planar Area [Cut]:	**4.4187497474909<<<<Cross-section in Square Feet**
Negative Planar Area [Fill]:	2.5250913671836E-007
Blanked Planar Area:	13.58125
Total Planar Area:	18

Surface Areas

Positive Surface Area [Cut]:	5.7080588704276
Negative Surface Area [Fill]:	2.526421860012E-007

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 07\Rodman\OklawahaBlue\Oklawaha Blue 9-07 SURFER XYZ T3BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	258
Original Data:	258
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.1	0.5	0
25%-tile:	1.6665	1.4	0
Median:	3.2	1.95	0
75%-tile:	4.5	2.24442	0
Maximum:	5.6	2.7	0.66
Midrange:	2.85	1.6	0.33
Range:	5.5	2.2	0.66
Interquartile Range:	2.8335	0.84442	0
Median Abs. Deviation:	1.35	0.45	0
Mean:	3.0501821705426	1.7745624418605	0.024147286821705
Trim Mean (10%):	3.0683632478632	1.7915983333333	0.0017948717948718
Standard Deviation:	1.5942309741642	0.57103042152364	0.10597027525125
Variance:	2.5415723989844	0.32607574230547	0.011229699236825
Coef. of Variation:			4.3884961500516
Coef. of Skewness:			4.6474890629164

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.446	0.121
Y:		1.000	0.040
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	2.5415723989844	-0.40570835827429	0.020485911153176
Y:		0.32607574230547	0.0024456433612764
Z:			0.011229699236825

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.011551945730664	0.021873336078634	-0.049903852764376
Standard Error:	0.0045894137435241	0.0128129522831	0.032242000829751

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.446	-0.748
B:		1.000	0.899
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.074857800368025	0.037428900184013	3.3816
Residual:	255	2.8224046027327	0.01106825334405	
Total:	257	2.8972624031008		

Coefficient of Multiple Determination (R^2): 0.025837425111343

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.02222	0
25%-tile:	0.050249378105604	0
Median:	0.053851648071345	0
75%-tile:	0.058309518948453	0
Maximum:	0.34409301068171	0.64

Midrange:	0.18315650534085	0.32
Range:	0.32187301068171	0.64
Interquartile Range:	0.0080601408428484	0
Median Abs. Deviation:	0.0038516480713451	0
Mean:	0.067863270217325	0.015348837209302
Trim Mean (10%):	0.059103331013652	0.001025641025641
Standard Deviation:	0.048694669457837	0.07715429533957
Variance:	0.002371170833608	0.0059527852893456
Coef. of Variation:	0.7175408627067	5.0267192418205
Coef. of Skewness:	3.4942043561896	6.2296297163987
Root Mean Square:	0.083526009591011	0.078666206804595
Mean Square:	0.0069765942781977	0.0061883720930233

Complete Spatial Randomness

Lambda:	21.322314049587
Clark and Evans:	0.62673211188472
Skellam:	241.14450909942

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	6.5E-007
Y Duplicate Tolerance:	2.6E-007

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	1
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 07\Rodman\OklawahaBlue\OklawahaBlue_9-07.grd
Grid Size:	61 rows x 121 columns
Total Nodes:	7381
Filled Nodes:	7381
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	6
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-0.32931531856656
Z 25%-tile:	-0.093850815718461
Z Median:	-0.013977374731127
Z 75%-tile:	0.011834200593412
Z Maximum:	0.68867191012325
Z Midrange:	0.17967829577835
Z Range:	1.0179872286898
Z Interquartile Range:	0.10568501631187
Z Median Abs. Deviation:	0.04253545003506
Z Mean:	-0.010212294742361
Z Trim Mean (10%):	-0.026274626095364
Z Standard Deviation:	0.16162503137099
Z Variance:	0.026122650765674
Z Coef. of Variation:	-1
Z Coef. of Skewness:	1.868114795289
Z Root Mean Square:	0.16194734245914
Z Mean Square:	0.026226941729579

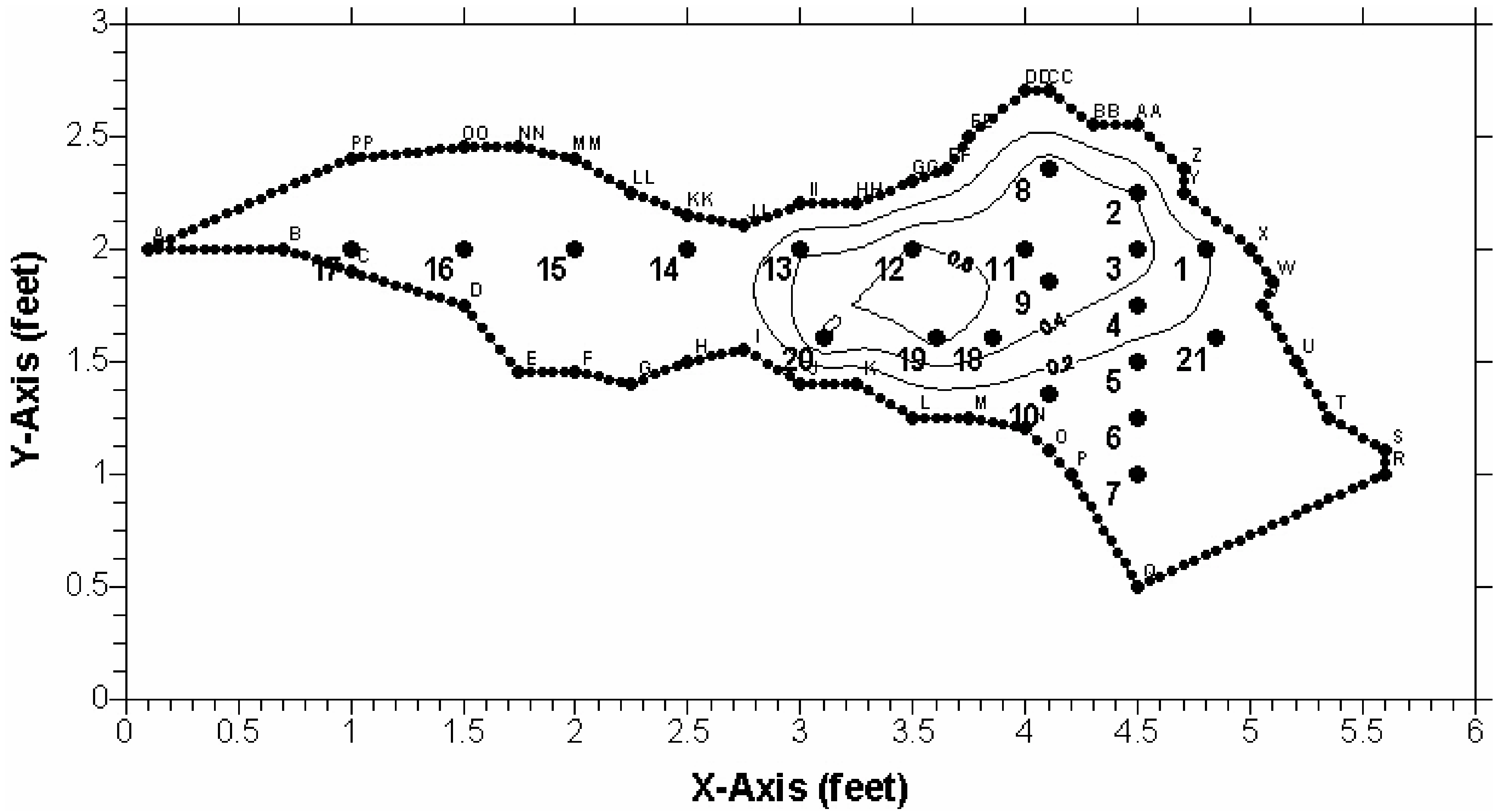

Figure 4. Discharge measurement cross-section; Blue Spring, Marion County, Florida, September 27, 2007 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. See Table 1 for station velocities. Boundary of cross section is shown as connected, lettered points. X- and Y-axis scales are shown in feet.

Table 3. Blue Spring (Marion County) XYZ Grid Data September 27, 2007.						
X	**Y**	**Z (Velocity)**	**Station #**		**X Plot**	**Y Plot**
4.8	**2**	**0.23**	**1**		96	40
4.5	**2.25**	**0.39**	**2**		90	45
4.5	**2**	**0.48**	**3**		90	40
4.5	**1.75**	**0.31**	**4**		90	35
4.5	**1.5**	**0.12**	**5**		90	30
4.5	**1.25**	**0.03**	**6**		90	25
4.5	**1**	**0.02**	**7**		90	20
4.1	**2.35**	**0.54**	**8**		82	47
4.1	**1.85**	**0.54**	**9**		82	37
4.1	**1.35**	**0.06**	**10**		82	27
4	**2**	**0.53**	**11**		80	40
3.5	**2**	**0.64**	**12**		70	40
3	**2**	**0.38**	**13**		60	40
2.5	**2**	**0.01**	**14**		50	40
2	**2**	**0.04**	**15**		40	40
1.5	**2**	**0.01**	**16**		30	40
1	**2**	**0**	**17**		20	40
3.85	**1.6**	**0.49**	**18**		77	32
3.6	**1.6**	**0.66**	**19**		72	32
3.1	**1.6**	**0.62**	**20**		62	32
4.85	**1.6**	**0.13**	**21**		97	32
0.1	**2**	**0**	**A**		2	40
0.7	**2**	**0**	**B**		14	40
1	**1.9**	**0**	**C**		20	38
1.5	**1.75**	**0**	**D**		30	35
1.75	**1.45**	**0**	**E**		35	29
2	**1.45**	**0**	**F**		40	29
2.25	**1.4**	**0**	**G**		45	28
2.5	**1.5**	**0**	**H**		50	30
2.75	**1.55**	**0**	**I**		55	31
3	**1.4**	**0**	**J**		60	28
3.25	**1.4**	**0**	**K**		65	28
3.5	**1.25**	**0**	**L**		70	25
3.75	**1.25**	**0**	**M**		75	25
4	**1.2**	**0**	**N**		80	24
4.1	**1.1**	**0**	**O**		82	22
4.2	**1**	**0**	**P**		84	20
4.5	**0.5**	**0**	**Q**		90	10
5.6	**1**	**0**	**R**		112	20
5.6	**1.1**	**0**	**S**		112	22
5.35	**1.25**	**0**	**T**		107	25
5.2	**1.5**	**0**	**U**		104	30
5.05	**1.75**	**0**	**V**		101	35
5.1	**1.85**	**0**	**W**		102	37
5	**2**	**0**	**X**		100	40

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
4.7	**2.25**	**0**	**Y**		94	45
4.7	**2.35**	**0**	**Z**		94	47
4.5	**2.55**	**0**	**AA**		90	51
4.3	**2.55**	**0**	**BB**		86	51
4.1	**2.7**	**0**	**CC**		82	54
4	**2.7**	**0**	**DD**		80	54
3.75	**2.5**	**0**	**EE**		75	50
3.65	**2.35**	**0**	**FF**		73	47
3.5	**2.3**	**0**	**GG**		70	46
3.25	**2.2**	**0**	**HH**		65	44
3	**2.2**	**0**	**II**		60	44
2.75	**2.1**	**0**	**JJ**		55	42
2.5	**2.15**	**0**	**KK**		50	43
2.25	**2.25**	**0**	**LL**		45	45
2	**2.4**	**0**	**MM**		40	48
1.75	**2.45**	**0**	**NN**		35	49
1.5	**2.45**	**0**	**OO**		30	49
1	**2.4**	**0**	**PP**		20	48
0.15	**2**	**0**	**A1**		3	40
0.2	**2**	**0**	**A2**		4	40
0.25	**2**	**0**	**A3**		5	40
0.3	**2**	**0**	**A4**		6	40
0.35	**2**	**0**	**A5**		7	40
0.4	**2**	**0**	**A6**		8	40
0.45	**2**	**0**	**A7**		9	40
0.5	**2**	**0**	**A8**		10	40
0.55	**2**	**0**	**A9**		11	40
0.6	**2**	**0**	**A10**		12	40
0.65	**2**	**0**	**A11**		13	40
0.75	**1.9835**	**0**	**B1**		15	39.67
0.8	**1.967**	**0**	**B2**		16	39.34
0.85	**1.9505**	**0**	**B3**		17	39.01
0.9	**1.934**	**0**	**B4**		18	38.68
0.95	**1.9175**	**0**	**B5**		19	38.35
1.05	**1.885**	**0**	**C1**		21	37.7
1.1	**1.87**	**0**	**C2**		22	37.4
1.15	**1.855**	**0**	**C3**		23	37.1
1.2	**1.84**	**0**	**C4**		24	36.8
1.25	**1.825**	**0**	**C5**		25	36.5
1.3	**1.81**	**0**	**C6**		26	36.2
1.35	**1.795**	**0**	**C7**		27	35.9
1.4	**1.78**	**0**	**C8**		28	35.6
1.45	**1.765**		**C9**		29	35.3
1.5415	**1.7**	**0**	**D1**		30.83	34

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
1.583	**1.65**	**0**	**D2**		31.66	33
1.6245	**1.6**	**0**	**D3**		32.49	32
1.6665	**1.55**	**0**	**D4**		33.33	31
1.7075	**1.5**	**0**	**D5**		34.15	30
1.8	**1.45**	**0**	**E1**		36	29
1.85	**1.45**	**0**	**E2**		37	29
1.9	**1.45**	**0**	**E3**		38	29
1.95	**1.45**	**0**	**E4**		39	29
2.05	**1.44**	**0**	**F1**		41	28.8
2.1	**1.43**	**0**	**F2**		42	28.6
2.15	**1.42**	**0**	**F3**		43	28.4
2.2	**1.41**	**0**	**F4**		44	28.2
2.3	**1.42**	**0**	**G1**		46	28.4
2.35	**1.44**	**0**	**G2**		47	28.8
2.4	**1.46**	**0**	**G3**		48	29.2
2.45	**1.48**	**0**	**G4**		49	29.6
	0					
2.55	**1.51**	**0**	**H1**		51	30.2
2.6	**1.52**	**0**	**H2**		52	30.4
2.65	**1.53**	**0**	**H3**		53	30.6
2.7	**1.54**	**0**	**H4**		54	30.8
2.8	**1.52**	**0**	**I1**		56	30.4
2.85	**1.49**	**0**	**I2**		57	29.8
2.9	**1.46**	**0**	**I3**		58	29.2
2.95	**1.43**	**0**	**I4**		59	28.6
3.05	**1.4**	**0**	**J1**		61	28
3.1	**1.4**	**0**	**J2**		62	28
3.15	**1.4**	**0**	**J3**		63	28
3.2	**1.4**	**0**	**J4**		64	28
3.3	**1.37**	**0**	**K1**		66	27.4
3.35	**1.34**	**0**	**K2**		67	26.8
3.4	**1.31**	**0**	**K3**		68	26.2
3.45	**1.28**	**0**	**K4**		69	25.6
3.55	**1.25**	**0**	**L1**		71	25
3.6	**1.25**	**0**	**L2**		72	25
3.65	**1.25**	**0**	**L3**		73	25
3.7	**1.25**	**0**	**L4**		74	25
3.8	**1.24**	**0**	**M1**		76	24.8
3.85	**1.23**	**0**	**M2**		77	24.6
3.9	**1.22**	**0**	**M3**		78	24.4

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
3.95	**1.21**	**0**	**M4**		79	24.2
4.05	**1.15**	**0**	**N1**		81	23
4.15	**1.05**	**0**	**O1**		83	21
4.23	**0.95**	**0**	**P1**		84.6	19
4.26	**0.9**	**0**	**P2**		85.2	18
4.29	**0.85**	**0**	**P3**		85.8	17
4.32	**0.8**	**0**	**P4**		86.4	16
4.35	**0.75**	**0**	**P5**		87	15
4.38	**0.7**	**0**	**P6**		87.6	14
4.41	**0.65**	**0**	**P7**		88.2	13
4.44	**0.6**	**0**	**P8**		88.8	12
4.47	**0.55**	**0**	**P9**		89.4	11
4.55	**0.52273**	**0**	**Q1**		91	10.4545
4.6	**0.54545**	**0**	**Q2**		92	10.909
4.65	**0.56818**	**0**	**Q3**		93	11.3635
4.7	**0.5909**	**0**	**Q4**		94	11.818
4.75	**0.61363**	**0**	**Q5**		95	12.2725
4.8	**0.63635**	**0**	**Q6**		96	12.727
4.85	**0.65908**	**0**	**Q7**		97	13.1815
4.9	**0.6818**	**0**	**Q8**		98	13.636
4.95	**0.70453**	**0**	**Q9**		99	14.0905
5	**0.72725**	**0**	**Q10**		100	14.545
5.05	**0.74998**	**0**	**Q11**		101	14.9995
5.1	**0.7727**	**0**	**Q12**		102	15.454
5.15	**0.79543**	**0**	**Q13**		103	15.9085
5.2	**0.81815**	**0**	**Q14**		104	16.363
5.25	**0.84088**	**0**	**Q15**		105	16.8175
5.3	**0.8636**	**0**	**Q16**		106	17.272
5.35	**0.88633**	**0**	**Q17**		107	17.7265
5.4	**0.90905**	**0**	**Q18**		108	18.181
5.45	**0.93178**	**0**	**Q19**		109	18.6355
5.5	**0.9545**	**0**	**Q20**		110	19.09
5.55	**0.97723**	**0**	**Q21**		111	19.5445
5.6	**1.05**	**0**	**R1**		112	21
5.55	**1.13**	**0**	**S1**		111	22.6
5.5	**1.16**	**0**	**S2**		110	23.2
5.45	**1.19**	**0**	**S3**		109	23.8
5.4	**1.22**	**0**	**S4**		108	24.4
5.32	**1.3**	**0**	**T1**		106.4	26
5.29	**1.35**	**0**	**T2**		105.8	27
5.26	**1.4**	**0**	**T3**		105.2	28

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
5.23	**1.45**	**0**	**T4**		104.6	29
5.17	**1.55**	**0**	**U1**		103.4	31
5.14	**1.6**	**0**	**U2**		102.8	32
5.11	**1.65**	**0**	**U3**		102.2	33
5.08	**1.7**	**0**	**U4**		101.6	34
5.075	**1.8**	**0**	**V1**		101.5	36
5.0665	**1.9**	**0**	**W1**		101.33	38
5.033	**1.95**	**0**	**W2**		100.66	39
4.95	**2.04167**	**0**	**X1**		99	40.8333
4.9	**2.08333**	**0**	**X2**		98	41.6666
4.85	**2.125**	**0**	**X3**		97	42.4999
4.8	**2.16666**	**0**	**X4**		96	43.3332
4.75	**2.20833**	**0**	**X5**		95	44.1665
4.7	**2.3**	**0**	**Y1**		94	46
4.65	**2.4**	**0**	**Z1**		93	48
4.6	**2.45**	**0**	**Z2**		92	49
4.55	**2.5**	**0**	**Z4**		91	50
4.45	**2.55**	**0**	**AA1**		89	51
4.4	**2.55**	**0**	**AA2**		88	51
4.35	**2.55**	**0**	**AA3**		87	51
4.25	**2.5875**	**0**	**BB1**		85	51.75
4.2	**2.625**	**0**	**BB2**		84	52.5
4.15	**2.6625**	**0**	**BB3**		83	53.25
4.05	**2.7**	**0**	**CC1**		81	54
3.95	**2.66**	**0**	**DD1**		79	53.2
3.9	**2.62**	**0**	**DD2**		78	52.4
3.85	**2.58**	**0**	**DD3**		77	51.6
3.8	**2.54**	**0**	**DD4**		76	50.8
3.7165	**2.45**	**0**	**EE1**		74.33	49
3.683	**2.4**	**0**	**EE2**		73.66	48
3.6	**2.3335**	**0**	**FF1**		72	46.67
3.55	**2.317**	**0**	**FF2**		71	46.34
3.45	**2.28**	**0**	**GG1**		69	45.6
3.4	**2.26**	**0**	**GG2**		68	45.2
3.35	**2.24**	**0**	**GG3**		67	44.8

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
3.3	**2.22**	**0**	**GG4**		66	44.4
3.2	**2.2**	**0**	**HH1**		64	44
3.15	**2.2**	**0**	**HH2**		63	44
3.1	**2.2**	**0**	**HH3**		62	44
3.05	**2.2**	**0**	**HH4**		61	44
2.95	**2.18**	**0**	**II1**		59	43.6
2.9	**2.16**	**0**	**II2**		58	43.2
2.85	**2.14**	**0**	**II3**		57	42.8
2.8	**2.12**	**0**	**II4**		56	42.4
	0					
2.7	**2.11**	**0**	**JJ1**		54	42.2
2.65	**2.12**	**0**	**JJ2**		53	42.4
2.6	**2.13**	**0**	**JJ3**		52	42.6
2.55	**2.14**	**0**	**JJ4**		51	42.8
2.45	**2.17**	**0**	**KK1**		49	43.4
2.4	**2.19**	**0**	**KK2**		48	43.8
2.35	**2.21**	**0**	**KK3**		47	44.2
2.3	**2.23**	**0**	**KK4**		46	44.6
2.2	**2.28**	**0**	**LL1**		44	45.6
2.15	**2.31**	**0**	**LL2**		43	46.2
2.1	**2.34**	**0**	**LL3**		42	46.8
2.05	**2.37**	**0**	**LL4**		41	47.4
1.95	**2.41**	**0**	**MM1**		39	48.2
1.9	**2.42**	**0**	**MM2**		38	48.4
1.85	**2.43**	**0**	**MM3**		37	48.6
1.8	**2.44**	**0**	**MM4**		36	48.8
1.7	**2.45**	**0**	**NN1**		34	49
1.65	**2.45**	**0**	**NN2**		33	49
1.6	**2.45**	**0**	**NN3**		32	49
1.55	**2.45**	**0**	**NN4**		31	49
1.45	**2.445**	**0**	**OO1**		29	48.9
1.4	**2.44**	**0**	**OO2**		28	48.8
1.35	**2.435**	**0**	**OO3**		27	48.7
1.3	**2.43**	**0**	**OO4**		26	48.6
1.25	**2.425**	**0**	**OO5**		25	48.5
1.2	**2.42**	**0**	**OO6**		24	48.4
1.15	**2.415**	**0**	**OO7**		23	48.3
1.1	**2.41**	**0**	**OO8**		22	48.2
1.05	**2.405**	**0**	**OO9**		21	48.1
0.95	**2.37774**	**0**	**PP1**		19	47.5548

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
0.9	**2.35552**	**0**	**PP2**		18	47.1104
0.85	**2.3333**	**0**	**PP3**		17	46.666
0.8	**2.31108**	**0**	**PP4**		16	46.2216
0.75	**2.28886**	**0**	**PP5**		15	45.7772
0.7	**2.26664**	**0**	**PP6**		14	45.3328
0.65	**2.24442**	**0**	**PP7**		13	44.8884
0.6	**2.2222**	**0**	**PP8**		12	44.444
0.55	**2.19998**	**0**	**PP9**		11	43.9996
0.5	**2.17776**	**0**	**PP10**		10	43.5552
0.45	**2.15554**	**0**	**PP11**		9	43.1108
0.4	**2.13332**	**0**	**PP12**		8	42.6664
0.35	**2.1111**	**0**	**PP13**		7	42.222
0.3	**2.08888**	**0**	**PP14**		6	41.7776
0.25	**2.06666**	**0**	**PP15**		5	41.3332
0.2	**2.04444**	**0**	**PP16**		4	40.8888
0.15	**2.02222**	**0**	**PP17**		3	40.4444

CALIBRATION CERTIFICATE

Model: 2000 Serial Number: 2002679

Unit Gain Ratio: ____________ Time Constant: ____________

Type of Reading

Velocity:
- [x] FPS
- [ ] CMS
- [ ] ______

Level:
- [ ] IN
- [ ] CM
- [x] N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	NA
Measured:	0.00	2.00	NA

- [x] Factory Calibration

- [ ] Field Profile Calibration;
  Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: [illegible] Date: 4-20-07

QA Technician: [illegible] Date: 20APR07

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY

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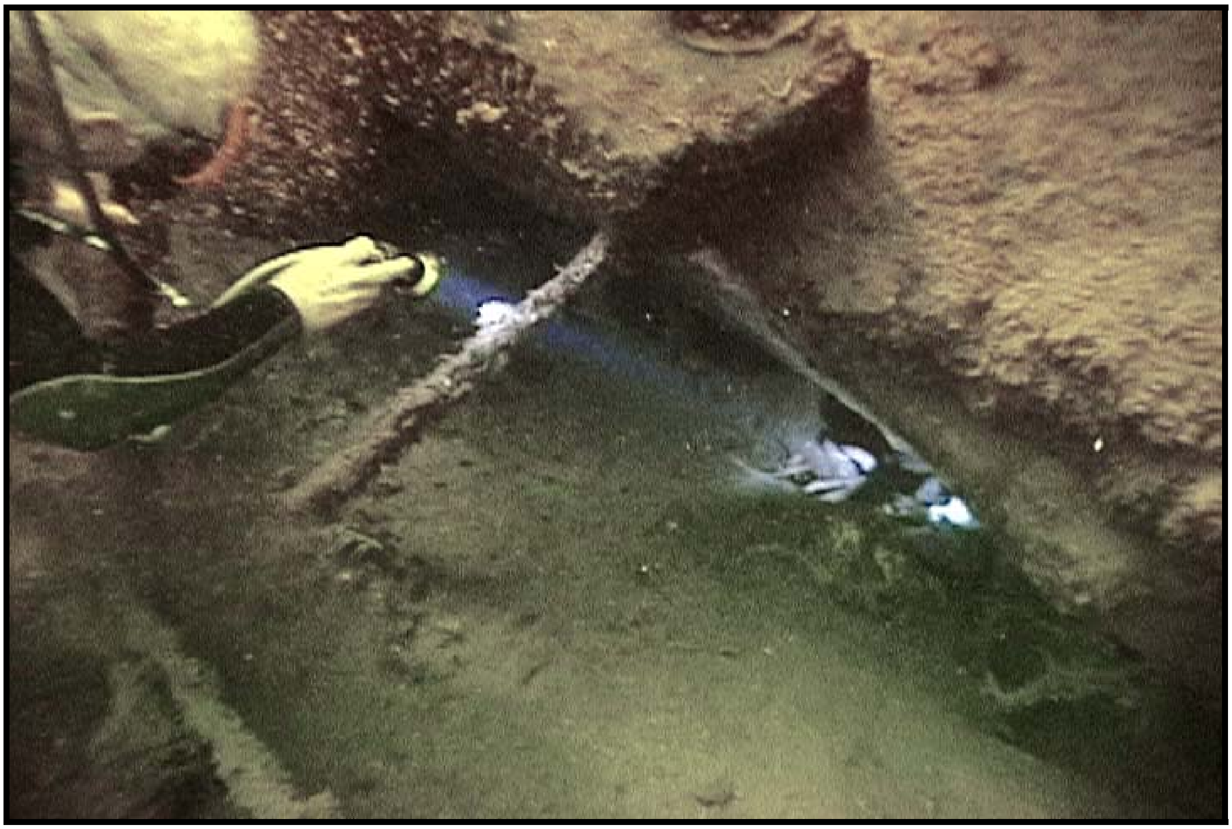
P/N 101001 301

Flowmeter Calibration Certificate.

Discharge Measurement:
Bright Angel Spring,
Rodman Reservoir/Ocklawaha River,
Marion County, Florida;
September 27, 2007



Prepared for:

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Prepared by:

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Discharge Measurement: Bright Angel Spring, Marion County, Florida; September 27, 2007

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Results of Discharge Measurements of Bright Angel Spring, Marion County, Florida; September 27, 2007

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to perform discharge measurements of the submerged springs that discharge into the Rodman Reservoir/Ocklawaha River, in Marion and Putnam Counties, Florida. This report documents the results of the measurement made at Bright Angel Spring on September 27, 2007. A summary of the results and collected data for that measurement are presented on Table 1.

PURPOSE and SCOPE OF WORK

The purpose of this work was to obtain an initial discharge measurement of Bright Angel Spring, which is a source of groundwater discharge into the Rodman Reservoir/Ocklawaha River. A program of discharge measurements was to be made of the springs in the Rodman Reservoir/Ocklawaha River during September of 2007.

SITE DESCRIPTION

Bright Angel Spring is located on the south side of the Rodman Reservoir and the Ocklawaha River channel, southeast of the public boat ramp at Kenwood Landing, at 416452 Easting/3265529 Northing (UTM Zone 17, NAD 1983 HARN, meters), or Lat. N29.516572°, Long. W81.862090° (WGS84).

The spring discharges primarily from a low, wide vent in bedrock at the bottom of a large basin. The vent was about 24 to 26 feet deep (during this measurement). The vent is about 10 feet wide, and has an opening with a maximum height of about 1.5 feet at its extreme right side (when viewed from downstream) and tapering to just a few inches high on the left. The vent was too small to allow for diver entry, and conditions around it during this measurement were very silty. See Figure 1.

Since the vent of this spring is located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, the spring vent opening provided a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

PERSONNEL

Fieldwork for this discharge measurement was conducted by KES personnel Peter Butt and Tom Morris. Jeff Davis of the SJRWMD was also on site during the measurement, and provided logistics support. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech of Orlando, Florida.

METHODS

Instrumentation

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 20, 2007. A copy of the Calibration Certificate is included with this report.

A video record of the site was made on August 29, 2007.

Field Operations

Velocity measurements were taken at the 1.5 foot high end of the vent. The measurement site was 24-26 feet deep. The rest of the vent was blocked with plastic bubble wrap sheets to eliminate areas that could not be measured, and divert flow to the measurement cross-section. Cross-section dimensions were approximately 1.5 feet high by 2 feet wide.

Five telescoping aluminum poles with 0.1, 0.25, 0.5 and one-foot interval markings were positioned vertically and horizontally to provide a positioning grid for velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a low-profile metal spring clamp. Conduit dimensions around the grid were measured with a collapsible steel tape. See Figure 2.

Peter Butt positioned the sensor and recorded positional data, while Tom Morris took the velocity readings after taking reset cues from Butt. During all measurements, the sensor handler was able to move away from the measurement cross-section, and remove himself from the cross section of the flow. The meter operator was also positioned above and away from the cross-section. This minimized or eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in the “Fixed Point Averaging” mode. Fixed Point Averaging is an average of velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Thirteen station readings were made.

Data Processing

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 2. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, and anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1. The results of the contour processing are illustrated in Figures 3 and 4.

Discharge and measurement cross-section area are given on the Grid Volume Computations and Gridding Report feature of the software, included in this report on page 1 of Table 2. The total discharge is shown as the "**Net Volume (Cut-Fill)**". The Net Volume value is used because a Surfer 8 "blanking file" operation was used to define the measurement cross-section boundary and eliminate artifacts present in the contouring process that would create inaccuracies in the flow calculations. The software also calculated the total cross-sectional area of the measurement location within the passage, and is shown in square feet as the "**Positive Planar Area (Cut)**".

RESULTS AND DISCUSSION

This measurement is the first one performed at Bright Angel Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Bright Angel Spring on September 27, 2007 was 0.445 CFS (cubic feet per second). This result is also expressed as 200 GPM (gallons per minute) or 0.288 MGD (million gallons per day), see Table 1. Thirteen (13) readings were made, see Figures 2 and 4. The point velocity readings ranged from 0.04 to 0.29 feet per second (fps), with an overall average station reading of 0.20 fps. The total cross-sectional area was calculated as 2.52 square feet. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 14:28 hours and were completed by 14:57.

	UNDERWATER DISCHARGE MEASUREMENT				
	Location:	**BRIGHT ANGEL SPRING**		Date:	**September 27, 2007**
	Rodman Reservoir/Ocklawaha River			Time Start:	14:28
		Marion County, Florida		Time End:	14:57
	Personnel:	Peter Butt, Tom Morris			
	Method:	Grid within irregular conduit			
	Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles			
	Analysis Method: Surfer 8 with kriging				
	Bright Angel Spring Total Discharge:				
	CFS	**0.445**			
	MGD	**0.288**			
	GPM	**200**			
	Total Cross-sectional Area:		2.52	square feet	
	Avg. Station Point Velocity:		0.20	feet/second	
	Cross-section Depth:		24-26	feet deep	
	Msmt. Periods:		60 seconds		
	Velocity Reading by Station:		(All velocity readings in feet per second.)		
	Station #	Point Velocity			
	1	0.15			
	2	0.22			
	3	0.29			
	4	0.24			
	5	0.04			
	6	0.2			
	7	0.28			
	8	0.26			
	9	0.28			
	10	0.13			
	11	0.2			
	12	0.22			
	13	0.09			

Table 1. Discharge of Bright Angel Spring, Marion County, Florida on September 27, 2007. Data record and calculation of discharge measurement.

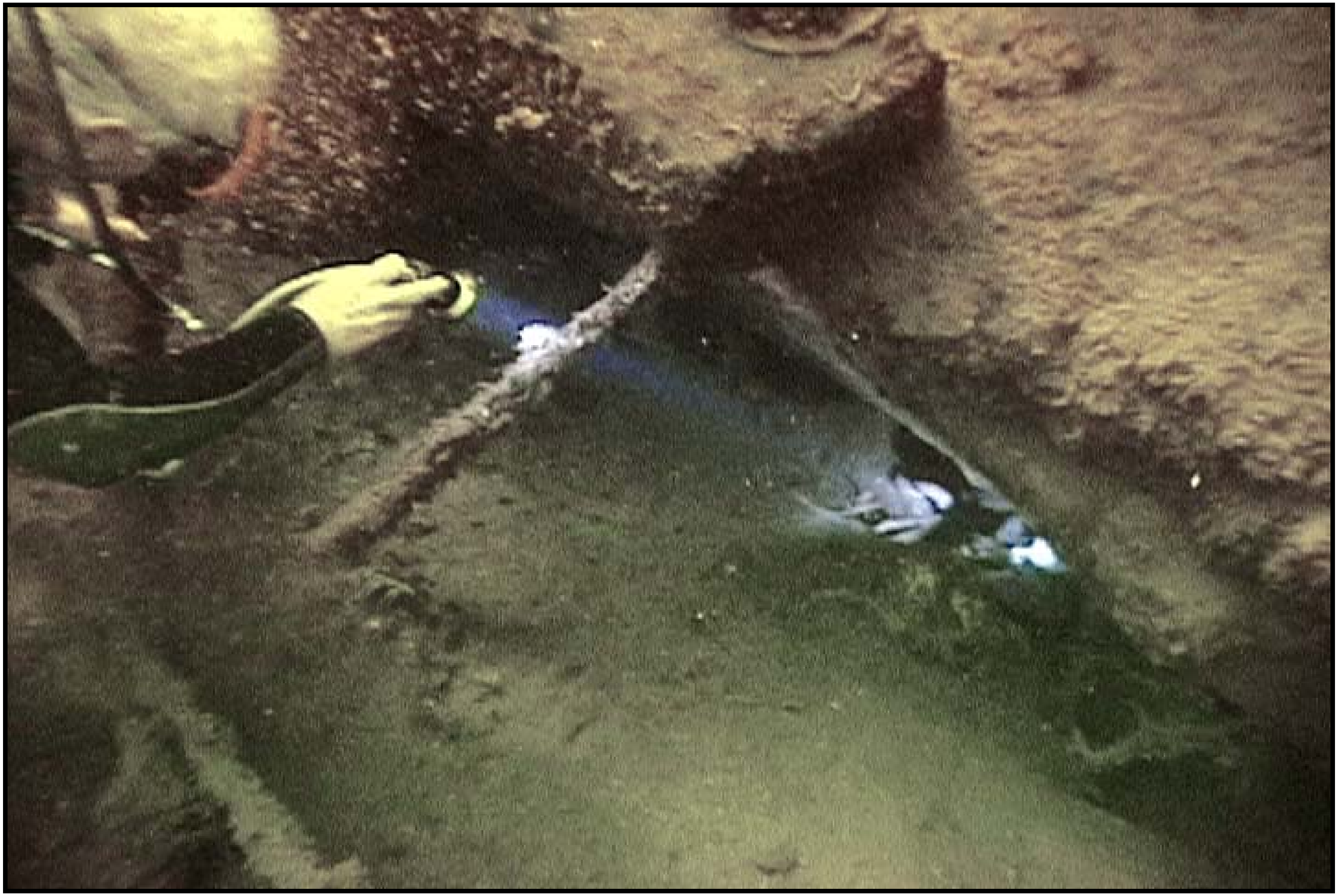

Figure 1. Underwater video still of Bright Angel Spring, Marion County, Florida. Measurement cross-section area is on the right side of the vent.

KARST ENVIRONMENTAL SERVICES, INC. 2007

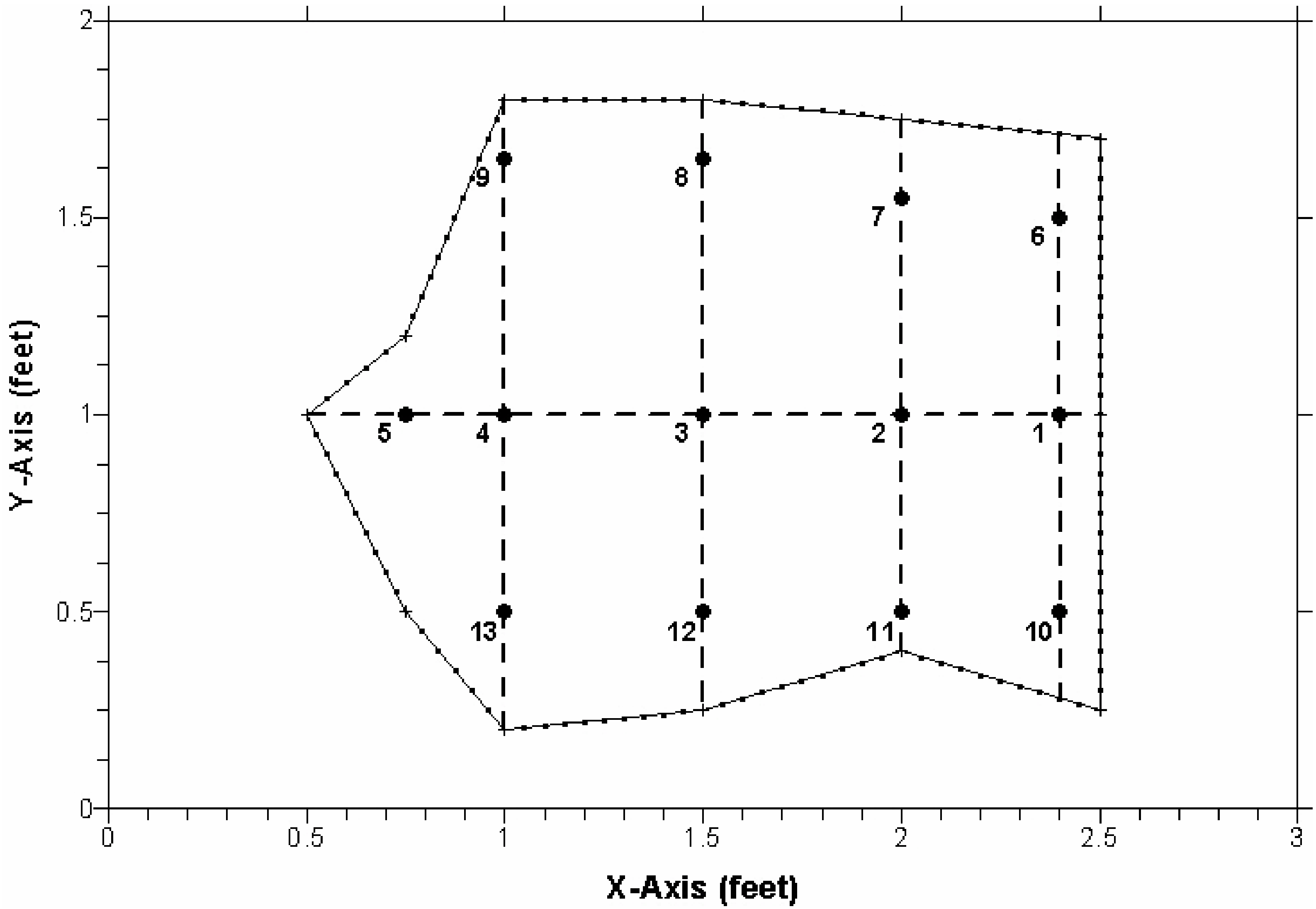

Figure 2. Discharge measurement cross-section; Bright Angel Spring, Marion County, Florida, September 27, 2007 measurement. Cross-section is viewed to the upstream of observer, and is located between the 24- to 26-foot depth levels. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected, lettered points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

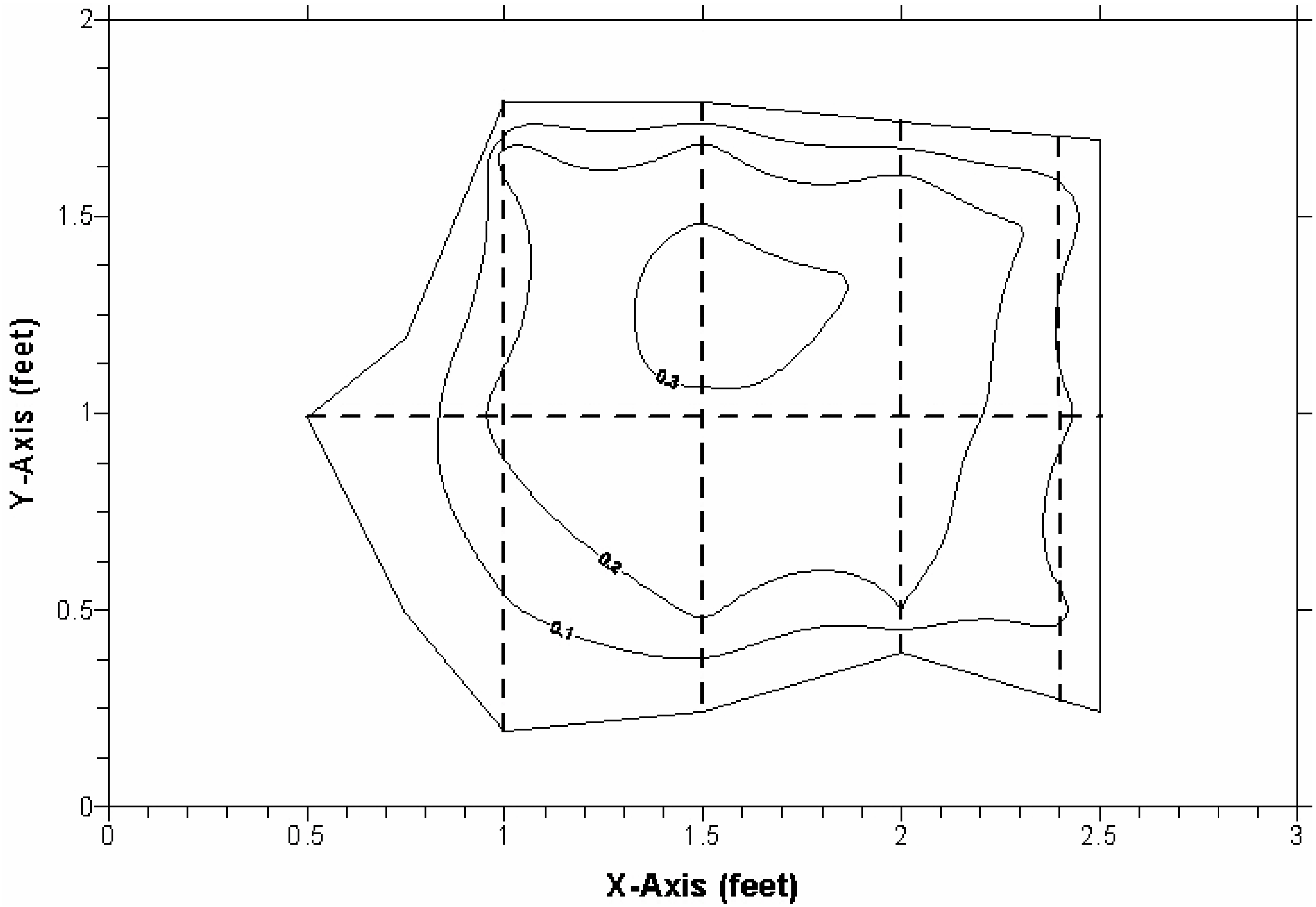

Figure 3. Discharge measurement cross-section; Bright Angel Spring, Marion County, Florida, September 27, 2007 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

TABLE 2. BRIGHT ANGEL SPRING, SEPTEMBER 27, 2007.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Rodman\bright angel\2007-09\BrightAngel_9-07.bln.grd
Grid Size:	81 rows x 121 columns
X Minimum:	0
X Maximum:	3
X Spacing:	0.025
Y Minimum:	0
Y Maximum:	2
Y Spacing:	0.025
Z Minimum:	-0.000265858310875
Z Maximum:	0.31638284826777

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES

Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	0.44544245532653
Simpson's Rule:	0.44549858576893
Simpson's 3/8 Rule:	0.44543409662667

CUT & FILL VOLUMES

Positive Volume [Cut]:	0.44544262731012
Negative Volume [Fill]:	1.7198358398693E-007
Net Volume [Cut-Fill]:	**0.44544245532653<<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the use of a blanking file operation in the calculations. Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas

Positive Planar Area [Cut]:	**2.5168358361802<<<<Cross-section in Square Feet**
Negative Planar Area [Fill]:	3.9163819753962E-005
Blanked Planar Area:	3.483125
Total Planar Area:	6

Surface Areas

Positive Surface Area [Cut]:	2.970149017277
Negative Surface Area [Fill]:	4.0162044215428E-005

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Rodman\bright angel\2007-09\Bright Angel 9-07 SURFER XYZ T3BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	135
Original Data:	135
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	0.2	0
25%-tile:	1	0.385	0
Median:	1.7	1	0
75%-tile:	2.4	1.65	0
Maximum:	2.5	1.8	0.29
Midrange:	1.5	1	0.145
Range:	2	1.6	0.29
Interquartile Range:	1.4	1.265	0
Median Abs. Deviation:	0.7	0.645	0
Mean:	1.6597148148148	1.0109259259259	0.019259259259259
Trim Mean (10%):	1.6728577235772	1.0113821138211	0.0083739837398374
Standard Deviation:	0.68737047949182	0.59111639048974	0.063358236386202
Variance:	0.47247817607682	0.34941858710562	0.0040142661179698
Coef. of Variation:			3.2897545815912
Coef. of Skewness:			3.2350898861509

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.000	0.005
Y:		1.000	0.051
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.47247817607682	-4.4106310013709E-005	0.00023512208504801
Y:		0.34941858710562	0.0019006858710562
Z:			0.0040142661179698

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.00049814365821325	0.0054396300382277	0.012933419816727
Standard Error:	0.0080123311148857	0.0093170143289772	0.017202174531924

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.000	-0.773
B:		1.000	0.548
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.0014115805919557	0.00070579029597784	0.17236
Residual:	132	0.54051434533397	0.0040948056464695	
Total:	134	0.54192592592593		

Coefficient of Multiple Determination (R^2): 0.0026047482218974

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.05	0
Median:	0.050249378105604	0
75%-tile:	0.054230987451825	0
Maximum:	0.5	0.28

Midrange:	0.275	0.14
Range:	0.45	0.28
Interquartile Range:	0.004230987451825	0
Median Abs. Deviation:	0.00024937810560467	0
Mean:	0.066286304330351	0.016222222222222
Trim Mean (10%):	0.055802762921756	0.0060975609756098
Standard Deviation:	0.057274727207928	0.055522656925788
Variance:	0.0032803943767426	0.0030827654320988
Coef. of Variation:	0.86405069322447	3.4226295365212
Coef. of Skewness:	5.3539694352169	3.5638003315434
Root Mean Square:	0.087602902454876	0.057843979167463
Mean Square:	0.0076742685185185	0.0033459259259259

Complete Spatial Randomness

Lambda:	42.1875
Clark and Evans:	0.86108435209606
Skellam:	274.62142596877

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	2.3E-007
Y Duplicate Tolerance:	1.9E-007

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	1
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Rodman\bright angel\2007-09\BrightAngel_9-07.grd
Grid Size:	81 rows x 121 columns
Total Nodes:	9801
Filled Nodes:	9801
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	3
X Spacing:	0.025
Y Minimum:	0
Y Maximum:	2
Y Spacing:	0.025

Grid Statistics

Z Minimum:	-0.23896026886856
Z 25%-tile:	-0.084321271676576
Z Median:	-0.029557250809516
Z 75%-tile:	0.15417492050885
Z Maximum:	0.31638284826777
Z Midrange:	0.038711289699605
Z Range:	0.55534311713633
Z Interquartile Range:	0.23849619218543
Z Median Abs. Deviation:	0.08643241801018
Z Mean:	0.023094483073074
Z Trim Mean (10%):	0.019771300553881
Z Standard Deviation:	0.14742174571651
Z Variance:	0.021733171110104
Z Coef. of Variation:	6.3834182930203
Z Coef. of Skewness:	0.53832497168732
Z Root Mean Square:	0.14921972476357
Z Mean Square:	0.022266526258516

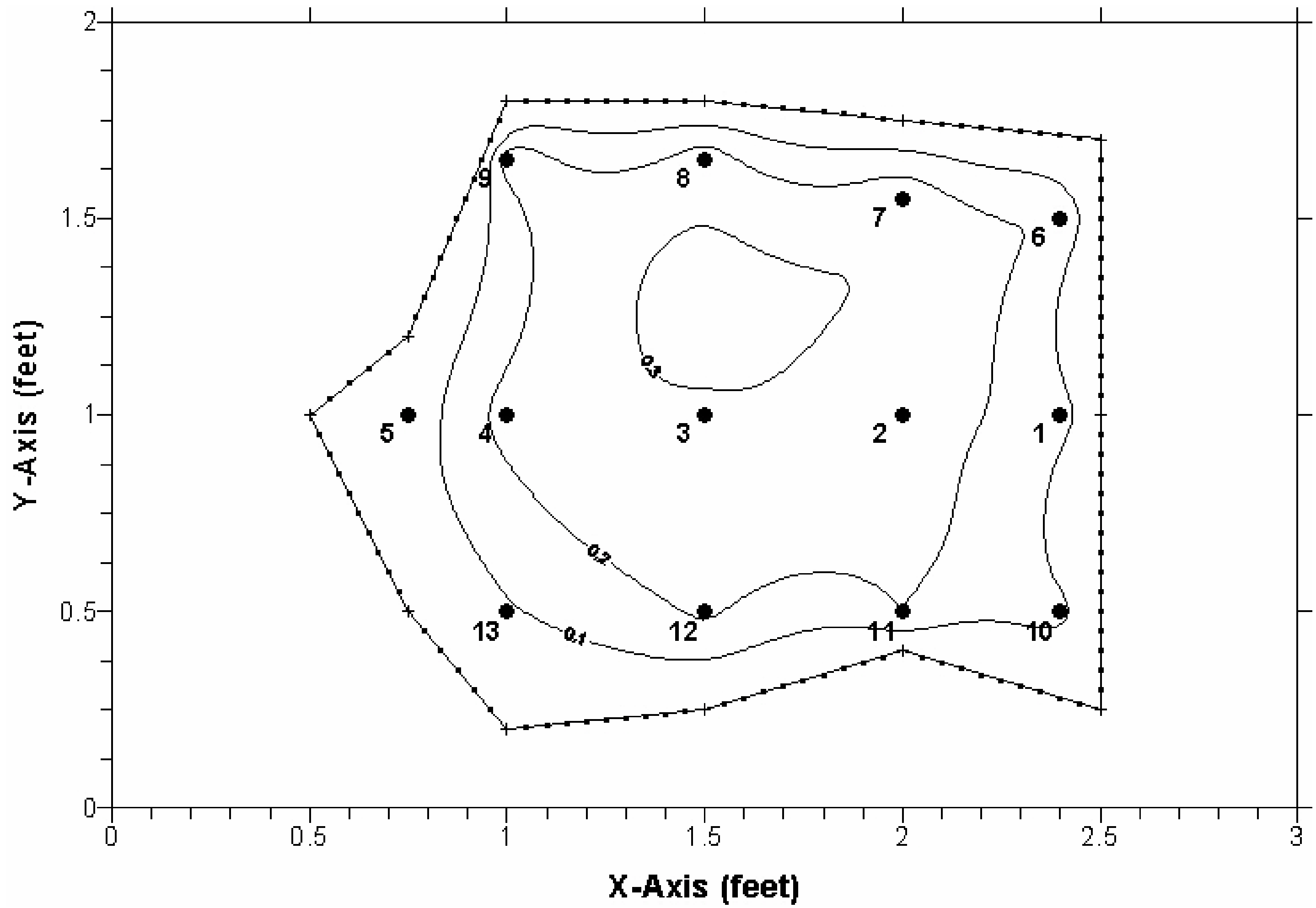

Figure 4. Discharge measurement cross-section; Bright Angel Spring, Marion County, Florida, September 27, 2007 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. See Table 1 for station velocities. Boundary of cross section is shown as connected, lettered points. X- and Y-axis scales are shown in feet.

Table 3. Bright Angel Spring XYZ Grid Data September 27, 2007.						
X	**Y**	**Z (Velocity)**	**Station #**		**X Plot**	**Y Plot**
2.4	**1**	**0.15**	**1**		48	20
2	**1**	**0.22**	**2**		40	20
1.5	**1**	**0.29**	**3**		30	20
1	**1**	**0.24**	**4**		20	20
0.75	**1**	**0.04**	**5**		15	20
2.4	**1.5**	**0.2**	**6**		48	30
2	**1.55**	**0.28**	**7**		40	31
1.5	**1.65**	**0.26**	**8**		30	33
1	**1.65**	**0.28**	**9**		20	33
2.4	**0.5**	**0.13**	**10**		48	10
2	**0.5**	**0.2**	**11**		40	10
1.5	**0.5**	**0.22**	**12**		30	10
1	**0.5**	**0.09**	**13**		20	10
0.5	**1**	**0**	**A**		10	20
0.75	**0.5**	**0**	**B**		15	10
1	**0.2**	**0**	**C**		20	4
1.5	**0.25**	**0**	**D**		30	5
2	**0.4**	**0**	**E**		40	8
2.5	**0.25**	**0**	**F**		50	5
2.5	**1**	**0**	**G**		50	20
2.5	**1.7**	**0**	**H**		50	34
2	**1.75**	**0**	**I**		40	35
1.5	**1.8**	**0**	**J**		30	36
1	**1.8**	**0**	**K**		20	36
0.75	**1.2**	**0**	**L**		15	24
		0				
0.525	**0.95**	**0**	**A1**		10.5	19
0.55	**0.9**	**0**	**A2**		11	18
0.575	**0.85**	**0**	**A3**		11.5	17
0.6	**0.8**	**0**	**A4**		12	16
0.625	**0.75**	**0**	**A5**		12.5	15
0.65	**0.7**	**0**	**A6**		13	14
0.675	**0.65**	**0**	**A7**		13.5	13
0.7	**0.6**	**0**	**A8**		14	12
0.725	**0.55**	**0**	**A9**		14.5	11
		0				
0.7915	**0.45**	**0**	**B1**		15.83	9
0.833	**0.4**	**0**	**B2**		16.66	8
0.8745	**0.35**	**0**	**B3**		17.49	7
0.916	**0.3**	**0**	**B4**		18.32	6
0.9575	**0.25**	**0**	**B5**		19.15	5
		0				
1.05	**0.205**	**0**	**C1**		21	4.1
1.1	**0.21**	**0**	**C2**		22	4.2
1.15	**0.215**	**0**	**C3**		23	4.3

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
1.2	**0.22**	**0**	**C4**		24	4.4
1.25	**0.225**	**0**	**C5**		25	4.5
1.3	**0.23**	**0**	**C6**		26	4.6
1.35	**0.235**	**0**	**C7**		27	4.7
1.4	**0.24**	**0**	**C8**		28	4.8
1.45	**0.245**	**0**	**C9**		29	4.9
1.55	**0.265**	**0**	**D1**		31	5.3
1.6	**0.28**	**0**	**D2**		32	5.6
1.65	**0.295**	**0**	**D3**		33	5.9
1.7	**0.31**	**0**	**D4**		34	6.2
1.75	**0.325**	**0**	**D5**		35	6.5
1.8	**0.34**	**0**	**D6**		36	6.8
1.85	**0.355**	**0**	**D7**		37	7.1
1.9	**0.37**	**0**	**D8**		38	7.4
1.95	**0.385**	**0**	**D9**		39	7.7
2.05	**0.385**	**0**	**E1**		41	7.7
2.1	**0.37**	**0**	**E2**		42	7.4
2.15	**0.355**	**0**	**E3**		43	7.1
2.2	**0.34**	**0**	**E4**		44	6.8
2.25	**0.325**	**0**	**E5**		45	6.5
2.3	**0.31**	**0**	**E6**		46	6.2
2.35	**0.295**	**0**	**E7**		47	5.9
2.4	**0.28**	**0**	**E8**		48	5.6
2.45	**0.265**	**0**	**E9**		49	5.3
2.5	**0.3**	**0**	**F1**		50	6
2.5	**0.35**	**0**	**F2**		50	7
2.5	**0.4**	**0**	**F3**		50	8
2.5	**0.45**	**0**	**F4**		50	9
2.5	**0.5**	**0**	**F5**		50	10
2.5	**0.55**	**0**	**F6**		50	11
2.5	**0.6**	**0**	**F7**		50	12
2.5	**0.65**	**0**	**F8**		50	13
2.5	**0.7**	**0**	**F9**		50	14
2.5	**0.75**	**0**	**F10**		50	15
2.5	**0.8**	**0**	**F11**		50	16
2.5	**0.85**	**0**	**F12**		50	17
2.5	**0.9**	**0**	**F13**		50	18
2.5	**0.95**	**0**	**F14**		50	19
2.5	**1.05**	**0**	**G1**		50	21
2.5	**1.1**	**0**	**G2**		50	22
2.5	**1.15**	**0**	**G3**		50	23
2.5	**1.2**	**0**	**G4**		50	24
2.5	**1.25**	**0**	**G5**		50	25
2.5	**1.3**	**0**	**G6**		50	26

Table 3. Bright Angel Spring XYZ Grid Data, September 27, 2007.

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
2.5	**1.35**	**0**	**G7**		50	27
2.5	**1.4**	**0**	**G8**		50	28
2.5	**1.45**	**0**	**G9**		50	29
2.5	**1.5**	**0**	**G10**		50	30
2.5	**1.55**	**0**	**G11**		50	31
2.5	**1.6**	**0**	**G12**		50	32
2.5	**1.65**	**0**	**G13**		50	33
2.45	**1.705**	**0**	**H1**		49	34.1
2.4	**1.71**	**0**	**H2**		48	34.2
2.35	**1.715**	**0**	**H3**		47	34.3
2.3	**1.72**	**0**	**H4**		46	34.4
2.25	**1.725**	**0**	**H5**		45	34.5
2.2	**1.73**	**0**	**H6**		44	34.6
2.15	**1.735**	**0**	**H7**		43	34.7
2.1	**1.74**	**0**	**H8**		42	34.8
2.05	**1.745**	**0**	**H9**		41	34.9
1.95	**1.755**	**0**	**I1**		39	35.1
1.9	**1.76**	**0**	**I2**		38	35.2
1.85	**1.765**	**0**	**I3**		37	35.3
1.8	**1.77**	**0**	**I4**		36	35.4
1.75	**1.775**	**0**	**I5**		35	35.5
1.7	**1.78**	**0**	**I6**		34	35.6
1.65	**1.785**	**0**	**I7**		33	35.7
1.6	**1.79**	**0**	**I8**		32	35.8
1.55	**1.795**	**0**	**I9**		31	35.9
1.45	**1.8**	**0**	**J1**		29	36
1.4	**1.8**	**0**	**J2**		28	36
1.35	**1.8**	**0**	**J3**		27	36
1.3	**1.8**	**0**	**J4**		26	36
1.25	**1.8**	**0**	**J5**		25	36
1.2	**1.8**	**0**	**J6**		24	36
1.15	**1.8**	**0**	**J7**		23	36
1.1	**1.8**	**0**	**J8**		22	36
1.05	**1.8**	**0**	**J9**		21	36
0.979	**1.75**	**0**	**K1**		19.58	35
0.958	**1.7**	**0**	**K2**		19.16	34
0.937	**1.65**	**0**	**K3**		18.74	33
0.916	**1.6**	**0**	**K4**		18.32	32
0.895	**1.55**	**0**	**K5**		17.9	31
0.874	**1.5**	**0**	**K6**		17.48	30
0.853	**1.45**	**0**	**K7**		17.06	29
0.832	**1.4**	**0**	**K8**		16.64	28
0.811	**1.35**	**0**	**K9**		16.22	27
0.79	**1.3**	**0**	**K10**		15.8	26

X	Y	Z (Velocity)	Station #		X Plot	Y Plot
0.769	**1.25**	**0**	**K11**		15.38	25
0.7	**1.16**	**0**	**L1**		14	23.2
0.65	**1.12**	**0**	**L2**		13	22.4
0.6	**1.08**	**0**	**L3**		12	21.6
0.55	**1.04**	**0**	**L4**		11	20.8

CALIBRATION CERTIFICATE

Model: 2000 Serial Number: 2002679

Unit Gain Ratio: ____________ Time Constant: ____________

Type of Reading

Velocity:
- [x] FPS
- [ ] CMS
- [ ] ______

Level:
- [ ] IN
- [ ] CM
- [x] N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	NA
Measured:	0.00	2.00	NA

- [x] Factory Calibration

- [ ] Field Profile Calibration;
  Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: [signature] Date: 4-20-07

QA Technician: [signature] Date: 20APR07

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY

A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
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www.marsh-mcbirney.com

P/N 101001 301

Flowmeter Calibration Certificate.

Discharge Measurement: Fish Hook Spring #1, Rodman Reservoir/Ocklawaha River, Marion County, Florida; September 27, 2006

Prepared for:

St. Johns River Water Management District

4049 Reid Street, Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.

5779 NE County Road 340, High Springs, Florida 32643

(386) 454-3556 (386) 454-3541 FAX kes@atlantic.net

Discharge Measurement: Fish Hook Spring #1, Marion County, Florida; September 27, 2006

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1. Results of Discharge Measurements of Fish Hook Spring #1, Marion County, Florida; September 27, 2006.

2. Table 1. Discharge of Fish Hook Spring #1, Marion County, Florida on September 27, 2006. Data record and calculation of discharge measurement.

3. Figure 1. Underwater video still of Fish Hook Spring #1, Marion County, Florida.

4. Figure 2. Vent Discharge Capture Device (VDCD). Sensor is attached to and centered on the gray PVC tube at the top of the 0.5 foot diameter pipe.

5. Flowmeter Calibration Certificate.

Results of Discharge Measurements of Fish Hook Spring #1, Marion County, Florida; September 27, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct discharge measurements of selected springs in the Rodman Reservoir/Ocklawaha River in Marion County, Florida. This report documents the results of the measurement made at Fish Hook Spring #1 on September 27, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Fish Hook Spring #1, which is among the many sources of groundwater discharging into the Rodman Reservoir/Ocklawaha River. A program of discharge measurements was to be made of the springs in the Rodman Reservoir/Ocklawaha River during September of 2007.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Tom Morris, both of KES. Jeff Davis of the SJRWMD was also on site during the measurement, and provided logistics support. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech of Orlando, Florida provided oversight.

SITE DESCRIPTION

Fish Hook Spring #1 is comprised of a single small vent, less than two feet in diameter, and is about 8 feet deep. It is located at 412625 Easting/3264772 Northing (UTM Zone 17, NAD 1983 HARN, meters), or Lat. N29.509497°, Long. W81.901514° (WGS84). It lies just offshore of the south bank, in an area of heavy aquatic vegetation, and about 230 feet east of Fish Hook Spring #2. See Figure 1.

Since the vent of this spring is located on the bottom of the reservoir, its discharge cannot be measured by conventional discharge measurement methods. However, the spring vent opening provides a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

Instrumentation

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 20, 2007. A copy of the Calibration Certificate is included with this report.

Field Operations and Calculations

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD). See Figure 2.

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section.

This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

RESULTS AND DISCUSSION

This measurement is the first one performed at Fish Hook Spring #1 applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Fish Hook Spring #1 on September 27, 2006 was 0.09 CFS (cubic feet per second). This result is also expressed as 40 GPM (gallons per minute) or 0.057 MGD (million gallons per day), see Table 1. Four readings were made. Individual point velocity readings ranged from 0.44 to 0.49 feet per second (fps), with an overall average station reading of 0.47 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 8 feet. The measurements commenced at about 16:00 hours and were completed by 16:10 hours.

	UNDERWATER DISCHARGE MEASUREMENT					
	Location:	**FISH HOOK SPRING #1**			Date:	**September 27, 2007**
		Rodman Reservoir/Ocklawaha River			Time Start:	16:00
		Marion County, Florida			Time End:	16:10
	Personnel:	Peter Butt, Tom Morris, Jeff Davis				
	Method:	Vent Discharge Capture Device		(0.49' Diameter)		
	Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe				
	Calculation Method: Discharge = V x *pi* x r^2					
	Measurement Periods:		60 seconds			
	Fish Hook Spring #1 Total Discharge:			**Vent 1**		
	CFS	**0.09**		**0.088**		
	MGD	**0.057**		**0.057**		
	GPM	**40**		**40**		
	Vent Depth (feet deep):			8		
	Velocity Readings:		(All velocity readings in feet per second.)			
	Vent 1					
	Reading #	Point Velocity				
	1	0.44				
	2	0.47				
	3	0.47				
	4	0.49				
	Average:	0.47				
	Discharge:	0.088				

Table 1. Discharge of Fish Hook Spring #1, Marion County, Florida on September 27, 2007 Data record and calculation of discharge measurement.

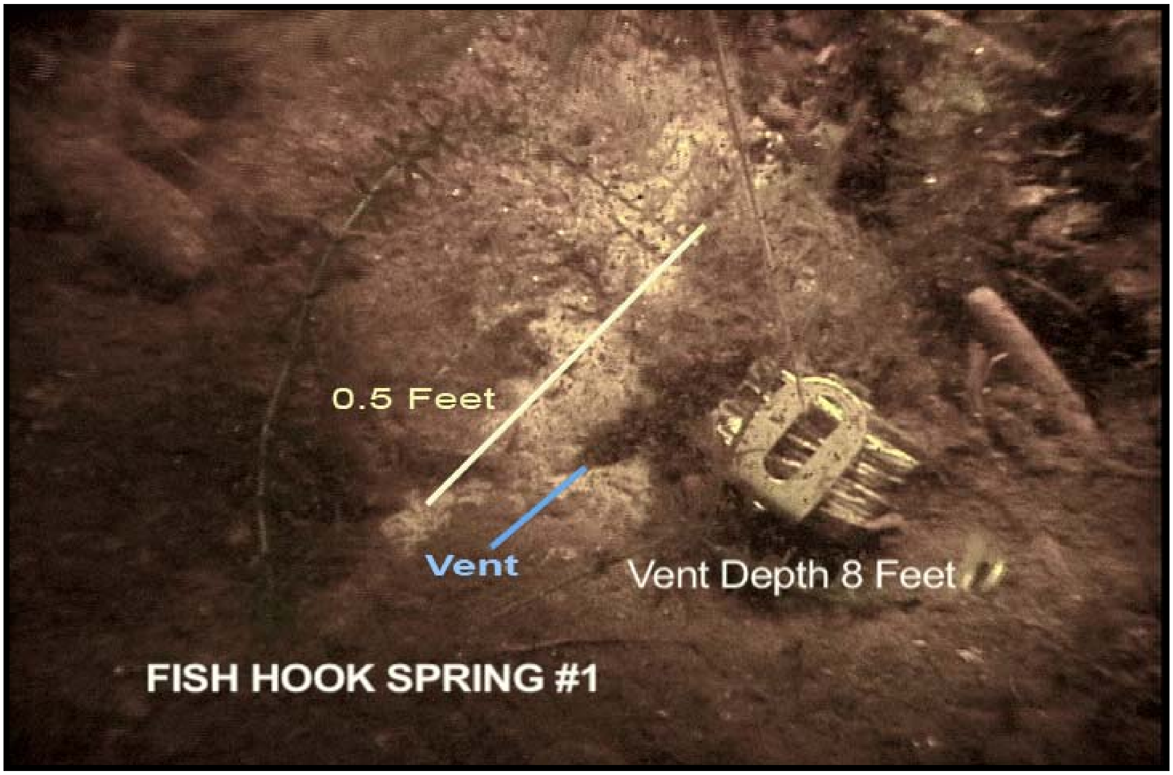

Figure 1. Underwater video still of Fish Hook Spring #1, Marion County, Florida.

Figure 2. Vent Discharge Capture Device (VDCD). Sensor is attached to and centered on the gray PVC tube at the top of the 0.5 foot diameter pipe.

CALIBRATION CERTIFICATE

Model: 2000 Serial Number: 2002679

Unit Gain Ratio: ____________ Time Constant: ____________

Type of Reading

Velocity:
- ☑ FPS
- ☐ CMS
- ☐ ______

Level:
- ☐ IN
- ☐ CM
- ☑ N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	NA
Measured:	0.00	2.00	NA

☒ Factory Calibration

☐ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: ____________ Date: 4-20-07

QA Technician: ____________ Date: 20APR07

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For product information, service, or calibration, please contact the Customer Service Department.

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Flowmeter Calibration Certificate.

Discharge Measurement: Catfish Convention Hall Spring, Silver Springs, Group, Marion County, Florida; September 11, 2007

Prepared for:

St. Johns River Water Management District

4049 Reid Street, Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.

5779 NE County Road 340, High Springs, Florida 32643

(386) 454-3556 (386) 454-3541 FAX kes@atlantic.net

Discharge Measurement: Catfish Convention Hall Spring, Silver Springs Group, Marion County, Florida; September 11, 2007

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6. Figure 4. Vent Discharge Capture Device (VDCD). Sensor is attached to and centered on the gray PVC tube at the top of the 0.5 foot diameter pipe.

7. Flowmeter Calibration Certificate.

Results of Discharge Measurements of Catfish Convention Hall Spring, Marion County, Florida; September 11, 2007

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Catfish Convention Hall Spring on September 11, 2007.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Catfish Convention Hall Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2007.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt, Tom Morris and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech of Orlando, Florida provided oversight.

SITE DESCRIPTION

Catfish Convention Hall Spring is comprised of two clusters of small vents, and a few additional scattered vents, about 20 feet deep, and located directly downstream from Shipwreck Spring and the bow of the namesake sunken boat. They lie in the eastern end of the basin that is an extension of the Shipwreck Spring basin. See Figure 1. The main vent cluster contains about five small vents within an area of about six feet in diameter, all discharging through sediments. Six vent locations were identified for measurement. See Figures 2 and 3.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

<u>Instrumentation</u>

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 20, 2007. A copy of the Calibration Certificate is included with this report.

Field Operations

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. See Figure 3. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD). See Figure 4.

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

Data Processing

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the second one of this type performed at Catfish Convention Hall Spring by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Catfish Convention Hall Spring on September 11, 2007 was 0.546 CFS (cubic feet per second). This result is also expressed as 245 GPM (gallons per minute) or 0.353 MGD (million gallons per day), see Table 1. Three readings were made at each of six vents, for a total of eighteen (18) readings. Individual point velocity readings ranged from 0.13 to 0.87 feet per second (fps), with an overall average station reading of 0.48 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 19 to 20 feet. The measurements commenced at about 10:27 hours and were completed by 11:06 hours.

UNDERWATER DISCHARGE MEASUREMENT								
Location:	**CATFISH CONVENTION HALL SPRING**			Date:	**September 11, 2007**			
	Silver Springs Group,			Time Start:	10:27			
	Marion County, Florida			Time End:	11:06			
Personnel:	Peter Butt, Tom Morris, Mark Long							
Method:	Vent Discharge Capture Device			(0.49' Diameter)				
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe							
Calculation Method: Discharge = V x *pi* x r^2								
Measurement Periods:		60 seconds						
Catfish Convention Hall Spring Total Discharge:			**Vent 1**	**Vent 2**	**Vent 3**	**Vent 4**	**Vent 5**	**Vent 6**
CFS	**0.546**		**0.069**	**0.093**	**0.028**	**0.133**	**0.163**	**0.060**
MGD	**0.353**		**0.045**	**0.060**	**0.018**	**0.086**	**0.105**	**0.039**
GPM	**245**	All Vents:	**31**	**42**	**12**	**60**	**73**	**27**
Avg. Point Velocity (ft/sec):		0.48	0.37	0.49	0.15	0.71	0.86	0.32
Vent Depth (feet deep):		19-20	19	19	19	19	19	19
Velocity Readings:		(All velocity readings in feet per second.)						
Vent 1		**Vent 2**		**Vent 3**		**Vent 4**		
Tagged vent								
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity	
1	0.37	1	0.49	1	0.13	1	0.7	
2	0.36	2	0.5	2	0.16	2	0.71	
3	0.37	3	0.49	3	0.15	3	0.71	
Average:	0.37	Average:	0.49	Average:	0.15	Average:	0.71	
Discharge:	0.069	Discharge:	0.093	Discharge:	0.028	Discharge:	0.133	
Vent 5		**Vent 6**						
Reading #	Point Velocity	Reading #	Point Velocity					
1	0.86	1	0.31					
2	0.86	2	0.32					
3	0.87	3	0.32					
Average:	0.86	Average:	0.32					
Discharge:	0.163	Discharge:	0.060					

Table 1. Discharge of Catfish Convention Hall Spring, Silver Springs Group, Marion County, Florida on September 11, 2007. Data record and calculation of discharge measurement.

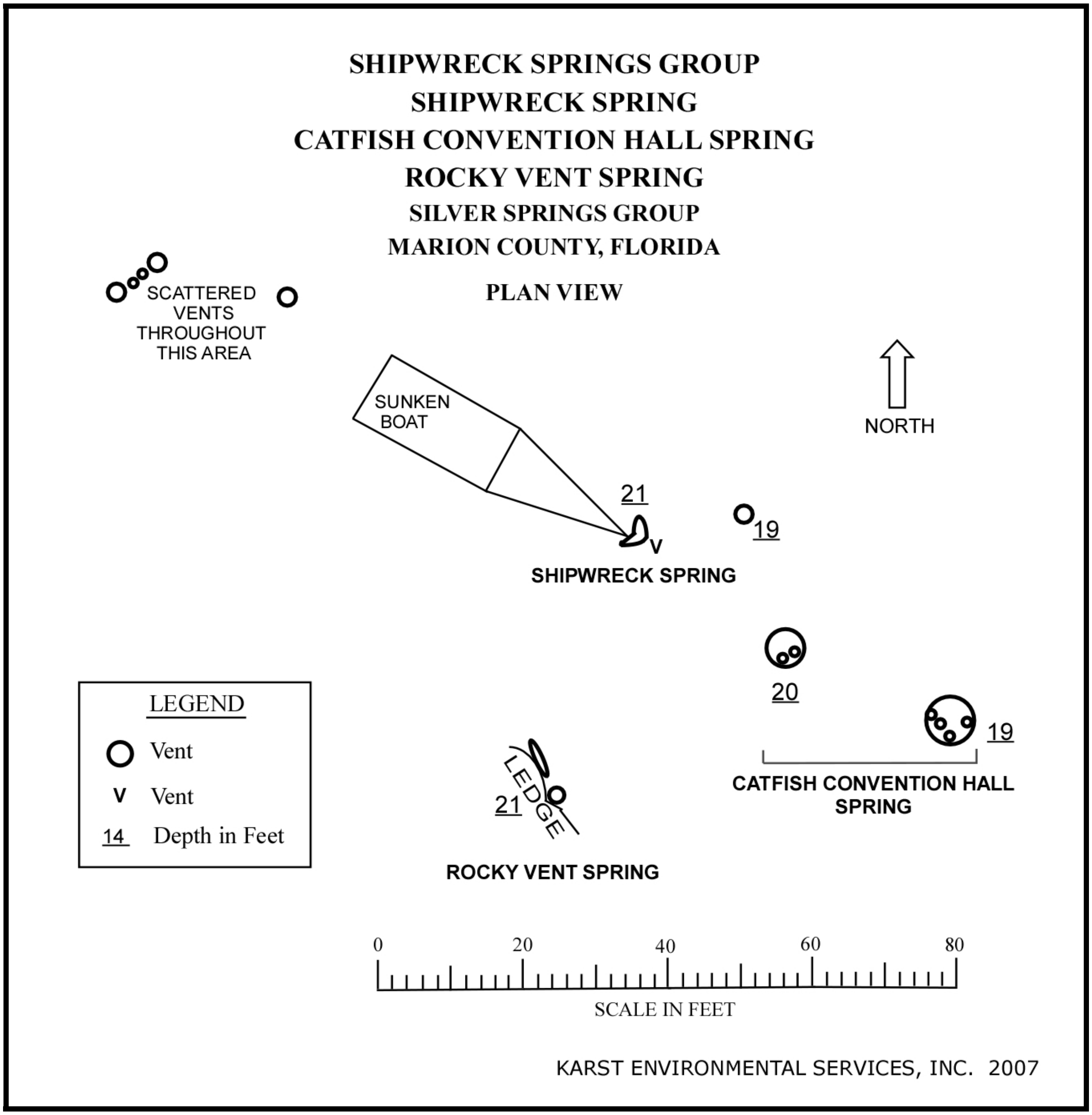

Figure 1. Map of Catfish Convention Hall Spring, Silver Springs Group, Marion County, Florida.

Figure 2. Underwater photograph of Catfish Convention Hall Spring, Silver Springs Group, Marion County, Florida. Vents that comprise this spring lie in front of the diver.

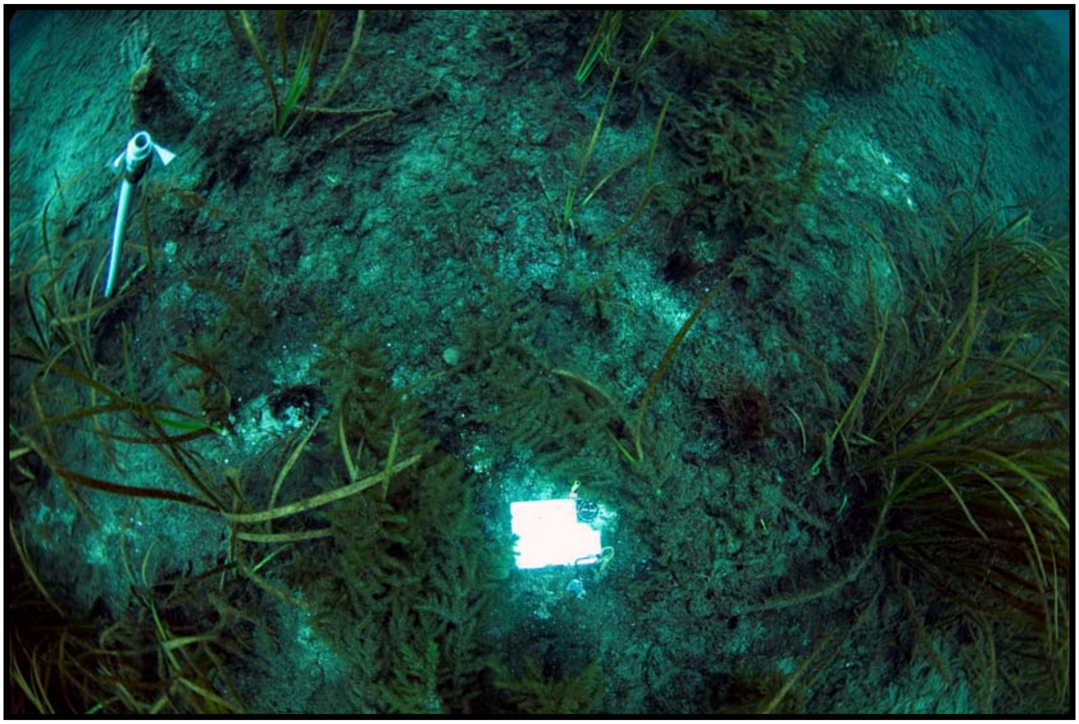

Figure 3. Underwater photograph of Catfish Convention Hall Spring vent, Silver Springs Group, Marion County, Florida. This area contains the main vent cluster.

Figure 4. Vent Discharge Capture Device (VDCD). Sensor is attached to and centered on the gray PVC tube at the top of the 0.5 foot diameter pipe.

CALIBRATION CERTIFICATE

Model: 2000 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

Type of Reading

Velocity:
- ☑ FPS
- ☐ CMS
- ☐ ______

Level:
- ☐ IN
- ☐ CM
- ☑ N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	NA
Measured:	0.00	2.00	NA

☒ Factory Calibration

☐ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: ______ Date: 4-20-07

QA Technician: ______ Date: 20APR07

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For product information, service, or calibration, please contact the Customer Service Department.

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P/N 101001 301

Flowmeter Calibration Certificate.

Discharge Measurement:
Lost River Spring,
Silver Springs Group,
Marion County, Florida;
September 11, 2007

Prepared for:

St. Johns River Water Management District

4049 Reid Street, Palatka, Florida 32177

Prepared by:

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Discharge Measurement: Lost River Spring, Silver Springs Group, Marion County, Florida; September 11, 2007

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3. Figure 1. Map showing location of Lost River Spring, Silver Springs Group, Marion County, Florida.

4. Figure 2. Underwater photograph of Lost River Spring, Silver Springs Group, Marion County, Florida.

5. Figure 3. Vent Discharge Capture Device (VDCD). Sensor is attached to and centered on the gray PVC tube at the top of the 0.5 foot diameter pipe.

6. Flowmeter Calibration Certificate.

Results of Discharge Measurements of Lost River Spring, Marion County, Florida; September 11, 2007

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Lost River Spring on September 11, 2007.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Lost River Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2007.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt, Tom Morris and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech of Orlando, Florida provided oversight.

SITE DESCRIPTION

Lost River Spring is located about 70 feet east of the main linear vent of the Garden of Eden Springs Group and east of the Jungle Cruise boat dock Log Spring lies about 40 feet further upstream of Lost River Spring. The run for Lost River and Log Spring is log choked and slough-like. See Figure 1.

Lost River Spring is comprised of a vent that is about 10 feet deep and roughly two feet in diameter. It discharges gently through bottom sediments and a matrix of logs, branches and filamentous algae. See Figure 2.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

<u>Instrumentation</u>

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter.

One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 20, 2007. A copy of the Calibration Certificate is included with this report.

Field Operations

This spring consists of a vent discharging through a mixed bottom of logs, detritus, sediments and a thick algal layer. See Figure 2. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD). See Figure 3.

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

Data Processing

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Lost River Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Lost River Spring on September 11, 2007 was 0.253 CFS (cubic feet per second). This result is also expressed as 113 GPM (gallons per minute) or 0.163 MGD (million gallons per day), see Table 1. Three readings were made at one vent. Individual point velocity readings ranged from 0.88 to 0.91 feet per second (fps), with an overall average station reading of 0.89 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 10 feet. The measurements commenced at about 16:48 hours and were completed by 16:52 hours.

	UNDERWATER DISCHARGE MEASUREMENT					
	Location:	**LOST RIVER SPRING**		Date:	**September 11, 2007**	
		Silver Springs Group,		Time Start:	16:48	
		Marion County, Florida		Time End:	16:52	
	Personnel:	Peter Butt, Tom Morris, Mark Long				
	Method:	Vent Discharge Capture Device		(0.49' Diameter)		
	Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
	Calculation Method: Discharge = V x *pi* x r^2					
	Measurement Periods:		60 seconds			
	Lost River Spring ESTIMATED Discharge:					
	CFS	**0.253**				
	MGD	**0.163**				
	GPM	**113**				
	(Multiplier:)	(1.5)				
	Lost River Spring Measured Discharge:					
	CFS	**0.169**				
	MGD	**0.109**				
	GPM	**76**				
	Avg. Point Velocity (ft/sec):		0.89			
	Vent Depth (feet deep):		10			
	Velocity Readings:		(All velocity readings in feet per second.)			
	Reading #	Point Velocity				
	1	0.91				
	2	0.89				
	3	0.88				
	Average:	0.89				
	Discharge:	0.169				
	Multiplier:	1.5				
	Est. Discharge:	**0.253**				

Table 1. Discharge of Lost River Spring, Marion County, Florida on September 11, 2007. Data record and calculation of discharge measurement.

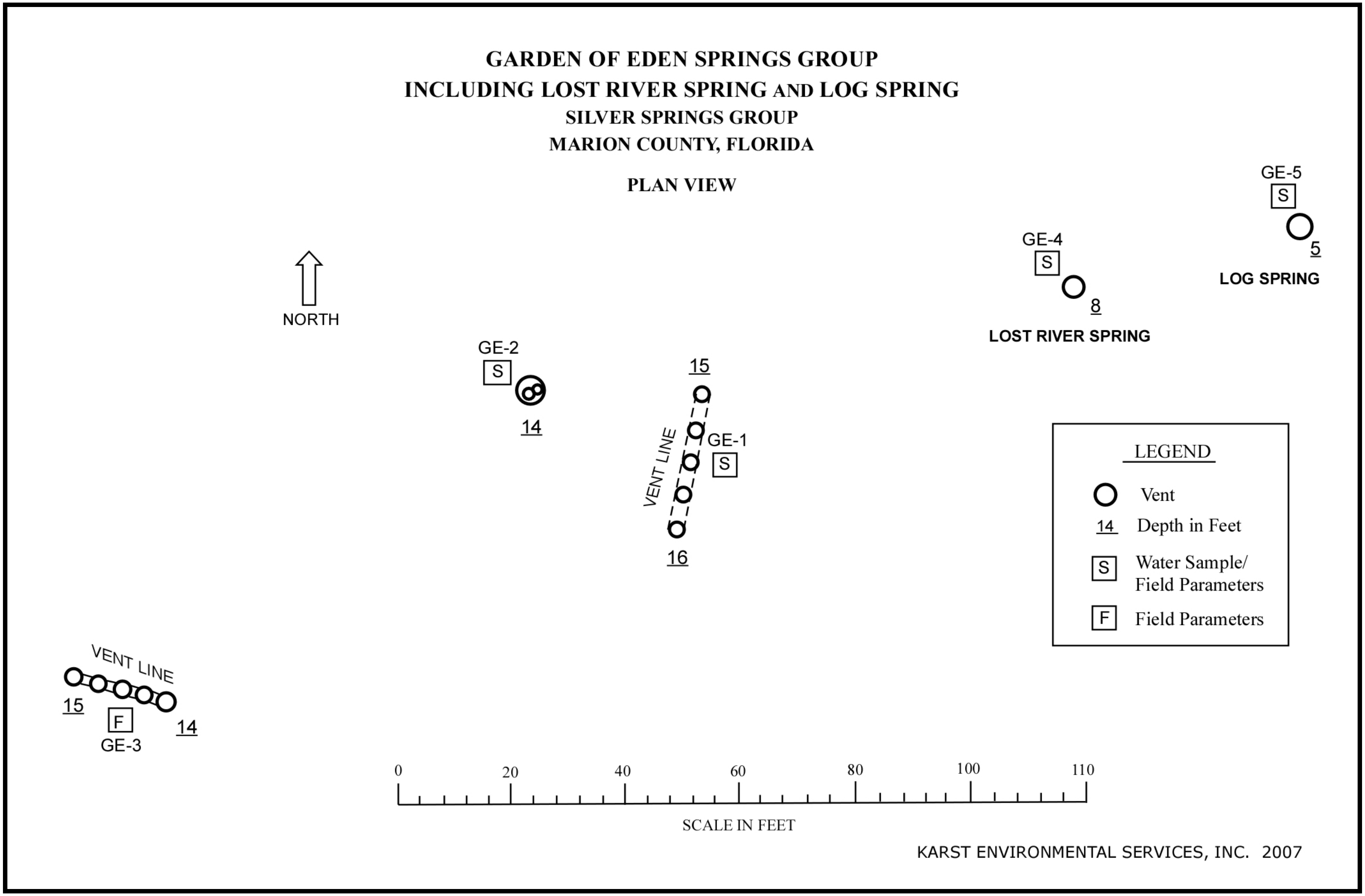

Figure 1. Map showing location of Lost River Spring, Silver Springs Group, Marion County, Florida.

Figure 2. Underwater photograph of Lost River Spring, Silver Springs Group, Marion County, Florida.

Figure 3. Vent Discharge Capture Device (VDCD). Sensor is attached to and centered on the gray PVC tube at the top of the 0.5 foot diameter pipe.

CALIBRATION CERTIFICATE

Model: 2000 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

Type of Reading

Velocity:
- [x] FPS
- [ ] CMS
- [ ] ______

Level:
- [ ] IN
- [ ] CM
- [x] N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	NA
Measured:	0.00	2.00	NA

- [x] Factory Calibration

- [ ] Field Profile Calibration;
  Site Coefficient or Velocity Multiplier: ______

Calibration Technician: [illegible] Date: 4-20-07

QA Technician: [illegible] Date: 20APR07

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement
4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 • (800)-368-2723 • FAX (301) 874-2172
www.marsh-mcbirney.com

P/N 101001 301

Flowmeter Calibration Certificate.

Discharge Measurement: Mammoth Spring, Silver Springs Group, Marion County, Florida; September 10, 2007

Prepared for:

St. Johns River Water Management District

4049 Reid Street, Palatka, Florida 32177

Prepared by:

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Discharge Measurement: Mammoth Spring, Silver Springs Group, Marion County, Florida; September 10, 2007

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Results of Discharge Measurements of Mammoth Spring, Marion County, Florida; September 10, 2007

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a discharge measurement at Mammoth Spring of the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at the site on September 10, 2007. A summary of the results and collected data for that measurement are presented in Table 1.

PURPOSE and SCOPE OF WORK

The purpose of this work was to obtain accurate discharge measurements of the Mammoth Spring, the headspring and major source of groundwater discharge into the Silver River. A discharge measurement was to be made at the vent of Mammoth Spring during September, 2007.

SITE DESCRIPTION

Mammoth Spring is the largest spring of the Silver Springs Group, and is the headspring of the Silver River. The spring lies within a spring pool surrounded by the Silver Springs theme park. Mammoth Spring's vent is a wide, oval-shaped opening about 69 feet across, with floor to ceiling heights that vary from under 2 to over 6 feet. The depth of this vent ranges between 25 and 34 feet deep. The rock that comprises the ceiling of this vent is solid and self-supported, with the floor beneath composed of a layer of boulders and rubble. See Figure 1.

A large cavern with a complex network of cave passages lies inside of this vent. These cave passages supply waters of varying characteristics to the cavern, where some mixing occurs before these waters exit the vent. The inside of the cavern is a complex structure of breakdown boulders, bedding planes, and small passageways. It was determined during prior investigations that discharge measurements of individual water sources within the cavern would be problematic, if not impossible. The outer edge of this spring vent provided the best location for an underwater discharge measurement with an appropriately adapted instrument.

PERSONNEL

Fieldwork for this discharge measurement was conducted by KES personnel Peter Butt, Tom Morris, Mark Long and Wayne Kinard. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech of Orlando, Florida.

METHODS

<u>Instrumentation</u>

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter.

One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 20, 2007. A copy of the Calibration Certificate is included with this report.

Field Operations

Velocity measurements were taken just inside the ceiling edge of the vent. At the measurement site, the floor of the vent was 34 feet deep, and the ceiling was 26 feet deep.

A positioning grid of telescoping aluminum poles with 0.1, 0.25, 0.5 and one-foot interval markings that provided support for the sensor was set up by Pete Butt. Butt also recorded measurements of the grid and surrounding walls. Seventeen poles were positioned vertically to provide the primary positioning grid for velocity measurements. Eight horizontal poles were used as a spacing reference, and fastened to the vertical poles for support. Conduit dimensions around the grid were measured with a collapsible steel tape. As all sensor-support poles were positioned at roughly right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was attached to the poles with a low-profile metal spring clamp. Most measurement stations were set using one-foot intervals on the vertical poles. Velocity stations and boundary points are identified with alpha-numeric labels, based on the letter assigned to identify each vertical pole. See Figure 2.

Tom Morris positioned the sensor and recorded positional data. Mark Long took the velocity readings after taking reset cues from Morris, and also recorded positional data. During all measurements, the sensor handler was able to move away from the measurement cross-section, and remove himself from the cross section of the flow. The meter operator was also positioned downstream and away from the cross-section. This minimized or eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in the "Fixed Point Averaging" mode. Fixed Point Averaging is an average of velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. One-hundred and thirty-two (132) station readings were made.

Data Processing

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 1. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 3 at an angle of 0°, and a variogram slope of 1.0. The anisotropy ratio used was selected due to the extremely elongated horizontal aspect of the measurement cross-section. The results of the contour processing are illustrated in Figures 3 and 4.

During this measurement, two negative velocities were measured. These negative velocity stations represent slight back eddies near walls. In order to incorporate these negative values, calculations were made using a Surfer 8 "blanking file" operation to define the measurement cross-section boundary. The blanking file operation also assists in the elimination of artifacts present in the contouring process that would create inaccuracies in the flow calculations.

The total discharge is shown on Table 2 as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on page 1 of Table 2 as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the third one performed at Mammoth Spring applying the method and data processing used at other spring sites by KES. This measurement also represents the largest cross-section and amount of discharge measured to date by KES. Based on KES' experience at other springs, the estimate of discharge for this measurement should be considered to be a minimum value. Based on results of the prior measurement performed here, additional velocity station readings close to the boundary walls of the cross-section were made to provide the additional data needed for Surfer to more accurately account for the higher flows present near the boundary edge and adjust the contours more appropriately. Due to the extremely elongated cross-section, a high anisotropy ratio setting was used to minimize a "bull's eye" or "curtain" effect that occurs in the contouring and has the unwanted effect of lowering the actual discharge value.

The estimated discharge of Mammoth Spring on September 10, 2007 was 207.78 CFS (cubic feet per second). This result is also expressed as 93258 GPM (gallons per minute) or 134.291 MGD (million gallons per day), see Table 1. One-hundred and thirty-two (132) readings were made, see Figures 2, 3 and 4. The point velocity readings ranged from -0.06 to 0.96 feet per second (fps), with an overall average station reading of 0.61 fps. The total cross-sectional area was calculated as 321.36 square feet. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 12:50 hours and were completed by 16:42 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**MAMMOTH SPRING (Silver Springs Group)**			Marion County, Florida	
Personnel:	Peter Butt, Tom Morris, Mark Long, Wayne Kinard				
Method:	Grid within irregular conduit/cross-section				
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles				
Analysis Method:	Surfer 8 with kriging				
Mammoth Spring Total Discharge:			**Date:**	**September 10, 2007**	
CFS	**207.78**		Time Start:	12:50	
MGD	**134.291**		Time End:	16:42	
GPM	**93258**				
Total Cross-sectional Area:		321.36	square feet		
Avg. Station Point Velocity:		0.61	feet/second		
Cross-section Depth:		26-34	feet deep		
Msmt. Periods:		60 seconds			
Velocity Reading by Station:		(All velocity readings in feet per second.)			
Station #	Point Velocity	Station #	Point Velocity	Station #	Point Velocity
A1	0.12	G1	0	L3	0.69
A2	0.27	G2	0.6	L4	0.8
A3	0.21	G3	0.83	L5	0.82
A4	0.38	G4	0.76	L6	0.78
A5	0.54	G5	0.81	L7	0.87
AH1	0.1	G6	0.69	L8	0.86
AH2	-0.02	GH	0.84	LM	0.82
AB	0.36	H1	0.25	M1	0.04
B1	0.03	H2	0.66	M2	0.14
B2	0.04	H3	0.81	M3	0.63
B3	0.28	H4	0.82	M4	0.7
B4	0.38	H5	0.86	M5	0.8
B5	0.43	H6	0.92	M6	0.8
B6	0.71	H7	0.86	M7	0.87
B7	0.3	HI	0.84	M8	0.91
B8	0.01	I1	0.02	MN	0.8
BC	0.69	I2	0.06	N1	-0.06
C1	0.56	I3	0.78	N2	0.14
C2	0.76	I4	0.79	N3	0.71
C3	0.85	I5	0.75	N4	0.74
C4	0.85	I6	0.83	N5	0.75
C5	0.96	I7	0.82	N6	0.88
C6	0.75	I8	0.8	N7	0.81
CD	0.86	IJ	0.71	N8	0.68
D1	0.71	J1	0.08	NO	0.82
D2	0.84	J2	0.3	O1	0.36
D3	0.9	J3	0.76	O2	0.61
D4	0.92	J4	0.78	O3	0.76
D5	0.95	J5	0.83	O4	0.81
D6	0.44	J6	0.89	O5	0.63
DE	0.86	J7	0.86	OP	0.77
E1	0.11	J8	0.83	P1	0.43
E2	0.66	JK	0.78	P2	0.73
E3	0.73	K1	0.39	P3	0.8
E4	0.78	K2	0.53	P4	0.82
E5	0.89	K3	0.65	P5	0.76
E6	0.82	K4	0.72	PQ	0.39
EF	0.91	K5	0.79	Q1	0.1
F1	0.04	K6	0.76	Q2	0.19
F2	0.84	K7	0.87	Q3	0.23
F3	0.93	K8	0.8	Q4	0.3
F4	0.94	KL	0.88	Q5	0.3
F5	0.85	L1	0.27	QH1	0.24
FG	0.91	L2	0.55	QH2	0.09

Table 1. Discharge of Mammoth Spring, Silver Springs Group, Marion County, Florida on September 10, 2007. Data record and calculation of discharge measurement.

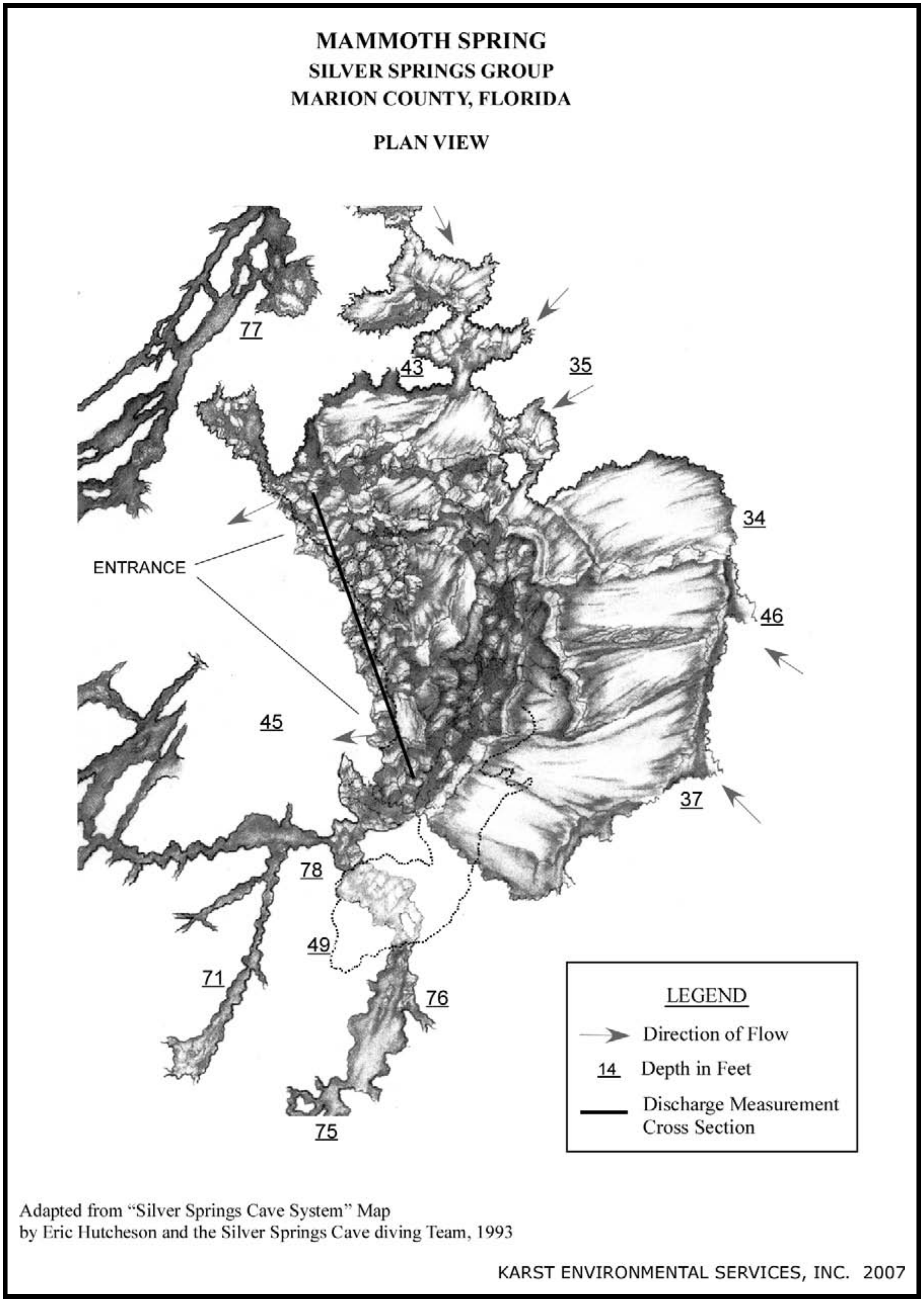

Figure 1. Map of Mammoth Spring, Silver Springs Group, Marion County, Florida.

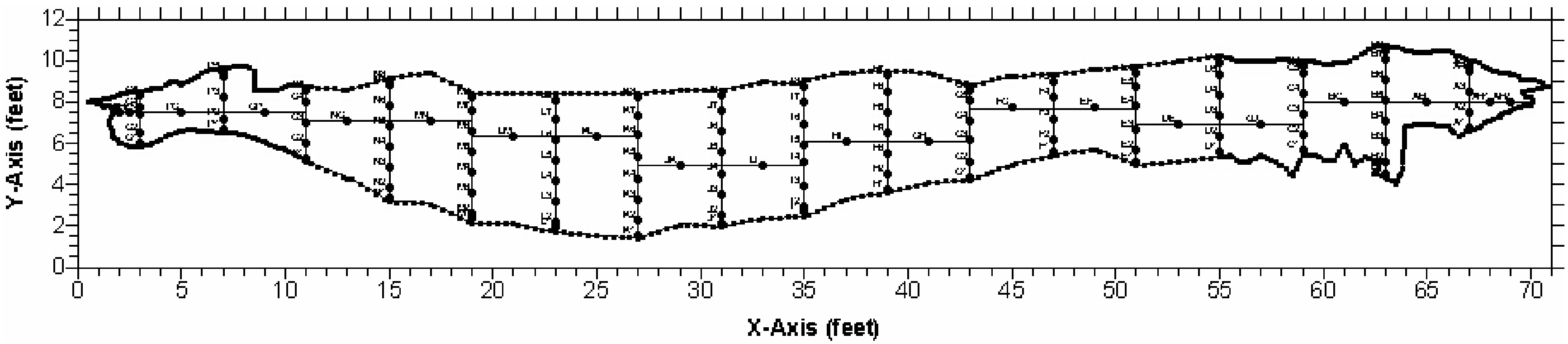

Figure 2. Discharge measurement cross-section; Mammoth Spring, Marion County, Florida, September 10, 2007 measurement. Cross-section is viewed to the upstream of observer, and is located between the 26- and 34-foot depth levels. Support poles are represented by dashed lines. Velocity measurement stations are shown as points along the support poles. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

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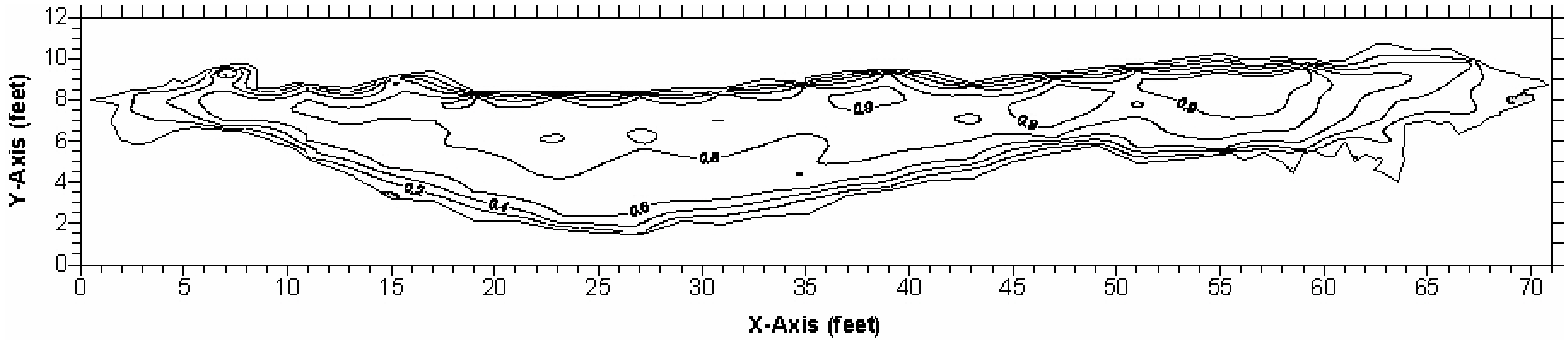

Figure 3. Discharge measurement cross-section; Mammoth Spring, Marion County, Florida, September 10, 2007 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

TABLE 2. MAMMOTH SPRING, SEPTEMBER 10, 2007.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 07\Mammoth_9-07.bln.grd
Grid Size:	61 rows x 356 columns
X Minimum:	0
X Maximum:	71
X Spacing:	0.2
Y Minimum:	0
Y Maximum:	12
Y Spacing:	0.2
Z Minimum:	-0.034316339959011
Z Maximum:	0.99097829840165

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:

Trapezoidal Rule:	207.77507328005
Simpson's Rule:	207.87237878945
Simpson's 3/8 Rule:	207.86180500243

CUT & FILL VOLUMES
Positive Volume [Cut]: 207.78021158709
Negative Volume [Fill]: 0.0051383070426337
Net Volume [Cut-Fill]: 207.77507328005<<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 321.36 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 320.87326059558
Negative Planar Area [Fill]: 0.48673940442225
Blanked Planar Area: 530.64
Total Planar Area: 852

Surface Areas
Positive Surface Area [Cut]: 352.84575345995
Negative Surface Area [Fill]: 0.49183331134998

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 07\Mammoth 9-07 SURFER XYZ T3 750ptsBLF2.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	750
Original Data:	750
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	1.4	-0.06
25%-tile:	14.8	5.25	0
Median:	39	7.4	0
75%-tile:	59.3	9.05	0
Maximum:	70.8	10.7	0.96
Midrange:	35.65	6.05	0.45
Range:	70.3	9.3	1.02
Interquartile Range:	44.5	3.8	0
Median Abs. Deviation:	22	1.9	0
Mean:	37.107971826667	7.02198304	0.108
Trim Mean (10%):	37.268178801775	7.1205950887574	0.072233727810651
Standard Deviation:	23.059067233641	2.4236970117194	0.26369173922088
Variance:	531.72058168559	5.8743072046177	0.069533333333333
Coef. of Variation:			2.4415901779711
Coef. of Skewness:			2.2040540058234

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.140	-0.048
Y:		1.000	-0.026
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	531.72058168559	7.8064232576822	-0.28988762394667
Y:		5.8743072046177	-0.01651616832
Z:			0.0695333333333333

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.000513936706 43368	-0.0021286188185886	0.14201827406578
Standard Error:	0.00042198513441429	0.0040147689826763	0.031772415802934

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.140	-0.369
B:		1.000	0.818
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.13810538803796	0.069052694018982	0.99174
Residual:	747	52.011894611962	0.069627703630471	
Total:	749	52.15		

Coefficient of Multiple Determination (R^2): 0.0026482337111786

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.0499999999999997	0
25%-tile:	0.11661903789691	0
Median:	0.20396078054371	0
75%-tile:	0.40049968789001	0
Maximum:	2.0303940504247	0.91

Midrange:	1.0401970252123	0.455
Range:	1.9803940504247	0.91
Interquartile Range:	0.28388064999311	0
Median Abs. Deviation:	0.099557715454609	0
Mean:	0.31299595633224	0.058
Trim Mean (10%):	0.27102220218972	0.02207100591716
Standard Deviation:	0.30584150156674	0.17807938304775
Variance:	0.0935390240806	0.031712266666667
Coef. of Variation:	0.97714202173941	3.0703341904784
Coef. of Skewness:	2.9410502101801	3.5343485345225
Root Mean Square:	0.43761340560012	0.18728658966052
Mean Square:	0.19150549276093	0.035076266666667

Complete Spatial Randomness
Lambda: 1.1471573441013
Clark and Evans: 0.67047133875302
Skellam: 1035.2502796423

Exclusion Filtering
Exclusion Filter String: Not In Use

Duplicate Filtering
Duplicate Points to Keep: First
X Duplicate Tolerance: 8.3E-006
Y Duplicate Tolerance: 1.1E-006
No duplicate data were found.

Breakline Filtering
Breakline Filtering: Not In Use

Gridding Rules
Gridding Method: Kriging
Kriging Type: Point

Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model
Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 3
Variogram Slope: 1

Search Parameters
No Search (use all data): true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 07\Mammoth_9-07.grd
Grid Size:	61 rows x 356 columns
Total Nodes:	21716
Filled Nodes:	21716
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	71
X Spacing:	0.2
Y Minimum:	0
Y Maximum:	12
Y Spacing:	0.2

Grid Statistics

Z Minimum:	-3.6281612141484
Z 25%-tile:	-1.1764521731005
Z Median:	-0.25697093763238
Z 75%-tile:	0.59596069694474
Z Maximum:	0.99097829840165
Z Midrange:	-1.3185914578734
Z Range:	4.61913951255
Z Interquartile Range:	1.7724128700453
Z Median Abs. Deviation:	0.8834879030336
Z Mean:	-0.4238572527302
Z Trim Mean (10%):	-0.36894639109803
Z Standard Deviation:	1.0632967461044
Z Variance:	1.1305999702763
Z Coef. of Variation:	-1
Z Coef. of Skewness:	-0.56158676877364
Z Root Mean Square:	1.144663680287
Z Mean Square:	1.3102549409683

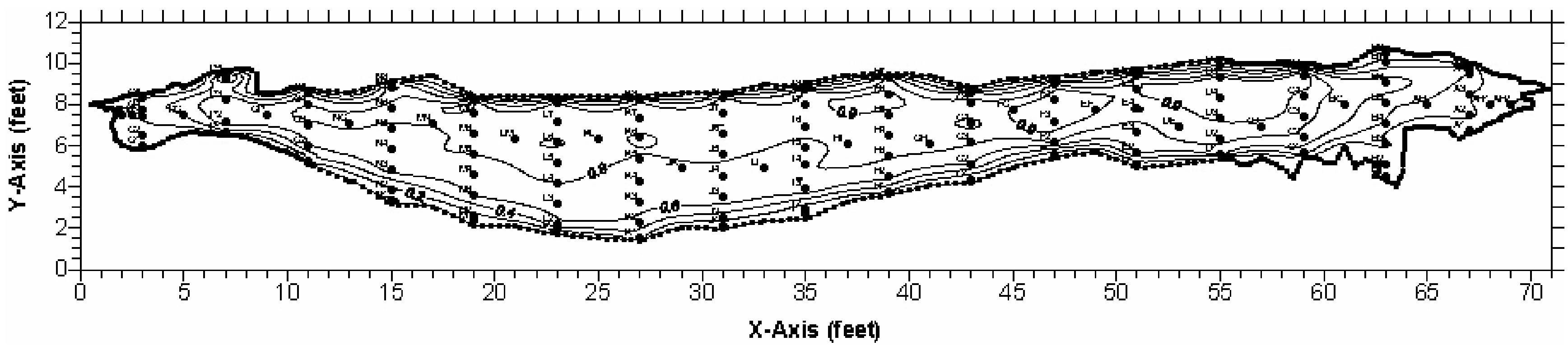

Figure 4. **Discharge measurement cross-section; Mammoth Spring, Marion County, Florida, September 10, 2007 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (labeled points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.**

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Table 3. Mammoth Spring (Silver Springs Group) XYZ Grid Data, September 10, 2007.					
(Minor boundary points have been edited for processing in Surfer.)					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
67	6.75	0.12	A1	670	67.5
67	7.5	0.27	A2	670	75
67	8.5	0.21	A3	670	85
67	9.5	0.38	A4	670	95
67	9.75	0.54	A5	670	97.5
68	8	0.1	AH1	680	80
69	8	-0.02	AH2	690	80
65	8	0.36	AB	650	80
63	4.55	0.03	B1	630	45.5
63	5.05	0.04	B2	630	50.5
63	6.05	0.28	B3	630	60.5
63	7.05	0.38	B4	630	70.5
63	8.05	0.43	B5	630	80.5
63	9.05	0.71	B6	630	90.5
63	10.05	0.3	B7	630	100.5
63	10.45	0.01	B8	630	104.5
61	8	0.69	BC	610	80
59	5.65	0.56	C1	590	56.5
59	6.4	0.76	C2	590	64
59	7.4	0.85	C3	590	74
59	8.4	0.85	C4	590	84
59	9.4	0.96	C5	590	94
59	9.7	0.75	C6	590	97
57	6.9	0.86	CD	570	69
55	5.55	0.71	D1	550	55.5
55	6.3	0.84	D2	550	63
55	7.3	0.9	D3	550	73
55	8.3	0.92	D4	550	83
55	9.3	0.95	D5	550	93
55	9.9	0.44	D6	550	99
53	6.9	0.86	DE	530	69
51	5.05	0.11	E1	510	50.5
51	5.7	0.66	E2	510	57
51	6.7	0.73	E3	510	67
51	7.8	0.78	E4	510	78
51	8.7	0.89	E5	510	87
51	9.4	0.82	E6	510	94
49	7.7	0.91	EF	490	77
47	5.55	0.04	F1	470	55.5
47	6.2	0.84	F2	470	62

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
47	7.2	0.93	F3	470	72
47	8.2	0.94	F4	470	82
47	9	0.85	F5	470	90
45	7.7	0.91	FG	450	77
43	4.35	0	G1	430	43.5
43	5.1	0.6	G2	430	51
43	6.2	0.83	G3	430	62
43	7.1	0.76	G4	430	71
43	8.1	0.81	G5	430	81
43	8.6	0.69	G6	430	86
41	6.1	0.84	GH	410	61
39	3.75	0.25	H1	390	37.5
39	4.5	0.66	H2	390	45
39	5.5	0.81	H3	390	55
39	6.5	0.82	H4	390	65
39	7.5	0.86	H5	390	75
39	8.5	0.92	H6	390	85
39	9.3	0.86	H7	390	93
37	6.1	0.84	HI	370	61
35	2.7	0.02	I1	350	27
35	2.95	0.06	I2	350	29.5
35	3.95	0.78	I3	350	39.5
35	5.05	0.79	I4	350	50.5
35	5.95	0.75	I5	350	59.5
35	6.95	0.83	I6	350	69.5
35	7.95	0.82	I7	350	79.5
35	8.75	0.8	I8	350	87.5
33	4.95	0.71	IJ	330	49.5
31	2.1	0.08	J1	310	21
31	2.55	0.3	J2	310	25.5
31	3.55	0.76	J3	310	35.5
31	4.55	0.78	J4	310	45.5
31	5.55	0.83	J5	310	55.5
31	6.55	0.89	J6	310	65.5
31	7.55	0.86	J7	310	75.5
31	8.35	0.83	J8	310	83.5
29	4.95	0.78	JK	290	49.5
27	1.55	0.39	K1	270	15.5
27	2.3	0.53	K2	270	23
27	3.3	0.65	K3	270	33
27	4.3	0.72	K4	270	43
27	5.3	0.79	K5	270	53
27	6.4	0.76	K6	270	64

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
27	7.3	0.87	K7	270	73
27	8.2	0.8	K8	270	82
25	6.3	0.88	KL	250	63
23	1.95	0.27	L1	230	19.5
23	2.2	0.55	L2	230	22
23	3.2	0.69	L3	230	32
23	4.2	0.8	L4	230	42
23	5.2	0.82	L5	230	52
23	6.2	0.78	L6	230	62
23	7.2	0.87	L7	230	72
23	8.1	0.86	L8	230	81
21	6.3	0.82	LM	210	63
19	2.35	0.04	M1	190	23.5
19	2.6	0.14	M2	190	26
19	3.6	0.63	M3	190	36
19	4.6	0.7	M4	190	46
19	5.6	0.8	M5	190	56
19	6.6	0.8	M6	190	66
19	7.6	0.87	M7	190	76
19	8.2	0.91	M8	190	82
17	7.1	0.8	MN	170	71
15	3.35	-0.06	N1	150	33.5
15	3.85	0.14	N2	150	38.5
15	4.85	0.71	N3	150	48.5
15	5.85	0.74	N4	150	58.5
15	6.85	0.75	N5	150	68.5
15	7.85	0.88	N6	150	78.5
15	8.85	0.81	N7	150	88.5
15	9.05	0.68	N8	150	90.5
13	7.1	0.82	NO	130	71
11	5.25	0.36	O1	110	52.5
11	6	0.61	O2	110	60
11	7	0.76	O3	110	70
11	8	0.81	O4	110	80
11	8.6	0.63	O5	110	86
9	7.5	0.77	OP	90	75
7	6.7	0.43	P1	70	67
7	7.2	0.73	P2	70	72
7	8.2	0.8	P3	70	82
7	9.2	0.82	P4	70	92
7	9.5	0.76	P5	70	95
5	7.5	0.39	PQ	50	75
3	6	0.1	Q1	30	60

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
3	6.5	0.19	Q2	30	65
3	7.4	0.23	Q3	30	74
3	7.7	0.3	Q4	30	77
3	8.3	0.3	Q5	30	83
2.5	7.5	0.24	QH1	25	75
2	7.5	0.09	QH2	20	75
70.1	8	0	AE	701	80
70	7.85	0	AESA	700	78.5
69.5	7.75	0	AESB	695	77.5
69	7.55	0	AESC	690	75.5
68.75	7.5	0	AESD	687.5	75
68.5	7.35	0	AESE	685	73.5
68.5	7.25	0	AESF	685	72.5
68	7.1	0	AESG	680	71
67.75	7	0	AESH	677.5	70
67.5	6.75	0	AESI	675	67.5
67.45	6.75	0	AESJ	674.5	67.5
67	6.6	0	AS	670	66
66.5	6.3	0	ABSA	665	63
66	6.85	0	ABSB	660	68.5
65.5	6.85	0	ABSC	655	68.5
65	6.95	0	ABS	650	69.5
64.5	6.9	0	ABSD	645	69
64	6.8	0	ABSE	640	68
63.9	6.75	0	ABSF	639	67.5
63.9	6.55	0	ABSG	639	65.5
63.9	6.3	0	ABSH	639	63
63.9	6.05	0	ABSI	639	60.5
63.9	5.8	0	ABSJ	639	58
63.8	5.55	0	ABSK	638	55.5
63.8	5.3	0	ABSL	638	53
63.85	5.05	0	ABSM	638.5	50.5
63.8	4.8	0	ABSN	638	48
63.7	4.55	0	ABSO	637	45.5
63.5	4	0	ABSP	635	40
63	4.35	0	BS	630	43.5
62.4	4.55	0	BCSA	624	45.5
62.65	4.8	0	BCSB	626.5	48
62.75	5.05	0	BCSC	627.5	50.5
62.65	5.15	0	BCSD	626.5	51.5
62.5	5.1	0	BCSE	625	51
62	5.35	0	BCSF	620	53.5
61.5	4.95	0	BCSG	615	49.5
61	5.9	0	BCS	610	59
60.5	5.2	0	BCSH	605	52
60	5.2	0	BCSI	600	52
59.5	5.45	0	BCSJ	595	54.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
59	5.4	0	CS	590	54
58.5	4.45	0	CDSA	585	44.5
58	4.9	0	CDSB	580	49
57.5	5.15	0	CDSC	575	51.5
57	5.4	0	CDS	570	54
56.5	5.15	0	CDSD	565	51.5
56	5.05	0	CDSE	560	50.5
55.5	5.4	0	CDSF	555	54
55	5.3	0	DS	550	53
53	5.1	0	DES	530	51
51	4.9	0	ES	510	49
49	5.7	0	EFS	490	57
47	5.4	0	FS	470	54
45	4.95	0	FGS	450	49.5
43	4.2	0	GS	430	42
41	4.1	0	GHS	410	41
39	3.6	0	HS	390	36
37	3.3	0	HIS	370	33
35	2.45	0	IS	350	24.5
33	2.35	0	IJS	330	23.5
31	1.95	0	JS	310	19.5
29	2.05	0	JKS	290	20.5
27	1.4	0	KS	270	14
25	1.5	0	KLS	250	15
23	1.7	0	LS	230	17
21	2.1	0	LMS	210	21
19	2.1	0	MS	190	21
17	3.05	0	MNS	170	30.5
15	3.15	0	NS	150	31.5
13	4.3	0	NOS	130	43
11	5.1	0	OS	110	51
10.5	5.45	0	OPSA	105	54.5
10	5.7	0	OPSB	100	57
9.5	5.85	0	OPSC	95	58.5
9	6.05	0	OPS	90	60.5
8.5	6.25	0	OPSD	85	62.5
8	6.4	0	OPSE	80	64
7.5	6.5	0	OPSF	75	65
7	6.5	0	PS	70	65
6.5	6.55	0	PQSA	65	65.5
6	6.6	0	PQSB	60	66
5.5	6.65	0	PQSC	55	66.5
5	6.6	0	PQS	50	66
4.5	6.45	0	PQSD	45	64.5
4	6.2	0	PQSE	40	62
3.5	5.95	0	PQSF	35	59.5
3	5.8	0	QS	30	58
2.5	5.85	0	QSA	25	58.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2.1	6	0	QSB	21	60
2	6	0	QSC	20	60
1.8	6.25	0	QSD	18	62.5
1.7	6.3	0	QSE	17	63
1.7	6.5	0	QSF	17	65
1.6	6.75	0	QSG	16	67.5
1.5	7	0	QSH	15	70
1.6	7.25	0	QSI	16	72.5
1.7	7.5	0	QE	17	75
1.85	7.75	0	QTF	18.5	77.5
0.5	8	0	QTE	5	80
1.7	8.25	0	QTD	17	82.5
1.8	8.25	0	QTC	18	82.5
2	8.35	0	QTB	20	83.5
2.5	8.45	0	QTA	25	84.5
3	8.5	0	QT	30	85
3.5	8.6	0	PQTF	35	86
4	8.65	0	PQTE	40	86.5
4.5	9	0	PQTD	45	90
5	8.85	0	PQT	50	88.5
5.5	9.05	0	PQTC	55	90.5
6	9.4	0	PQTB	60	94
6.5	9.55	0	PQTA	65	95.5
7	9.65	0	PT	70	96.5
7.5	9.7	0	OPTJ	75	97
8	9.75	0	OPTI	80	97.5
8.55	9.45	0	OPTH	85.5	94.5
8.5	9.2	0	OPTG	85	92
8.5	8.95	0	OPTF	85	89.5
8.5	8.7	0	OPTE	85	87
8.5	8.6	0	OPTD	85	86
9	8.55	0	OPT	90	85.5
9.5	8.55	0	OPTC	95	85.5
10	8.75	0	OPTB	100	87.5
10.5	8.85	0	OPTA	105	88.5
11	8.75	0	OT	110	87.5
13	8.55	0	NOT	130	85.5
15	9.15	0	NT	150	91.5
17	9.4	0	MNT	170	94
19	8.4	0	MT	190	84
21	8.4	0	LMT	210	84
23	8.4	0	LT	230	84
25	8.4	0	KLT	250	84
27	8.4	0	KT	270	84
29	8.55	0	JKT	290	85.5
31	8.55	0	JT	310	85.5
33	8.95	0	IJT	330	89.5
35	9.05	0	IT	350	90.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
37	9.4	0	HIT	370	94
39	9.5	0	HT	390	95
41	9.4	0	GHT	410	94
43	8.8	0	GT	430	88
45	9.25	0	FGT	450	92.5
47	9.3	0	FT	470	93
49	9.55	0	EFT	490	95.5
51	9.7	0	ET	510	97
53	9.95	0	DET	530	99.5
55	10.2	0	DT	550	102
55.5	10.1	0	CDTF	555	101
56	9.95	0	CDTE	560	99.5
56.5	9.95	0	CDTD	565	99.5
57	9.95	0	CDT	570	99.5
57.5	10	0	CDTC	575	100
58	10.05	0	CDTB	580	100.5
58.5	10	0	CDTA	585	100
59	9.95	0	CT	590	99.5
59.5	9.95	0	BCTF	595	99.5
60	9.8	0	BCTE	600	98
60.5	9.85	0	BCTD	605	98.5
61	9.85	0	BCT	610	98.5
61.5	10.1	0	BCTC	615	101
62	10.4	0	BCTB	620	104
62.5	10.7	0	BCTA	625	107
63	10.7	0	BT	630	107
63.5	10.65	0	ABTF	635	106.5
64	10.45	0	ABTE	640	104.5
64.5	10.4	0	ABTD	645	104
65	10.4	0	ABT	650	104
65.5	10.5	0	ABTC	655	105
66	10.45	0	ABTB	660	104.5
66.5	10.2	0	ABTA	665	102
67	10	0	AT	670	100
67.5	9.9	0	AETM	675	99
67.7	9.75	0	AETL	677	97.5
68	9.6	0	AETK	680	96
68.2	9.5	0	AETJ	682	95
68.5	9.4	0	AETI	685	94
69	9.35	0	AETH	690	93.5
69.4	9.25	0	AETG	694	92.5
69.5	9.1	0	AETF	695	91
70.4	9	0	AETE	704	90
70.8	8.75	0	AETD	708	87.5
69.6	8.5	0	AETC	696	85
69.75	8.25	0	AETB	697.5	82.5
70	8.2	0	AETA	700	82

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
69.9	7.83	0	AESA1	699	78.3
69.7	7.79	0	AESA3	697	77.9
69.4	7.71	0	AESB1	694	77.1
69.2	7.63	0	AESB3	692	76.3
68.9	7.53	0	AESC1	689	75.3
68.6	7.38	0	AESD2	686	73.8
68.4	7.22	0	AESF1	684	72.2
68.2	7.16	0	AESF3	682	71.6
67.9	7.06	0	AESG1	679	70.6
67.6	6.8	0	AESH2	676	68
67.3	6.69	0	AESJ2	673	66.9
67.1	6.63	0	AESJ4	671	66.3
66.9	6.54	0	AS1	669	65.4
66.7	6.42	0	AS3	667	64.2
66.3182	6.5	0	ABSA2	663.182	65
66.2273	6.6	0	ABSA3	662.273	66
66.1364	6.7	0	ABSA4	661.364	67
66.0445	6.8	0	ABSA5	660.445	68
65.8	6.85	0	ABSB2	658	68.5
65.6	6.85	0	ABSB4	656	68.5
65.3	6.89	0	ABSC2	653	68.9
65.1	6.93	0	ABSC4	651	69.3
64.9	6.94	0	ABS1	649	69.4
64.7	6.92	0	ABS3	647	69.2
64.4	6.88	0	ABSD1	644	68.8
64.2	6.84	0	ABSD3	642	68.4
63.6385	4.4	0	ABSO2	636.3848	44
63.577	4.2	0	ABSO4	635.7696	42
63.3	4.14	0	ABSP2	633	41.4
63.1	4.28	0	ABSP4	631	42.8
62.8	4.41666	0	BS2	628	44.1666

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
62.6	4.48332	0	BS4	626	44.8332
62.525	4.675	0	BCSA1	625.25	46.75
62.7	4.9	0	BCSB1	627	49
62.4	5.15	0	BCSE1	624	51.5
62.2	5.25	0	BCSE3	622	52.5
61.8	5.21	0	BCSF2	618	52.1
61.6	5.07	0	BCSF4	616	50.7
61.3947	5.2	0	BCSG2	613.9474	52
61.2895	5.4	0	BCSG4	612.8949	54
61.1842	5.6	0	BCSG6	611.8422	56
61.079	5.8	0	BCSG8	610.7896	58
60.9286	5.8	0	BCS1	609.2858	58
60.7857	5.6	0	BCS3	607.8574	56
60.6429	5.4	0	BSC5	606.429	54
60.4	5.2	0	BCSH1	604	52
60.2	5.2	0	BCSH3	602	52
59.8	5.3	0	BCSI2	598	53
59.6	5.4	0	BCSI4	596	54
59.3	5.43	0	BCSJ2	593	54.3
59.1	5.41	0	BCSJ4	591	54.1
58.8947	5.2	0	CS2	588.9474	52
58.7895	5	0	CS4	587.8948	50
58.6842	4.8	0	CS6	586.8422	48
58.579	4.6	0	CS8	585.7896	46
58.4	4.54	0	CDSA1	584	45.4
58.2	4.72	0	CDSA3	582	47.2
57.9	4.95	0	CDSB1	579	49.5
57.7	5.05	0	CDSB3	577	50.5
57.3	5.25	0	CDSC2	573	52.5
57.1	5.35	0	CDSC4	571	53.5
56.9	5.35	0	CDS1	569	53.5
56.7	5.25	0	CDS3	567	52.5
56.4	5.13	0	CDSD1	564	51.3

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
56.2	5.09	0	CDSD3	562	50.9
55.8	5.19	0	CDSE2	558	51.9
55.6	5.33	0	CDSE4	556	53.3
55.3	5.36	0	CDSF2	553	53.6
55.1	5.32	0	CDSF4	551	53.2
54.6	5.26	0	DS4	546	52.6
54.2	5.22	0	DS8	542	52.2
53.8	5.18	0	DS12	538	51.8
53.4	5.14	0	DS16	534	51.4
52.6	5.06	0	DES4	526	50.6
52.2	5.02	0	DES8	522	50.2
51.8	4.98	0	DES12	518	49.8
51.4	4.94	0	DES16	514	49.4
50.8	4.98	0	ES2	508	49.8
50.4	5.14	0	ES6	504	51.4
50	5.3	0	ES10	500	53
49.6	5.46	0	ES14	496	54.6
49.2	5.62	0	ES18	492	56.2
48.8	5.67	0	EFS2	488	56.7
48.4	5.61	0	EFS6	484	56.1
48	5.55	0	EFS10	480	55.5
47.6	5.49	0	EFS14	476	54.9
47.2	5.43	0	EFS18	472	54.3
46.8	5.355	0	FS2	468	53.55
46.4	5.265	0	FS6	464	52.65
46	5.175	0	FS10	460	51.75
45.6	5.085	0	FS14	456	50.85
45.2	4.995	0	FS18	452	49.95
44.8	4.874	0	FGS2	448	48.74
44.4	4.722	0	FGS6	444	47.22
44	4.57	0	FGS10	440	45.7
43.8	4.494	0	FGS12	438	44.94
43.4	4.342	0	FGS16	434	43.42
42.6	4.18	0	GS4	426	41.8
42.2	4.16	0	GS8	422	41.6
41.8	4.14	0	GS12	418	41.4
41.4	4.12	0	GS16	414	41.2
40.8	4.05	0	GHS2	408	40.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
40.4	3.95	0	GHS6	404	39.5
40	3.85	0	GHS10	400	38.5
39.6	3.75	0	GHS14	396	37.5
39.2	3.65	0	GHS18	392	36.5
38.6	3.54	0	HS4	386	35.4
38.2	3.48	0	HS8	382	34.8
37.8	3.42	0	HS12	378	34.2
37.4	3.36	0	HS16	374	33.6
36.8	3.215	0	HIS2	368	32.15
36.4	3.045	0	HIS6	364	30.45
36	2.875	0	HIS10	360	28.75
35.6	2.705	0	HIS14	356	27.05
35.2	2.535	0	HIS18	352	25.35
34.6	2.43	0	IS4	346	24.3
34.2	2.41	0	IS8	342	24.1
33.8	2.39	0	IS12	338	23.9
33.4	2.37	0	IS16	334	23.7
32.8	2.315	0	IJS2	328	23.15
32.4	2.245	0	IJS6	324	22.45
32	2.175	0	IJS10	320	21.75
31.6	2.105	0	IJS14	316	21.05
31.2	2.035	0	IJS18	312	20.35
30.6	1.97	0	JS4	306	19.7
30.2	1.99	0	JS8	302	19.9
29.8	2.01	0	JS12	298	20.1
29.4	2.03	0	JS16	294	20.3
28.8	1.984	0	JKS2	288	19.84
28.4	1.852	0	JKS6	284	18.52
28	1.72	0	JKS10	280	17.2
27.6	1.588	0	JKS14	276	15.88
27.2	1.456	0	JKS18	272	14.56
26.6	1.42	0	KS4	266	14.2
26.2	1.44	0	KS8	262	14.4
25.8	1.46	0	KS12	258	14.6
25.4	1.48	0	KS16	254	14.8
24.6	1.54	0	KLS4	246	15.4
24.2	1.58	0	KLS8	242	15.8
23.8	1.62	0	KLS12	238	16.2
23.4	1.66	0	KLS16	234	16.6

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
22.8	1.74	0	LS2	228	17.4
22.4	1.82	0	LS6	224	18.2
22	1.9	0	LS10	220	19
21.6	1.98	0	LS14	216	19.8
21.2	2.06	0	LS18	212	20.6
20.6	2.1	0	LMS4	206	21
20.2	2.1	0	LMS8	202	21
19.8	2.1	0	LMS12	198	21
19.4	2.1	0	LMS16	194	21
18.8	2.196	0	MS2	188	21.96
18.4	2.388	0	MS6	184	23.88
18	2.58	0	MS10	180	25.8
17.6	2.772	0	MS14	176	27.72
17.2	2.964	0	MS18	172	29.64
16.6	3.07	0	MNS4	166	30.7
16.2	3.09	0	MNW8	162	30.9
15.8	3.11	0	MNS12	158	31.1
15.4	3.13	0	MNS16	154	31.3
14.8	3.275	0	NS2	148	32.75
14.4	3.525	0	NS6	144	35.25
14	3.775	0	NS10	140	37.75
13.6	4.025	0	NS14	136	40.25
13.2	4.275	0	NS18	132	42.75
12.8	4.38	0	NOS2	128	43.8
12.4	4.54	0	NOS6	124	45.4
12	4.7	0	NOS10	120	47
11.6	4.86	0	NOS14	116	48.6
11.2	5.02	0	NOS18	112	50.2
10.9	5.17	0	OS1	109	51.7
10.7	5.31	0	OS3	107	53.1
10.4	5.5	0	OPSA1	104	55
10.2	5.6	0	OPSA3	102	56
9.9	5.73	0	OPSB1	99	57.3
9.7	5.79	0	OPSB3	97	57.9
9.3	5.93	0	OPSC2	93	59.3
9.1	6.01	0	OPSC4	91	60.1
8.9	6.09	0	OPS1	89	60.9
8.7	6.17	0	OPS3	87	61.7

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
8.4	6.28	0	OPSD1	84	62.8
8.2	6.34	0	OPSD3	82	63.4
7.8	6.44	0	OPSE2	78	64.4
7.6	6.48	0	OPSE4	76	64.8
7.3	6.5	0	OPSF2	73	65
7.1	6.5	0	OPSF4	71	65
6.9	6.51	0	PS1	69	65.1
6.7	6.53	0	PS3	67	65.3
6.4	6.56	0	PQSA1	64	65.6
6.2	6.58	0	PQSA3	62	65.8
5.8	6.62	0	PQSB2	58	66.2
5.6	6.64	0	PQSB4	56	66.4
5.3	6.63	0	PQSC2	53	66.3
5.1	6.61	0	PQSC4	51	66.1
4.9	6.57	0	PQS1	49	65.7
4.7	6.51	0	PQS3	47	65.1
4.4	6.4	0	PQSD1	44	64
4.2	6.3	0	PQSD3	42	63
3.8	6.1	0	PQSE2	38	61
3.6	6	0	PQSE4	36	60
3.3	5.89	0	PQSF2	33	58.9
3.1	5.83	0	PQSF4	31	58.3
2.9	5.81	0	QS1	29	58.1
2.7	5.83	0	QS3	27	58.3
2.3	5.91	0	QSA2	23	59.1
1.9	6.125	0	QSC1	19	61.25
1.66	6.6	0	QSF1	16.6	66
1.52	6.9	0	QSG2	15.2	69
1.54	7.1	0	QSH1	15.4	71
1.68	7.4	0	QSI2	16.8	74

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.76	7.6	0	QTF1	17.6	76
1.7	7.77776	0	QTE12	17	77.7776
1.5	7.8148	0	QTE10	15	78.148
1.3	7.85184	0	QTE8	13	78.5184
1.1	7.88888	0	QTE6	11	78.8888
0.9	7.92592	0	QTE4	9	79.2592
0.7	7.96296	0	QTE2	7	79.6296
0.7	8.0334	0	QTD10	7	80.334
0.9	8.06672	0	QTD8	9	80.6672
1.1	8.10004	0	QTD6	11	81.0004
1.3	8.13336	0	QTD4	13	81.3336
1.5	8.16668	0	QTD2	15	81.6668
1.9	8.3	0	QTB1	19	83
2.1	8.37	0	QTA4	21	83.7
2.3	8.41	0	QTA2	23	84.1
2.7	8.47	0	QT3	27	84.7
2.9	8.49	0	QT1	29	84.9
3.1	8.52	0	PQTF4	31	85.2
3.3	8.56	0	PQTF2	33	85.6
3.6	8.61	0	PQTE4	36	86.1
3.8	8.63	0	PQTE2	38	86.3
4.2	8.79	0	PQTD3	42	87.9
4.4	8.93	0	PQTD1	44	89.3
4.7	8.94	0	PQT3	47	89.4
4.9	8.88	0	PQT1	49	88.8
5.1	8.89	0	PQTC4	51	88.9
5.3	8.97	0	PQTC2	53	89.7
5.6	9.12	0	PQTB4	56	91.2
5.8	9.26	0	PQTB2	58	92.6
6.2	9.46	0	PQTA3	62	94.6
6.4	9.52	0	PQTA1	64	95.2
6.7	9.59	0	PT3	67	95.9
6.9	9.63	0	PT1	69	96.3

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
7.1	9.66	0	OPTJ4	71	96.6
7.3	9.68	0	OPTJ2	73	96.8
7.7	9.72	0	OPTI3	77	97.2
7.9	9.74	0	OPTI1	79	97.4
8.1	9.7227	0	OPTH5	81	97.227
8.3	9.61362	0	OPTH3	83	96.1362
8.5	9.50454	0	OPTH1	85	95.0454
8.52	9.3	0	OPTG1	85.2	93
8.5	9.1	0	OPTF2	85	91
8.5	8.8	0	OPTE1	85	88
8.7	8.58	0	OPT3	87	85.8
8.9	8.56	0	OPT1	89	85.6
9.1	8.55	0	OPTC4	91	85.5
9.3	8.55	0	OPTC2	93	85.5
9.6	8.59	0	OPTB4	96	85.9
9.8	8.67	0	OPTB2	98	86.7
10.2	8.79	0	OPTA3	102	87.9
10.4	8.83	0	OPTA1	104	88.3
10.7	8.81	0	OT3	107	88.1
10.9	8.77	0	OT1	109	87.7
11.2	8.73	0	NOT18	112	87.3
11.6	8.69	0	NOT14	116	86.9
12	8.65	0	NOT10	120	86.5
12.4	8.61	0	NOT6	124	86.1
12.8	8.57	0	NOT2	128	85.7
13.2	8.61	0	NT18	132	86.1
13.6	8.73	0	NT14	136	87.3
14	8.85	0	NT10	140	88.5
14.4	8.97	0	NT6	144	89.7
14.8	9.09	0	NT2	148	90.9
15.2	9.175	0	MNT18	152	91.75
15.6	9.225	0	MNT14	156	92.25
16	9.275	0	MNT10	160	92.75
16.4	9.325	0	MNT6	164	93.25

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
16.8	9.375	0	MNT2	168	93.75
17.2	9.3	0	MT18	172	93
17.6	9.1	0	MT14	176	91
18	8.9	0	MT10	180	89
18.4	8.7	0	MT6	184	87
18.8	8.5	0	MT2	188	85
19.4	8.4	0	LMT16	194	84
19.8	8.4	0	LMT12	198	84
20.2	8.4	0	LMT8	202	84
20.6	8.4	0	LMT4	206	84
21.4	8.4	0	LT16	214	84
21.8	8.4	0	LT12	218	84
22.2	8.4	0	LT8	222	84
22.6	8.4	0	LT4	226	84
23.4	8.4	0	KLT16	234	84
23.8	8.4	0	KLT12	238	84
24.2	8.4	0	KLT8	242	84
24.6	8.4	0	KLT4	246	84
25.4	8.4	0	KT16	254	84
25.8	8.4	0	KT12	258	84
26.2	8.4	0	KT8	262	84
26.6	8.4	0	KT4	266	84
27.4	8.43	0	JKT16	274	84.3
27.8	8.46	0	JKT12	278	84.6
28.2	8.49	0	JKT8	282	84.9
28.6	8.52	0	JKT4	286	85.2
29.4	8.55	0	JT16	294	85.5
29.8	8.55	0	JT12	298	85.5
30.2	8.55	0	JT8	302	85.5
30.6	8.55	0	JT4	306	85.5
31.2	8.59	0	IJT18	312	85.9
31.6	8.67	0	IJT14	316	86.7
32	8.75	0	IJT10	320	87.5
32.4	8.83	0	IJT6	324	88.3
32.8	8.91	0	IJT2	328	89.1
33.2	8.94	0	IT18	332	89.4
33.6	8.92	0	IT14	336	89.2
34	8.9	0	IT10	340	89
34.4	8.88	0	IT6	344	88.8

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
34.8	8.86	0	IT2	348	88.6
35	8.85	0	IT0	350	88.5
35.2	9.085	0	HIT18	352	90.85
35.6	9.155	0	HIT14	356	91.55
36	9.225	0	HIT10	360	92.25
36.4	9.295	0	HIT6	364	92.95
36.8	9.365	0	HIT2	368	93.65
37.4	9.42	0	HT16	374	94.2
37.8	9.44	0	HT12	378	94.4
38.2	9.46	0	HT8	382	94.6
38.6	9.48	0	HT4	386	94.8
39.4	9.48	0	GHT16	394	94.8
39.8	9.46	0	GHT12	398	94.6
40.2	9.44	0	GHT8	402	94.4
40.6	9.42	0	GHT4	406	94.2
41.2	9.34	0	GT18	412	93.4
41.6	9.22	0	GT14	416	92.2
42	9.1	0	GT10	420	91
42.4	8.98	0	GT6	424	89.8
42.8	8.86	0	GT2	428	88.6
43.2	8.845	0	FGT18	432	88.45
43.6	8.935	0	FGT14	436	89.35
44	9.025	0	FGT10	440	90.25
44.4	9.115	0	FGT6	444	91.15
44.8	9.205	0	FGT2	448	92.05
45.2	9.255	0	FT18	452	92.55
45.6	9.265	0	FT14	456	92.65
46	9.275	0	FT10	460	92.75
46.4	9.285	0	FT6	464	92.85
46.8	9.295	0	FT2	468	92.95
47.2	9.325	0	EFT18	472	93.25
47.6	9.375	0	EFT14	476	93.75
48	9.425	0	EFT10	480	94.25
48.4	9.475	0	EFT6	484	94.75
48.8	9.525	0	EFT2	488	95.25
49.2	9.565	0	ET18	492	95.65
49.6	9.595	0	ET14	496	95.95
50	9.625	0	ET10	500	96.25
50.4	9.655	0	ET6	504	96.55
50.8	9.685	0	ET2	508	96.85

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
51.2	9.725	0	DET18	512	97.25
51.6	9.775	0	DET14	516	97.75
52	9.825	0	DET10	520	98.25
52.4	9.875	0	DET6	524	98.75
52.8	9.925	0	DET2	528	99.25
53.2	9.975	0	DT18	532	99.75
53.6	10.025	0	DT14	536	100.25
54	10.075	0	DT10	540	100.75
54.4	10.125	0	DT6	544	101.25
54.8	10.175	0	DT2	548	101.75
55.1	10.18	0	CDTF4	551	101.8
55.3	10.14	0	CDTF2	553	101.4
55.6	10.07	0	CDTE4	556	100.7
55.8	10.01	0	CDTE2	558	100.1
56.2	9.95	0	CDTD3	562	99.5
56.4	9.95	0	CDTD1	564	99.5
56.7	9.95	0	CDT3	567	99.5
56.9	9.95	0	CDT1	569	99.5
57.1	9.96	0	CDTC4	571	99.6
57.3	9.98	0	CDTC2	573	99.8
57.6	10.01	0	CDTB4	576	100.1
57.8	10.03	0	CDTB2	578	100.3
58.2	10.03	0	CDTA3	582	100.3
58.4	10.01	0	CDTA1	584	100.1
58.7	9.98	0	CT3	587	99.8
58.9	9.96	0	CT1	589	99.6
59.1	9.95	0	BCTF4	591	99.5
59.3	9.95	0	BCTF2	593	99.5
59.6	9.92	0	BCTE4	596	99.2
59.8	9.86	0	BCTE2	598	98.6
60.2	9.82	0	BCTD3	602	98.2
60.4	9.84	0	BCTD1	604	98.4
60.7	9.85	0	BCT3	607	98.5
60.9	9.85	0	BCT1	609	98.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
61.1	9.9	0	BCTC4	611	99
61.3	10	0	BCTC2	613	100
61.6	10.16	0	BCTB4	616	101.6
61.8	10.28	0	BCTB2	618	102.8
62.2	10.52	0	BCTA3	622	105.2
62.4	10.64	0	BCTA1	624	106.4
62.7	10.7	0	BT3	627	107
62.9	10.7	0	BT1	629	107
63.1	10.69	0	ABTF4	631	106.9
63.3	10.67	0	ABTF2	633	106.7
63.6	10.62	0	ABTE4	636	106.2
63.8	10.53	0	ABTE2	638	105.3
64.2	10.43	0	ABTD3	642	104.3
64.4	10.41	0	ABTD1	644	104.1
64.7	10.4	0	ABT3	647	104
64.9	10.4	0	ABT1	649	104
65.1	10.42	0	ABTC4	651	104.2
65.3	10.46	0	ABTC2	653	104.6
65.6	10.49	0	ABTB4	656	104.9
65.8	10.47	0	ABTB2	658	104.7
66.2	10.35	0	ABTA3	662	103.5
66.4	10.25	0	ABTA1	664	102.5
66.7	10.12	0	AT3	667	101.2
66.9	10.04	0	AT1	669	100.4
67.1	9.98	0	AETM4	671	99.8
67.3	9.94	0	AETM2	673	99.4
67.85	9.675	0	AETK1	678.5	96.75
68.35	9.45	0	AETI1	683.5	94.5
68.7	9.38	0	AETH3	687	93.8
68.9	9.36	0	AETH1	689	93.6
69.2	9.3	0	AETG2	692	93

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
69.6	9.08888	0	AETE8	696	90.8888
69.8	9.06666	0	AETE6	698	90.6666
70	9.04444	0	AETE4	700	90.4444
70.2	9.02222	0	AETE2	702	90.2222
70.6	8.875	0	AETD2	706	88.75
70.7	8.72913	0	AETC11	707	87.2913
70.5	8.68747	0	AETC9	705	86.8747
70.3	8.64581	0	AETC7	703	86.4581
70.1	8.60415	0	AETC5	701	86.0415
69.9	8.56249	0	AETC3	699	85.6249
69.7	8.52083	0	AETC1	697	85.2083
69.63	8.4	0	AETB2	696.3	84
69.9	8.22	0	AETA1	699	82.2
70.05	8.1	0	AET1	700.5	81

CALIBRATION CERTIFICATE

Model: 2000 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

Type of Reading

Velocity:
- [x] FPS
- [ ] CMS
- [ ] ______

Level:
- [ ] IN
- [ ] CM
- [x] N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	NA
Measured:	0.00	2.00	NA

- [x] Factory Calibration

- [ ] Field Profile Calibration;
  Site Coefficient or Velocity Multiplier: ______

Calibration Technician: ______ Date: 4-20-07

QA Technician: ______ Date: 20APR07

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For product information, service, or calibration, please contact the Customer Service Department.

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SUMMARY OF DISCHARGE MEASUREMENT ACTIVITIES															
MAMMOTH SPRING (SILVER SPRINGS GROUP)					**Marion County, Florida**										
Performed by Karst Environmental Services, Inc., High Springs, Florida															
DATE	**DISCHARGE (CFS)**	**INSTR. USED**	**CALC. METHOD**	**NUMBER STATIONS**	**X-SECTION AREA** (sq.feet)	**Avg. Station Point Velocity** (fps)	**High Msmt.** (fps)	**Low Msmt.** (fps)	**TIME START:**	**TIME FINISH:**	**Depth** (feet)	**Neg. PV's**	**Blanking Used?**	**NOTES:**
3/24/2005	**300.29**	MMB 201	Grid Count	115	323.06	0.96	1.33	-0.14	14:00	17:50	25-34	3	yes	
9/19/2006	**240.07**	MMB 201	Grid Count	138	308.16	0.71	1.16	-0.39	13:40	17:50	26-32	8	yes	
9/10/2007	**207.78**	MMB 201	Grid Count	132	321.36	0.61	0.96	-0.06	12:50	16:42	26-34	2	yes	

Table 4. Summary of Discharge Measurement Activities; Mammoth Spring, Marion County, Florida.