

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

**WATER QUALITY CHARACTERIZATION OF
SOUTHERN MIAMI-DADE COUNTY AND NEARBY FPL
TURKEY POINT POWER PLANT
MIAMI-DADE COUNTY, FLORIDA**

Technical Publication WS-31



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Executive Summary

In February and March of 2009, a surface water and groundwater sampling program was conducted to assist with development of the FPL Turkey Point Power Plant (Plant) Groundwater, Surface Water, and Ecological Monitoring Plan (Monitoring Plan). The investigation examined the viability of using various parameters as tracers to estimate the vertical and horizontal extent of the hypersaline groundwater plume seeping from the cooling canal system (CCS), an approximately 5,900-acre network of unlined canals south of the Plant, and the relative contribution of the plume to surrounding groundwater and surface waters. Additionally, a preliminary geochemical characterization of waters of the CCS and surrounding surface and groundwater with respect to water quality was used as a screening tool for development of the Monitoring Plan and the proposed tracer suite.

Sample collection, analysis, data evaluation, and reporting were a joint effort of the South Florida Water Management District (SFWMD), the Miami-Dade County Department of Environmental Resource Management (DERM), and researchers from several university groups with expertise in parameters selected for the study. Sample collection and analysis was assigned to teams consisting of individuals from the SFWMD, DERM, and Florida International University (FIU). Statistical analysis and data evaluation were performed by researchers from FIU, University of Miami Rosenstiel School of Marine and Atmospheric Science, Division of Marine Geology and Geophysics (MGG/RSMAS), and Division of Marine and Atmospheric Chemistry (DMAC) at RSMAS. This report documents sample collection and analysis and summarizes the findings of the university groups. Each university group prepared a report documenting data evaluation and conclusions, which are presented as Appendices C, D, and F in this report, and will be collectively referred to herein as the “University Reports.”

The investigation included collection and analysis of surface and groundwater samples from locations within and proximal to the Plant. Samples were collected from thirty-five (35) surface water locations within the CCS, Biscayne Bay east of the CCS, tidal canals and other water bodies north, east and south of the CCS, and freshwater canals west of the CCS. Seventeen (17) groundwater monitoring wells were sampled, sixteen (16) from monitoring wells completed in the Biscayne aquifer to the north and west of the CCS, and one from an upper Floridan aquifer monitoring well at the Black Point Wastewater Treatment Plant (WWTP) approximately eight miles north of the CCS. Sample analysis included major cations and anions, total dissolved solids (TDS), alkalinity, sulfides, nutrients, and metals; the stable isotope ratios of oxygen ($^{18}\text{O}/^{16}\text{O}$), deuterium ($^2\text{H}/^1\text{H}$), carbon ($^{13}\text{C}/^{12}\text{C}$), and strontium ($^{87}\text{Sr}/^{86}\text{Sr}$); and the unstable isotope tritium (^3H).

Based on the findings of this study, the following several parameters have potential for use of a tracer.

- Major anions and cations, and stable isotope ratios of oxygen and deuterium relative to the Vienna standard mean ocean water ($\delta^{18}\text{O}$ and δD , respectively) were found to be useful for distinguishing between water from the CCS and Biscayne Bay as a salinity source where the mixture's salinity is greater than Biscayne Bay, such as in the groundwater samples from monitoring wells relatively near the CCS;
- Tritium was identified as the single parameter that can be used as a definitive tracer of CCS water in mixtures where salinity is both below and above that of Biscayne Bay. Samples from six monitoring wells and two surface water locations appeared to be mainly mixtures of water from the CCS and fresh groundwater/surface water; four surface water samples appeared to be a mixture of water from the CCS and Biscayne Bay, and samples from three monitoring wells appeared to be mixtures of fresh groundwater, Biscayne Bay water, and another source of very low tritium water (possibly Floridan aquifer).
- Barium, $\delta^{13}\text{C}$, and $^{87}\text{Sr}/^{86}\text{Sr}$ in mixing diagrams were found to be of limited use for mixtures where salinity is lower than Biscayne Bay;
- The strontium isotope ratio was useful for identification of surface waters and groundwater that had lower strontium isotope ratios than can be explained by equilibration with modern Biscayne Bay surface water, which implies a proportional input of Floridan Aquifer groundwater, a constituent within the CCS.

Relatively higher calcium concentrations within fresh groundwater samples indicate the presence of two types of fresh groundwater from two monitoring wells grouped very close to one another along Tallahassee Road. The University Reports conclude that one source may be remnant connate water from a previous saltwater intrusion event.

The University Reports describe data interpretation limitations including insufficient depth and spatial control, lack of groundwater data to the north, east, and south of the CCS; the limited number of samples; lack of seasonal data; the half-life of ^3H , lack of age data for the CCS groundwater plume; and lack of information regarding construction of some of the wells sampled. Recommendations include construction of nested wells at progressively increasing distances from the CCS and screened within possible flow paths within the Biscayne Aquifer; a seasonal sampling program for the parameters in this study and lithium isotopes ($^6\text{Li}/^7\text{Li}$), and for age-dating parameters helium-3 (^3He), in combination with chlorofluorocarbons (CFCs), or sulfur hexafluoride (SF_6).

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Abbreviations and Acronyms

General Acronyms

app.	approximate
bls	below land surface (for wells in Biscayne Bay, datum is below bottom of bay)
BN	Biscayne National Park
CAS	Columbia Analytical Services, Inc.
CCS	Cooling Canal System
°C	Degrees Celsius
CERP	Comprehensive Everglades Restoration Plan
DERM	Miami-Dade County Department of Environmental Resource Management
DIC	dissolved inorganic carbon
DO	dissolved oxygen
DMAC	Division of Marine and Atmospheric Chemistry
DMAC/RSMAS	University of Miami Rosenstiel School of Marine and Atmospheric Science, Division of Marine and Atmospheric Chemistry
FDEP	Florida Department of Environmental Protection
FIU	Florida International University
FKAA	Florida Keys Aqueduct Authority
FPL	Florida Power & Light Company
ID	Interceptor Ditch
MDWASD	Miami-Dade Water and Sewer Department
MGG	Division of Marine Geology and Geophysics
MGG/RSMAS	University of Miami Rosenstiel School of Marine and Atmospheric Science, Division of Marine Geology and Geophysics

μS/cm	microsiemens per centimeter
mg	milligrams
mg/L	milligrams per liter
ml	milliliters
mV	millivolts
NGVD29	National Geodetic Vertical Datum of 1929
NA	Parameter not analyzed for
ND	Data Not Available
NWIS	National Water Information System
ORP	oxidation reduction potential
pH	percent hydrogen
ppm	parts per million
psu	practical salinity units
RPM	Reductive Precipitation Method
RSMAS	University of Miami Rosenstiel School of Marine and Atmospheric Science
SFWMD	South Florida Water Management District
SM	Standard Method
SMOW	Standard Mean Ocean Water
SOP	Standard Operating Procedures
TDS	Total Dissolved Solids
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
V-PDB	Vienna Pee Dee Belemnite
V-SMOW	Vienna standard mean ocean water
WWTP	Wastewater Treatment Plant

Chemical Elements Acronyms

As arsenic

Ba barium

Be beryllium

B³⁻ boron

Br⁻ bromide

Ca²⁺ calcium

Cd cadmium

Cl⁻ chloride

Cr chromium

Cu copper

F⁻ fluoride

Fe iron

Pb lead

Hg mercury

Mg²⁺ magnesium

Mn manganese

Mo molybdenum

Ni nickel

Na⁺ sodium

K⁺ potassium

Se selenium

Sr²⁺ strontium

SO₄²⁻ sulfate

S²⁻ sulfide
Tl thallium
V vanadium
Zn zinc

Isotope Acronyms

²H deuterium
³H tritium
¹³C carbon
¹⁸O oxygen
⁸⁷Sr strontium
 $\delta^{18}\text{O}$ oxygen isotope ratio
 δD deuterium isotope ratio
⁸⁷Sr/⁸⁶Sr strontium isotope ratio
Tritium (³H)

Introduction

PURPOSE AND SCOPE

In February and March, 2009 a surface water and groundwater sampling program was conducted to assist with development of the FPL Turkey Point Power Plant Groundwater, Surface Water, and Ecological Monitoring Plan (Monitoring Plan) by the SFWMD, FDEP, DERM, and FPL. The purpose of the Monitoring Plan was to provide information to determine the vertical and horizontal extent of hypersaline water originating from the Cooling Canal System (CCS) and effect, if any, on potential receptors including surface water, groundwater and ecological environments surrounding the FPL Turkey Point Power Plant (Plant). The investigation examined the viability of using various parameters as tracers for identification of the vertical and horizontal extent of the hypersaline groundwater plume seeping from the CCS, and relative contribution of the plume to surrounding groundwater and surface waters. Additionally, a preliminary geochemical characterization of waters of the CCS and surrounding surface and groundwater with respect to water quality was used as a screening tool for development of the Monitoring Plan and the proposed tracer suite. Subsequent to completion of the sampling event, the Monitoring Plan was finalized on October 14, 2009 (SFWMD, 2009).

Samples were collected to obtain preliminary geochemical data near the Plant, located in southeastern Miami-Dade County, Florida (Figure 1, Appendix A). This investigation included collection and analysis of surface and groundwater samples from locations within and proximal to the Plant. Samples were collected from thirty-five (35) surface water locations within the CCS, Biscayne Bay east of the CCS, tidal canals and other water bodies north, east and south of the CCS, and freshwater canals west of the CCS. Seventeen (17) groundwater monitoring wells were sampled, sixteen (16) from monitoring wells completed in the Biscayne aquifer to the north and west of the CCS, and one from an upper Floridan aquifer monitoring well at the Black Point Wastewater Treatment Plant (WWTP) approximately eight miles north of the CCS. Sample analysis included major cations and anions, total dissolved solids (TDS), alkalinity, sulfides, nutrients, metals; the stable isotope ratios of oxygen ($^{18}\text{O}/^{16}\text{O}$), deuterium ($^2\text{H}/^1\text{H}$), carbon ($^{13}\text{C}/^{12}\text{C}$), and strontium ($^{87}\text{Sr}/^{86}\text{Sr}$); and the unstable isotope tritium (^3H).

PREVIOUS STUDIES

Substantial amounts of engineering, geotechnical and geochemical reports were generated by FPL and their consultants regarding design and construction of the Turkey Point facility in the early 1970s. Preliminary hydrogeologic investigations in 1971 provided hydrogeologic and water quality data near the CCS prior to construction (Brown and Root, 1971, Dames and Moore, 1971). Monitoring well networks were installed and monitored by FPL in the early to mid-1970s to the west of the CCS (Dames and Moore, March 31st, 1976), west and southwest of the CCS (Dames and Moore, November 19, 1976), and north, east and south of the CCS (Dames and Moore, June 25, 1976). FPL has submitted monitoring reports documenting water quality and temperature conditions west of the CCS on a quarterly, semi-annual, and/or annual basis since 1972; however, the scope of monitoring has decreased over time. FPL (Dames and Moore, 1978) published a report that estimated the existing salt-water interface with estimates of impacts from the CCS on the future position of the salt-water interface; however, this report did not anticipate the current salinity levels with the CCS. The 1978 report also presents results of tritium sampling of monitoring wells surrounding the CCS.

FPL has submitted Annual Radiological Environmental Operating Reports for Turkey Point Units 3 and 4 to the Nuclear Regulatory Agency (NRC) for the years 2005 through 2009 (Florida Department of Health, 2007, 2008, and 2009). These reports document results of quarterly sampling of vegetation, fish and invertebrates, surface water and air in and around the Plant for radiological constituents. Quarterly groundwater sampling of monitoring wells within the Plant and to the west was begun in 2007, and is documented in Appendix D of the 2007, 2008, and 2009 Annual Reports to the NRC.

The USGS has published many water resource investigations documenting groundwater quality and conditions associated with saltwater intrusion within the Biscayne aquifer in southern Miami-Dade County and the study area (Figure 1). These include Parker (1945), Klein (1957), Kohout (1964), Hull and Meyer (1973), Klein, et al. (1978), Klein and Waller (1985), Fish and Stewart (1991), Sonenshein (1997), and more recently Renken et al. (2005).

The FCAA and the United States Geological Survey (USGS) have conducted salt-water intrusion monitoring of several monitoring wells within the western portion of the study area since the late 1940s. Constituents have included specific conductance and chlorides in addition to major ions. Monitoring results are available on the USGS National Water Information System (NWIS) website (<http://nwis.waterdata.usgs.gov/fl/nwis/si>). Integrated chloride monitoring data for south Florida is available at two USGS websites, 1) The USGS Cooperative Salinity and Chloride Monitoring Program in South Florida available at (http://www.sflorida.er.usgs.gov/sal_data/index.html), and 2) the Saline Intrusion Monitoring IMS website available at (<http://www.envirobase.usgs.gov/FLIMS>).

The SFWMD maintains a real-time surface water and groundwater network in the area inclusive of the northern and western portions of the study area, including water level elevations and water quality parameters of temperature, specific conductance, salinity (calculated), and others. The SFWMD data can be accessed at the DBHYDRO database (http://my.sfwmd.gov/dbhydroplsql/show_dbkey_info.main_menu)

DESCRIPTION OF THE STUDY AREA

Study Area and Surrounding Properties

The study area includes approximately 90 square miles within southeastern Miami-Dade County and includes the CCS and adjacent areas, as shown in Figure 1. The area is largely undeveloped, and includes, from east to west, Biscayne Bay and Card Sound, mangrove shoreline, and freshwater to saltwater wetlands. The area enclosed by the Plant and CCS is approximately two miles wide and six miles long and is located west of Biscayne Bay. The Everglades Mitigation Bank, approximately 13,000 acres of relatively undisturbed freshwater to saltwater wetlands, is west and south of the CCS. The Comprehensive Everglades Restoration Plan (CERP) study area, part of a multi-agency project for restoration of Biscayne Bay and adjacent wetlands, borders the Plant and CCS to the south, west, and north. Biscayne National Park headquarters are located approximately two miles north of the Plant, adjacent to and north of the Metropolitan Miami-Dade County Homestead Bayfront Park. Biscayne National Park and Biscayne Bay Aquatic Preserve border the Plant and CCS to the north, east and southeast. Everglades National Park is approximately seven miles southwest of the site. The nearest town city limits are Florida City, 8 miles west, and Homestead, 9 miles northwest of the CCS.

Major canals within the study area include the freshwater canals L-31E, C-103, C-104, C-105, C-106, and the C-107 that are west of the CCS; tidal canals S-20 Discharge Canal (an eastward extension of the C-107), Card Sound Canal, and Sea Dade Canal that are south of the CCS, and the Card Sound Road Canal, approximately four miles southwest of the CCS, was a tidal canal at the time of this investigation but has since had an earthen plug installed approximately 2 miles northwest of Card Sound. The S-20 Structure is located near the intersection of the C-107 and L-31E Canals, approximately one-half mile west of the southwestern portion of the CCS. Additional development is generally within the northern and western portions of the study area and includes numerous unpaved and paved roads, agricultural fields, aggregate mining, and commercial and residential structures.

The study area includes groundwater of various origins including freshwater to the west, saline water from Biscayne Bay to the east, and hypersaline water from the CCS in the central portion. The regional groundwater gradient is generally from west to east; however, near the CCS a westward saline “toe” is present in the lower portions of the aquifer that extends to the west beneath freshwater (Dames and Moore, 1978). A vertical salinity gradient from hypersaline in the lower portions of

the aquifer to fresh water in the upper portions of the aquifer has been documented in monitoring wells on the L-31E Levee, approximately 1,000 feet west of the CCS (Golder Associates, 2009.)

Description and Function of the CCS

According to FPL-generated reports and other information, the CCS, constructed in the early 1970s, was designed to dissipate heated cooling water from four power generation units (Units 1, 2, 3, and 4) through a series of north-to-south oriented shallow canals. Units 1 and 2 are oil-fired and began operation in 1967. Units 3 and 4 are nuclear powered and began operation in 1972 and 1973, respectively. Prior to the beginning of operation of the CCS, in February of 1973, heated cooling water was discharged directly into Biscayne Bay and/or Card Sound. The Unit 5 (gas-fired) began operation in 2007 and discharges cooling water into the CCS.

The CCS, shown in Figure 2 (located in Appendix A), functions as a gravity-driven circulatory system and consists of an approximately 5,900-acre network of canals south of the Plant, and the Interceptor Ditch (ID), west of the CCS (Golder Associates, 2008). The warm discharge water from the Plant is conveyed via the Feeder canal that is an east-west canal on the northwest corner of the CCS. The discharge water flows west along the Feeder Canal and then south through the 32 westernmost cooling canals (running north and south) to the Collector Canal at the south end of the CCS. The water then flows east through the Collector Canal, and finally north back to the Plant through one large canal (the Grand Canal) and six smaller canals on the east side of the CCS. Water levels within the CCS rise and fall with tidal water level in Biscayne Bay, in part due to the exceptionally porous nature of substrate. At the southern end of the system, water levels are approximately equal to Biscayne Bay. Water level in the northwestern (discharge) portion of the CCS is reportedly about three feet higher than water level in the northeast (return) side

The 32 supply side and six return side canals are approximately three feet deep. The canals along the north side (Feeder Canal) and south side (Collector Canal) are up to approximately 18 feet deep, and the canal along the east side (Canal E-6) and the Grand Canal are up to approximately 21 feet deep (Ray L. Lyerly & Associates, 1976). Each canal ranges between approximately 200 and 300 feet wide. The ID is a canal that is approximately 18 feet deep, which parallels and is approximately 60 feet west of the westernmost canal of the CCS. The ID's intended function is to maintain an eastward groundwater gradient between the L-31E Canal, which is a north-south oriented fresh-water canal parallel to and approximately 900 feet west of the ID, and the CCS by maintaining a lower surface water elevation at all times. During the dry season, when water levels to the west are relatively low, water within the ID is often pumped by Plant operators into the CCS to maintain a lower water level. Pumping typically does not occur during the wet season when water levels to the west are relatively high.

The CCS lies within and is in direct contact with the highly permeable and transmissive Biscayne Aquifer, approximately 70 to 100 feet thick within the study area. The CCS is not lined, and groundwater interacts with water in the canal system. Evaporative and seepage loss from the canal system is replaced by process water, rainfall, storm-water runoff and groundwater infiltration from the west and Biscayne Bay (Golder Associates, 2008, p. 4). Water in the canals is hypersaline due to the effects of evaporation and Plant operation, with salinity concentrations approximately twice that of Biscayne Bay (Golder Associates, 2008).

Field Investigation

INVESTIGATION STRATEGY

The investigation strategy was developed with the cooperation of the SFWMD, DERM, FDEP and FPL. Sample parameters were chosen from constituents known or suspected to be present in the CCS based on review of previous reports and potentially would be useful in a subsequent monitoring program to identify water originating from the CCS and its relative contribution of saltwater within the aquifer relative to water from Biscayne Bay. CCS surface water was sampled to characterize the source of the hypersaline plume. Surrounding surface and groundwater was sampled to quantify those parameters in potentially down gradient receiving waters, and in locations remote enough to potentially be representative of background conditions. A range of sample locations was chosen to be representative of the various salinity conditions in surface and groundwater in the study area. Surface water sample locations included the CCS (hypersaline), freshwater canals west of the CCS, brackish water canals and creeks north, east and south of the CCS, and Biscayne Bay/Card Sound. Groundwater monitoring wells completed within the Biscayne aquifer were representative of hypersaline conditions (along the L-31E Canal approximately 900 feet west of the CCS), fresh to brackish conditions west of the L-31E Canal, and saline conditions within Biscayne Bay. One monitoring well completed in the upper Floridan aquifer at the Black Point Wastewater Treatment Plant (WWTP) was sampled as representative of background upper Floridan aquifer conditions. The rationale for including the following parameter groups as potential tracers of CCS waters is discussed below.

- Major cations and anions present in seawater are also present in the CCS due to its proximity to Biscayne Bay and the highly permeable nature of subsurface strata between the CCS and Biscayne Bay. Evaporative effects are known to have increased concentrations of dissolved solids in CCS waters to hypersaline conditions.
- Isotope ratios of oxygen ($^{18}\text{O}/^{16}\text{O}$) and deuterium ($^2\text{H}/^1\text{H}$) are known to vary based on the evaporative history of the water. As a result of fractionalization of water during evaporation, residual water bodies become enriched in the heavier isotopes. Comparison of the $^{18}\text{O}/^{16}\text{O}$ and $^2\text{H}/^1\text{H}$ ratios relative to the Vienna standard mean ocean water (SMOW - $\delta^{18}\text{O}$ and δD , respectively) can provide an indication of the relative contribution of waters with different evaporative histories, such as meteoric water, Biscayne Bay water, and water from the CCS, to a subsequent mixture, such as groundwater around the CCS.

- The isotope ratio of carbon ($^{13}\text{C}/^{12}\text{C}$) within dissolved inorganic carbon (DIC) is isotopically negative in waters from Biscayne Bay due to degradation of organic material, and further depleted within aquifers due to sulfate reduction. Comparison of the $^{13}\text{C}/^{12}\text{C}$ ratio relative to Vienna Pee Dee Belemnite ($\delta^{13}\text{C}$) may be used to differentiate between waters from CCS, Biscayne Bay, and fresh groundwater.
- The strontium isotope ratio ($^{87}\text{Sr}/^{86}\text{Sr}$) was sampled and analyzed as an indicator of water from the Floridan aquifer. Groundwater from the Floridan aquifer is known to have a lower $^{87}\text{Sr}/^{86}\text{Sr}$ ratio than water from the Biscayne aquifer, which has a lower $^{87}\text{Sr}/^{86}\text{Sr}$ ratio than Biscayne Bay surface water. Floridan aquifer water has been discharged into the CCS since initial start-up of Unit 5 in approximately January of 2007 (Golden, personal communication), therefore, the presence of Floridan aquifer water in surface or groundwater near the CCS could be an indication of a contribution of water from the CCS.
- Nutrients and/or metals within the CCS are potentially at concentrations above surrounding surface and groundwater, and therefore may be useful as tracers. Nutrients were sampled in CCS water, most surface water locations outside of the CCS, and monitoring wells relatively close to the CCS. Metals were only sampled in water from the CCS and select monitoring wells and surface water locations relatively close to the CCS. The samples for metals analysis from monitoring wells were placed on hold for subsequent analysis only if results from the CCS were above threshold concentrations.
- Tritium (^3H), produced as a byproduct of nuclear reactors, is present in CCS waters at concentrations at least two orders of magnitude above surrounding surface and groundwater, and therefore considered a potential tracer of waters from the CCS. Tritium was not sampled for on FPL-owned property including the CCS and monitoring wells G-21, G-28, L-3 and L-5 because FPL did not grant approval of the analysis.

Sample collection, analysis, data evaluation and reporting was a joint effort of the SFWMD, DERM, and researchers from several university groups with expertise in parameters selected for study. Sample collection and analysis was assigned to teams consisting of individuals from the SFWMD, DERM, and FIU. Statistical analysis and data evaluation were performed by the following researchers: Dr. Stalker, Dr. Price, and Dr. McFarlane of FIU evaluated results for dissolved cations and anions, dissolved barium, and the stable oxygen, hydrogen and strontium isotopes; Dr. Swart of MGG/RSMAS evaluated results for stable isotopes of oxygen, hydrogen and carbon; and Dr. Happell of DMAC/RSMAS evaluated results for tritium and carbon isotopes. Reports presenting data analysis and findings of each university group are presented in Appendices C, D, and F, respectively.

SAMPLE COLLECTION AND ANALYSIS

Samples were collected during nine days between February 11 and March 18, 2009. Collection of surface water and groundwater samples, including field parameters,

was primarily conducted by the SFWMD. However, responsibilities for sample bottle preparation, storage, transportation, and analysis were assigned to teams consisting of personnel from the SFWMD, DERM, and FIU according to specific parameter groups. The SFWMD was responsible for major cation and anions, other dissolved solids, nutrients, and metals; FIU for stable isotopes of oxygen, hydrogen, carbon and the barium ion; and DERM for tritium. Typically, representatives of each sample team were present during sampling at each site. Surface water and groundwater sample locations are summarized in Tables 1A and 1B (located in Appendix B), respectively, as shown in Figure 3 (located in Appendix A). Parameter groups analyzed for each sample are listed in Tables 2A and 2B (located in Appendix B), and constituents and analytical methods for parameter groups listed in Table 3.

Surface Water Sample Locations

CCS Surface Water

Eight surface water samples were collected from five locations within the CCS. Samples were collected from approximately one-foot below the water surface and one-foot above the canal bottom to detect vertical stratification if present, in all but two locations along the western perimeter canal, CCSW02 and CCSW03. At these locations the current was moving too fast to allow collection of a top water sample, and to confirm that the bottom water sample was collected from one-foot above the bottom. Sample locations in which both a “top” and “bottom” sample were collected were CCSW011 (Feeder Canal), CCSW04 (Collector Canal at southwest corner), and CCSW05 (east perimeter canal). Top-water samples are identified with a “T”, and bottom samples are identified with a “B.”

Freshwater Canals

Thirteen surface water samples were collected from ten locations within freshwater canals. Prior to sample collection conductance and temperature surveys were conducted to help identify areas within the canals with elevated salinity. On February 4, 2009, SFWMD staff collected vertical temperature and specific conductance measurements (profiles) at 28 locations at approximately 0.25-mile intervals along a 6.5-mile reach of the L-31E Canal, from the intersection with Palm Drive on the north to approximately 0.75 miles south of the intersection of the L-31E with the C-107 Canal on the south. The report documenting this work is included as Appendix F. At each location, SFWMD staff collected a specific conductance and water temperature profile from the surface of the canal to the bottom. On March 16 and 18, 2009, SFWMD staff collected additional temperature and specific conductance readings from the L-31E Canal, the C-104 Canal, the C-107 Canal, and a ditch on the west side of Tallahassee Road north of the intersection with the C-107 Canal. The temperature and specific conductance of the upper one-foot, middle, and lower one-foot of the water column were measured.

Based on the results of the above surveys and spatial relationships relative to the CCS, the sample locations within freshwater canals discussed below were chosen. The specific conductance measurements cited were taken the day of sample collection:

- Sample L31ESW05 was collected from the bottom of the L-31E Canal (approximately nine feet deep). The specific conductance reading at this location on March 16, 2009 was 23,736 microsiemens per centimeter ($\mu\text{S}/\text{cm}$) immediately prior to sample collection, which was the highest reading from within the L-31E Canal. This location is approximately 25 feet west of the S20 Structure, a gate that separates the canal from the tidal portion of the C-107 Canal, referred to as the S20 Discharge Canal in this report. It is possible that the high conductivity measurements at this location are resultant of seepage of saltwater from the tidal portion of the C-107 Canal under or around the S20 Structure.
- Sample L31ESW01T and L31ESW01B (top and bottom samples, respectively), and L31ESW06, a mid-depth level sample, were collected from the L-31E at its northern terminus with Palm Drive, approximately one mile north of the CCS. This was the point where the highest specific conductance readings were recorded from the L-31E north of L31ESW05. The specific conductance measurements at L31ESW06 on March 16, 2009 were 2053 $\mu\text{S}/\text{cm}$, 2084 $\mu\text{S}/\text{cm}$, and 2211 $\mu\text{S}/\text{cm}$ for the top, middle, and bottom sample locations, respectively.
- Samples L31ESW02 and 03 (top and bottom samples at each) were chosen because these locations were near the L-3 and L-5 monitor well locations and west of surface water samples within the CCS.
- Sample L31ESW07 (mid level) was collected approximately 100 feet south of the intersection of the L-31E Canal and the C-107 Canal, and is the southernmost sample location within the L-31E Canal. This location was chosen because the specific conductivities steadily increased to the south from this point, indicating that a salinity source may have been to the south. A specific conductance measurement on March 18, 2009 was 2005 $\mu\text{S}/\text{cm}$ immediately prior to sample collection.
- Sample L31ESW04 (mid level) was collected at the intersection with the C-104 Canal, approximately one-mile north of Palm Drive, and is the northernmost sample location within the L-31E Canal. A specific conductance measurement on March 18, 2009 was 915 $\mu\text{S}/\text{cm}$ immediately prior to sample collection.
- Samples L31ESW08 and L31ESW09 were collected from freshwater sources upgradient and west of the L-31E. Sample L31ESW08 was collected from 1.4 feet below water surface at the intersection of the C-107 Canal and Tallahassee Road, approximately 2.5 miles west of the L-31E Canal. The specific conductance measurement on March 18, 2009 was 972 $\mu\text{S}/\text{cm}$. Sample L31ESW09 was collected from 4.2 feet below water surface from an un-named ditch along the west side of Tallahassee Road, approximately three miles west of the L-31E Canal. The specific conductance measurement on March 18, 2009 was 620 $\mu\text{S}/\text{cm}$.

Tidal Canals/Creeks/Other

Six surface water locations were sampled in tidal canals and natural water bodies. The three samples collected from tidal canals included (1) Card Sound Canal from the Card Sound Canal south of the CCS, (2) S20 Getaway Culvert from the S-20 Discharge Canal approximately one-third mile south of the CCS, and (3) L31EDC01B from the S-20 Discharge Canal approximately south of the southwest corner of the CCS. The two samples collected from tidal creeks included (1) Culvert Tidal from a creek approximately one mile north of the CCS and (2) Tidal Creek from a tidal creek approximately one-half mile northeast of the CCS. A pond sample was collected from a depression within intertidal wetlands approximately one-third mile east of the CCS.

Biscayne Bay/Card Sound

Eight surface water sites were sampled in Biscayne Bay and Card Sound Canal, up to approximately one-half mile east of the CCS. From north to south, samples were collected from BBCW10SW01, BBSW05, TP Peninsula, BBSW02, Benthic Feature, BBSW03, East of SE CCS, and BBSW04.

Groundwater Sample Locations

Groundwater sample locations were limited to the availability of existing monitoring wells. Fifteen (15) onshore and two offshore groundwater monitoring wells were sampled. Fourteen (14) of the wells are completed in the Biscayne aquifer and are shallower than 90 feet bls. One well is completed in the upper Floridan aquifer. Well construction information (screen/open hole interval, diameter, etc.) is presented in Table 1B.

On-shore Groundwater

On-shore monitoring wells sampled were located west and north of the CCS. Four wells, G-3164, FKS-9, BBCW-6, and Newton Well Field Pump 1, are located west of the western extent of salt-water intrusion at the base of the Biscayne Aquifer identified by the USGS (Prinos, 2011), shown in Figure 3. Nine (9) monitoring wells, BBCW-4, BBCW-5, FKS-4, BBCW-6, BBCW-9, G-21, G-28, COH-MW-Trig, and Sec34-MW-03-FS, are located between the western extent of salt-water intrusion and either the L-31E Canal or Biscayne Bay/Card Sound and are representative of freshwater to brackish groundwater conditions. Two wells, L-3 and L-5, approximately 1,000 feet west of the CCS and just east of the L-31E Canal, were known to be representative of hypersaline groundwater conditions based on historic FPL monitoring reports. One upper Floridan aquifer well, MDWSA_BZ1, located at the Black Point Wastewater Treatment Plant (WWTP) was sampled. The well, approximately eight miles north of the CCS, is a monitoring well with an open-hole interval of 1,005 to 1,037 feet bls.

Offshore Groundwater

One offshore monitoring well cluster consisting of a shallow and deep monitoring well was sampled. BBCW10-GW1 and BBCW10-GW2 (deep and shallow well, respectively) are located approximately one-half mile east of the shoreline and two and one-half miles north of the CCS. The wells are representative of saline to brackish groundwater conditions beneath Biscayne Bay.

Sample Collection Methodology

Collection of surface water and groundwater samples, including field parameters, was primarily conducted by SFWMD. However, responsibilities for sample bottle preparation, storage, transportation, and analysis were assigned to teams consisting of personnel from SFWMD, DERM, and FIU according to specific parameter groups. The SFWMD was responsible for major cation and anions, other dissolved solids, nutrients, and metals; FIU for stable isotopes of oxygen, hydrogen, carbon and the barium ion; and DERM for tritium. Typically, representatives of each sample team were present during sampling at each site. As described in the following sections, a Model B-212 Geotech peristaltic pump was used for sample collection and field parameters were collected with a YSI 600 XL sensor with a YSI 650 hand-held unit. Variances to the above-described protocol are described in the following sections.

Surface water

SFWMD collected surface water samples with the use of a peristaltic pump and ¼-inch inside diameter (ID) Teflon-coated polyethylene tubing with silicon pump head tubing. Samples were collected in accordance with the SFWMD Water Quality Assessment Division Field Sampling Quality Manual and SOPs. New tubing was used for each sample location. Tubing was weighted down with a stainless steel fitting to reach sample depth. Prior to sample collection, sample depths relative to surface or bottom were either measured with a tape or estimated using the depth of tubing. The field parameters specific conductance, salinity (calculated), dissolved oxygen (DO), pH, temperature, and oxidation reduction potential (ORP) were collected on most samples with a YSI meter prior to sample collection, shown in Table 4a (located in Appendix B). The YSI meter was pre-calibrated and post calibrated for specific conductance, DO, and pH.

Samples collected by DERM and FIU were collected without field water quality measurements and were collected using a horizontal Niskin water sampling bottle (General Oceans Inc., Model 1010H Series), with the exception of the surface water sample “Pond”, which was collected at the surface by direct collection into the sample bottle. DERM collected surface water samples S137&SW376 Culvert, S20 Getaway Culvert, Culvert Tidal, Tidal Creek, East of SE CCS, Pond, Benthic Feature, T.P. Peninsula, and Card Sound Canal.

Groundwater

Each groundwater sample was collected by SFWMD with the exception of Newton Pump 1, collected by DERM. Samples from 15 of the 17 monitoring wells were collected with a peristaltic pump and ¼-inch ID Teflon-coated polyethylene tubing with Masterflex silicon pump head tubing. New tubing was used for each sample location. Newton Pump 1 and MDWSA_BZ1 were collected with dedicated plumbing. Prior to sample collection, depth-to-water was measured with an electronic water level indicator. Water quality parameters for specific conductance, salinity (calculated), dissolved oxygen (DO), pH, and temperature, were collected with a YSI meter prior to sample collection, shown in Table 4b (located in Appendix B). The YSI meter was pre-calibrated and post calibrated for specific conductance, DO, and pH. Water quality parameters stabilized prior to sample collection for each of the monitoring wells sampled.

Two purging methods were used – equipment volume and well volume. Equipment volume was used for collecting samples from L-3, L-5, G-21, G-28, FKS-5, FKS-9, G-3164, BBCW-5, and BBCW-6. Tubing was dropped to about two feet above bottom, in the lower portion of the screened interval, using a stainless steel weight tied with PVC tie wraps about two feet below sample intake. Wells were purged a minimum of one equipment volume prior to sample collection. Well volume was used for purging monitoring wells BBCW-9, BBCW-4, BBCW-10GW1 and BBCW10-GW2. Depth-to-water measurements were conducted. Well samples were purged one well volume each prior to collection of water quality parameters, followed by water quality parameter collection for each ¼ well volume until stabilization per FDEP Standard Operating Procedure (SOP) DEP-SOP-001/01 FS 2200. Tubing intake was placed within the upper two feet of the water column.

Newton Pump 1 and MDWSA_BZ1 were both purged with the use of dedicated equipment. The sample from Newton Pump 1 was collected from a spigot as the well was pumping and the sample from MDWSA_BZ1 was collected after purging for approximately 24 hours.

Sample Parameters, Analytical Methods and Results

Due to the wide range in type of analysis required, samples were transported to different laboratories based upon laboratory capabilities. Analytical methods and laboratories selected for analysis are presented in Table 3 (located in Appendix B) and discussed below.

Major Cations and Anions, Other Dissolved Solids, Alkalinity, Sulfides, Nutrients, and Metals

Samples for constituents below were transported at the end of each day by SFWMD for overnight shipment to CAS Laboratories (CAS) in Kelso, Washington for analysis.

- Samples were analyzed for boron (B^{3-}), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+) using EPA Method (SW846) 6010B, and strontium (Sr^{2+}) using EPA Method 6010LL; for bromide (Br^-), chloride (Cl^-), and sulfate (SO_4^{2-}) using EPA Method 300; for fluoride (F^-) using Standard Method (SM) 4500-F-C, and sulfide (S^{2-}) using SM 4500-S2-D. All of the above samples except sulfide were field filtered (dissolved) with a Millipore 0.45 μm filter. Sample results for major cations and anions, and ionic balance calculated by CAS, are presented in Tables 5a and 5b (located in Appendix B).
- Samples were analyzed for total dissolved solids (TDS) using SM2540C and for total alkalinity (as $CaCO_3$), bicarbonate alkalinity (calculated), and carbonate alkalinity (calculated) using SM2320B. Sample results are presented in Tables 5a and 5b.
- Samples were analyzed for nitrate and nitrite as N using EPA Method 353.2; for ammonia as N using EPA Method 350.1; for total and dissolved Kjeldahl N using ASTM D1426-93B; for total N (calculated); for orthophosphate as P using EPA Method 353.3, soluble reactive P and total P using EPA Method 353.1; and for Silica using SM 4500-SiO₂ C. Samples for nitrate and nitrite as N, dissolved Kjeldahl N, and soluble reactive P were field filtered with a Millipore 0.45 μm filter. Sample results for nutrients are presented in Tables 6a and 6b (located in Appendix B).
- Samples were analyzed for arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), molybdenum (Mo), nickel (Ni), thallium (Tl), and zinc (Zn) using EPA Method 200.8; manganese (Mn) and vanadium (V) using EPA Method 6010LL; iron (Fe) using EPA Method 6010B; for low-level (ultra trace) mercury (Hg) using EPA Method 1631E; and for selenium using EPA Method 7742. One field filtered and one sample not field filtered were collected for each analyte. The field filtered samples were archived and not analyzed. Sample results for metals are presented in Tables 7a and 7b (located in Appendix B).

The Reductive Precipitation Method (RPM/EPA Method 1640) was used for select metal samples as determined by CAS upon sample receipt. Using standard laboratory methods, samples with chlorides concentrations above 10 parts per thousand (ppt) may require dilution and therefore method detection limits (MDLs) would be raised to levels above project goals. RPM is a preparatory procedure that incorporates chemical separation to remove matrix components, so that final analysis can be performed using inductively coupled plasma-mass spectroscopy (ICP-MS). RPM was selectively used with salinity thresholds between 10 to 35 ppt, based on the metal and MDL requirements, to achieve MDL goals for analysis for As, Be, Cd, Cr, Cu, Pb, Ni, Tl and Zn.

Strontium Isotope Ratio ($^{87}Sr/^{86}Sr$)

Samples for $^{87}Sr/^{86}Sr$ were transported to the Department of Earth and Environment at FIU by FIU staff for analysis by Dr. Andrew McFarlane using the VG-

354 multi-collector TIMS. Laboratory results for $^{87}\text{Sr}/^{86}\text{Sr}$ are presented in Appendix C (Stalker *et al.*, 2009, Table 6). The report provides further discussion of sampling methods, laboratory analysis, and findings.

Oxygen ($^{18}\text{O}/^{16}\text{O}$), Deuterium (D/H), Carbon ($^{13}\text{C}/^{12}\text{C}$) Isotope Ratios and Barium

Samples for $^{18}\text{O}/^{16}\text{O}$, D/H, $^{13}\text{C}/^{12}\text{C}$ isotope ratios and barium ion were transported by FIU staff to the MGG/RSMAS Stable Isotope Laboratory for analysis by Dr. Peter Swart. Oxygen and hydrogen isotopic measurements were made using a water equilibration system (WEST) attached to a Europa GEO. Carbon isotopes were measured using a method of acidification and extraction of the CO_2 under a flowing stream of He and analyzed using a Europa 20-20. Dissolved barium was analyzed using Inductively Coupled Plasma Optical Emission Spectra (ICP-OES analysis). Laboratory results for $\delta^{18}\text{O}$ and δD are presented in Appendix C (Stalker *et al.* 2009, Appendices 1 and 2) and Appendix D (Swart, 2009). Laboratory results for $\delta^{13}\text{C}$ are presented in Appendix D (Swart, 2009). Laboratory results for dissolved barium are presented in Appendix C (Stalker *et al.* 2009). The reports referenced above provide further discussion of sampling methods, laboratory analysis, and findings.

Tritium

Samples for tritium were transported to DMAC/RSMAS tritium laboratory by DERM for analysis under the supervision of Dr. James Happell. The analytical method used to analyze the tritium samples was the low-level count with electrolytic enrichment method. Laboratory results for tritium are presented in Tables 8a and 8b (located in Appendix B) of this report. A further discussion of sampling methods, laboratory analysis, and findings are presented in Appendix E (Happell, 2009).

Data Evaluation and Results

Scientists from FIU, MGG/RSMAS, and DMAC/RSMAS evaluated sample results and published reports presented in Appendices C, D, and E, respectively. Each team evaluated specific parameter groups with respect to salinity characteristics and their use as tracers to differentiate waters from the CCS from waters of Biscayne Bay and groundwater. This report does not attempt to discuss each of their findings. However, a summary of the most relevant report findings are presented below. For a comprehensive discussion of University Report findings, see Appendices C, D, and E.

Results for dissolved cations and anions, dissolved barium, and $^{87}\text{Sr}/^{86}\text{Sr}$ were evaluated at FIU (Stalker *et al.* 2009). The study performed statistical analysis using binary and ternary mixing models and Piper diagrams for characterization of CCS surface waters, surrounding canals, Biscayne Bay, and groundwater. Results for $^{87}\text{Sr}/^{86}\text{Sr}$ were evaluated by Stalker (2009) and plotted against the strontium ionic concentration. Significant findings of the Stalker (2009) report include:

- The use of major cations and anions alone was not able to differentiate waters from the CCS, from waters from Biscayne Bay in mixtures with salinities less than that of Biscayne Bay. However, because ionic concentrations in samples from monitoring wells L-3 and L-5 are well above that of Biscayne Bay water, they must include water from the CCS.
- When plotted against chlorides, barium did not plot linearly and potentially can be used to distinguish water from the CCS, Biscayne Bay, and freshwater sources. In a ternary diagram with CCS waters, Biscayne Bay surface waters, and fresh groundwater as end members, groundwater samples from G-28, L-3, and L-5 fall between the three end members, which may indicate these samples contain a mixture of each.
- Calcium has relatively higher concentrations within fresh groundwater. Piper diagrams showed the presence of two types of fresh groundwater end members in mixing lines of fresh groundwater with Biscayne Bay/CCS water. The groundwater samples from COH-MW-Trig, SEC34-MW-03-FS, and G-21, grouped very close to one another along Tallahassee Road (see Figure 3), contained higher-calcium relative to other freshwater sources. The report states that this type of groundwater is similar to other groundwater in the C-111 Basin that has been described as connate water, possibly from an older seawater intrusion event.

- When plotted against chlorides, Ba^{2+} did not plot linearly and potentially can be used to distinguish water from the CCS, Biscayne Bay, and freshwater sources. In a ternary diagram with CCS waters, Biscayne Bay surface waters, and fresh groundwater as end members, groundwater samples from G-28, L-3, and L-5 fall between the three end members, which may indicate these samples contain a mixture of each. This study is limited in that only one well sample was used as the fresh groundwater end member, which increases uncertainty.
- The lowest strontium isotope ratio was found in the sample collected from the upper Floridan aquifer monitoring well (FLOGW01). The strontium isotope ratios indicated a significant difference between Floridan aquifer groundwater, modern Biscayne Bay surface water, and waters of the CCS. The report concludes that surface waters from the CCS and LDCSW01B (adjacent and south of the CCS), and groundwater from monitoring wells L-3, L-5, and G-28 have lower strontium isotope ratios than can be explained by equilibration with modern Biscayne Bay surface water. This implies a proportional input of Floridan aquifer groundwater.
- The reports describe limitations of the study including insufficient spatial sampling, and that without better spatial sampling, it would be premature to rule out any ionic or isotopic constituent as a possible tracer. Additional limitations include a lack of information regarding construction of some of the wells sampled and lack of groundwater data to the north, east, and south of the CCS.

Stable oxygen, hydrogen, and carbon isotopes results were analyzed at MGG/RSMAS (Swart, 2009). Results for the isotopic ratios of $^{18}O/^{16}O$ and $D/^{1}H$ was compared with Vienna standard mean ocean water (V-SMOW) resulting in comparative values $\delta^{18}O$ and δD . The isotope ratio $^{13}C/^{12}C$ was compared with Vienna Pee Dee Belemnite (V-PDB), resulting in comparative values $\delta^{13}C$. Comparative values were then plotted against salinity. Significant findings of the Swart (2009) report include:

- The use of oxygen or hydrogen isotopes alone were not able to differentiate waters from the CCS versus water from Biscayne Bay in mixtures with salinities less than that of Biscayne Bay. Water from L-3 and L-5 is shown to be derived in part from water from the CCS based on the isotope ratios that are greater than those for Biscayne Bay water.
- The $\delta^{13}C$ in waters from the CCS were slightly more isotopically negative than water from Biscayne Bay. The report concludes that plotting $\delta^{13}C$ against $\delta^{18}O$ or δD shows that water from G-21 and G-28 fall on a mixing line between fresh groundwater, water from the CCS, and water from Biscayne Bay, and had to be produced by mixing between a fluid with a composition intermediary between Biscayne Bay, the CCS, and a groundwater end member.
- The absence of adequate well control surrounding the CCS at the time of this investigation precluded the rigorous use of any geochemical tracer in understanding the origin of the groundwater.

- Recommendations included in the report include construction of nested wells at progressively increasing distances from the CCS and screened within possible flow paths within the Biscayne Aquifer, sampling surface waters and groundwater seasonally and analysis for a number of relevant isotopes, and an additional lithium isotopic indicator ($^6\text{Li}/^7\text{Li}$).

^3H was evaluated by Happell (2009) at DMAC/RSMAS. A review of local ^3H background data and potential alternative sources in South Florida was presented. A ternary mixing model using ^3H and specific conductance was plotted using the three end members of samples: from the CCS (high ^3H and high specific conductance); surface and groundwater from Biscayne Bay (low ^3H and moderate specific conductance, and surface and groundwater on land (low ^3H and low specific conductance). Significant findings of the Happell (2009) report include:

- Average ^3H values in ground and surface water in South Florida range between approximately 4 and 14 picocuries per liter (pCi/L). An estimate of 15 pCi/L is suggested as maximum background ^3H concentration in local surface and groundwater.
- ^3H is a useful tracer of CCS water in surface and groundwater surrounding the CCS, and is unique among the tracer parameters evaluated in that it is clearly useful in mixtures with salinity below that of Biscayne Bay. The report identified samples from six monitoring wells (L-3, L-5, G-28, G-21, COH-MW-Trig-BS, and BBCW4GW01) and two surface water locations (S20 and L31ESW05) that appear to be mainly mixtures of water from the CCS and fresh groundwater/surface water; four surface water samples (Pond, Eastbay, Benthic, and BBSW04) that appear to be a mixture of water from the CCS and Biscayne Bay, and samples from three monitoring wells (BBCW5GW01, FKS4GW01, and Sec34-MW-03-FS) that appear to be mixtures of fresh groundwater, Biscayne Bay water, and another source of very low ^3H water (possibly the Floridan aquifer).
- The half-life of ^3H is 12.3 years; therefore, the amount of ^3H in groundwater as it moves away from the CCS will decrease. Unless time information is known, any estimates of the fraction of CCS water in mixtures should be considered a minimum value. The age of the CCS water plume could be estimated in the future by measuring other parameters such as helium-3 (^3He), in combination with chlorofluorocarbons (CFCs), or sulfur hexafluoride (SF_6).
- The report also concludes that better depth and spatial control for groundwater sample points would facilitate estimates of the fraction of CCS water in mixtures. A series of well clusters with multiple screen depths surrounding the CCS on all sides, and measurement at a minimum of ^3H , Ba^{2+} , $\delta^{13}\text{C}/^{12}\text{C}$, and conductivity (or proxy) are recommended. Additionally, measurement of all stable isotopes, major ions, and components for age identification would complement the tracer suite.

Conclusions

The purpose of this investigation was to investigate the viability of using various parameters to identify possible sources of saline water in the vicinity of southern Miami-Dade County and as tracers for identification of the vertical and horizontal extent of the hypersaline groundwater plume from the CCS, and relative contribution of the plume to surrounding groundwater and surface waters. This has been treated as a three-end member mixing problem, between hypersaline water from the CCS, saline water from Biscayne Bay, and freshwater from the Biscayne aquifer. Based on the findings of this study, several parameters have potential for use as a tracer.

Binary mixing models show a linear relationship of samples from the CCS, Biscayne Bay, and freshwater from the Biscayne aquifer plotted against chloride with respect to most of the major anions and cations, and $\delta^{18}\text{O}$ and δD . Therefore, most major anions and cations and $\delta^{18}\text{O}$ and δD were found to be useful for distinguishing between water from the CCS and Biscayne Bay as a salinity source where the mixture's salinity is greater than Biscayne Bay, such as in the groundwater samples from monitoring wells L-3 and L-5.

Barium, $\delta^{13}\text{C}$, and $^{87}\text{Sr}/^{86}\text{Sr}$ in mixing diagrams were found to be of limited use for mixtures where salinity is lower than Biscayne Bay. Plotting the barium ion and $\delta^{13}\text{C}$ against chlorides, $\delta^{18}\text{O}$ and δD was useful in distinguishing water from the CCS in samples from two monitoring wells, G-21 and G-28. Plotting the strontium isotope ratio against strontium ion showed that surface waters from the CCS and L31EDC01B (adjacent and south of the CCS), and groundwater from monitoring wells L-3, L-5, and G-28 have lower strontium isotope ratios than can be explained by equilibration with modern Biscayne Bay surface water, which implies a proportional input of Floridan aquifer groundwater, a constituent within the CCS.

The reports identified tritium as the single parameter evaluated that can be used as a definitive tracer of CCS water in mixtures where salinity is below that of Biscayne Bay. The report identified samples from six monitoring wells (L-3, L-5, G-28, G-21, COH-MW-Trig-BS, and BBCW4GW01) and two surface water locations (S20 Getaway and L31ESW05) that appear to be mainly mixtures of water from the CCS and fresh groundwater/surface water; four surface water samples (Pond, Eastbay, Benthic, and BBSW04) that appear to be a mixture of water from the CCS and Biscayne Bay, and samples from three monitoring wells (BBCW5GW01, FKS4GW01, and Sec34-MW-03-FS) that appear to be mixtures of fresh groundwater, Biscayne Bay water, and another source of very low tritium water (possibly the Floridan aquifer).

Relatively higher calcium concentrations within fresh groundwater samples indicate the presence of two types of fresh groundwater. The groundwater samples from COH-MW-Trig, SEC34-MW-03-FS, and G-21, grouped very close to one another along Tallahassee Road, contained higher calcium relative to other freshwater sources. This type of groundwater has been described as connate water, possibly from an older seawater intrusion event. This needs to be investigated and further validated.

The reports describe data interpretation limitations including insufficient depth and spatial control, including lack of groundwater data to the north, east, and south of the CCS; the limited number of samples; lack of seasonal data; the half-life of ^3H and lack of age data for the CCS groundwater plume; and lack of information regarding construction of some of the wells sampled. Recommendations include construction of nested wells at progressively increasing distances from the CCS and screened within possible flow paths within the Biscayne Aquifer; a seasonal sampling program for the parameters in this study and lithium isotopes ($^6\text{Li}/^7\text{Li}$), and for age-dating parameters ^3He in combination with CFCs, or SF_6 .

5

References

- Brown & Root, Inc. January 1971. Turkey Point Pilot Reservoir Study for Florida Power and Light Company.
- Dames and Moore. July 23, 1971. Geohydrologic Conditions Related to the Construction of the Cooling Ponds, Florida Power and Light Company Steam Generating Station, Turkey Point, Florida, for Brown and Root.
- Dames and Moore. March 31, 1976. Groundwater Monitoring Program, G-Series Wells, Turkey Point Power Plant, Florida Power and Light Company.
- Dames and Moore. June 25, 1976. Summary Report, Ground-water Monitoring Program, E-Series Wells, Turkey Point, Florida Power and Light Company.
- Dames and Moore. November 19, 1976. Data Summary, F-Series Wells Ground-water Monitoring Program, Turkey Point Generating Station, Florida Power and Light Company.
- Dames and Moore. January 1978. Salinity Evaluation, Turkey Point Cooling Canal System, Florida Power and Light Company.
- Fish and Stewart. 1991. Hydrogeology of the Surficial Aquifer System, Dade County, Florida. U. S. Geological Survey Water-Resources Investigation Report 90-4108.
- Florida Department of Health. 2007. Annual Radiological Environmental Operating Report for Turkey Point Units 3 and 4, Florida DOH, March 20, 2008
- Florida Department of Health, 2008 Annual Radiological Environmental Operating Report for Turkey Point Units 3 and 4, Florida DOH, May 14, 2009
- Florida Department of Health. 2009. Annual Radiological Environmental Operating Report for Turkey Point Units 3 and 4, Florida DOH, April 4, 2010
- Golder Associates. February 19, 2008. Final Report on Florida Power and Light Company Turkey Point New Nuclear Project Cooling Canal Data and Analysis Report, submitted to Florida Power & Light Company, Juno Beach, Florida.
- Golder Associates. September 18, 2009. 2009 Annual Report, Ground-water Monitoring Program, Turkey Point Plant, Dade County, Florida.

- Happell, J.D. 2009. Use of Tritium as a Tracer of Cooling Canal System Water Movement into the Surficial Aquifer System Surrounding the Turkey Point Nuclear Power Plant in Southeastern Miami-Dade County, Florida. 22p.
- Hull, J.E. and Meyer, F.W. 1973. Salinity Studies in East Glades Agricultural Area, Southeastern Dade County, Florida. Florida Department of Natural Resources Report of Investigation No. 66, Tallahassee, Florida, 39.
- Klein, Howard. 1957. Salt-water encroachment in Dade County, Florida. Florida Geological Survey Information Circular 9, 17 p.
- Klein, Howard, and Hull, J.E. 1978. Biscayne Aquifer, Southeast Florida. U.S.G.S. Water-resources Investigations Report 78-107, 52 p.
- Klein, Howard, and Waller, B.G. 1985. Synopsis of Saltwater Intrusion in Dade County, Florida through 1984. U.S.G.S. Water-Resources Investigations Report 85-4101.
- Kohout, F.A. 1964. The flow of fresh water and salt water in the Biscayne aquifer of the Miami area in Sea Water in Coastal Aquifers: U.S. Geological Survey Water-Resources Investigations Report 93-4164, 1 sheet.
- Parker, Gerald G. 1945. Salt Water Encroachment in Southern Florida. Journal of the American Water Works Association, V 37, no. 6, p 526-542.
- Ray L. Lyerly & Associates. 1976. Survey of the Turkey Point Cooling Canal System, for Florida Power and Light Company, June 8, 1976.
- Renken, R. A., Dixon, Joann, Koehmstedt, John, Ishman, Scott, Lietz, A.C., Marella, R. L., Telis, Pamela, Rogers, Jeff, and Memberg, Steven. 2005. Impact of Anthropogenic Development on Coastal Ground-Water Hydrology in Southeastern Florida, 1900-200. Reston, Va., U.S. Geological Survey Circular 1275, 77 p.
- SW-846, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, United States EPA
- SM – Standard Methods for the Examination of Water & Wastewater
- Sonenshein, R.S., 1997, Delineation and Extent of Saltwater Intrusion in the Biscayne Aquifer, Eastern Dade County, Florida, 1995: U.S. Geological Survey Water Resources Investigation Report 96-4285.
- South Florida Water Management District. 2009. FPL Turkey Point Power Plant Groundwater, Surface Water, and Ecological Monitoring Plan, Exhibit B. 54 p.
- Stalker, J.C., Price R.M., and McFarlane, A. 2009. Geochemical investigation of the surface water and groundwater in the immediate vicinity of Florida Power and Light Turkey Point Cooling Canals. SFWMD report. 42 pp.

Swart, P. K. 2009. Analysis of Stable H, O, and C Isotopic Composition of Waters in the Vicinity of Turkey Point Power Plant, South Florida. SFWMD report. 22pp.

USGS National Water Information System (NWIS) website and SFWMD Water Use Division Permit Database.

USGS (2011 - provisional data, or personal communication, 2008.)

Appendix A

FIGURES

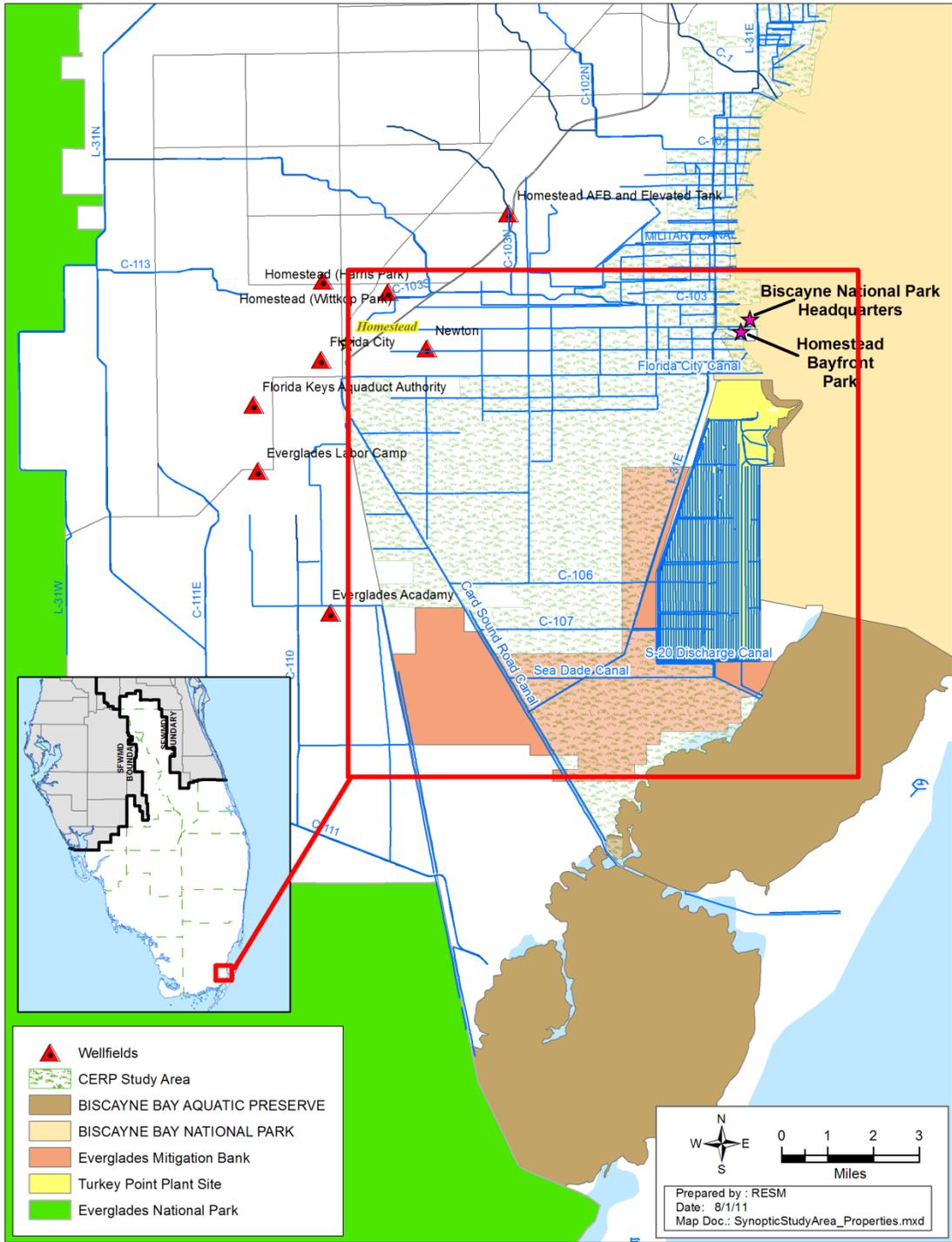


Figure 1. Study Areas and Surrounding Properties

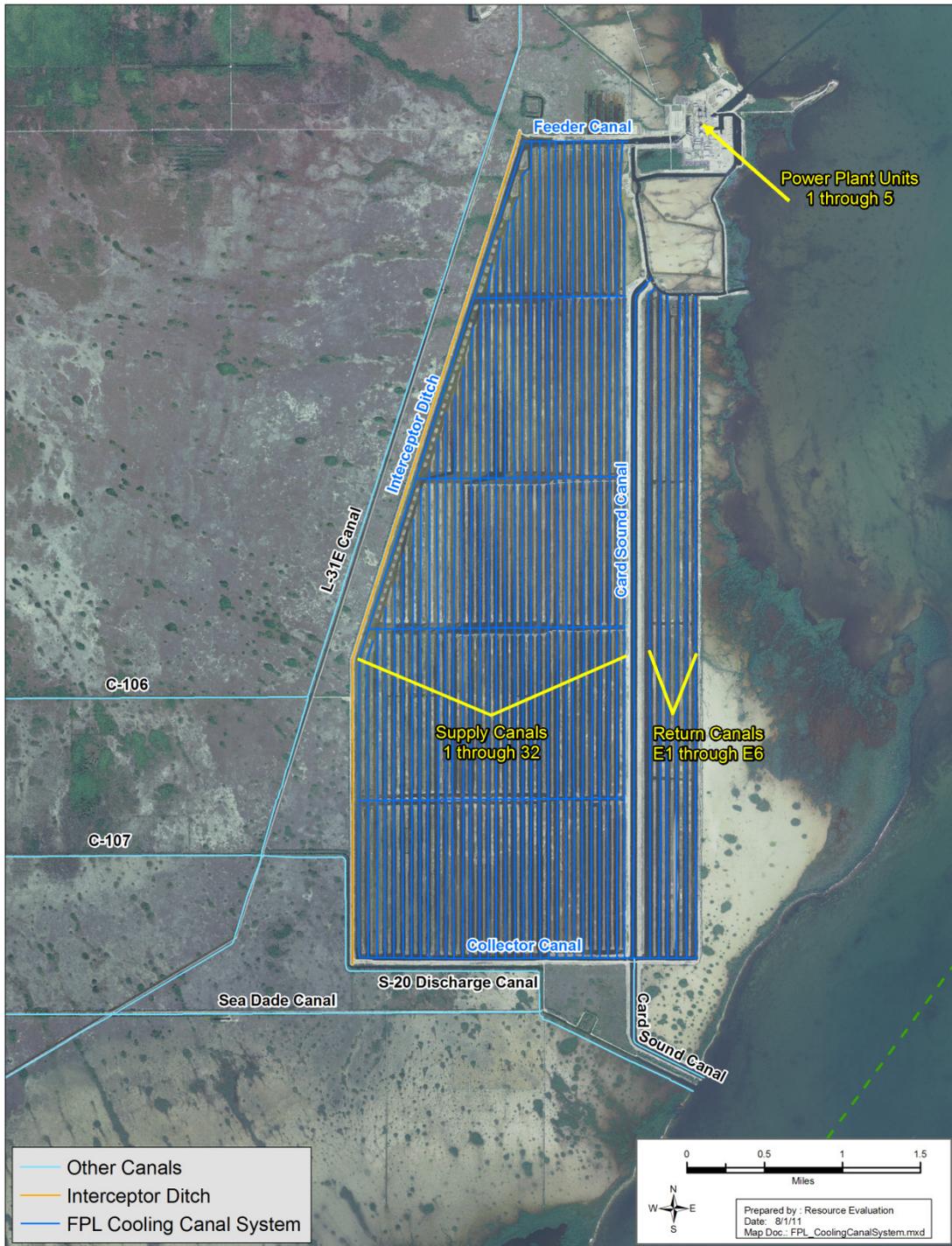


Figure 2. FPL Cooling Canal System



Figure 3. Sample Location Map

Appendix B

TABLES

Table 1a. Surface water locations

SAMPLE NAME	AREA DESCRIPTION	LOCATION DESCRIPTION	DEPTH (feet below surface)	LOCATION LATITUDE	LOCATION LONGITUDE	COLLECTION TEAM	COLLECTION DATE
CCSSW01T	Cooling Canal System	CCS - Feeder Canal, surface	1.6	25° 26' 00.68"	80° 20' 36.47"	SFWMD*	2/11/2009
CCSSW01B	Cooling Canal System	CCS- Feeder Canal, bottom***	11.1	25° 26' 00.68"	80° 20' 36.47"	SFWMD*	2/11/2009
CCSSW02B	Cooling Canal System	CCS - west perimeter canal, bottom***	1.5	25° 25' 08.33"	80° 21' 16.74"	SFWMD*	2/11/2009
CCSSW03B	Cooling Canal System	CCS - west perimeter canal, bottom***	1	25° 23' 27.90"	80° 21' 51.95"	SFWMD*	2/11/2009
CCSSW04T	Cooling Canal System	CCS - Collector Canal, surface	1.6	25° 21' 26.82"	80° 22' 00.09"	SFWMD*	2/11/2009
CCSSW04B	Cooling Canal System	CCS - Collector Canal, bottom***	14.0	25° 21' 26.82"	80° 22' 00.09"	SFWMD*	2/11/2009
CCSSW05T	Cooling Canal System	CCS - Card Sound Canal, surface	1.6	25° 24' 06.33"	80° 19' 54.37"	SFWMD*	2/12/2009
CCSSW05B	Cooling Canal System	CCS - Card Sound Canal, bottom***	14.0	25° 24' 06.33"	80° 19' 54.37"	SFWMD*	2/12/2009
L31ESW01T	Freshwater Canal	L-31E Canal, south of Palm Drive, surface	1.6	25° 26' 51.00"	80° 20' 59.60"	SFWMD*	2/18/2009
L31ESW01B	Freshwater Canal	L-31E Canal, south of Palm Drive, bottom***	8.9	25° 26' 51.00"	80° 20' 59.60"	SFWMD*	2/18/2009
L31ESW02T	Freshwater Canal	L-31E Canal, S-20A Structure, surface	1.6	25° 25' 11.30"	80° 21' 28.60"	SFWMD*	2/18/2009
L31ESW02B	Freshwater Canal	L-31E Canal, S-20A Structure, bottom***	8.4	25° 25' 11.30"	80° 21' 28.60"	SFWMD*	2/18/2009
L31ESW03T	Freshwater Canal	L-31E Canal, surface	1.6	25° 23' 23.10"	80° 22' 07.40"	SFWMD*	2/18/2009
L31ESW03B	Freshwater Canal	L-31E Canal, bottom***	6.4	25° 23' 23.10"	80° 22' 07.40"	SFWMD*	2/18/2009
L31ESW04	Freshwater Canal	L-31E, north of Palm Drive (C-104), center****	5	25° 27' 47.30"	80° 20' 48.80"	SFWMD*	3/16/2009
L31ESW05	Freshwater Canal	L-31E, next to S20 Structure, at bottom***	9	25° 22' 01.70"	80° 22' 35.60"	SFWMD*	3/16/2009
L31ESW06	Freshwater Canal	L-31E, south of Palm Drive, center****	4	25° 26' 52.20"	80° 20' 59.40"	SFWMD*	3/16/2009
L31ESW07	Freshwater Canal	L-31E, south of S-20 Structure, center****	4	25° 22' 00.80"	80° 22' 36.40"	SFWMD*	3/18/2009
L31ESW08	Freshwater Canal	C-107 and Tallahassee Rd., center****	1.4	25° 22' 01.70"	80° 24' 44.40"	SFWMD*	3/18/2009
L31ESW09	Freshwater Canal	Tallahassee Road north of C-106, center****	4.2	25° 23' 45.10"	80° 24' 43.70"	SFWMD*	3/18/2009
L31EDC01B	Tidal Canal	S-20 Discharge Canal, bottom***	3.1	25° 21' 23.85"	80° 22' 02.69"	SFWMD*	2/12/2009
Card Sound Canal	Tidal Canal	Card Sound Canal**	1 foot off bottom	25° 21' 23.97"	80° 20' 18.87"	DERM**	3/4/2009

Table 1a. Surface water locations (continued)

SAMPLE NAME	AREA DESCRIPTION	LOCATION DESCRIPTION	DEPTH (feet below surface)	LOCATION LATITUDE	LOCATION LONGITUDE	COLLECTION TEAM	COLLECTION DATE
S20 Getaway Culvert	Tidal Canal	S-20 Getaway Culvert, surface	1	25° 21' 08.38"	80° 20' 52.38"	DERM**	3/4/2009
East of SE CCS	Tidal Canal	East of SE CCS***	1 foot off bottom	25° 21' 22.42"	80° 19' 30.68"	DERM**	3/4/2009
Pond	Saltwater Wetlands	East of CCS, surface	0.5	25° 22' 47.6"	80° 19' 36.5"	DERM	3/17/2009
Culvert Tidal	Tidal Creek/other	Tidal creek, bottom***	1 foot off bottom	25° 26' 53.20"	80° 20' 22.24"	DERM**	3/4/2009
Tidal Creek	Tidal Creek/other	Tidal creek, bottom***	1 foot off bottom	25° 26' 33.64"	80° 19' 55.26"	DERM**	3/4/2009
BBSW01	Biscayne Bay	Biscayne Bay, bottom***	8.5	25° 26' 23.20"	80° 19' 30.20"	SFWMD*	3/4/2009
BBSW02	Biscayne Bay	Biscayne Bay, bottom***	2.1	25° 25' 22.90"	80° 19' 10.10"	SFWMD*	3/4/2009
BBSW03	Biscayne Bay	Biscayne Bay, bottom***	1.4	25° 24' 05.00"	80° 19' 28.70"	SFWMD*	3/4/2009
BBSW04	Biscayne Bay	Biscayne Bay, bottom***	5.9	25° 20' 45.50"	80° 19' 50.80"	SFWMD*	3/4/2009
BBSW05	Biscayne Bay	Biscayne Bay, bottom***	1.3	25° 26' 33.90"	80° 19' 43.90"	SFWMD*	3/4/2009
BBCW10SW01	Biscayne Bay	Biscayne Bay, next to BBCW10 Platform, surface	2.2	25° 28' 19.70"	80° 19' 55.60"	SFWMD*	3/5/2009
Benthic Feature	Biscayne Bay	Benthic Feature, surface	1	25° 24' 25.96"	80° 19' 38.24"	DERM**	3/4/2009
T.P. Peninsula	Biscayne Bay	Turkey Point Peninsula, surface	1	25° 26' 16.20"	80° 19' 15.78"	DERM**	3/4/2009

* Samples collected by SFWMD were with a peristaltic pump and tubing.

** Samples collected by DERM were with a horizontal Niskin sampler except "Pond" sample, collected directly into the sample container.

*** Bottom samples were collected from approximately 1 foot above sediment surface.

**** Center samples were collected from the approximate center of the water column.

Table 1b. Groundwater locations

SAMPLE NAME	WELL NAME	LOCATION DESCRIPTION	SCREEN INTERVAL (feet bls)	PURGE METHOD AND TUBE INTAKE DEPTH	TOC ELEVATION (NGDV 29)	LOCATION LATITUDE	LOCATION LONGITUDE	SAMPLE COLLECTION TEAM	SAMPLE COLLECTION DATE
L3GW01	L-3	L-31E Canal Levee	app. 5 - 70	equipment purge, app. 68 feet	ND	25° 25' 09.80"	80° 21' 28.70"	SFWMD	2/24/2009
L5GW01	L-5	L-31E Canal Levee	app. 5 - 70	equipment purge, app. 68 feet	ND	25° 23' 20.90"	80° 22' 07.50"	SFWMD	2/24/2009
G21GW01	G-21	Tallahassee Road (137th Ave.)	app. 5 - 70	equipment purge, app. 68 feet	ND	25° 25' 34.90"	80° 24' 43.00"	SFWMD	2/24/2009
G28GW01	G-28	Tallahassee Road (137th Ave.)	app. 15 - 70	equipment purge, app. 68 feet	ND	25° 23' 25.50"	80° 24' 43.50"	SFWMD	2/24/2009
FKS4GW01	FKS-4	Card Sound Road	10 - 40	equipment purge, app. 38 feet	ND	25° 22' 22.70"	80° 26' 01.20"	SFWMD	2/25/2009
FKS9GW01	FKS-9	352nd (west of Tallahassee Road)	30 - 80	equipment purge, dedicated tubing @ 75	ND	25° 26' 27.10"	80° 26' 29.60"	SFWMD	2/25/2009
G3164GW01	G-3164	156nd St. (west of Tallahassee Road)	75 - 85	equipment purge, app. 83 feet	ND	25° 25' 19.0"	80° 26' 11.0"	SFWMD	2/25/2009
BBCW4GW01	BBCW-4	110th Ave. (north of Palm Drive)	36.5 - 39	well purge	4.82	25° 27' 20.50"	80° 22' 02.70"	SFWMD	2/25/2009
BBCW5GW01	BBCW-5	117th Ave. (South of Palm Drive)	45 - 47.5	equipment purge, app. 45 feet	6.45	25° 26' 26.70"	80° 22' 46.70"	SFWMD	2/25/2009
BBCW6GW01	BBCW-6	364th St. (west of Tallahassee Road)	42.5 - 45	equipment purge, app. 43 feet	2.90	25° 25' 47.40"	80° 26' 01.00"	SFWMD	2/25/2009
BBCW9GW01	BBCW-9	Near the S-20F Structure and L-31E	31 - 33.5	well purge	3.87	25° 28' 21.20"	80° 20' 48.70"	SFWMD	2/25/2009
Sec34-MW-03-FS	Sec34-MW-03	Tallahassee Road next to G-21	20 - 86	equipment purge, app. 84 feet	ND	25° 25' 35.01"	80° 24' 43.23"	SFWMD	3/11/2009
COH-MW-Trig	COH-MW-Trig-BS	Palm Drive west of Homestead-Miami Speedway	85 - 90	equipment purge, app. 88 feet	6.32	25° 26' 50.24"	80° 25' 27.84"	SFWMD	3/11/2009
BBCW10GW01	BBCW-10GW1	Biscayne Bay east of C-103 discharge	16 - 18.5	well purge	6.90	25° 28' 19.70"	80° 19' 55.60"	SFWMD	3/5/2009
BBCW10GW02	BBCW10-GW2	Biscayne Bay east of C-103 discharge	38.5 - 41	well purge	6.90	25° 28' 19.80"	80° 19' 55.60"	SFWMD	3/5/2009
Newton Pump 1	DERM-Newton Well Field Pump 1	Newton Pump 1	50 - 65	Well purge from pump head spigot, production well operations prior to sample collection	ND	25° 21' 23.97"	80° 20' 18.87"	DERM	3/11/2009
FLOGW01	MDWSA_BZ1 (MW for IW-5)	Blackpoint WWTP	1005 - 1037	well purge, pump head spigot	ND	25° 32' 57.10"	80° 19' 56.10"	SFWMD	2/25/2009

Equipment Purge = a minimum of one equipment volume (tubing and pump)

Well Purge = a minimum of one well volume followed by stabilization of water quality parameters

Table 2a. Groundwater sample locations and parameter groups

Sample Name	Major Cations/Anions, Total Dissolved Solids, Alkalinity ¹ , Sulfides	Nutrients ²	Trace Elements ³	Barium ⁴	¹³ C/ ¹² C Isotope Ratio ⁵	Stable Isotopes of Dueterium and Oxygen ⁶	⁸⁷ Sr/ ⁸⁶ Sr Isotope Ratio ⁷	Unstable Isotopes of Tritium ⁸
Groundwater Samples								
L3GW01	X	X	X	X	X	X	NA	NA
L5GW01	X	X	X	X	X	X	X	NA
G21GW01	X	NA	X	X	X	X	X	NA
G28GW01	X	NA	X	X	X	X	X	NA
FKS4GW01	X	NA	X*	X	X	X	NA	X
FKS9GW01	X	NA	X*	X	X	X	NA	NA
G3164GW01	X	NA	X*	X	X	X	NA	NA
BBCW4GW01	X	NA	X*	X	X	X	X	X
BBCW5GW01	X	NA	X*	X	X	X	X	X
BBCW6GW01	X	NA	X*	X	X	X	NA	X
BBCW9GW01	X	NA	X*	X	X	X	X	NA
Sec34-MW-03-FS	X	NA	X*	X	X	X	NA	X
COH-MW-Trig	X	NA	X*	X	X	X	NA	X
BBCW10GW01	X	X	X*	X	X	X	X	X
BBCW10GW02	X	X	X*	X	X	X	NA	X
Newton Pump 1	NA	NA	NA	NA	NA	NA	NA	X
FLOGW01	X	NA	X*	X	X	X	X**	X

Notes:

X = Parameter analyzed for

1 = Analytical results are presented in Table 5 of this report.

2 = Analytical results are presented in Table 6 of this report.

3 = Analytical results are presented in Table 7 of this report.

4 = Analytical results are presented in Appendices 1 and 2 of (Stalker et al. 2009)

5 = Analytical results are presented in Tables 1 and 2 of (Swart, 2009).

6 = Analytical results are presented in Appendices 1 and 2 of (Stalker et al. 2009) and Tables 1 and 2 of (Swart, 2009).

7 = Analytical results are presented in Table 6 of (Stalker et al. 2009).

8 = Analytical results are presented in Table 8 of this report.

X* = Barium and Iron were the only ions analyzed in this sample.

**In Table 6 of (Stalker et al. 2009), L31ESW05 as S20WEST, L31ESW06 as PALM & L31E, L31EDC01B as L31DCSW01B, and FLOGW01 as FLOG01.

Table 2b. Surface water sample locations and parameter groups

Sample Name	Major Cations/Anions, Total Dissolved Solids, Alkalinity ¹ , Sulfides	Nutrients ²	Trace Elements ³	Barium ⁴	¹³ C/ ¹² C Isotope Ratio ⁵	Stable Isotopes of Dueterium and Oxygen ⁶	⁸⁷ Sr/ ⁸⁶ Sr Isotope Ratio ⁷	Unstable Isotopes of Tritium ⁸
Surface Water Samples								
CCSSW01T	X	NA	X*	X	X	X	NA	NA
CCSSW01B	X	X	X	X	X	X	NA	NA
CCSSW02B	X	X	X	X	X	X	X	NA
CCSSW03B	X	X	X	X	X	X	NA	NA
CCSSW04T	X	NA	X*	X	X	X	X	NA
CCSSW04B	X	X	X	X	X	X	NA	NA
CCSSW05T	X	NA	X*	X	X	X	NA	NA
CCSSW05B	X	X	X	X	X	X	NA	NA
L31ESW01T	X	NA	X	NA	NA	NA	NA	X
L31ESW01B	X	X	X	X	X	X	X	X
L31ESW02T	X	NA	X	NA	NA	NA	NA	NA
L31ESW02B	X	X	X	X	X	X	X	X
L31ESW03T	X	NA	X	NA	NA	NA	NA	NA
L31ESW03B	X	X	X	X	X	X	X	X
L31ESW04	X	X	X*	NA	X	NA	NA	X
L31ESW05	X	X	X*	NA	X	NA	X**	X
L31ESW06	X	X	X*	NA	X	NA	X**	X
L31ESW07	X	X	X*	NA	X	X	X	X
L31ESW08	X	X	X*	X	X	X	NA	X
L31ESW09	X	X	X*	X	X	X	X	X
L31EDC01B	X	X	X	X	X	X	X**	NA
Card Sound Canal	NA	NA	NA	NA	X	NA	X	NA
S20 Getaway Culvert	NA	NA	NA	NA	X	NA	NA	X
East of SE CCS	NA	NA	NA	NA	NA	NA	NA	X
Pond	NA	NA	NA	NA	NA	NA	NA	X
Culvert Tidal	NA	NA	NA	NA	NA	NA	NA	X
Tidal Creek	NA	NA	NA	NA	X	NA	NA	X
BBSW01	X	X	X*	X	X	X	NA	X
BBSW02	X	X	X*	X	X	X	NA	X

Table 2b. Surface water sample locations and parameter groups (continued)

Sample Name	Major Cations/Anions, Total Dissolved Solids, Alkalinity ¹ , Sulfides	Nutrients ²	Trace Elements ³	Barium ⁴	¹³ C/ ¹² C Isotope Ratio ⁵	Stable Isotopes of Dueterium and Oxygen ⁶	⁸⁷ Sr/ ⁸⁶ Sr Isotope Ratio ⁷	Unstable Isotopes of Tritium ⁸
Surface Water Samples								
BBSW03	X	X	X*	X	X	X	NA	X
BBSW04	X	X	X*	X	X	X	NA	X
BBSW05	X	X	X*	X	X	X	NA	X
BBCW10SW01	X	X	X*	X	X	X	X	X
Benthic Feature	NA	NA	NA	NA	X	X	X	X
T.P. Peninsula	NA	NA	NA	NA		X	NA	X

Notes:

X = Parameter analyzed for

1 = Analytical results are presented in Table 5 of this report.

2 = Analytical results are presented in Table 6 of this report.

3 = Analytical results are presented in Table 7 of this report.

4 = Analytical results are presented in Appendices 1 and 2 of (Stalker et al. 2009).

5 = Analytical results are presented in Tables 1 and 2 of (Swart, 2009).

6 = Analytical results are presented in Appendices 1 and 2 of (Stalker et al. 2009) and Tables 1 and 2 of (Swart, 2009).

7 = Analytical results are presented in Table 6 of (Stalker et al. 2009).

8 = Analytical results are presented in Table 8 of this report.

X* = Barium and Iron were the only ions analyzed in this sample.

**In Table 6 of (Stalker et al. 2009), L31ESW05 as S20WEST, L31ESW06 as PALM & L31E, L31EDC01B as L31DCSW01B, and FLOGW01 as FLOG01.

Table 3. Laboratory Methods

Parameter Group	Constituents Analyzed	Method Used	Lab	Filtered
Major Cations and Anions, Alkalinity and Sulfides	K ⁺ , B ³⁻ , Ca ²⁺ , Na ⁺ , Mg ²⁺	Method 6010B	CAS	Y
	Sr ²⁺	Method 6010LL	CAS	Y
	F ⁻	SM 4500-F- C	CAS	Y
	Br ⁻	300	CAS	Y
	Cl ⁻	300	CAS	Y
	SO ₄ ²⁻	300	CAS	Y
	S ²⁻	Method SM 4500-S2- D	CAS	Y
Solids, Alkalinity, Salinity	Alkalinity CaCO ₃ , total; BiCarb Alkalinity (calculated); and Carb Alkalinity (calculated)	Method SM-2320B	CAS	N
	TDS	SM 2540C	CAS	N
Nutrients	NITRATE-N, Nitrate + Nitrite-N	Method 353.2	CAS	Y
	Nitrite as N	Method 353.2	CAS	Y
	Ammonia, Total as N	Method 350.1	CAS	N
	Total Kjeldahl Nitrogen	Method ASTM D1426-93B,	CAS	N
	Dissolved Kjeldahl Nitrogen	Method ASTM D1426-93B,	CAS	Y
	Nitrogen	Calculated	CAS	N
	Soluble Reactive Phosphorous & Phosphate	Method 365.1	CAS	Y
	Total Phosphate as P	Method 365.1	CAS	N
	Ortho Phosphate as P	Method 365.3	CAS	N
	Silica	Method SM 4500-SIO2 C	CAS	Y
Metals	Mn, V	Method 6010LL	CAS*	N
	As*, Ba, Be*, Cd*, Cr*, Cu*, Pb*, Mo, Ni*, Tl*, Zn*	Method 200.8/1640*	CAS*	N
	Fe	Method 6010B	CAS*	N
	Se	Method 7742	CAS*	N
	Hg (low level)	Method 1631E	CAS*	N
	Ba	ICP-OES	MGG/RSMAS	Y
Stable Isotopes	Dueterium (² H/ ¹ H)	Water Equilibration System/Europa GEO	MGG/RSMAS	Y
	Oxygen (¹⁸ O/ ¹⁶ O)	Water Equilibration System/Europa GEO	MGG/RSMAS	Y
	Strontium Isotope Ratio (⁸⁷ Sr/ ⁸⁶ Sr)	VG-354 multicollector TIMS	FIU	Y
	Carbon Isotope Ratio (¹³ C/ ¹² C)	Flowing Stream Helium using Europa 20-20	MGG/RSMAS	Y
Unstable Isotopes	Tritium (³ H)	Low Level Count, Electrolytic Enrichment	DMAC/RSMAS	N

* = The Reductive Precipitation Method (RPM/EPA Method 1640) was used for select high salinity trace metal samples.

Table 4a. Surface water field parameters collected during investigation

Sample Name	Date Sampled	Water Temperature (°C)	Conductivity (µS/cm)	Salinity (psu)	Water pH (unit-less)	Dissolved Oxygen (mg/L)	Oxidation-Reduction Potential (mV)
Surface Water Field Parameters							
CCSSW01T	02/11/2009	31.6	93,022	66.4	7.8	6.1	176
CCSSW01B	02/11/2009	31.9	93,005	66.4	7.8	4.5	NA
CCSSW02B	02/11/2009	31.4	93,402	66.8	7.8	6.4	NA
CCSSW03B	02/11/2009	30.5	88,867	63.0	7.8	7.4	NA
CCSSW04T	02/11/2009	28.9	84,198	59.7	7.9	7.8	155
CCSSW04B	02/11/2009	24.1	90,278	64.5	7.8	6.0	151
CCSSW05T	02/12/2009	25.4	92,090	65.9	7.8	3.1	NA
CCSSW05B	02/12/2009	25.3	92,120	65.9	7.8	2.9	NA
L31ESW01T	02/18/2009	21.1	2,058	<2	7.8	10.7	218
L31ESW01B	02/18/2009	19.8	2,169	<2	7.4	2.5	<-8.2
L31ESW02T	02/18/2009	21.2	1,879	<2	7.9	12.3	174
L31ESW02B	02/18/2009	21.0	1,892	<2	8.0	12.3	54
L31ESW03T	02/18/2009	21.6	1,725	<2	7.9	13.9	163
L31ESW03B	02/18/2009	21.1	1,733	<2	7.9	14.0	105
L31ESW04	03/16/2009	24.7	915	<2	8.1	10.4	NA
L31ESW05	03/16/2009	25.1	23,736	11.1	7.5	4.0	NA
L31ESW06	03/16/2009	25.6	2,231	<2	8.8	2.1	NA
L31ESW08	03/18/2009	21.8	972	<2	7.3	1.6	NA
L31BSW07	03/18/2009	24.6	2,005	<2	8.3	7.0	NA
L31BSW09	03/18/2009	23.6	620	3.4	7.7	3.2	NA
L31EDC01B	02/12/2009	23.5	46,195	30.0	7.2	4.5	NA
Card Sound Canal	3/4/2009	NA	NA	NA	NA	NA	NA
S20 Getaway Culvert	3/4/2009	NA	NA	NA	NA	NA	NA
East of SE CCS	3/4/2009	NA	NA	NA	NA	NA	NA

Table 4a. Surface water field parameters collected during investigation (continued)

Sample Name	Date Sampled	Water Temperature (°C)	Conductivity (µS/cm)	Salinity (psu)	Water pH (unit-less)	Dissolved Oxygen (mg/L)	Oxidation-Reduction Potential (mV)
Surface Water Field Parameters							
Pond	3/17/2009	NA	NA	NA	NA	NA	NA
Culvert Tidal	3/4/2009	NA	NA	NA	NA	NA	NA
Tidal Creek	3/4/2009	NA	NA	NA	NA	NA	NA
BBSW01	03/04/2009	17.4	52,360	34.6	8.2	7.8	NA
BBSW02	03/04/2009	17.3	55,865	37.2	8.2	8.1	NA
BBSW03	03/04/2009	17.6	56,750	37.8	8.1	8.3	NA
BBSW04	03/04/2009	19.3	55,723	37.0	8.2	7.8	NA
BBSW05	03/04/2009	18.9	50,459	33.1	8.4	10.8	NA
BBCW10SW01	03/05/2009	19.2	46004	29.32	7.08	7.88	NA
Benthic Feature	3/4/2009	NA	NA	NA	NA	NA	NA
T.P. Peninsula	3/4/2009	NA	NA	NA	NA	NA	NA

Table 4b. Groundwater field parameters collected during investigation

Sample Name	Date Sampled	Water Temperature (°C)	Conductivity (µS/cm)	Salinity (psu)	Water pH (unit-less)	Dissolved Oxygen (mg/L)	Oxidation-Reduction Potential (mV)
Groundwater Field Parameters							
L3GW01	02/24/2009	27.6	77,719	53.9	6.9	0.8	NA
L5GW01	02/24/2009	27.1	73,543	50.6	6.8	0.6	NA
G21GW01	02/24/2009	23.8	10,887	6.2	6.7	0.9	NA
G28GW01	02/24/2009	22.3	35,380	22.3	6.8	0.7	NA
FKS4GW01	02/25/2009	24.7	15,655	9.1	6.8	1.2	NA
FKS9GW01	02/25/2009	22.7	525	<2	7.0	4.9	NA
G3164GW01	02/25/2009	23.6	969	NA	6.9	1.0	NA
BBCW4GW01	02/25/2009	23.6	15,339	NA	7.8	0.3	NA
BBCW5GW01	02/25/2009	23.6	19,902	11.9	6.6	1.4	NA
BBCW6GW01	02/25/2009	24.3	543	NA	7.0	0.9	NA
BBCW9GW01	02/25/2009	22.3	790	NA	6.7	4.5	NA
Sec34-MW-0	03/11/2009	24.7	10,092	4.6	6.7	0.9	NA
COH-MW-Tri	03/11/2009	24.2	7,669	3.4	6.8	0.9	NA
BBCW10GW1	03/05/2009	24.2	51993	NA	0.12	6.93	NA
BBCW10GW2	03/05/2009	25.1	53,778	NA	0.2	6.9	NA
Newton Pump 1	3/11/2009	NA	NA	NA	NA	NA	NA
FLOGW01	02/25/2009	24.2	3,076	NA	7.4	0.5	NA

Table 5a. CAS Sample Results: Surface Water Samples/Major Cations and Anions, Total Dissolved Solids, Alkalinity, Sulfides

Sample Name	Date Sampled	Total Dissolved Solids	Bicarbonate Alkalinity	Carbonate Alkalinity	Total Alkalinity (as CaCO ₃)	Chloride	Sulfate	Fluoride	Sulfide	Bromide	Sodium	Potassium	Calcium	Magnesium	Strontium	Ionic Balance Percent Difference*
		All Concentrations are in mg/L														
Surface Water Sample Results																
CCSSW01T	02/11/2009	69,800	205	<1	205	38,500	4,260	0.7	NA	90.0	20,600	772	830	2,580	15.6	<1
CCSSW01B	02/11/2009	67,100	213	<1	213	38,600	4,810	0.7	<0.003	94.0	20,200	747	803	2,530	15.4	3
CCSSW02B	02/11/2009	69,300	217	<1	217	38,400	4,850	0.7	<0.003	102.0	20,700	778	840	2,660	16.0	<1
CCSSW03B	02/11/2009	74,200	212	<1	212	36,600	5,030	0.7	<0.003	112.0	18,600	696	757	2,380	14.2	7
CCSSW04T	02/11/2009	58,500	222	<1	222	33,000	4,090	0.7	NA	83.0	18,100	670	742	2,290	14.0	3
CCSSW04B	02/11/2009	63,800	235	<1	235	36,800	4,490	0.7	<0.003	92.0	19,500	741	794	2,500	15.1	<1
CCSSW05T	02/12/2009	65,400	209	<1	209	37,100	5,120	0.7	NA	101.0	20,200	768	830	2,590	15.4	0.2
CCSSW05B	02/12/2009	67,200	209	<1	209	35,400	3,180	0.7	<0.003	76.0	19,900	734	794	2,430	14.6	2
L31ESW01T	02/18/2009	1,090	206	<1	206	486	43.6	0.2	NA	1.4	270	8.7	108	26.9	1.2	2
L31ESW01B	02/18/2009	1,040	209	<1	209	498	43.3	0.2	NA	1.5	266	8.6	106	26.6	1.2	<1
L31ESW02T	02/18/2009	1030	208	<1	208	422	36.7	0.2	NA	1.3	234	6.9	109	21.2	1.2	3
L31ESW02B	02/18/2009	1030	206	<1	206	425	39.2	0.2	NA	2.1	233	6.9	108	21.0	1.2	2
L31ESW03T	02/18/2009	963	228	<1	228	362	28.7	0.2	NA	1.2	200	5.3	119	16.1	1.2	3
L31ESW03B	02/18/2009	961	234	<1	234	361	28.5	0.2	NA	1.2	206	5.4	120	16.4	1.3	3
L31ESW04	03/16/2009	446	156	<1	156	131	51.6	0.2	0.003	0.5	75	10.7	70.6	10.8	0.9	<1
L31ESW05	03/16/2009	15000	197	<1	197	7240	1030	0.4	0.008	22.0	4,250	164.0	235	524.0	3.9	3
L31ESW06	03/16/2009	1080	212	<1	212	477	37.8	0.2	0.01	1.4	234	7.7	100	24.9	1.2	3
L31ESW08	03/18/2009	532	244	<1	244	145	1.9	0.1	0.016	0.3	69	3.3	103	6.8	0.7	<1

* = using milliequivalents of Ca²⁺, Mg²⁺, K⁺, Na⁺, Cl⁻, SO₄²⁻, and alkalinity as HCO₃

Table 5a. CAS Sample Results: Surface Water Samples/Major Cations and Anions, Total Dissolved Solids, Alkalinity, Sulfides (continued)

Sample Name	Date Sampled	Total Dissolved Solids	Bicarbonate Alkalinity	Carbonate Alkalinity	Total Alkalinity (as CaCO ₃)	Chloride	Sulfate	Fluoride	Sulfide	Bromide	Sodium	Potassium	Calcium	Magnesium	Strontium	Ionic Balance Percent Difference*
All Concentrations are in mg/L																
Surface Water Sample Results																
L31BSW07	03/18/2009	1,030	212	<1	151	499	12	0.1	0.032	1.0	262	7.59	72	31	1.0	1
L31BSW09	03/18/2009	327	235	<1	221	44.9	10.8	0.1	0.006	0.1	26	4.6	85.1	4.8	0.7	<1
L31EDC01B	02/12/2009	30,500	234	<1	234	15300	1800	0.4	0.008	<3	9,090	332.0	445	1140.0	7.5	5
Card Sound Canal	3/4/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S20 Getaway Culvert	3/4/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
East of SE CCS	3/4/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pond	3/17/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Culvert Tidal	3/4/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tidal Creek	3/4/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBSW01	03/04/2009	34,800	153	<1	153	18,600	2,450	0.9	<0.003	53.0	10,900	468	382	1,290	7.6	3
BBSW02	03/04/2009	39,100	146	<1	146	19,400	2,670	0.9	<0.003	58.0	11,700	517	400	1,400	8.3	4
BBSW03	03/04/2009	41,000	142	<1	142	19,600	2,750	0.9	<0.003	59.0	11,900	540	414	1,420	8.6	4
BBSW04	03/04/2009	37,200	138	<1	138	19,200	2,650	0.9	<0.003	58.0	11,900	516	391	1,430	8.2	5
BBSW05	03/04/2009	35,700	159	<1	159	17,000	2,210	1.1	<0.003	47.4	10,600	472	368	1,270	7.6	6
BBCW10SW 01	03/05/2009	31,400	163	4	166	14,500	2,170	0.8	<0.003	51.0	9,280	410	326	1,100	6.7	7
Benthic Feature	3/4/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
T.P. Peninsula	3/4/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

* = using milliequivalents of Ca⁺², Mg⁺², K⁺, Na⁺, Cl⁻, SO₄⁻², and alkalinity as HCO₃

Table 5b. CAS Sample Results: Groundwater Samples/Major Cations and Anions, Total Dissolved Solids, Alkalinity, Sulfides

Sample Name	Date Sampled	Total Dissolved Solids	Bicarbonate Alkalinity	Carbonate Alkalinity	Total Alkalinity (as CaCO ₃)	Chloride	Sulfate	Fluoride	Sulfide	Bromide	Sodium	Potassium	Calcium	Magnesium	Strontium	Ionic Balance Percent Difference*
		All Concentrations are in mg/L														
Groundwater Sample Results																
L3GW01	02/24/2009	56,500	160	<1	160	31,200	3,970	0.4	NA	93.0	17,200	696	60.7	2,000	12.4	<1
L5GW01	02/24/2009	52,300	186	<1	186	28,500	4,520	0.3	NA	89.0	15,600	656	62.8	1,830	14.6	1
G21GW01	02/24/2009	7,300	183	<1	183	3,490	117	0.2	NA	18.1	1,640	23.4	43.7	114	5.2	<1
G28GW01	02/24/2009	20,900	214	<1	214	10,400	1,370	0.2	NA	36.0	6,750	152	53	741	7.4	8
FKS4GW01	02/25/2009	9,100	203	<1	203	5,070	666	0.2	0.012	16.0	2,850	84.2	287	291	3.8	1
FKS9GW01	02/25/2009	347	200	<1	200	32	22	0.2	<0.003	0.1	20	7.58	76.9	4	0.9	<1
G3164GW01	02/25/2009	412	198	<1	198	177	10	0.2	0.021	0.5	76	1.71	102	6	1.8	<1
BBCW4GW01	02/25/2009	8,920	321	<1	321	4,810	502	0.2	0.007	15.0	2,730	79.5	286	286	4.0	2
BBCW5GW01	02/25/2009	11,600	272	<1	272	6,190	359	0.2	0.78	18.0	3,560	64.2	411	340	5.6	2
BBCW6GW01	02/25/2009	386	202	<1	202	26	15	0.2	0.015	0.1	21	7.43	91.4	4	0.9	9
BBCW9GW01	02/25/2009	481	172	<1	172	100	44	0.2	<0.003	0.4	64	10.1	75.8	8	0.9	3
Sec34-MW-0	03/11/2009	6,090	187	<1	187	3,880	95	0.1	0.019	NA	1,650	21.7	383	92	4.7	8
COH-MW-Tri	03/11/2009	4,250	166	<1	166	2,760	54	0.1	0.011	NA	998	18.9	429	55	5.4	7
BBCW10GW1	03/05/2009	35,500	169	<1	169	17,400	2,430	0.8	2.21	55.0	10,600	471	362	1,260	7.7	4
BBCW10GW2	03/05/2009	36,000	121	<1	121	19,000	2,680	0.7	0.038	59.0	10,900	498	432	1,270	8.7	4
Newton Pump 1	3/11/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FLOGW01	02/25/2009	1,730	206	<1	206	670	287	2.2	0.39	2.0	511	24.2	50.7	60	3.3	NC

* = using milliequivalents of Ca²⁺, Mg²⁺, K⁺, Na⁺, Cl⁻, SO₄²⁻, and alkalinity as HCO₃

Table 6a. Surface Water Sample Results: CAS Sample Results/Nutrients

Sample Location	Date Sampled	Ammonium as N	Nitrate+Nitrite as N	Nitrate as N	Nitrite as N	Dissolved Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	Total Nitrogen	Orthophosphate as P	Soluble Reactive Phosphorus	Total Phosphorus	Silica
		All Concentrations are in mg/L										
Surface Water Sample Results												
CCSSW01T	02/11/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW01B	02/11/2009	0.100	<0.004	<0.004	<0.005	2.3	2.4	2.4	NA	<0.004	<0.004	0.63
CCSSW02B	02/11/2009	0.100	<0.004	<0.004	<0.005	2.0	2.2	2.2	NA	<0.004	<0.004	0.57
CCSSW03B	02/11/2009	0.090	<0.004	<0.004	<0.005	1.5	1.7	1.7	NA	<0.004	<0.004	0.66
CCSSW04T	02/11/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW04B	02/11/2009	0.070	<0.004	<0.004	<0.005	1.9	2.9	2.9	NA	<0.004	0.020	0.51
CCSSW05T	02/12/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW05B	02/12/2009	0.060	<0.004	<0.004	<0.005	3.3	3.2	3.2	<0.004	<0.004	<0.004	0.52
L31ESW01T	02/18/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW01B	02/18/2009	0.010	0.014	0.014	<0.005	1.6	0.9	0.8	0.02	0.003	0.030	NA
L31ESW02T	02/18/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW02B	02/18/2009	0.010	0.012	0.012	<0.005	2.2	1.2	1.2	0.02	0.010	0.030	NA
L31ESW03T	02/18/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW03B	02/18/2009	0.010	0.017	0.017	<0.005	1.5	0.7	0.7	0.009	0.030	0.020	NA
L31ESW04	03/16/2009	0.030	1.560	1.540	0.020	1.2	1.0	2.6	0.005	<0.004	0.020	NA
L31ESW05	03/16/2009	0.210	0.015	0.006	0.009	1.1	2.5	2.5	0.01	<0.004	0.040	NA
L31ESW06	03/16/2009	<0.004	<0.009	<0.005	0.009	0.8	1.0	1.0	0.03	<0.004	0.040	NA
L31ESW07	03/18/2009	0.030	<0.009	<0.009	0.014	1.6	2.2	2.2	<0.004	<0.004	0.040	NA
L31ESW08	03/18/2009	0.390	<0.009	<0.009	0.019	2.3	1.9	1.9	0.08	0.080	0.140	NA
L31ESW09	03/18/2009	<0.004	0.029	0.029	<0.005	1.3	1.1	1.1	0.007	<0.004	0.030	NA

Table 6a. Surface water sample results: CAS Sample results/nutrients (continued)

Sample Location	Date Sampled	Ammonium as N	Nitrate+Nitrite as N	Nitrate as N	Nitrite as N	Dissolved Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	Total Nitrogen	Orthophosphate as P	Soluble Reactive Phosphorus	Total Phosphorus	Silica
All Concentrations are in mg/L												
Surface Water Sample Results												
L31EDC01B	02/12/2009	0.470	<0.004	<0.004	<0.005	2.8	6.6	6.6	<0.004	<0.004	0.010	1.40
Card Sound Canal	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S20 Getaway Culvert	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
East of SE CCS	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pond	03/17/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Culvert Tidal	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tidal Creek	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBSW01	03/04/2009	0.008	<0.009	<0.009	<0.005	0.7	0.9	0.9	0.004	0.004	0.009	NA
BBSW02	03/04/2009	<0.004	<0.009	<0.009	<0.005	0.8	2.0	2.0	<0.004	<0.004	0.007	NA
BBSW03	03/04/2009	<0.004	0.011	0.011	<0.005	0.9	1.1	1.1	<0.004	<0.004	0.008	NA
BBSW04	03/04/2009	<0.004	<0.009	<0.009	<0.005	1.0	0.9	0.9	<0.004	<0.004	0.009	NA
BBSW05	03/04/2009	<0.004	<0.009	<0.009	<0.005	1.3	0.9	0.9	0.004	<0.004	0.009	NA
BBCW10SW01	03/05/2009	0.020	<0.009	<0.009	<0.005	0.9	0.9	0.9	0.004	<0.004	0.010	NA
Benthic Feature	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
T.P. Peninsula	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 6b. Groundwater Sample Results: CAS Sample Results/Nutrients

Sample Location	Date Sampled	Ammonium as N	Nitrate+Nitrite as N	Nitrate as N	Nitrite as N	Dissolved Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	Total Nitrogen	Orthophosphate as P	Soluble Reactive Phosphorus	Total Phosphorus	Silica
		All Concentrations are in mg/L										
Groundwater Sample Results												
L3GW01	02/24/2009	1.620	0.025	0.007	0.018	3.2	2.8	2.8	0.02	0.030	0.050	NA
L5GW01	02/24/2009	1.610	0.016	0.005	0.011	2.7	3.6	3.6	0.05	0.050	0.060	NA
G21GW01	02/24/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
G28GW01	02/24/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FKS4GW01	02/25/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.57
FKS9GW01	02/25/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.85
G3164GW01	02/25/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.30
BBCW4GW01	02/25/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.59
BBCW5GW01	02/25/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.93
BBCW6GW01	02/25/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.33
BBCW9GW01	02/25/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.36
Sec34-MW-0	03/11/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
COH-MW-Tri	03/11/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBCW10GW1	03/05/2009	0.490	<0.009	<0.009	0.009	2.4	1.0	1.0	0.007	<0.02	0.020	NA
BBCW10GW2	03/05/2009	0.330	<0.009	<0.009	<0.005	1.1	1.6	1.6	0.01	0.010	0.020	NA
Newton Pump 1	03/11/2009	0.330	<0.009	<0.009	<0.005	1.1	1.6	1.6	0.01	0.010	0.020	NA
FLOGW01	02/25/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	10.70

Table 7a. CAS Sample Results/Trace Elements

Sample Name	Date Sampled	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Thallium	Vanadium	Zinc
		All Concentrations are in µg/L																
Surface Water Sample Results																		
CCSSW01T	02/11/2009	NA	NA	NA	10.20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW01B	02/11/2009	0.35	88.4	<0.002	10.00	<0.006	0.08	0.469	12	0.019	8.6	0.5	2.43	0.99	<0.4	<0.004	<1.6	0.8
CCSSW02B	02/11/2009	0.34	90.2	<0.002	10.50	<0.006	0.08	0.447	13	0.026	7.8	0.5	2.33	0.89	<0.4	0.004	<1.6	0.6
CCSSW03B	02/11/2009	0.24	89.3	<0.002	9.30	<0.006	0.04	0.400	<8	0.015	6.8	0.4	2.41	0.84	<0.4	<0.004	<1.6	0.5
CCSSW04T	02/11/2009	NA	NA	NA	8.97	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW04B	02/11/2009	0.21	89.1	<0.002	9.92	<0.006	<0.04	0.241	13	<0.012	10.0	0.6	2.44	0.97	<0.4	<0.004	<1.6	0.4
CCSSW05T	02/12/2009	NA	NA	NA	10.10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW05B	02/12/2009	0.34	86.3	0.068	9.46	<0.006	0.06	0.378	10	0.097	12.4	0.5	2.95	0.97	<0.4	0.034	<1.6	0.6
L31ESW01T	02/18/2009	<5	8.2	<0.09	0.10	<0.2	<0.9	<0.8	5.7	<3	2.6	NA	0.60	0.7	<6	<2	<0.8	1.2
L31ESW01B	02/18/2009	<5	8.2	<0.09	0.10	<0.2	<0.9	<0.8	<4	<3	2.5	NA	<0.5	<0.5	<6	<2	0.8	1.1
L31ESW02T	02/18/2009	<5	8.1	<0.09	0.09	<0.2	<0.9	<0.8	<4	<3	1.3	NA	0.50	<0.5	<6	<2	<0.8	1.6
L31ESW02B	02/18/2009	<5	7.9	<0.09	0.08	<0.2	<0.9	<0.8	5.7	<3	1.2	NA	<0.5	<0.5	<6	<2	0.8	1.2
L31ESW03T	02/18/2009	<5	8.2	0.100	0.07	<0.2	<0.9	<0.8	7.4	<3	1.6	NA	<0.5	<0.5	<6	<2	<0.8	1
L31ESW03B	02/18/2009	<5	8.2	<0.09	0.07	<0.2	<0.9	<0.8	7.5	<3	1.6	NA	<0.5	<0.5	<6	<2	<0.8	<0.6
L31ESW04	03/16/2009	NA	NA	NA	0.08	NA	NA	NA	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW05	03/16/2009	NA	NA	NA	1.70	NA	NA	NA	33	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW06	03/16/2009	NA	NA	NA	0.09	NA	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31BSW07	03/18/2009	NA	NA	NA	0.07	NA	NA	NA	19	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW08	03/18/2009	NA	NA	NA	0.02	NA	NA	NA	58	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31BSW09	03/18/2009	NA	NA	NA	0.04	NA	NA	NA	5	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31EDC01B	02/12/2009	0.45	79.6	0.052	3.97	<0.006	0.16	0.047	34.8	0.075	24.6	0.6	2.36	0.13	<0.4	0.012	<1.6	0.4

Table 7a. CAS Sample Results, Trace Elements (continued)

Sample Name	Date Sampled	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Thallium	Vanadium	Zinc
		All Concentrations are in µg/L																
Surface Water Sample Results																		
CCSSW01T	02/11/2009	NA	NA	NA	10.20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW01B	02/11/2009	0.35	88.4	<0.002	10.00	<0.006	0.08	0.469	12	0.019	8.6	0.5	2.43	0.99	<0.4	<0.004	<1.6	0.8
CCSSW02B	02/11/2009	0.34	90.2	<0.002	10.50	<0.006	0.08	0.447	13	0.026	7.8	0.5	2.33	0.89	<0.4	0.004	<1.6	0.6
CCSSW03B	02/11/2009	0.24	89.3	<0.002	9.30	<0.006	0.04	0.400	<8	0.015	6.8	0.4	2.41	0.84	<0.4	<0.004	<1.6	0.5
CCSSW04T	02/11/2009	NA	NA	NA	8.97	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW04B	02/11/2009	0.21	89.1	<0.002	9.92	<0.006	<0.04	0.241	13	<0.012	10.0	0.6	2.44	0.97	<0.4	<0.004	<1.6	0.4
CCSSW05T	02/12/2009	NA	NA	NA	10.10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CCSSW05B	02/12/2009	0.34	86.3	0.068	9.46	<0.006	0.06	0.378	10	0.097	12.4	0.5	2.95	0.97	<0.4	0.034	<1.6	0.6
L31ESW01T	02/18/2009	<5	8.2	<0.09	0.10	<0.2	<0.9	<0.8	5.7	<3	2.6	NA	0.60	0.7	<6	<2	<0.8	1.2
L31ESW01B	02/18/2009	<5	8.2	<0.09	0.10	<0.2	<0.9	<0.8	<4	<3	2.5	NA	<0.5	<0.5	<6	<2	0.8	1.1
L31ESW02T	02/18/2009	<5	8.1	<0.09	0.09	<0.2	<0.9	<0.8	<4	<3	1.3	NA	0.50	<0.5	<6	<2	<0.8	1.6
L31ESW02B	02/18/2009	<5	7.9	<0.09	0.08	<0.2	<0.9	<0.8	5.7	<3	1.2	NA	<0.5	<0.5	<6	<2	0.8	1.2
L31ESW03T	02/18/2009	<5	8.2	0.100	0.07	<0.2	<0.9	<0.8	7.4	<3	1.6	NA	<0.5	<0.5	<6	<2	<0.8	1
L31ESW03B	02/18/2009	<5	8.2	<0.09	0.07	<0.2	<0.9	<0.8	7.5	<3	1.6	NA	<0.5	<0.5	<6	<2	<0.8	<0.6
L31ESW04	03/16/2009	NA	NA	NA	0.08	NA	NA	NA	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW05	03/16/2009	NA	NA	NA	1.70	NA	NA	NA	33	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW06	03/16/2009	NA	NA	NA	0.09	NA	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31BSW07	03/18/2009	NA	NA	NA	0.07	NA	NA	NA	19	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31ESW08	03/18/2009	NA	NA	NA	0.02	NA	NA	NA	58	NA	NA	NA	NA	NA	NA	NA	NA	NA
L31BSW09	03/18/2009	NA	NA	NA	0.04	NA	NA	NA	5	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 7a. CAS Sample Results, Trace Elements (continued)

Sample Name	Date Sampled	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Thallium	Vanadium	Zinc
		All Concentrations are in µg/L																
Surface Water Sample Results																		
L31EDC01B	02/12/2009	0.45	79.6	0.052	3.97	<0.006	0.16	0.047	34.8	0.075	24.6	0.6	2.36	0.13	<0.4	0.012	<1.6	0.4
Card Sound Canal	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S20 Getaway Culvert	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
East of SE CCS	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pond	03/17/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Culvert Tidal	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tidal Creek	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBSW01	03/04/2009	NA	NA	NA	4.70	NA	NA	NA	17	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBSW02	03/04/2009	NA	NA	NA	5.20	NA	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBSW03	03/04/2009	NA	NA	NA	5.30	NA	NA	NA	5	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBSW04	03/04/2009	NA	NA	NA	5.20	NA	NA	NA	<4	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBSW05	03/04/2009	NA	NA	NA	4.60	NA	NA	NA	<4	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBCW10SW01	03/05/2009	NA	NA	NA	3.90	NA	NA	NA	5	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benthic Feature	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
T.P. Peninsula	03/04/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 7b. Surface Water Sample Results: CAS Sample Results/Trace Elements

Sample Name	Date Sampled	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Thallium	Vanadium	Zinc
		All Concentrations are in µg/L																
Groundwater Sample Results																		
L3GW01	02/24/2009	<10	96.2	<0.18	7.66	<0.4	<1.8	<1.6	21	<6	32.2	NA	1.40	<1	<12	<4	<1.6	4.2
L5GW01	02/24/2009	<10	133.0	<0.18	6.97	<0.4	<1.8	<1.6	840	<6	46.4	NA	1.00	<1	<12	<4	<1.6	5.2
G21GW01	02/24/2009	<5	322.0	<0.09	0.15	0.2	<0.9	1.300	332	3.900	18.3	NA	0.70	<0.5	<6	<2	<0.8	3.1
G28GW01	02/24/2009	<5	222.0	<0.09	1.08	0.2	<0.9	<0.8	2970	<3	29.7	NA	1.50	<0.5	<6	<2	<0.8	2.1
FKS4GW01	02/25/2009	NA	NA	NA	1.06	NA	NA	NA	380	NA	NA	NA	NA	NA	NA	NA	NA	NA
FKS9GW01	02/25/2009	NA	NA	NA	0.05	NA	NA	NA	<4	NA	NA	NA	NA	NA	NA	NA	NA	NA
G3164GW01	02/25/2009	NA	NA	NA	0.03	NA	NA	NA	126	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBCW4GW01	02/25/2009	NA	NA	NA	0.70	NA	NA	NA	2490	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBCW5GW01	02/25/2009	NA	NA	NA	0.41	NA	NA	NA	3870	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBCW6GW01	02/25/2009	NA	NA	NA	0.05	NA	NA	NA	681	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBCW9GW01	02/25/2009	NA	NA	NA	0.08	NA	NA	NA	<4	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sec34-MW-0	03/11/2009	NA	NA	NA	0.13	NA	NA	NA	417	NA	NA	NA	NA	NA	NA	NA	NA	NA
COH-MW-Tri	03/11/2009	NA	NA	NA	0.09	NA	NA	NA	1600	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBCW10GW1	03/05/2009	NA	NA	NA	4.70	NA	NA	NA	5	NA	NA	NA	NA	NA	NA	NA	NA	NA
BBCW10GW2	03/05/2009	NA	NA	NA	4.80	NA	NA	NA	349	NA	NA	NA	NA	NA	NA	NA	NA	NA
Newton Pump 1	03/11/2009	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA
FLOGW01	02/25/2009	NA	NA	NA	0.61	NA	NA	NA	108	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 8a. Surface Water Sample Results

Surface Water Sample Results			
Sample Location	Date Sampled	Result in Tus*	Result in pCi/L
CCSSW01T	02/11/2009	NA	NA
CCSSW01B	02/11/2009	NA	NA
CCSSW02B	02/11/2009	NA	NA
CCSSW03B	02/11/2009	NA	NA
CCSSW04T	02/11/2009	NA	NA
CCSSW04B	02/11/2009	NA	NA
CCSSW05T	02/12/2009	NA	NA
CCSSW05B	02/12/2009	NA	NA
L31ESW01T	02/18/2009	1.53	4.90
L31ESW01B	02/18/2009	13.5	43.20
L31ESW02T	02/18/2009	NA	NA
L31ESW02B	02/18/2009	12.2	39.04
L31ESW03T	02/18/2009	5.98	19.14
L31ESW03B	02/18/2009	NA	NA
L31ESW04	03/16/2009	2.18	6.98
L31ESW05	03/16/2009	58.6	187.52
L31ESW06	03/16/2009	14.4	46.08
L31ESW08	03/18/2009	5.95	19.04
L31ESW07	03/18/2009	13.3	42.56
L31ESW09	03/18/2009	3.85	12.32
L31EDC01B	02/12/2009	NA	NA
Card Sound Canal	03/04/2009	NA	NA
S20 Getaway Culvert	03/04/2009	123	393.60
East of SE CCS	03/04/2009	6.79	21.73
Pond	03/17/2009	7.66	24.51
Culvert Tidal	03/04/2009	3.54	11.33
Tidal Creek	03/04/2009	3.10	9.92
BBSW01	03/04/2009	2.90	9.28
BBSW02	03/04/2009	2.95	9.44
BBSW03	03/04/2009	4.14	13.25
BBSW04	03/04/2009	6.05	19.36
BBSW05	03/04/2009	2.72	8.70
BBCW10SW01	03/05/2009	2.58	8.26
Benthic Feature	03/04/2009	5.85	18.72
TP Peninsula	03/04/2009	3.08	9.86

* 1 TU = 3.2 pCi/L

Table 8b. Groundwater Sample Results

Groundwater Sample Results			
Station	Date Sampled	Result in TUs	Result in pCi/L
L3GW01	2/24/2009	NA	NA
L5GW01	2/24/2009	NA	NA
G21GW01	2/24/2009	NA	NA
G28GW01	2/24/2009	NA	NA
FKS4GW01	2/25/2009	0.89	2.85
FKS9GW01	2/25/2009	NA	NA
G3164GW01	2/25/2009	NA	NA
BBCW4GW01	2/25/2009	7.22	23.10
BBCW5GW01	2/25/2009	0.74	2.37
BBCW6GW01	2/25/2009	2.20	7.04
BBCW9GW01	2/25/2009	NA	NA
Sec34-MW-0	3/11/2009	3.27	10.46
COH-MW-Tri	3/11/2009	9.4	30.08
BBCW10GW1	3/5/2009	2.60	8.32
BBCW10GW2	3/5/2009	1.14	3.65
Newton Pump	3/11/2009	1.84	5.89
FLOGW01	2/25/2009	NA	NA

* 1 TU = 3.2 pCi/L

Appendix C

GEOCHEMICAL INVESTIGATION



Geochemical Investigation of the surface water and groundwater in the
immediate Vicinity of Florida Power and Light Turkey Point Cooling Canals

Revised Final Report:

Final Revision

January 21st, 2010

By

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Summary of Findings

- The Florida Power and Light (FPL) Turkey Point Cooling Canals display hypersaline conditions, including the highest concentrations of all cations and anions of waters sampled in this study. This concentration makes them distinctive in the immediate vicinity around the cooling canals.
- When mixed with significant amounts of fresh groundwater or seawater, the cooling canal water becomes indistinguishable from surface Biscayne Bay waters with respect to the major cations and anions.
- Dissolved Barium concentrations show a distinction between the cooling canal water and the surface Biscayne Bay water and can be used in a ternary mixing diagram.
- Piper diagrams show two distinct sources of fresh and brackish groundwater one related to the FKS9GW01 well, and one source defined by the COH-MW-Trig well. The COH-MW-Trig well is similar to water sampled in previous studies (Price and Swart, 2006) and may be remnant “connate” water from a previous saltwater intrusion event.
- An analysis of multiple ions indicate that the concentrations in wells L3GW01 and L5GW01 can only be derived from significant volumes of cooling canal surface water mixing with Biscayne Bay surface water and fresh groundwater.
- Wells G21GW01 and G28GW01 have higher salinities than background freshwater. Using the Dissolved Barium concentration ternary mixing diagram, G28GW01 appears to be a mixture of fresh groundwater, Biscayne Bay water, and cooling canal surface water. Piper diagrams suggest the increased salinity at G21GW01 appears to be related to the “connate” (higher salinity) water found in the COH-MW-Trig well.
- Better depth control and spatial sampling of groundwater around the cooling canals (north, south, west and east) would improve ion/isotope modeling analysis.
- Multi-depth well clusters need to be installed to the west, north, south and east of the cooling canals to properly characterize the spatial extent and vertical structure of any high salinity water moving away from the cooling canals.
- An analysis of stable strontium isotope data suggests influence of Floridan groundwater in wells L3GW01, L5GW01, and G28GW01, in the L-31E surface sample L31DCSW01B, and in the cooling canal system.

Purpose

This report summarizes the initial analysis of the geochemistry of surface water and groundwater in the vicinity of the Florida Power and Light Turkey Point Nuclear Facility cooling canals. Data included in this report consists of dissolved cation and anion data provided by the South Florida Water Management District, stable isotopic composition of strontium performed at FIU by Dr. Andrew Mcfarlane, and the stable isotope composition of oxygen and hydrogen and dissolved barium provided by Dr. Peter Swart at the Stable Isotope Laboratory at the University of Miami School of Marine and Atmospheric Sciences (PO. 45-0003480). Analysis includes the initial characterization of surface waters in the cooling canals, surrounding canals, Biscayne Bay, and nearby groundwater. In addition, the analysis includes statistical analysis of related ions and related sample sites, as well as binary and ternary mixing diagrams. The report concludes with recommendations for further study.

Introduction

Groundwater and surface waters can interact provided the hydrologic and geologic conditions are conducive to transmission between the surface and subsurface. Surface water can recharge groundwater when water levels in surface water bodies are higher than the surrounding groundwater table, and vice versa, surface systems can be recharged by groundwater when the gradient is reversed. Further complications can arise when waters of different densities (related to either temperature or salinity) exist between or within the surface water and groundwater systems. These interactions can be determined using hydrologic principles but can be confounded in complex or heterogeneous hydrologic systems.

Groundwater and surface water interactions have been studied extensively using multiple approaches. Such investigations have included hydrograph separation (Hannula et al., 2003), physical measurements from seepage meters and piezometers (Harvey et al., 2002), temperature tracer studies (Conanat, 2004), chemical tracers including radon/radium (Cook et al., 2003), isotopes of oxygen, hydrogen, and carbon (Stalker et al., 2009, James et al., 2000), and ionic constituents (Stalker et al., 2009, Pinder and Jones, 1969). Isotopes of oxygen and hydrogen, and ionic concentrations of Ca^{2+} and Sr^{2+} have been used to determine recharge to aquifers from surface water systems and determine the input ratios from source waters to the canal system in South Florida (Stalker, 2008).

Ionic constituents are present in all natural waters. Equilibrium with atmospheric input, matrix mineral material in aquifer systems, and other inorganic and organic processes can all contribute to dissolved ion concentrations in ground, surface and meteoric water. In general, evaporation increases the concentration of dissolved ions in solutions. However, precipitation and/or dissolution of minerals can remove and/or add dissolved ions to a solution. The monovalent negatively charged ions of chloride (Cl^-) and bromide (Br^-) are widely accepted to behave conservatively compared to other major and minor cations and anions. Chloride and bromide do not participate in recrystallization (except at high concentrations), and generally do not sorb or desorb from particulate matter in water or matrix materials. These properties make Cl^- and Br^- useful tracers for hydrological studies, and a good comparison tool for the description of ion concentrations. Other ions such as calcium (Ca^{2+}), dissolved barium (Ba^{2+}), strontium (Sr^{2+}), magnesium (Mg^{2+}), sulfate (SO_4^{2-}), sodium (Na^+), and potassium (K^+) can also be used as tracers but readily participate in precipitation, dissolution, and adsorption processes.

The coastal hydrology of southeastern Florida is characterized by a highly permeable and transmissive Surficial Aquifer System (SAS), and a complex series of man-made canals that have direct contact with the aquifer system. There is still a lack of understanding of the magnitude, timing, and physical controls on the groundwater and surface water interactions between the canal system and the aquifer in the near coastal zone of south Florida. Construction of the canal system in south Florida began in the early 1900s to drain the Everglades for agricultural use. The canals channeled fresh water from the Everglades directly out to the ocean. The canal system was later expanded and control structures added to control flooding and raise groundwater levels in the coastal aquifer system in an attempt to curb saltwater intrusion (Fernald and Patterson, 1984). The groundwater and surface water interactions in the canal system are similar to those of a natural drainage system. When the water level in the canal is higher than the surrounding groundwater, water will flow from the canal into the aquifer. Alternatively, if the groundwater levels are higher than the stage in the canal, water will flow from the groundwater system into the canal. The net flux exchange of water in the canal system has been estimated using water balances, head estimates, and computer modeling (Chin, 1990; Swayze, 1987; Klein and Hull, 1978; Leach et al., 1972). Those studies generally showed a net flow from the canal into the aquifer. The temporal nature of water levels in the canal and aquifer may fluctuate, changing the direction of flow.

The hydrostratigraphy of south Florida consists of a local SAS, which is separated from the deeper Floridan aquifer system by the thick confining siliclastic unit of the Hawthorn Group. Many authors (Fish and Stewart, 1991; Reese and Cunnigham, 1999; Kohout, 1960) have contributed to the

description, classification, and stratigraphy of this system. The following is a synthesis of their work concerning the SAS in the study area. The SAS consists of an upper limestone aquifer named the Biscayne aquifer, a middle clastic unit, the Grey Limestone aquifer, and another clastic layer that terminates at the confining Hawthorn Group (Fish and Stewart, 1991). The Biscayne aquifer consists of the Miami Limestone, the Ft. Thompson Formation, the Key Largo Limestone, and other minor units. These limestones are composed of Pleistocene age oolitic, bryozoans, and fossiliferous carbonate rocks with minor sand lenses (Fish and Stewart, 1991). The limestone of this upper aquifer is karstified and highly transmissive as indicated by borehole analysis and aquifer testing (Reese and Cunningham, 1999; Fish and Stewart, 1991). The Biscayne aquifer is comprised of fresh water, with the exception of saltwater intrusion near the coast, and is the sole source aquifer for much of Miami-Dade, Broward, and Monroe counties (Fish and Stewart, 1991; Kohout, 1960). The Biscayne aquifer has been mapped as underlying the terrestrial extent of both Miami-Dade County and Biscayne Bay. The majority of canals in Miami-Dade County are completed in the Upper Biscayne aquifer in the Miami Limestone and Ft. Thompson Formations. The next deeper and older aquaclude is the Hawthorn Group. This group is comprised of sands and siltstones of Miocene age and acts as a low transmissivity hydrologic barrier between the lower Floridan aquifer system and the SAS above. The Floridan aquifer system is a thick sequence of limestone, dolomite, and inter-bedded sand and silts of Pliocene to early Miocene in age. The system is usually described in three zones, Upper, Middle, and Lower, each separated by confining units. Groundwater in each of these zones is progressively more saline with groundwater in the Lower Floridan (known also as the Boulder Zone), having a salinity similar to seawater. Wells finished in the Upper and Middle aquifer zone of the Floridan aquifer system are artesian. The Boulder Zone has a hydraulic head similar to mean sea level and is currently used in wastewater injection projects.

The strontium isotope ratios of marine limestones directly record the isotopic composition of the seawater they precipitated from, whether that precipitation was biogenic or abiogenic. A highly detailed record of seawater strontium isotopes in the literature documents a strong monotonic increase of $^{87}\text{Sr}/^{86}\text{Sr}$ from the Late Eocene time (35 million years ago) to the present day, caused principally by increasing inputs of radiogenic continental strontium to the oceans due to uplift of the Himalayan Mountains during this time interval (Capo and Depalolo, 1990; MacArthur et al, 2001). Limestones of the lower Hawthorne Group that comprise the Upper Floridan aquifer were deposited in the early Miocene and so possess $^{87}\text{Sr}/^{86}\text{Sr}$ values of 0.7086 and lower, compared to values of 0.70925 for modern seawater and 0.70915 and above for the late Pleistocene limestone that comprises the Biscayne aquifer. Although the exact isotopic composition of the lower Hawthorn Formation is not known directly, values

of $^{87}\text{Sr}/^{86}\text{Sr}$ below 0.7090 in water from the cooling canals or shallow groundwaters in the Biscayne aquifer would require a substantial component of water equilibrated with the Floridan aquifer. We proposed to measure stable strontium $^{87}\text{Sr}/^{86}\text{Sr}$ values in the surface and groundwaters near Turkey Point in order to see whether there was a component of Floridan groundwater in the cooling canal waters that could be used to chemically fingerprint them. This proposal was based on the fact that marine limestones obtain their strontium isotope compositions from seawater, and the observation that the strontium isotope ratio of seawater has increased steadily over the past 35 million years. Unlike oxygen and hydrogen isotopes, strontium isotope ratios are not fractionated by evaporation and precipitation processes. Therefore, strontium isotopes in groundwater in equilibrium with the Upper Floridan aquifer should be measurably different both from modern seawater and surficial ($\approx 120,000$ ka) limestones.

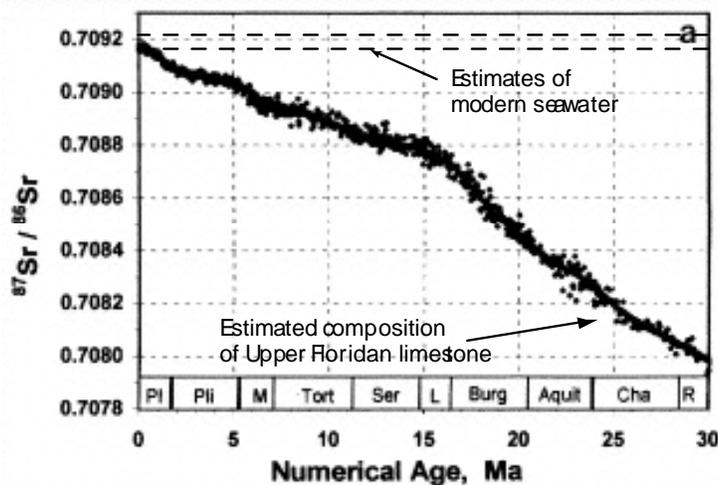


Figure 1. Modified from McArthur et al. (2001) shows the strontium isotope curve for seawater during the past 30 million years, the range of reported values for modern seawater, and the expected composition of early Miocene limestone in the Floridan aquifer. If enough Floridan groundwater is present in the cooling canal waters at Turkey point, the strontium isotope ratios would be displaced enough from modern seawater to serve as a useful tracer.

Objective

The purpose of this study was to characterize and differentiate the source waters in the groundwater and surface waters in the vicinity of the Florida Power and Light Turkey Point cooling canal system using geochemical constituents.

Methods

A total of 43 samples were collected in four phases from surface and groundwater and cooling canals in and around the Turkey Point nuclear energy facility in Miami-Dade County (Fig.2 A, B).

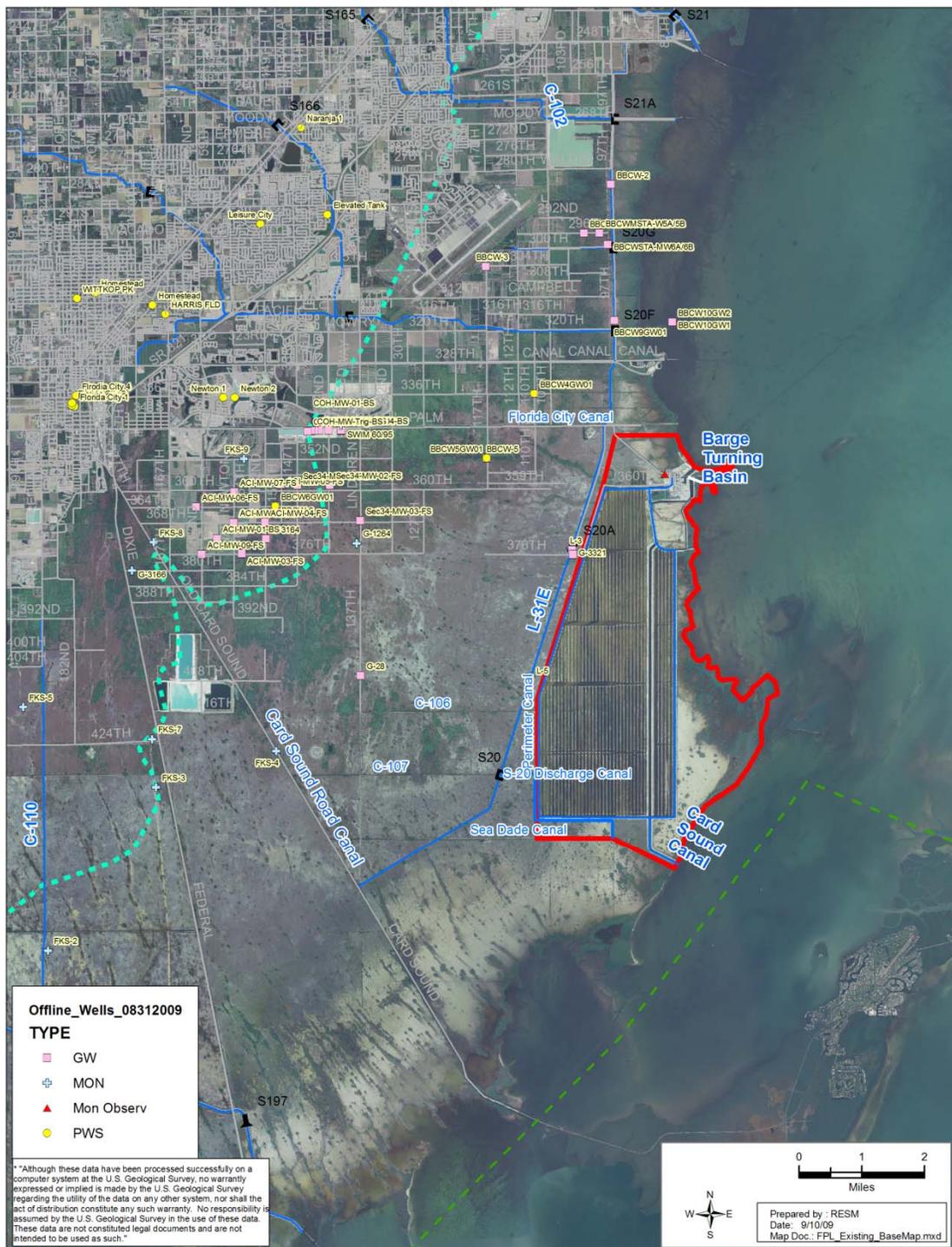


Figure 2A. Overview of surface and groundwater sampling in the vicinity of Turkey Point Cooling Canals. The Canals are blue text, surface water samples are indicated by orange circles, groundwater samples are indicated by pink squares.

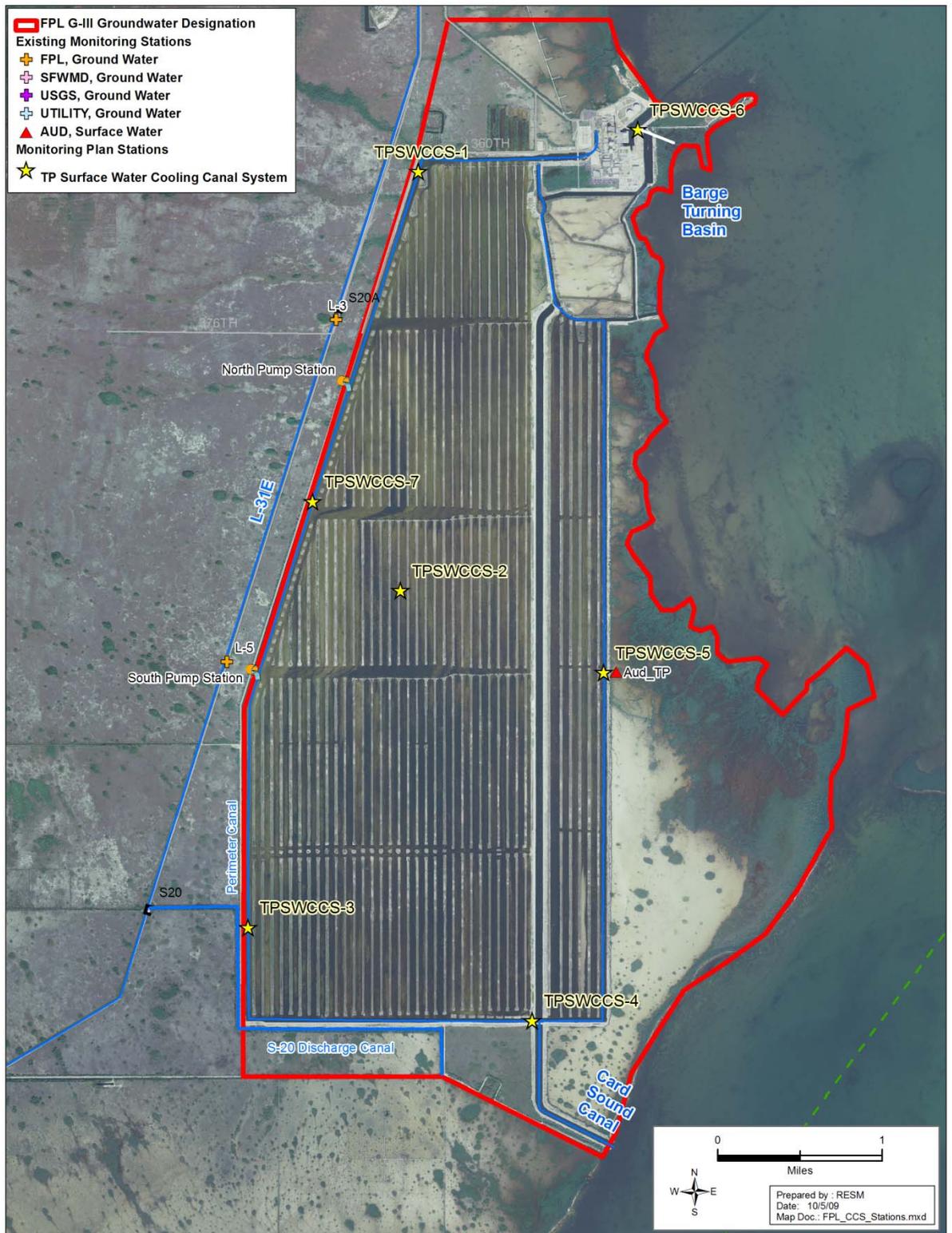


Figure 2B. Cooling Canal Surface and groundwater sampling stations. Surface Samples were collected at sites indicated by the yellow stars. Samples were taken from multiple depths at deeper sites. Groundwater samples were collected at sites indicated with orange crosses.

These samples included 6 surface water samples from adjacent Biscayne Bay, 8 surface samples from the cooling canal system on Florida Power and Light (FPL) Turkey Point property, and 13 surface samples from the South Florida Water Management District (SFWMD) canal system adjacent to the FPL Turkey Point Property. In addition, 16 groundwater samples were collected from various depths and distances to the west and northeast of the FPL Turkey Point Property. Surface water samples were collected at two depths, a top sample collected approximately one meter below the surface, and a second, bottom sample collected approximately ½ meter from the bottom. Only one sample was taken at a surface water site if the water depth was shallow (<2m).

Ionic analysis was conducted by a contract laboratory to the SFWMD and included the dissolved concentrations of Cl^- , Na^+ , Ca^{2+} , Sr^{2+} , Mg^{2+} , SO_4^{2-} , alkalinity, F^- , K^+ , Br^- , and Boron. Water samples were analyzed for the stable isotopes of oxygen and hydrogen at the Rosenstiel School of Marine and Atmospheric Sciences (RSMAS) Stable Isotope Laboratory by Dr. Peter Swart. In addition dissolved barium (Ba^{2+}) concentrations were analyzed by Dr. Peter Swart at the Rosenstiel School of Marine and Atmospheric Sciences (RSMAS) Stable Isotope Laboratory, using Inductively Coupled Plasma Optical Emission Spectra (ICP-OES) analysis. Detection limits for the Varian ICP-OES for Ba^{2+} are $\pm 0.0002 \mu\text{M}$. ICP analysis standards were created from International Association of Physical Sciences of the Oceans (IAPSO) standard seawater are analyzed every 10 samples to correct for instrument drift. Additionally, samples were analyzed in duplicate and averaged for quality control and to minimize analytical error. Surface water and groundwater samples were diluted 1/100 with ultrapure de-ionized water prior to analysis.

Values of $^{87}\text{Sr}/^{86}\text{Sr}$ were determined using the VG-354 multi-collector TIMS in the Department of Earth and Environment at FIU. Strontium was purified from water samples using standard chromatographic techniques, and aliquots corresponding to $\approx 1\mu\text{g}$ Sr were loaded onto Ta filaments in 1N ultrapure phosphoric acid. Data were collected in static multi-collection mode at ion beam intensities of at least 1.5V on mass 88, and typical runs averaged about 1.8-2.0V for up to 225 sets of ratios. Raw data were normalized against the average of 24 analyses of the SRM-987 strontium carbonate standard—a nominal value of 0.710248 was assumed for this standard.

Data Analysis

All ionic species were plotted against Cl^- to determine the behavior of the ions with changing chloride concentrations (a proxy for salinity) in the study sample waters. This analysis determined which ions behaved conservatively, and which ions were appropriate for binary and tertiary mixing models.

Ions determined appropriate for binary mixing models should have a generally linear relationship with increasing Cl⁻ concentrations. Ions that were determined appropriate for ternary mixing models had a complex (non-linear) relationship with increasing Cl⁻ concentrations. Major cations and anions (Ca²⁺, Na⁺, Cl⁻, Mg²⁺, HCO₃⁻, and SO₄²⁻) were used in Piper diagrams to help determine provenance of sample waters and to determine appropriate end-members for use in the mixing models. Piper diagrams were created using AquaChem 3.70 for windows.

Statistics

Two statistical approaches on the ion data set were calculated using the statistical Program SPSS 13.0. The first was a correlative analysis of each ion species with all other ion species. Correlative analysis produced a number between (1 and -1) for each ion pair. A correlative number near 0 indicated that the two ions do not have a strong relationship, that is to say the two ions behave randomly compared to one another across the range of data. In cases where the correlative relationship between the ion pair was close to 1 or -1, there was either a strong positive correlation (the two ions behave similarly) or a strong negative correlation (the two ions behave opposite of one another). This analysis helped determine redundancy in the ion spread.

The second statistical analysis was a cluster analysis dendrite classification. This analysis examined the entire data set by sample and clusters samples with similar attributes. This process produced a hierarchal plot that related each cluster of samples with the other clusters. Clusters that lie closer together (and were thus closely related) plotted closer on the hierarchal plot. This statistical analysis was used to determine end-members and qualitatively clarify the spatial relationship of samples.

Mixing Models

Two separate mixing models were used to quantify the dominant sources of water in the surface water and groundwater samples in the study area: one used binary mixing equations, the other used ternary mixing diagrams. The first model used the ion concentrations of Cl⁻, Br⁻, Na⁺, K⁺, δ¹⁸O, and δD in a binary mixing equation. Two iterations of this model were used, one with cooling canal water, and fresh groundwater as the end-members, and one model used Biscayne Bay surface water and fresh groundwater as the end-members. In the first model, the sum of the water sources contributing to a sample were composed of fresh groundwater (x) and cooling canal water/Biscayne Bay surface water (y); which are related according to the equation:

$$1 = x + y. \tag{1}$$

To utilize the ionic data, the equation was modified for each ionic constituent used in the modeling to yield:

$$[\text{Ion}]_{\text{sample}} = (v)[\text{Ion}]_{\text{fgw}} + (1-v) [\text{Ion}]_{\text{ccw/bbsw}}. \tag{2}$$

In equation 2, the term [Ion] with subscripts fgw and ccw/bbsw referred to the ion concentration of fresh groundwater and either cooling canal water or Biscayne Bay surface water end-members, respectively. The term [Ion]_{sample} referred to the ion concentration of the surface or groundwater samples. Equation 2 was then solved for (v). The variable (v) represented the ratio of fresh groundwater contribution to the sample and (1-v) represented the cooling canal or Biscayne surface water contribution to the sample. This method assumed two mixing members. For any given sample there may be three or more mixing members, and therefore, this model may be insufficient for characterizing all samples.

The second model utilized a graphical ternary mixing diagram and tie-line ratios to determine the influence of three end-members on a surface or groundwater sample. A plot of Ba²⁺ and Cl⁻ was constructed with cooling canal water, fresh groundwater (FKS4GW01) and Biscayne Bay surface water as the three end-members. Lines were connected between each end-member. Samples that fell within the boundary of this triangle were a mixture of these three end-member waters. A fourth line was drawn between an end-member and bisects the line between the other two end-members. The distances are 1) from the end-member to the sample point, and 2) between the sample point and the opposite triangle side were measured. Line (2) was then divided by the distance of the sum of lines 1+2. This determined the ratio of influence of the end-member on the sample. This procedure was repeated for each end-member until all three ratios were determined. A numerical matrix solution for these diagrams was developed to lower graphical error associated with producing tie-lines. The distance of any given measurement from end-member to sample point was relative to the size of the graph drafted, and the same ratio results would be obtained no matter what size graph was used. A larger graph would simply produce larger measurements, while a smaller graph would produce smaller measurements. The ratios of these measurements within the same graph would, however, be the same.

Results

All ion concentrations represent the dissolved portion and data is presented in millimolar (mM) format, to convert to parts per million, multiply the mM by the molecular weight of the element in question:

$$\text{mM} = \text{mg L}^{-1}/\text{MW} \quad \text{or} \quad \text{mg L}^{-1} = \text{mM} * \text{MW} \quad (3)$$

Table1. Molecular weights of elements analyzed

Element/ Molecule	Molecular Weight (MW)
Alkalinity as CaCO ₃	100.09
Chloride	35.453
Sulfate	32.066
Fluoride	18.998
Bromide	79.904
Sodium	22.990
Potassium	39.098
Calcium	40.08
Magnesium	24.305
Strontium	87.62
Barium	137.33

Ions

All ionic data are summarized in mM in Appendix 1, except for dissolved barium in μM and in mg/L and $\mu\text{g/L}$ in Appendix 2 (attached at end of Report). Ionic analysis was completed for dissolved concentrations of alkalinity (CaCO₃), chloride, sulfate, fluoride, bromide, sodium, potassium, calcium, magnesium, lithium, dissolved Barium, and strontium. Incomplete chemical analysis included dissolved concentrations of arsenic, silica, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, thallium, vanadium, and zinc. Only constituents with a complete analysis at all sites were used in the mixing models. All components were graphically compared to chloride, which was the most conservative ionic component in this analysis. This analysis produced two groups of ions: ions for which the mass was conserved through a range of chloride concentrations (Na⁺, K⁺, Br⁻, SO₄²⁻, and Mg²⁺, (linear) (Figures 3-7) and ions for which the mass was not conserved through the chloride range (Alk, F⁻, and Ba²⁺, Ca²⁺, Sr⁺²) (Figures 8-12).

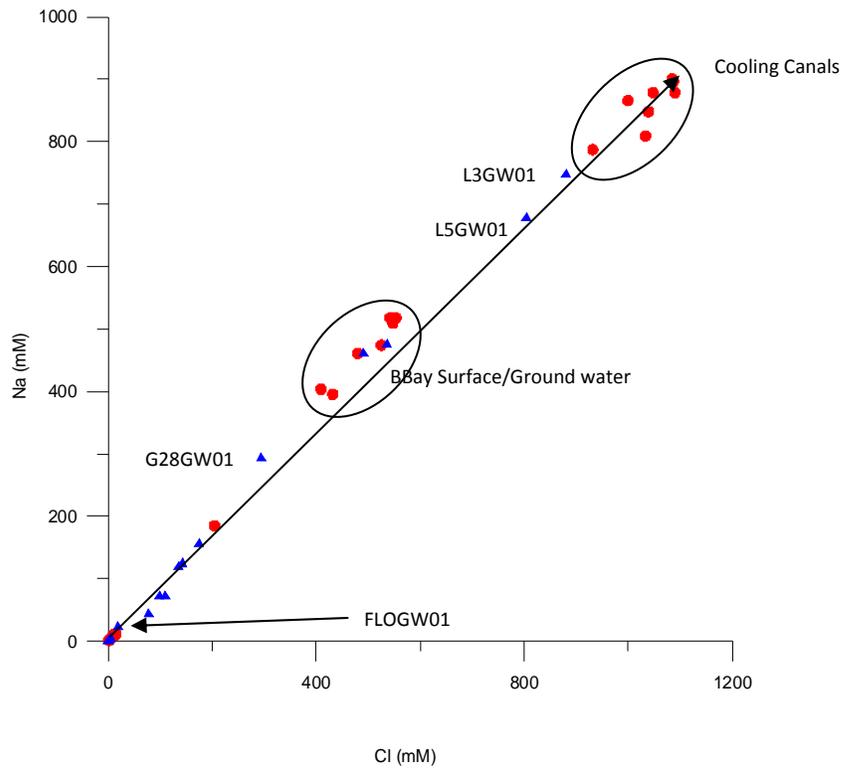


Figure 3. Plot of chloride concentration (mM) against sodium (mM). This plot shows a strong linear relationship between the two ions in both surface water and groundwater.

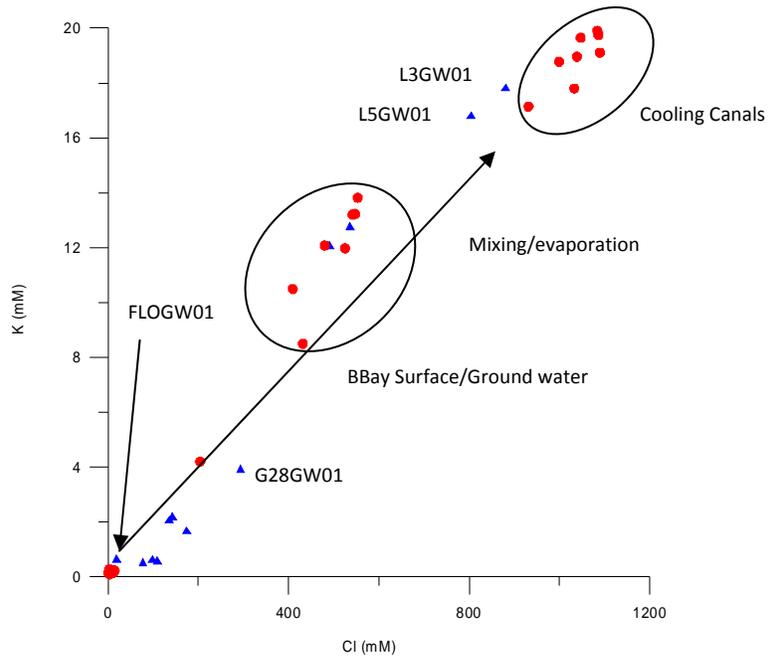


Figure 4. Plot of chloride concentration (mM) against potassium (mM). This plot shows a linear relationship between the two ions in both surface water and groundwater.

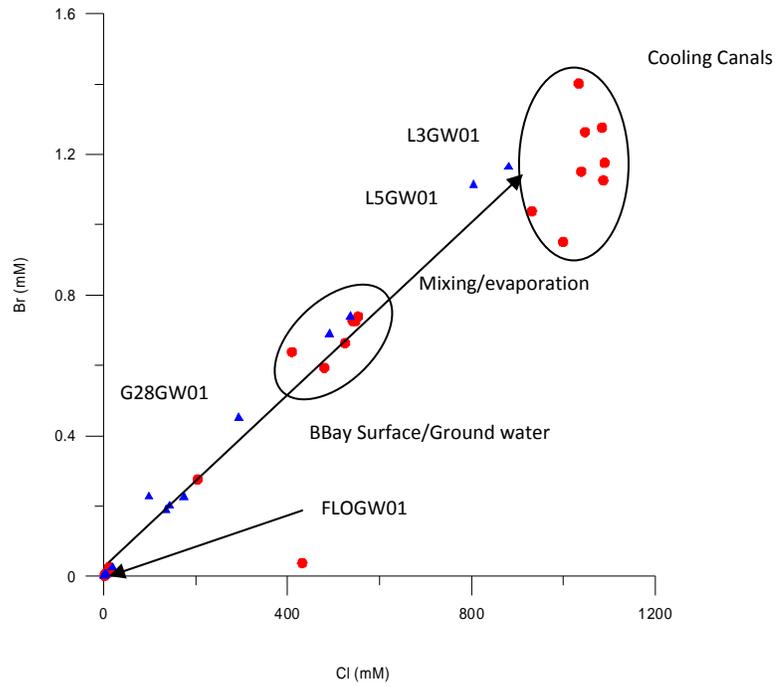


Figure 5. Plot of chloride concentration (mM) against bromide (mM). This plot shows a strong linear relationship between the two ions in both surface water and groundwater.

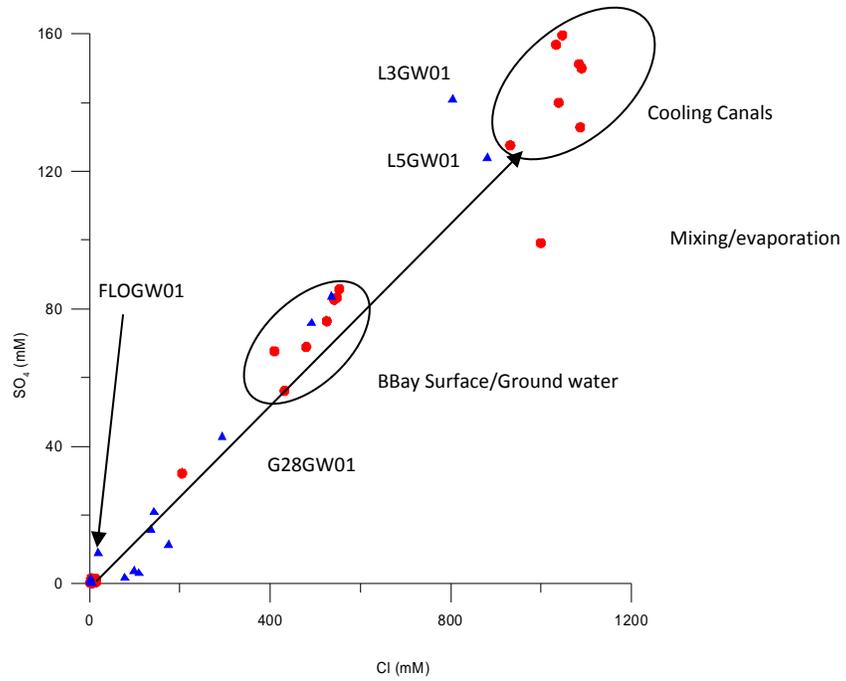


Figure 6. Plot of chloride concentration (mM) against sulfate (mM). This plot shows a strong linear relationship between the two ions in both surface water and groundwater.

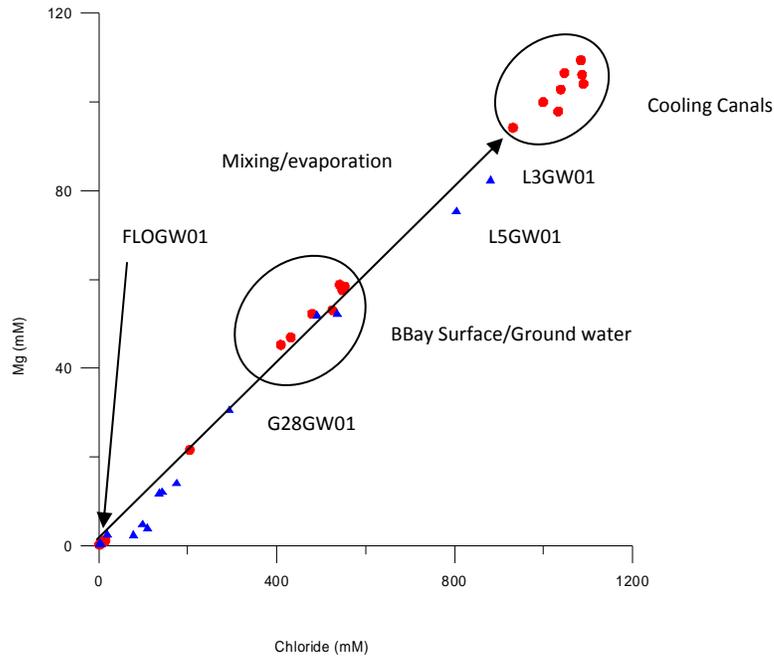


Figure 7. Plot of chloride concentration (mM) against magnesium (mM). This plot shows a strong linear relationship between the two ions in both surface water and groundwater.

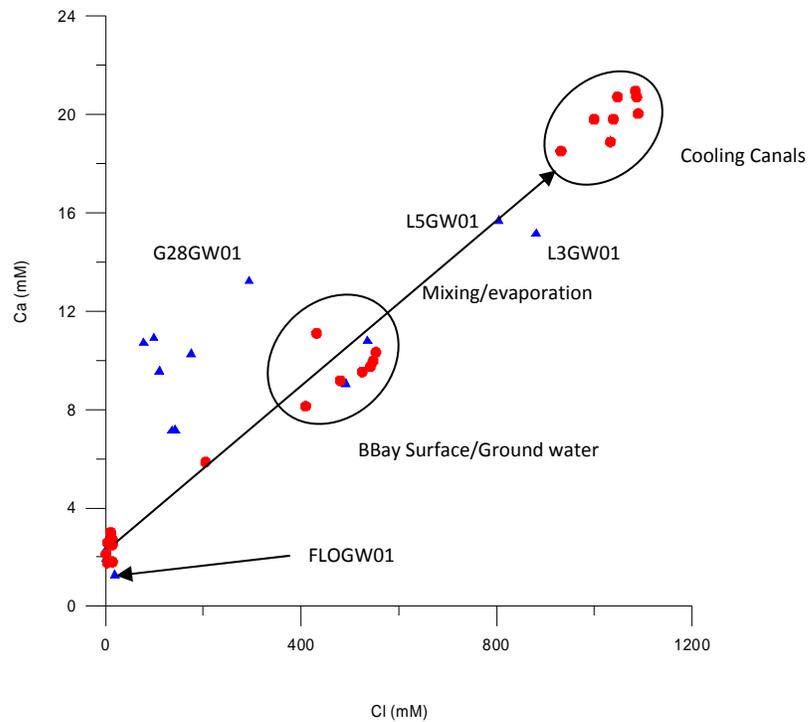


Figure 8. Plot of chloride concentration (mM) against calcium (mM). This plot shows a linear relationship between the two ions in most of the surface waters and only a few of the groundwaters. Most of the groundwaters, however, do not show a conservative nature of calcium versus chloride.

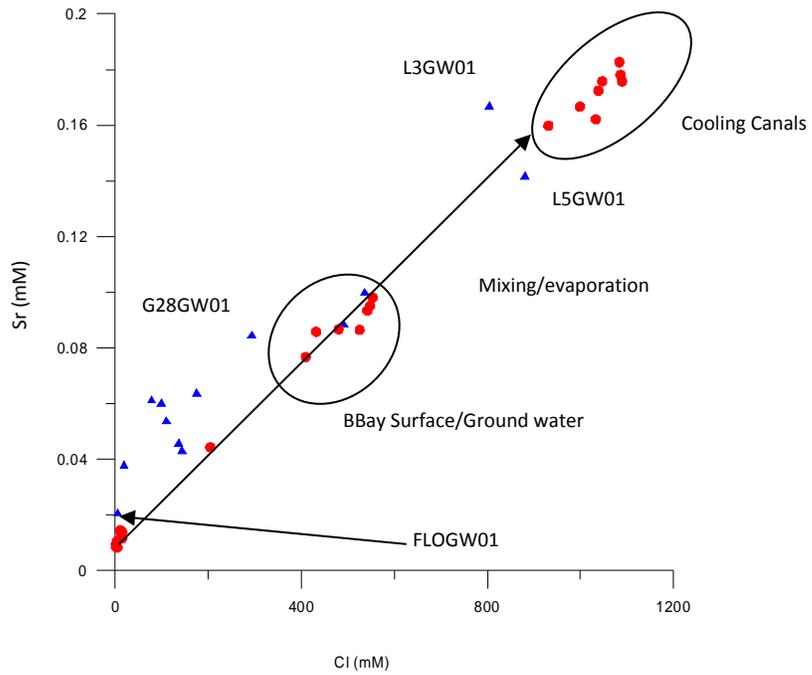


Figure 9. Plot of chloride (mM) versus strontium (mM). There was a strong linear relationship between the two ions in the surface waters. Most of the groundwaters showed a non-linear relationship between strontium and chloride.

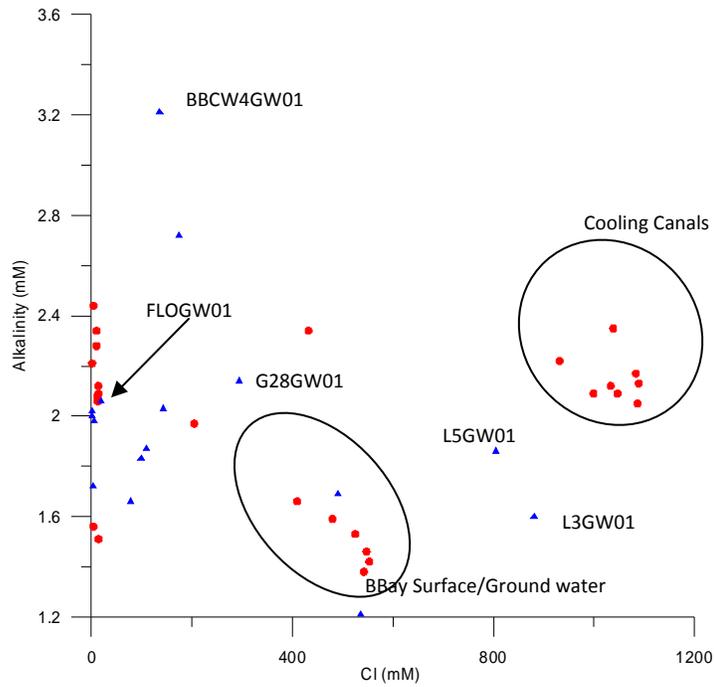


Figure 10. Plot of chloride (mM) versus alkalinity (CaCO_3) (mM). There is a complex relationship between these two parameters in both surface water and groundwater. Samples of Biscayne Bay surface and groundwater had lower alkalinity compared to either the L-31E or cooling canal surface waters.

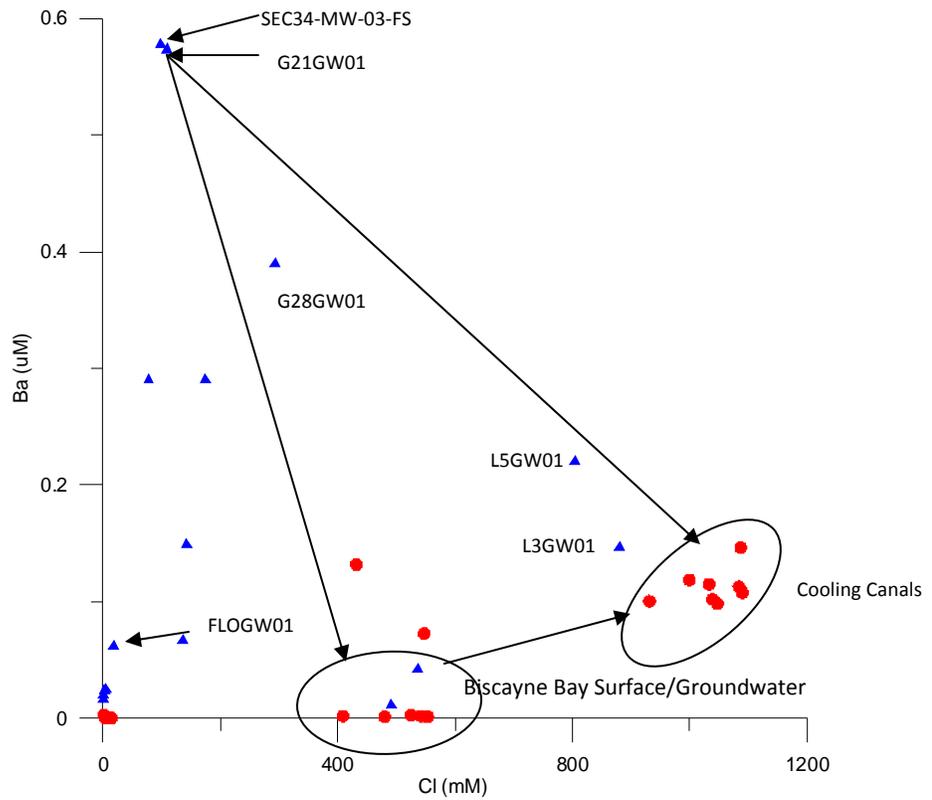


Figure 11. Plot of chloride (mM) versus dissolved barium (μM). This plot shows a separation of cooling canal surface waters, Biscayne Bay surface waters and fresh groundwater with respect to dissolved barium and chloride.

Surface waters

Cooling Canals

The cooling canal samples included CCSSW01T, CCSSW01B, CCSSW02B, CCSSW03B, CCSSW04T, CCSSW04B, CCSSW05T, and CCSSW05B. The range in ionic concentrations of the FPL cooling canals were Cl^- (930.81-1088.77 mM), Br^- (0.95-1.40 mM), Na^+ (787.3-900.3 mM), K^+ (17.14-19.90 mM), SO_4^{2-} (99.17-159.67 mM), Mg^{2+} (94.22-109.44 mM), Sr^{2+} (0.160-0.183 mM), F^- (0.037 mM), Ca^{2+} (18.51-20.96 mM) and Ba^{2+} (0.09-0.14 μM). Relative to the other water types, the cooling canals had the highest concentrations of Cl^- , Br^- , Na^+ , K^+ , SO_4^{2-} , Mg^{2+} , Sr^{2+} , and Ca^{2+} . Relative to Biscayne Bay surface waters, the cooling canal surface waters were depleted with respect to F^- , and equivalent with respect to Ba^{2+} , and CaCO_3 . Relative to some of the fresh groundwater samples (BBCWGW05, COH-MW-Trig, G21GW01, G28GW01, L3GW01, L5GW01, and SEC34-MW-03-FS), the cooling canals were depleted in dissolved barium.

Biscayne Bay Surface Waters

Biscayne Bay surface waters included sites BBCW10SW01, BBSW01, BBSW02, BBSW03, BBSW04, and BBSW05. These waters had ion concentration ranges of Cl^- (408.9-552.8 mM), Br^- (0.594-0.748 mM), Na^+ (403.6-517.6 mM), K^+ (10.49-13.81 mM), SO_4^{2-} (67.67-85.76 mM), Mg^{2+} (45.260-58.838 mM), Sr^{2+} (0.07-0.09 μM), Ca^{2+} (8.13-10.33 mM), Ba^{2+} (0.001-0.072 μM), F^- (0.042-0.058 mM), and alkalinity as CaCO_3 (1.38-1.66 mM). The concentrations of Cl^- , Br^- , Na^+ , K^+ , SO_4^{2-} , Mg^{2+} , Sr^{2+} , and Ca^{2+} were higher compared to either the fresh or brackish groundwaters and surface waters. Conversely, these ion concentrations were lower than the groundwater from wells L3GW01 and L5GW01 and the surface water in the cooling canals. Concentrations of dissolved barium in Biscayne Bay surface waters were lower than cooling canal waters and all groundwater samples. Concentrations of dissolved barium were equivalent to the fresh surface waters in the L31E canal. Alkalinity concentrations were equivalent with the some of the fresh and brackish groundwater samples, and depleted compared to the cooling canal waters and L31 canal samples.

L31 Surface Waters

Surface water samples from the L31E canal included sites L31ESW07, L31ESW09, L31EDC01B, L31ESW01B, L31ESW02B, L31ESW02T, L31ESW03B, L31ESW03T, L31ESW04, L31ESW05, L31ESW06, and L31ESW08. These samples ranged from fresh ($\text{Cl}^- < 2 \text{ mM}$) (L31SW09) to saline ($\text{Cl}^- > 400 \text{ mM}$) (L31EDC01B) and showed some minor stratification between the top and a bottom samples. These waters had ion concentration ranges of Cl^- (1.27-431.56 mM), Br^- (0.01-0.238 mM), Na^+ (1.14-395.3 mM), K^+ (0.08-8.49 mM), SO_4^{2-} (0.34-56.13 mM), Mg^{2+} (0.20-46.90 mM), Sr^{2+} (0.008-0.086 mM), Ca^{2+} (1.76-11.10 mM), Ba^{2+} (0.0007-0.1318 μM), F^- (0.007-0.021 mM), and alkalinity as CaCO_3 (1.51-2.44 mM).

Groundwater

Groundwater sites sampled in this study included a total of 16 wells. Fourteen wells (BBCW5GW01, BBCW6GW01, BBCW9GW01, COH-MW-Trig, FKS4GW01, FKS9GW01, G21GW01, G28GW01, G3164GW01, L3GW01, L5GW01, SEC34-MW-03-FS, BBCW10GW1, BBCW10GW2) were finished in the Biscayne aquifer, and one (FLOGW01) was finished in the Upper Floridan aquifer. The groundwater samples had ionic concentration ranges of Cl^- (0.72-880.04 mM), Br^- (0.001-1.164 mM), Na^+ (0.89-748.15 mM), K^+ (0.04-17.80 mM), SO_4^{2-} (0.31-140.96 mM), Mg^{2+} (0.17-82.29 mM), Sr^{2+} (0.010-0.167 mM), Ca^{2+} (1.26-15.67 mM), Ba^{2+} (0.0117-0.5774 μM), F^- (0.007-0.116 mM), and alkalinity as CaCO_3 (1.60-3.21 mM). Wells L3GW01 and L5GW01 had chloride concentrations higher than Biscayne Bay surface water (seawater) values. Groundwater from wells BBCW10GW1 and BBCW10GW1 had Cl^- concentrations at or near seawater values. Many of the fresher wells ($\text{Cl}^- < 400 \text{ mM}$) were enriched in calcium and strontium relative to surface waters with the same Cl^- content. In addition, several wells (BBCW5GW01, COH-MW-Trig-BS, FKS4GW01, L3GW01, L5GW01, G28W01, and G21GW01, and SEC34-MW-03) displayed elevated concentrations of dissolved barium with respect to all surface waters.

Piper Diagram

Ion concentrations were input to the computer program Aquachem in mM concentrations. The program converts the data to milliequivalents per liter (meq/L) and plots them on a tri-linear piper diagram. A Piper Diagram is a tri-linear diagram consisting of two triangles, and one diamond. On the left-hand triangle, each of the cations were plotted as a percentage of the total cations in (meq/L). On the right-hand triangle, the anions were plotted as a percentage of the total anions in meq/L. Once the cations and anions were plotted on the lower triangles, the compositions were projected into the upper diamond following lines that are parallel to the outer sides of the triangles. A point was plotted to represent the overall major ion chemistry of the water sample where the two points meet in the upper diamond. Regions of the diamonds are used to classify water samples based on their dominant ions.

For instance, the fresh water samples BBCW06GW, FKS9GW01, and L31ESW08 had Ca^{2+} as the dominant cation and HCO_3^- or CO_3^{2-} as the dominant anion, and a plot near the left corner of the diamond (Figure 11). Such water would be described as calcium-bicarbonate or carbonate type water, which would be typical of water in contact with limestone. Seawater would be dominated by the ions Na^+ and Cl^- , would plot near the right corner of the diamond, and would be called a sodium-chloride type water. The surface water and groundwater samples of Biscayne Bay, along with the surface water samples of the cooling canals, groundwater from wells L5GW01, L3GW01, and samples L31EDC01B and L31ESW05 could all be described as sodium-chloride type water and plotted on top of each other near the right corner of the diamond. Piper diagrams could also be used to identify mixing of different types of waters. For instance, many of the water samples fell in the diamond on a line between the fresh calcium-bicarbonate type waters and the sodium-chloride (seawater) type waters. These waters could be described as a mixing of these two water types. Groundwater samples SEC34-MW-03-FS, G21GW01, and COH-MW-Trig, along with sample L31ESW01T, fell along a line from the sodium-chloride (seawater) samples toward the upper corner of the diamond, indicating that these waters were mixtures of a seawater-type water with another type of water that contained higher concentrations of calcium. Interestingly, the groundwater from the Floridan aquifer well (FLOGW01) plotted by itself on the piper diagram (Figure 12).

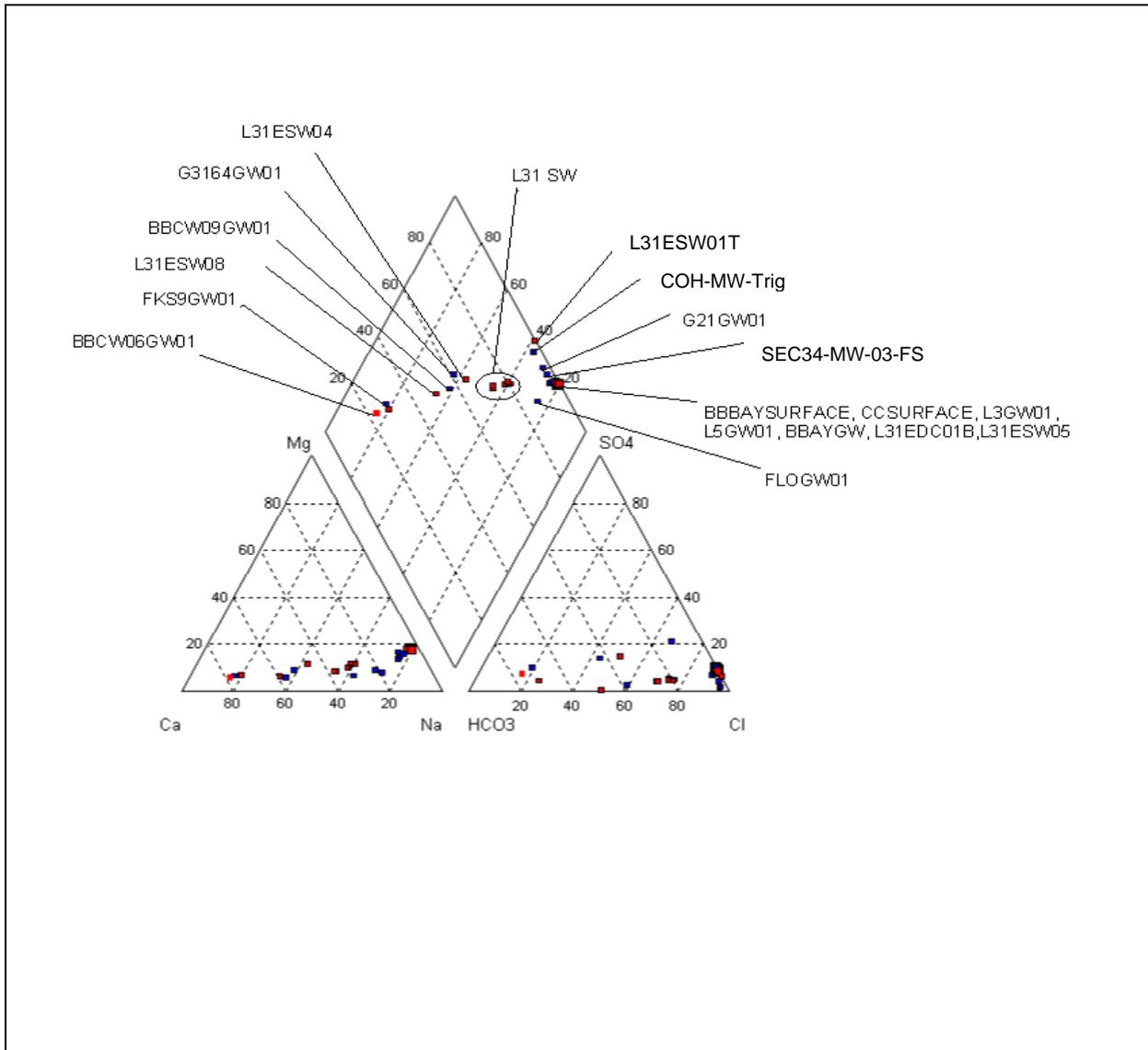


Figure 12. Piper diagram of groundwaters (blue squares) and surface waters (red squares).

Statistics

Correlative Analysis

A statistical correlation analysis was performed on all ions that had a complete data set associated with each sample site (Table 2). There are some ions which have partial data that were included in other analyses but not in this statistical test. Chloride, sulfate, bromide, sodium, potassium,

calcium, magnesium and strontium were all strongly positively correlated with each other. Alkalinity and fluoride were weakly correlated with the other ions.

Table 2. Statistical Correlative Analysis of Dissolved Ions in all Sampled Waters.

	Alkalinity as CaCO ₃	Chloride	Sulfate	Fluoride	Bromide	Sodium	Potassium	Calcium	Magnesium	Strontium
Alkalinity as CaCO ₃	1									
Chloride	-0.10023	1								
Sulfate	-0.15307	0.985133	1							
Fluoride	-0.29204	0.441093	0.459053	1						
Bromide	-0.17405	0.974504	0.982664	0.440819	1					
Sodium	-0.13171	0.997396	0.983482	0.462591	0.972488	1				
Potassium	-0.21544	0.985381	0.982288	0.497814	0.969636	0.99209	1			
Calcium	0.034973	0.960832	0.930469	0.331797	0.93196	0.955934	0.9181888	1		
Magnesium	-0.11584	0.998076	0.983838	0.46258	0.968986	0.998647	0.9892362	0.9536703	1	
Strontium	-0.06366	0.98711	0.974045	0.447594	0.966754	0.985558	0.9666457	0.9798638	0.982665751	1

Classification Diagram

The classification analysis was completed on sites that contained concentration values for alkalinity, chloride, sulfate, magnesium, calcium, sodium, potassium, fluorine, bromide, δD , $\delta^{13}C$, $\delta^{18}O$, and strontium. The significance of this analysis was in the qualitative classification of related water chemistries (Figure 13).

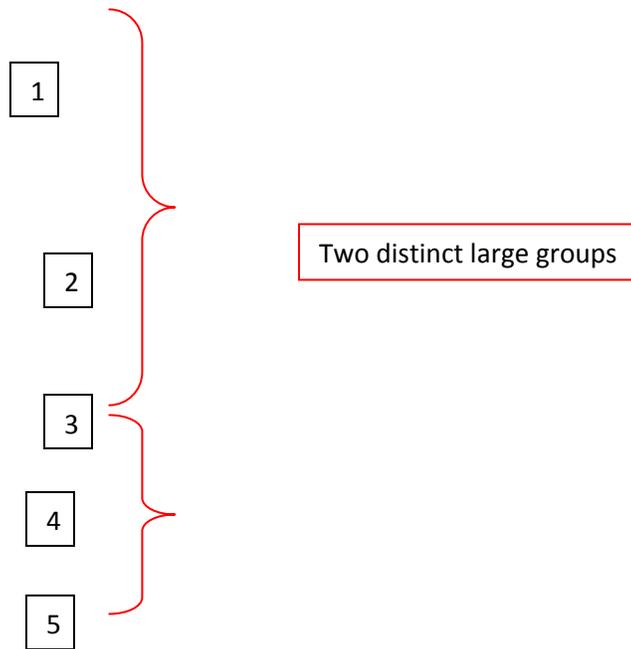


Figure 13. Dendrite Classification Cluster Analysis of Water Samples. Sample sites are on the far left-hand side of the graph. Lines indicate the relation of each cluster to the other clusters calculated for the parameters indicated in the upper right-hand corner of the graph. Five clusters were recognized within the sample group with two distinct larger groups, indicated by the right-hand side of the graph.

Sites were clustered into five groups:

- 1) BBCW6GW01, FKS9GW01, G3164GW01, BBCE9GW0, FLOGGW01, L31ESW07, BBCW4GW01, BBCW5GW01, FKS4GW01, G21GW01
- 2) BBCW10SW, L31EDC01, BBSW05, BBCW10GW01, BBSW02, BBSW03, BBSW04, BBSW01, BBCW10GW02
- 3) G28GW01
- 4) CCSSW01T, CCSSW02B, CCSSW01B, CCSSW04B, CCSSW05T, CCSSW03B, CCSSW05B
- 5) CCSSW04T, L3GW01, L5GW01

The first group includes fresh Biscayne aquifer groundwater, fresh water in the L31E canal and the Upper Floridan aquifer groundwater. The second group included Biscayne Bay surface, groundwater wells from Biscayne Bay, as well as brackish surface water from the L31E canal. Groundwater from well G28GW01 did not cluster with any group, but instead fell in place in the diagram between the Biscayne PO# 4500035001

Bay seawater samples and the cooling canal samples. Cooling canal surface samples clustered into group four and group five, along with groundwater from wells L3GW01 and L5GW01.

Mixing Models

Binary Mixing

For this report, binary mixing models were limited to groundwater wells that had elevated concentrations of chloride (L3GW01, L5GW01, and G28GW01) and a well that had a relatively low chloride concentration, but was in relatively close proximity to the cooling canals (G21GW01). For the final report, mixing models will be run on all ground and surface waters with elevated chloride levels. Two sets of Binary mixing models were run, 1) one using the end-members cooling canal surface water and fresh groundwater (CCSSW-FGW), and 2) a second using Biscayne Bay surface water and fresh groundwater (BBSW-FGW). Average values for the end-members of the cooling canal surface water, fresh groundwater, and Biscayne Bay surface water were calculated for each ion and isotope used. End-member proportions were then calculated utilizing chloride, bromine, sodium, potassium, oxygen and hydrogen isotopes (Tables 3A, 4), and the results were compared between all ions for consistency among the geochemical models (Tables 3B, 4).

Table 3 A, B. Binary Mixing Model Results of Cooling Canal Surface Water (CCSW) Mixing with Fresh Groundwater (FGW) A) Average Ion Concentration and Isotope Ratio Values for the End-Members B) Percentage of Cooling Canal Surface Water by Ion/Isotope and Average Fresh Groundwater and Cooling Canal Water Input by Site with Standard Deviation (SD) and Standard Error (SE) in Percentage.

A.

End Member	Cl ⁻ (mM)	Br ⁻ (mM)	Na ⁺ (mM)	K ⁺ (mM)	δ ¹⁸ O	δD
CCSSW	1038.668	1.173	857.982	18.882	6.111	38.404
FGW	23.792	0.003	15.926	0.248	-1.328	-4.477
BBSW	509.455	0.681	480.499	12.460	2.353	18.924

B.

Site	Cl ⁻ CCSSW (%)	Br ⁻ CCSSW (%)	Na ⁺ CCSSW (%)	K ⁺ CCSSW (%)	δ ¹⁸ O CCSSW (%)	δD CCSSW (%)	Average CCSSW (%)	Average FGW (%)	SD (%)	SE (%)
G21GW01	7.4	19.1	6.6	1.9	0.1	3.3	6.3	93.7	6.9	2.8
G28GW01	26.6	38.2	33.0	19.5	30.6	40.7	31.5	68.5	7.7	3.1
L3GW01	84.4	99.2	87.0	94.2	95.9	93.7	92.4	7.6	5.6	2.2
L5GW01	76.9	94.9	78.7	88.7	78.0	69.0	81.1	18.9	9.2	3.7

For the binary mixing model with a cooling canal end-member and a fresh groundwater end-member, Wells L3GW01 and L5GW01 had relatively low mixing proportions of fresh groundwater at 7.6% ±2.2% and 18.9% ±3.7% respectively, and reversely, high proportions of cooling canal surface water (81-92%). The G28GW01 well had a modeled fresh groundwater input percentage of 68.5% ± 3.1% and a cooling canal input of 31.5% ± 3.1%, while G21GW01 had a high fresh groundwater percentage of 93.7% ± 2.8%.

Table 4. Input percentage of Biscayne Bay Surface Water (BBSW) and Fresh Groundwater (FGW) determined by binary mixing models for wells G21GW01 and G28GW01.

Site	Cl ⁻ BBSW (%)	Br ⁻ BBSW (%)	Na ⁺ BBSW (%)	K ⁺ BBSW (%)	δ ¹⁸ O BBSW (%)	δD BBSW (%)	Average FGW (%)	Average BBSW (%)	SD (%)	SE(%)
G21GW01	84.6	67.1	88.1	97.1	99.8	93.9	88.7	11.3	12.2	5.0
G28GW01	44.5	34.0	40.2	70.2	38.2	25.4	42.0	58.0	15.2	6.2

The binary mixing diagram utilizing Biscayne Bay surface water (BBSW) and fresh groundwater (FGW) was completed for G28GW01 and G21GW01 (Table 4). Binary model results from G28GW01 display a fresh groundwater input of 42.0% ± 6.2 % and a Biscayne Bay surface water input of (58% ± 6.2 %). This result could be compared to the CCSW-FGW binary mixing model, which produced a fresh groundwater input that was higher (68.5% ± 3%). The salinities in wells L3GW01 and L5GW01 were higher than Biscayne Bay surface waters and could not be explained by the end-members used in this model. In both binary mixing model end-member sets (CCSW-FGW and BBSW-FGW), bromide produced the lowest mixing proportions of groundwater. Note that Br⁻ had the highest scatter of data (Fig. 4) for estimation of the cooling canal surface water end-member, which may be affecting the modeled estimations.

Ternary mixing diagram

A ternary mixing diagram with three mixing components and three end-members was constructed using chloride and dissolved barium (Fig. 14). The three end-members were Biscayne Bay surface water, cooling canal surface water, and fresh groundwater (FKS4GW01). This mixing model concentrated on groundwater as most surface sites were deplete in dissolved barium relative to the groundwater sites (Fig 11). Results of tie line calculations for each well within the boundaries of the

mixing members are presented in Table 5. Samples L3GW01, BBCW10GW01, and G28GW01 were a mixture of cooling canal surface water, fresh groundwater, and Biscayne Bay surface water. Groundwater sample L5GW01 appeared to be a direct mixture of cooling canal surface water and fresh groundwater with no input from Biscayne Bay surface water. The fresh groundwater input estimated from the ternary mixing model for sample L5GW01 (25%), and the cooling canal surface water input of (75%) was similar to the estimates of fresh groundwater (18.9 % ± 3.7), and cooling canal surface water input (81.1 ± 3.7) calculated by using simple binary mixing models (Table 3B).

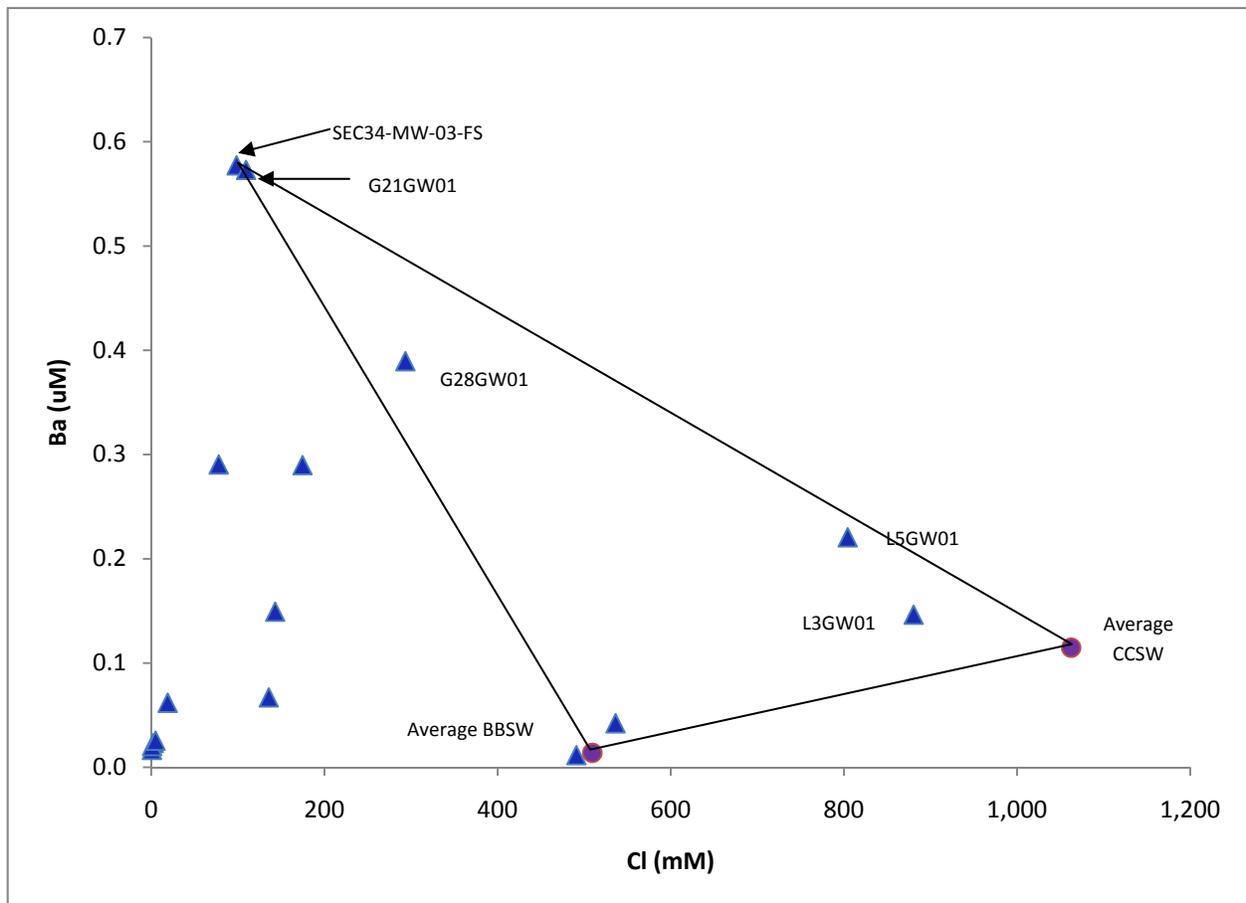


Figure 14. Ternary Tie-Line Mixing diagram of Dissolved Barium and Chloride concentrations. Purple circles are average surface water end-members. Blue triangles are groundwater samples. The triangle represents the mixing area of these three end-members, and sample points that fall within the boundaries are a mixture of the three.

Table 5. Biscayne Bay Surface water (BBSW), cooling canal surface water (CCSSW) and fresh groundwater (FGW) contribution percentages from the ternary mixing diagram of dissolved Barium vs. chloride.

Site	BBSW %	CCSSW %	FGW %
G28GW01	25	10	65
L3GW01	11	78	11
L5GW01	0	75	25
BBCW10GW01	86	7	7

Strontium Stable Isotopes

Data

Surface water samples

Strontium isotope ratios of surface waters are represented on a map in figure 15 and summarized with all samples in Table 6. A strontium isotope ratio value of < 0.7091 represents water that has some component of older (Floridan) water input. Most surface waters have $^{87}\text{Sr}/^{86}\text{Sr}$ slightly lower than the nominal $^{87}\text{Sr}/^{86}\text{Sr}$ value for modern seawater of ≈ 0.70920 , except for samples collected along the coast at the Card Sound Canal and S20 and seawater sample BBSW03. Surface water samples from the Turkey Point cooling canals have the lowest $^{87}\text{Sr}/^{86}\text{Sr}$, indicating a possible component of strontium from the Floridan aquifer in the cooling canal water. Samples CCSSW5B and CCSSW5T from the eastern margin of the canals contains strontium with higher $^{87}\text{Sr}/^{86}\text{Sr}$, more like seawater and very similar to the sample collected at the “Benthic Feature” just outside the canals. Taking a value of 0.708176 for Floridan groundwater and assuming a simple mixture between that value and modern seawater, sample CCSSW01T (the lowest $^{87}\text{Sr}/^{86}\text{Sr}$ of the canal samples) would contain a maximum 16% Floridan-derived Sr, and the other samples would contain less. This value represents a maximum because there may also be addition of slightly less radiogenic strontium from dissolution of very young near-surface limestone. The importance of equilibration of surface water with shallow limestone is impossible to evaluate without analyses of the shallow limestones themselves (and preferably a series of analyses with depth), but the $^{87}\text{Sr}/^{86}\text{Sr}$ of several ground and surface waters appear to be too low to be explained by this mechanism alone.

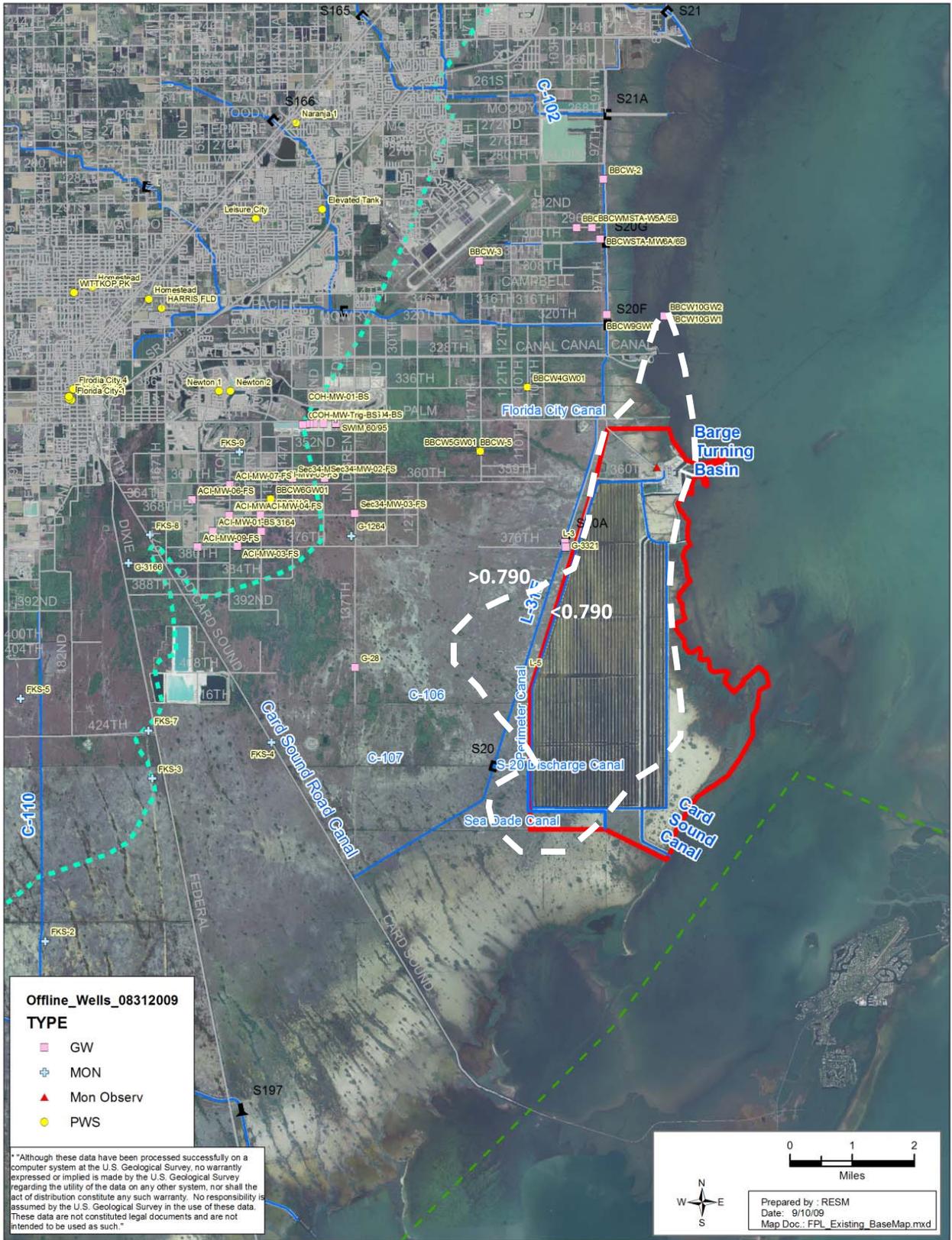


Figure 15. Map of strontium isotope values for sampled surface waters. The white 0.7901 dashed line indicates the strontium value that can only be explained by mixing with some percentage of older Floridan groundwater influence. Samples inside the dashed line are influenced by

Groundwater samples

Strontium isotope ratios of groundwaters are represented on a map in figure 16 and summarized with all samples in Table 6. Groundwater samples analyzed thus far have strontium isotope ratios slightly but distinctly lower than modern seawater. Some of this shift may represent equilibration of near-surface groundwater with young, shallow limestone having $^{87}\text{Sr}/^{86}\text{Sr}$ slightly lower than modern seawater, particularly waters with low Sr concentrations. Well samples G28GW01 and L5GW01 have low $^{87}\text{Sr}/^{86}\text{Sr}$ at high Sr^{2+} concentrations that are unlikely to be produced by equilibration with shallow limestone alone.



Figure 16. Map of strontium isotope values for sampled groundwater. The white 0.7901 dashed line indicates the strontium value that can only be explained by mixing with some percentage of older Floridan groundwater influence. Samples inside the dashed line are influenced by Floridan inputs; samples outside the dashed line are similar to modern seawater.

Table 6. Stable isotope ratios of ⁸⁷Sr to ⁸⁶Sr for Biscayne Surface Water, Cooling Canal Surface Water and Groundwater.

Sample	⁸⁷ Sr/ ⁸⁶ Sr	% error
CCSSW01T	0.709047	0.0011
CCSSW01B	0.709139	0.0016
CCSSW02B	0.709168	0.0014
CCSSW04T	0.709168	0.0011
FLOG01	0.708249	0.0020
FLOG01	0.708247	0.0016
L31DCSW01B	0.709139	0.0011
L31ESW02B	0.709198	0.0010
L31ESW03B	0.709000	0.0013
L31ESW07	0.709184	0.0013
L31ESW09	0.709305	0.0011
BBCW10SW01	0.709332	0.0013
BBCW4GW01	0.709138	0.0010
BBCW5GW01	0.709128	0.0011
BBCW10GW01	0.709159	0.0012
BBCW9GW01	0.709159	0.0011
G21GW01	0.709214	0.0015
G28GW01	0.708985	0.0012
L5GW01	0.709123	0.0013
CARD SOUND CANAL	0.709278	0.0013
PALM & L31E	0.709239	0.0012
BENTHIC FEATURE	0.709207	0.0011
S20WEST	0.709290	0.0013

Strontium appears to behave conservatively in the cooling canal waters and is concentrated to ≈ 15 mg/L, compared with only 3.3 mg/L in the sample from the Floridan aquifer (Figure 17). This means that a large proportion of Floridan water is needed to measurably shift the composition of the cooling canal water. Nevertheless, a surface low- $^{87}\text{Sr}/^{86}\text{Sr}$ anomaly is seen corresponding closely to the canals themselves. This is indicated by the white dashed contour in both figure 15 and 16 corresponding to $^{87}\text{Sr}/^{86}\text{Sr} = 0.7091$.

Surface water samples L31ESW03B and L31DCSW01B also have Sr isotope ratios distinctly lower than modern seawater and comparable to values in the cooling canals. This suggests that water from the cooling canals is spreading in the surface to the westward in the southwestern area of the canals. The area of low $^{87}\text{Sr}/^{86}\text{Sr}$ is much broader to the west of the cooling canals in the groundwater samples than in the surface water. The white dashed line again represents an approximate contour of $^{87}\text{Sr}/^{86}\text{Sr} = 0.7091$. This contour is shown as closed to the west, but this is not actually known due to the sparse availability of sampling. The lowest values are found in samples BBCW4GW01 from just NW of the power plant, L5GW01 from immediately west of the cooling canals, and G28GW01, one of the wells to the west of the cooling canals.

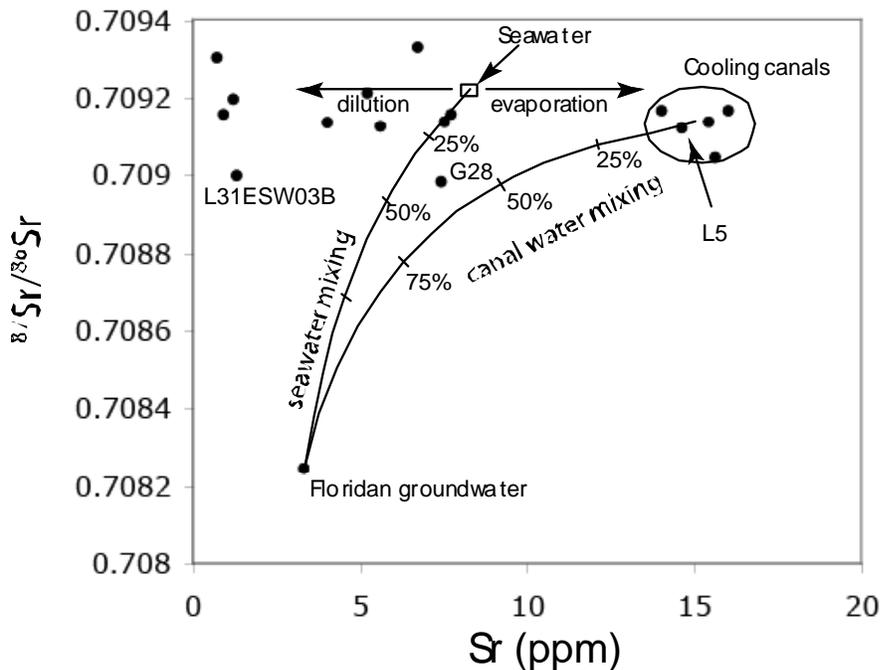


Figure 17. Graphical summary of the data analyzed, with curves plotted for mixing between Floridan groundwater and canal water, and between Floridan groundwater and seawater. The tick marks on the curves indicate the proportion of Floridan groundwater in the mixture.

Many of the surface water samples are represented by values of $^{87}\text{Sr}/^{86}\text{Sr}$ between 0.70910 and 0.70915, which are slightly low for seawater and may represent the surficial aquifer composition. Most of the samples from the L31E canal are representative of this. However, samples including L31ESW08 and the lowest of the cooling canal samples fall below this line and probably contain Sr from a deeper source such as the Floridan. Based on the simple mixing models, water in the cooling canals could be derived from evaporation of seawater with a small admixture (about 5-15%) of Floridan groundwater (Figure 17). There is not much evidence that this canal water has subsequently remixed with Floridan groundwater, although groundwater sample L5GW01 plots indistinguishably with the cooling canal water samples. The two samples of seawater analyzed for this study, BBCW10SW01 and BBSW03, plot along the 2 component mixing curve for seawater and the FLOGW01 well (Figure 17); the significance of this should be investigated with further sampling and analysis. Sample G28GW01 has the lowest strontium isotope ratios measured yet from any of the monitoring wells, and was collected about 2.5 miles west of the cooling canals. This sample in particular requires strontium from a deeper source than seawater or the surficial aquifer to explain its composition.

Discussion

The ionic signature of the cooling canals was distinct in that they contained the highest concentrations of the major cations and anions. Most of the ionic concentrations (Ca^{2+} , Na^+ , Br^- , Mg^{2+} , K^+ , SO_4^{2-} , and Sr^{2+}), when plotted linearly with chloride and the fresh groundwater on one end, Biscayne Bay surface water in the middle, and the cooling canals at the highest chloride levels. The high concentrations of the ions in the cooling canals could be explained by evaporation of Biscayne Bay surface water. Furthermore, the high concentrations of the major cations and anions in the cooling canals allowed for identification of cooling canal water in one of the canals (L31DCSW01B) and groundwater wells (L3GW01, L5GW01) in close proximity to the cooling canals.

Dilution of cooling canal water with fresh groundwater or Biscayne Bay surface water resulted in lower ionic concentrations that were similar to Biscayne Bay surface water. This does not allow for identification of inputs from the cooling canals from Biscayne Bay seawater. The one exception was dissolved barium, which occurred in different concentrations in each end member of interest (fresh groundwater, cooling canal water, and Biscayne Bay surface water). This tracer was useful (as indicated by the ternary mixing diagram in Figure 13), however, the error analysis was difficult to determine with so few samples.

The piper diagrams indicated the presence of two mixing lines (Figure 11). One line represented the mixture of fresh water in contact with limestone and a seawater-type water. The other line represented the mixture of seawater-type water and water higher in calcium. The elevated concentration of calcium in these samples was also observed in Figure 7. This second type of water was similar to deeper groundwater (> 100 ft) observed in the C-111 basin by Price et al. 2006, and was described as connate water, possibly from an older seawater intrusion event. This may suggest that the elevated sodium-chloride concentrations in wells around COH-MW-Trig may be related to interception of this “connate” water, as opposed to mixing with cooling canal surface water or Biscayne surface water.

The L31E surface canal samples were generally low in chloride and related to the FKS9GW01 and FKS4GW01 groundwater. Since the chloride levels in these surface water samples were less than that observed in the Biscayne Bay surface water, a distinction between the sources of the chloride, either seawater or the cooling canals could not be determined using salinity as a proxy. Given the high ion concentrations and salinity of the cooling canal water, it would be expected to sink into the aquifer system and may bypass underneath the L31E canal with only minor interaction. Multi-level wells in between the cooling canal system and to the west of the L-31E canal could confirm the location of the cooling canal water migration path.

A correlation analysis indicated that chloride, sodium, calcium, strontium, magnesium, sulfate, and potassium all had a strong positive correlation across the data set, and indicated that it may not be necessary to analyze for all these ions, selecting only a few for analysis. Of these analyses, chloride is the most important as it is a conservative constituent. Alkalinity and fluoride had poor correlation with the other ions and each other. This lack of correlation in itself is not a reason to stop analyzing for an ion. In these non-correlative cases the relationship of the concentrations may be useful in the Piper diagrams, (such as alkalinity) and the ternary diagrams, as is the case for dissolved barium. Dissolved barium would be non-correlative and would still be useful as a tracer. Classification analysis presented a good qualitative representation of the sample sites in the study and their relationship to one another. Generally, fresh groundwater and L31E surface waters clustered together, while Biscayne Surface water and cooling canal surface water were in their own cluster group. Wells G28GW01, L3GW01, and L5GW01 all seem to be influenced by the cooling canals, and in the case of G28GW01 influenced by Biscayne surface water as well (Fig 12). This analysis would be useful in describing water provenance and understanding the spatial relationship of the sampled waters.

The binary mixing models were robust with a low (3-9% error) among the ion/isotope models. However, the binary mixing models were only effective at describing partial mixing between fresh groundwater and either Biscayne Surface water or cooling canal water. This limitation did not allow for differentiation of the two saline sources and thus the cause of the salinization of groundwater. The ternary mixing diagram was more useful in differentiating between the two saline sources. The ternary model had limitations, however, in that it could not successfully describe the saline waters in most of the groundwater wells west and north of G28GW01 (Fig 1). This may be a result of the presence of the “connate” water described in the Piper diagrams (Fig 11). The second limitation was the analysis of error, as one end-member (fresh dissolved barium rich groundwater) was defined by one sample. This limitation could be remedied by multiple groundwater samples and the sampling of additional wells. The models were conclusive in describing the inputs of the cooling canal surface water to the groundwater in wells L3GW01 and L5GW01. The ionic and isotopic modeling data suggested significant inputs from the cooling canal water in these two wells. This result was further supported by both the binary and ternary mixing diagrams and could only be attributed to the mixing of either Biscayne Bay water or fresh groundwater with the cooling canal water. However, there was not a strong indication from this ion analysis of a presence of cooling canal water in well G28GW01. The ion concentrations in G28GW01 could be explained as a mixture of fresh groundwater with either Biscayne surface water or cooling canal water.

Strontium isotope ratios indicated a significant difference between Floridan groundwater and modern Biscayne Bay surface waters. This distinction could be useful in determining the presence of Floridan groundwater in samples around the cooling canal system. Wells L3GW01, L5GW01, and G28GW01, surface canal sample L31DCSW01B, and the cooling canal surface samples all have lower $^{87}\text{Sr}/^{86}\text{Sr}$ isotope ratios than can be explained by equilibration with modern Biscayne Bay surface water. This implies a proportional input of Floridan groundwater.

Conclusions and Recommendations

- The Florida Power and Light (FPL) Turkey Point Cooling Canals display hypersaline conditions, including the highest concentrations of all cations and anions of waters sampled in this study. This concentration makes them distinctive in the immediate vicinity around the cooling canals.

- When mixed with significant amounts of fresh groundwater or seawater, the cooling canal water becomes indistinguishable from surface Biscayne Bay waters with respect to the major cations and anions.
- Dissolved barium concentrations show a distinction between the cooling canal water and the surface Biscayne Bay water and can be used in a ternary mixing diagram.
- Piper diagrams show two distinct sources of fresh and brackish groundwater: one related to the FKS9GW01 well, and one source defined by the COH-MW-Trig well. The COH-MW-Trig well is similar to water sampled in previous studies (Price and Swart, 2006) and may be remnant “connate” water from a previous saltwater intrusion event.
- An analysis of multiple ions indicate that the concentrations in wells L3GW01 and L5GW01 can only be derived from significant volumes of cooling canal surface water mixing with Biscayne Bay surface water and fresh groundwater.
- Wells G21GW01 and G28GW01 have higher salinities than background freshwater. Using dissolved Barium concentrations in a ternary mixing diagram G28GW001 appears to be a mixture of fresh groundwater, Biscayne Bay water and cooling canal surface water. Piper diagrams suggest the increased salinity at G21GW01 appears to be related to the “connate” water found in COH-MW-Trig well.
- Better depth control and spatial sampling of groundwater around the cooling canals (north, south, west and east) would improve ion/isotope modeling analysis.
- Multi-depth well clusters need to be installed to the west, north, south and east of the cooling canals to properly characterize the spatial extent and vertical structure of any high salinity water moving away from the cooling canals.
- An analysis of stable strontium isotope data suggests influence of Floridan groundwater in wells L3GW01, L5GW01, and G28GW01, in L31 surface sample L31DCSW01B and in the cooling canal system.

The ionic data has promise as a qualitative tracer in the study area. With further development and increased spatial and temporal sampling, some ions (Cl^- , Na^+ , F^- and Ba^{2+}) and isotopes of oxygen and hydrogen could be good quantitative tracers. The ionic data is also critical in determining the influence of the “connate” water observed in well COH-MW-Trig.

While not in the scope of this report, elevated tritium levels were observed in the groundwater and surface water immediately adjacent to the cooling canal system, and were highly elevated within the cooling canal system. This tracer is worth further investigation and would be useful as a definitive quantitative tracer.

The spatial sampling of this pilot study is insufficient to describe the interaction of the cooling canal waters with the surrounding natural waters. There remain questions as to the construction, screened depth, and total depth of some of the wells sampled. There is a lack of data in the groundwater to the east under Biscayne Bay, and to the north, south, and east of the cooling canals. Multi-level wells should be installed to properly determine the extent and depth of the cooling canal/groundwater interaction. Without a better spatial sampling, it would be premature to rule out any ionic or isotopic constituent as a possible tracer. The interaction of cooling canal water with Biscayne Bay groundwater will be geochemically distinct to interaction with fresh ground/surface water, and different geochemical parameters would be useful in each system.

Appendix 1. Summary of Dissolved Ion and Stable Isotopic Compositions of Oxygen and Hydrogen. All ion values are in mM and μM . Isotopes are presented in standard δ notation as ‰.

*To convert to mg/L multiply the mM value by the molecular weight of the element in question. N/A = parameter not analyzed

Site	Alk as CaCO_3 (mM)	Chloride (mM)	Sulfate (mM)	Fluoride (mM)	Bromide (mM)	Sodium (mM)	Potassium (mM)	Calcium (mM)	Magnesium (mM)	Strontium (mM)	Barium (μM)	$\delta^{18}\text{O}$ ‰	δD ‰
BBCW10SW01	1.66	408.99	67.67	0.042	0.638	403.65	10.49	8.13	45.26	0.077	0.0022	1.99	18.72
BBSW01	1.53	524.64	76.40	0.047	0.663	474.12	11.97	9.53	53.08	0.086	0.0029	2.3	21.59
BBSW02	1.46	547.20	83.27	0.047	0.726	508.92	13.22	9.98	57.60	0.095	0.0728	2.54	18.42
BBSW03	1.42	552.84	85.76	0.047	0.738	517.62	13.81	10.33	58.42	0.098	0.0015	2.47	18.02
BBSW04	1.38	541.56	82.64	0.047	0.726	517.62	13.20	9.76	58.84	0.093	0.0022	2.49	17.74
BBSW05	1.59	479.51	68.92	0.058	0.593	461.07	12.07	9.18	52.25	0.087	0.0015	2.34	19.06
CCSSW01B	2.13	1088.77	150.00	0.037	1.176	878.64	19.11	20.03	104.09	0.176	0.1078	6.22	40.41
CCSSW01T	2.05	1085.94	132.85	0.037	1.126	896.04	19.75	20.71	106.15	0.178	0.1464	6.05	38.4
CCSW02B	2.17	1083.12	151.25	0.037	1.277	900.39	19.90	20.96	109.44	0.183	0.1129	6.21	41.49
CCSSW03B	2.12	1032.35	156.86	0.037	1.402	809.05	17.80	18.89	97.92	0.162	0.1151	6.15	36.15
CCSSW04B	2.35	1037.99	140.02	0.037	1.151	848.19	18.95	19.81	102.86	0.172	0.1019	5.95	34.34
CCSSW04T	2.22	930.81	127.55	0.037	1.039	787.30	17.14	18.51	94.22	0.160	0.1005	5.74	40.44
CCSSW05B	2.09	998.51	99.17	0.037	0.951	865.59	18.77	19.81	99.98	0.167	0.1187	6.23	38.68

Site	Alk as CaCO ₃ (mM)	Chloride (mM)	Sulfate (mM)	Fluoride (mM)	Bromide (mM)	Sodium (mM)	Potassium (mM)	Calcium (mM)	Magnesium (mM)	Strontium (mM)	Barium (μM)	δ ¹⁸ O ‰	δD ‰
CCSSW05T	2.09	1046.46	159.67	0.037	1.264	878.64	19.64	20.71	106.56	0.176	0.0983	6.34	37.34
L31ESW07	1.51	14.07	0.37	0.008	0.013	11.40	0.19	1.80	1.28	0.012	N/A	3.36	20.34
L31ESW09	2.21	1.27	0.34	0.008	0.001	1.14	0.12	2.12	0.20	0.009	0.0029	-0.66	-3.77
L31EDC01B	2.34	431.56	56.13	0.021	0.375	395.39	8.49	11.10	46.90	0.086	0.1318	2.65	16.16
L31ESW01B	2.09	14.05	1.35	0.009	0.019	11.57	0.22	2.64	1.09	0.014	0.0007	0.77	8.23
L31ESW01T	2.06	13.71	1.36	0.009	0.018	11.74	0.22	2.69	1.11	0.014	N/A	N/A	N/A
L31ESW02B	2.06	11.99	1.22	0.008	0.026	10.13	0.18	2.69	0.86	0.014	0.0007	0.12	7.37
L31ESW02T	2.08	11.90	1.14	0.009	0.016	10.18	0.18	2.72	0.87	0.014	N/A	N/A	N/A
L31ESW03B	2.34	10.18	0.89	0.009	0.015	8.96	0.14	2.99	0.67	0.014	0.0007	-0.7	-1.31
L31ESW03T	2.28	10.21	0.90	0.009	0.015	8.70	0.13	2.97	0.66	0.014	N/A	N/A	N/A
L31ESW04	1.56	3.70	1.61	0.011	0.006	3.27	0.27	1.76	0.44	0.011	N/A	N/A	N/A
L31ESW05	1.97	204.21	32.12	0.021	0.275	184.86	4.19	5.86	21.56	0.044	N/A	N/A	N/A
L31ESW06	2.12	13.45	1.18	0.008	0.018	10.18	0.20	2.50	1.02	0.013	N/A	N/A	N/A
L31ESW08	2.44	4.09	0.06	0.007	0.004	3.01	0.08	2.57	0.28	0.008	0.0007	0.48	8.37
BBCW10GW1	1.69	490.79	75.78	0.042	0.688	461.07	12.05	9.03	51.84	0.088	0.0117	1.45	17.8
BBCW10GW2	1.21	535.92	83.58	0.037	0.738	474.12	12.74	10.78	52.25	0.100	0.0422	1.37	18.01
BBCW4GW01	3.21	135.67	15.66	0.011	0.188	118.75	2.03	7.14	11.77	0.045	0.0670	-0.83	2.45
BBCW5GW01	2.72	174.60	11.20	0.010	0.225	154.85	1.64	10.25	13.99	0.063	0.2898	-0.86	0.27
BBCW6GW01	2.02	0.72	0.46	0.009	0.001	0.89	0.19	2.28	0.18	0.010	0.0167	-0.95	-5.45

Site	Alk as CaCO ₃ (mM)	Chloride (mM)	Sulfate (mM)	Fluoride (mM)	Bromide (mM)	Sodium (mM)	Potassium (mM)	Calcium (mM)	Magnesium (mM)	Strontium (mM)	Barium (μM)	δ ¹⁸ O ‰	δD ‰
BBCW9GW01	1.72	2.82	1.38	0.011	0.005	2.78	0.26	1.89	0.34	0.011	0.0233	-1.59	-3.22
COH-MW-Trig	1.66	77.85	1.68	0.007	N/A	43.41	0.48	10.70	2.25	0.061	0.2905	-1.27	-0.58
FKS4GW01	2.03	143.01	20.77	0.011	0.200	123.97	2.15	7.16	11.97	0.043	0.1493	-0.94	0.49
FKS9GW01	2.00	0.91	0.67	0.009	0.001	0.87	0.19	1.92	0.17	0.010	0.0204	-1.37	-4.02
FLOGW01	2.06	18.90	8.95	0.116	0.025	22.23	0.62	1.26	2.48	0.038	0.0619	-1.84	-7
G21GW01	1.83	98.44	3.65	0.008	0.227	71.34	0.60	10.90	4.69	0.060	0.5774	-1.39	-3.05
G28GW01	2.14	293.35	42.72	0.010	0.451	293.61	3.89	13.22	30.49	0.084	0.3896	0.95	12.98
G3164GW01	1.98	4.99	0.31	0.010	0.006	3.32	0.04	2.54	0.25	0.020	0.0255	-1.7	-4.72
L3GW01	1.60	880.04	123.81	0.021	1.164	748.15	17.80	15.14	82.29	0.142	0.1464	5.81	35.69
L5GW01	1.86	803.88	140.96	0.016	1.114	678.56	16.78	15.67	75.29	0.167	0.2206	4.48	25.13
SEC34-MW-03-FS	1.87	109.44	2.96	0.008	N/A	71.77	0.56	9.56	3.80	0.054	0.5731	-1.03	-4.99

Appendix 2. Summary of Dissolved Ion and Stable Isotopic Composition of Oxygen and Hydrogen Data. All ion values are in mg/L. Isotopes are presented in standard δ notation as ‰. N/A = Parameter not analyzed, *To convert to mM divide the mg/L value by the atomic weight of the element in question.

Site	Alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Bromide (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Strontium (mg/L)	Barium (μg/L)	δ ¹⁸ O ‰	δD ‰
BBCW10SW01	166	14500	2170	0.8	51	9280	410	326	1100	6.72	0.3	1.99	18.72
BBSW01	153	18600	2450	0.9	53	10900	468	382	1290	7.57	0.4	2.3	21.59

Site	Alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Bromide (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Strontium (mg/L)	Barium (µg/L)	δ ¹⁸ O ‰	δD ‰
BBSW02	146	19400	2670	0.9	58	11700	517	400	1400	8.33	10	2.54	18.42
BBSW03	142	19600	2750	0.9	59	11900	540	414	1420	8.59	0.2	2.47	18.02
BBSW04	138	19200	2650	0.9	58	11900	516	391	1430	8.18	0.3	2.49	17.74
CCSSW01T	205	38500	4260	0.7	90	20600	772	830	2580	15.6	20.1	6.05	38.4
CCSSW02B	217	38400	4850	0.7	102	20700	778	840	2660	16	15.5	6.21	41.49
CCSSW03B	212	36600	5030	0.7	112	18600	696	757	2380	14.2	15.8	6.15	36.15
CCSSW04B	235	36800	4490	0.7	92	19500	741	794	2500	15.1	14	5.95	34.34
CCSSW04T	222	33000	4090	0.7	83	18100	670	742	2290	14	13.8	5.74	40.44
CCSSW05B	209	35400	3180	0.7	76	19900	734	794	2430	14.6	16.3	6.23	38.68
CCSSW05T	209	37100	5120	0.7	101	20200	768	830	2590	15.4	13.5	6.34	37.34
L31ESW07	151	499	12	0.147	1	262	7.59	72	31	1.01	N/A	3.36	20.34
L31ESW09	221	44.9	10.8	0.147	0.1	26.3	4.58	85.1	4.77	0.748	0.4	-0.66	-3.77
L31EDC01B	234	15300	1800	0.4	30	9090	332	445	1140	7.51	18.1	2.65	16.16
L31ESW01B	209	498	43.3	0.169	1.5	266	8.61	106	26.6	1.2	0.1	0.77	8.23
L31ESW01T	206	486	43.6	0.174	1.4	270	8.69	108	26.9	1.21	N/A	N/A	N/A
L31ESW02B	206	425	39.2	0.16	2.1	233	6.86	108	21	1.2	0.1	0.12	7.37
L31ESW02T	208	422	36.7	0.162	1.3	234	6.91	109	21.2	1.22	N/A	N/A	N/A
L31ESW03B	234	361	28.5	0.164	1.2	206	5.35	120	16.4	1.26	0.1	-0.7	-1.31
L31ESW03T	228	362	28.7	0.17	1.2	200	5.25	119	16.1	1.24	N/A	N/A	N/A
L31ESW04	156	131	51.6	0.2	0.5	75.2	10.7	70.6	10.8	0.929	N/A	N/A	N/A

Site	Alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Bromide (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Strontium (mg/L)	Barium (µg/L)	δ ¹⁸ O ‰	δD ‰
L31ESW05	197	7240	1030	0.4	22	4250	164	235	524	3.87	N/A	N/A	N/A
L31ESW06	212	477	37.8	0.156	1.4	234	7.69	100	24.9	1.16	N/A	N/A	N/A
L31ESW08	244	145	1.9	0.124	0.3	69.2	3.32	103	6.78	0.722	0.1	0.48	8.37
BBCW10GW1	169	17400	2430	0.8	55	10600	471	362	1260	7.73	1.6	1.45	17.8
BBCW10GW2	121	19000	2680	0.7	59	10900	498	432	1270	8.73	5.8	1.37	18.01
BBCW4GW01	321	4810	502	0.2	15	2730	79.5	286	286	3.98	9.2	-0.83	2.45
BBCW5GW01	272	6190	359	0.192	18	3560	64.2	411	340	5.56	39.8	-0.86	0.27
BBCW6GW01	202	25.7	14.9	0.178	0.1	20.5	7.43	91.4	4.43	0.907	2.3	-0.95	-5.45
BBCW9GW01	172	100	44.4	0.2	0.377	63.8	10.1	75.8	8.36	0.922	3.2	-1.59	-3.22
COH-MW-Trig	166	2760	54	0.132	N/A	998	18.9	429	54.7	5.35	39.9	-1.27	-0.58
FKS4GW01	203	5070	666	0.2	16	2850	84.2	287	291	3.75	20.5	-0.94	0.49
FKS9GW01	200	32.1	21.5	0.179	0.1	20.1	7.58	76.9	4.12	0.87	2.8	-1.37	-4.02
FLOGW01	206	670	287	2.2	2	511	24.2	50.7	60.3	3.29	8.5	-1.84	-7
G21GW01	183	3490	117	0.157	18.1	1640	23.4	437	114	5.24	79.3	-1.39	-3.05
G28GW01	214	10400	1370	0.198	36	6750	152	530	741	7.39	53.5	0.95	12.98
G3164GW01	198	177	10.1	0.191	0.5	76.3	1.71	102	6.15	1.79	3.5	-1.7	-4.72
L3GW01	160	31200	3970	0.4	93	17200	696	607	2000	12.4	20.1	5.81	35.69
L5GW01	186	28500	4520	0.3	89	15600	656	628	1830	14.6	30.3	4.48	25.13
SEC34-MW-03-FS	187	3880	95	0.144	N/A	1650	21.7	383	92.3	4.69	78.7	-1.03	-4.99

References

- Capo R.C., DePaolo, D.J. (1990) Seawater strontium isotopic variation from 2.5 million years ago to the present: *EScience*, 249, pp. 51-55.
- Chin, D.A., (1990) A Method to Estimate Canal Leakage to the Biscayne Aquifer, Dade County, FL. USGS Water Resources Investigation Report 90-4135.
- Cook P.G., Favreau G., Dighton J.C. and Tickell S. (2003) Determining natural groundwater influx to a tropical river using radon, chlorofluorocarbons and ionic environmental tracers. *J. Hydrol.*, 277:74-88.
- Fish, J.E., Stewart, M., (1991). Hydrogeology of the Surficial Aquifer System, Dade County, Florida: *U.S. Geological Survey Water-Resources Investigations Report 90-4108*.
- Fernald, E.A., Patterson, D.J., (1984) Water Resources Atlas of Florida. Florida State University, Tallahassee, FL, 291 pgs.
- Hannula , S.R., Esposito, K.J., Chermak J.A. , Runnells D.D., Keith, D.C., Hall L.E., (2003) Estimating Ground Water Discharge by Hydrograph Separation. *Groundwater*, Vol. 41, No. 3 pp. 368 – 375. Chin, D.A., (1990). A Method to Estimate Canal Leakage to the Biscayne Aquifer, Dade County, FL. USGS Water Resources Investigation Report 90-4135.
- Harvey, Judson, W., Krupa, Steven, L., Krest, James, M. (2002) Ground Water Recharge and Discharge in the Central Everglades. *Groundwater* Vol. 42, No. 7, pp. 1090-1102.
- James, E.R., Manga, M., Rose, T.P., Hudson , G.B., (2000) The Use of Temperature and the Isotopes of O, H, C, and Noble Gases to determine the pattern and spatial Extent of Groundwater Flow. *Journal of Hydrology*, Vo. 237, Nos. 1-2, 100-112.
- Klein, H., Hull, J.E., (1978) Biscayne Aquifer, Southeast Florida. *USGS Water Resource Investigation No. 72-102*.
- Kohout. F.A., (1960) Cyclic Flow of Salt Water in the Biscayne Aquifer of South-eastern Florida. *Journal of Geophysical Research*, Vo. 65, pp. 2133-2141.
- Leach, S.D., Klein, H., Hampton, E.R., (1972) Hydrologic Effect of Water Control and Management in Southeastern Florida. *Florida Department of Natural Resources*, Bureau of Geology Report No. 60.
- McArthur, J.M., Howarth, R.J., Bailey, T.R. (2001) Strontium isotope stratigraphy: LOWESS version 3: best fit to the marine Sr-isotope curve for 0-509 Ma and accompanying look –up table for deriving numerical age: *Journal of Geology*, 109, p. 155-170.
- Pinder, G., Jones, J.F., (1969) Determination of the Groundwater Component of Peak Discharge from the Chemistry of Total Runoff. *Water Resources Research*, Vo. 5, No. 2, pp. 438-445.
- Price, R. M. and Swart, P.K. (2006) Geochemical Indicators of Groundwater Recharge in the surficial aquifer system: Everglades National Park, Florida, USA, in Harmon, R.S. and Wicks, D., eds. *Perspectives on karst geomorphology, hydrology, and geochemistry -A Tribute volume to Derek C. Ford and William B. White*: GSA Special Paper 404, p 251-266, doi: 10.1130/2006.2404(21).
- Reese, R. S., Cunningham, K. J., (1999) Hydrogeology of the Gray Limestone Aquifer in South Florida, USGS Water Resources Investigation Report, 99-4213.
- Stalker, J. C., Price, R. M., Swart. P. K. (2009) Determining Spatial and Temporal Inputs of Freshwater, Including Submarine Groundwater Discharge to a Subtropical Estuary Using Geochemical Tracers, Biscayne Bay, South Florida. *Estuaries and Coasts*, Doi: 10.1007/s12237-009-9155-y.
- Stalker, Jeremy, C. (2008) Hydrological dynamics between a coastal aquifer and the adjacent estuarine system, Biscayne Bay, South Florida. Dissertation, Florida International University, 230 pgs.
- Swayze, L.J., (1987) Ground-water Flow Beneath Levee 35A from Conservation Area 2, Broward County, FL. USGS Water Resources Investigations Report, 87-4280.

Appendix D

STABLE ISOTOPES

Initial Report

Analysis of the Stable H, O, and C Isotopic Composition of Waters in the Vicinity of Turkey Point Power Plant, South Florida



**Partial fulfillment of SFWMD PO 4500034800
South Water Management District
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Turkey Point

Executive Summary

- The FPL cooling ponds contain mean $\delta^{18}\text{O}$ and δD values of + 6.11 (0.19) and + 38.4 (2.4) ‰ respectively. These waters have salinity values between 58.5 and 74.2. These $\delta^{18}\text{O}$ and δD values are the most positive values of any water samples measured in South Florida.
- These positive $\delta^{18}\text{O}$ and δD values can be modeled by evaporating seawater into an atmosphere with a relative humidity of 73 %.
- The carbon isotopic composition ($\delta^{13}\text{C}$) of the cooling ponds is -4.4 (.14)‰, compared to ~0 to -2 ‰ in Biscayne Bay and ~ -10‰ in some of the groundwater. The negative values originate from the oxidation of organic material by oxygen in the cooling canals and by sulfate in the groundwater.
- As a result of the relative humidity and interactions between various ions in the evaporated seawater, these $\delta^{18}\text{O}$ and δD values are approximately the highest values that can be attained. The $\delta^{18}\text{O}$ and δD values might actually become lower with further evaporation.
- Based on the stable isotopic data alone, the waters in the L-3 and L-5 wells could have been derived only by mixing cooling pond water with groundwater or Biscayne Bay water.
- Carbon isotopic data support the assessment made using the oxygen isotopic data and furthermore suggest that the water at G-28 originated from a mixture of groundwater represented by G-21 and Biscayne Bay/cooling canal water.
- Comparison of isotopic data from these wells with data collected from a well in 1988 suggests that in 1988, the saline waters, originally generated in the cooling canals, had not advanced as far into the groundwater as they are today.
- Further confirmation of the origin of the water will need the installation of additional nested wells on all sides of the cooling canals (including in the Bay) combined with seasonal monitoring of all geochemical parameters.

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Preface

This study was carried out in order to investigate the possible use of stable isotopes of H, C, and O as tracers of water from the Florida Power and Light (FPL) cooling canals at the Turkey Point nuclear facility. It has been suggested that the waters in the cooling canals, which are evaporated and denser than the adjacent groundwater, are and have been sinking and spreading radially from the canal cooling system, possibly contaminating the well fields in south Dade County. To this end, water samples were collected from a number of surface and well locations and analyzed for their stable H and O isotopic compositions as well as the C isotopic composition of the dissolved inorganic carbon.

Introduction

A useful and sometimes invaluable tracer for the origin of and processes affecting groundwater is contained within the stable isotopic composition of oxygen and hydrogen of the water molecule itself. Both oxygen and hydrogen contain more than one stable isotope. In the case of oxygen, there are three stable isotopes, ^{16}O , ^{17}O , and ^{18}O , and in the case of hydrogen two ^1H , and ^2H . These are measured as ratios of the less abundant isotope relative to the more abundant isotope and reported in parts per thousand relative to an international standard. In the case of oxygen the abundance of ^{18}O relative to ^{16}O is described by the following formula:

$$\delta^{18}\text{O} = \left[\frac{{}^{18}\text{O}/{}^{16}\text{O}_{\text{sample}}}{{}^{18}\text{O}/{}^{16}\text{O}_{\text{V-SMOW}}} \right] - 1 \times 1000$$

The standard is Vienna standard mean ocean water (V-SMOW). Although oxygen has another stable isotope (^{17}O), it has a lower abundance than ^{18}O , and the abundance of this isotope can be accurately predicted by measuring ^{18}O . If a sample has a value of 0 then it has an identical $^{18}\text{O}/^{16}\text{O}$ ratio to V-SMOW. If the sample has a negative value, it has less ^{18}O ; if it has a positive value it has more ^{18}O . As for hydrogen, the same equation can be used with the exception of substituting ^2H for ^{18}O and ^1H for ^{16}O .

Carbon is also found in groundwater in the form of dissolved inorganic carbon (DIC). Carbon is also reported in a similar notation to O and H, but relative to a standard known as V-PDB (Vienna Pee Dee Belemnite). The carbon isotopic composition of the water is contained in the DIC and is therefore much more susceptible to alteration by processes after collection. In particular, dissolution of dissolved carbonate or bacterial activity can change the value. For this reason it is important to filter the sample and eliminate all biological activity by adding a poison to the sample.

The processes that control the $\delta^{18}\text{O}$ and δD of surface waters are well known and have been described in a large number of papers (Gonfiantini 1986). As a result of the fractionation of water during evaporation, residual water bodies become enriched in the heavier isotopes of hydrogen and oxygen. The absolute isotopic composition that can be attained by an evaporating body is primarily dictated by the relative humidity of the

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atmosphere and to a lesser degree, by the temperature of evaporation, the isotopic composition of the atmospheric water vapor, and the salinity of the fluid being evaporated (Gonfiantini 1986). High isotopic values can be attained in environments of low relative humidity while the maximum $\delta^{18}\text{O}$ of evaporating waters in South Florida, which has a mean humidity of approximately 75%, is approximately +5 to +6 ‰. Although the behavior of $\delta^{18}\text{O}$ and δD during evaporation is similar, slight differences between these elements produces a different relationship between $\delta^{18}\text{O}$ and δD when compared to the meteoric water line (MWL), the relationship seen in precipitation (Craig and Gordon 1965). Progressive deviations from the MWL occur during the evaporation of fluids into atmospheres of progressively lower relative humidity. The non-zero intercept is termed the “DH excess”. Modeling of the relationship between $\delta^{18}\text{O}$ and δD can therefore be used to calculate the relative humidity, assuming knowledge of the temperature of evaporation and the isotopic composition of atmospheric water vapor (Gonfiantini 1986; Swart 1991).

Further complications in the relationship between salinity and isotopic composition can be introduced during the evaporation of saline fluids as a result of interaction between different ions in the solution. As a result of this interaction, during the final stages of evaporation, the $\delta^{18}\text{O}$ and δD values can actually decrease, producing a different relationship between the $\delta^{18}\text{O}$ and δD values (Gonfiantini, 1986).

The isotope hydrology in south Florida has been studied by a number of authors (Lloyd 1964; Meyers, 1990; Meyers et al. 1993; Price, 2001; Price and Swart 2006; Price et al. 2008; Price et al. 2003; Sternberg and Swart 1987; Swart and Price 2002; Swart et al. 1989). The surface waters in the Everglades are typically considerably enriched in the heavier isotopes of hydrogen and oxygen, compared to rainfall. A plot of $\delta^{18}\text{O}$ vs. δD for all surface water data from the Everglades shows a strong positive correlation ($r=0.9$, $n=20$), with a slope of 7 compared to 8 for the meteoric water line (MWL). The intercept of this line with the MWL indicates a mean $\delta^{18}\text{O}$ and δD isotopic composition of rainfall of -3 and -16 ‰ respectively. The slope of the trend between the $\delta^{18}\text{O}$ and δD is controlled by a number of factors as outlined by Gonfiantini (1986), and agrees with model of $\delta^{18}\text{O}$ and δD during evaporation (Gonfiantini, 1986) using the mean atmospheric temperature and humidity of south Florida and the atmospheric composition in equilibrium with mean isotopic composition of precipitation.

Normal marine waters have $\delta^{13}\text{C}$ values close to zero, but in closed basins such as Biscayne Bay, the $\delta^{13}\text{C}$ of the DIC can be influenced by degradation of organic material and photosynthesis. Respiration causes the $\delta^{13}\text{C}$ of the DIC to become more isotopically negative, while photosynthesis has the reverse effect. Surface waters in South Florida typically become isotopically negative as a result of such processes. Within aquifers and in the absence of oxygen, sulfate reduction causes the $\delta^{13}\text{C}$ of DIC to become further depleted.

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Methods

Field samples were collected at a variety of sites denoted in Figures 1 and 2 (See Tables 1 and 2). These included sites within the cooling canals, reference surface sites, and a variety of groundwater sites both close to and some distance away from the canals. Water samples were taken by FIU and SFWMD personnel and stored in 100 ml polyethylene bottles. As a result of the fact that the oxygen and hydrogen in the water molecule are measured, no special precautions are needed during sampling. However, it is essential that the bottle is securely tightened and that no evaporation of the samples takes place prior to analysis. Samples for carbon isotopic analyses were preserved with HgCl_2 after filtering with a 0.5 μm filter. All samples were stored using minimum head space. Samples were recorded on a chain of custody form and taken directly from the sampling sites to the RSMAS stable isotope facility. Oxygen and hydrogen isotopic measurements were made in the Division of Marine Geology and Geophysics (MGG/RSMAS) at the University of Miami. Both measurements were made using a water equilibration system (WEST) attached to a Europa GEO (Swart 2000). In the water equilibration system, the $\delta^{18}\text{O}$ is determined on CO_2 which has been injected into serum bottles at slightly above atmospheric pressure containing 1 cm^3 of the sample. This method is similar to that described by Epstein and Mayeda (1953). The samples are subsequently equilibrated at 25°C for 12 hours without shaking. The process is entirely automated with the CO_2 injected and retrieved using an autosampler and the gas being transferred to a dual-inlet mass spectrometer through a cryogenic trap (-70°C) to remove water. The precision of this method for oxygen, determined by measuring 59 samples of our internal standard, is +/- 0.08‰ for $\delta^{18}\text{O}$. The hydrogen isotopic composition is determined using the same device as employed for CO_2 . Equilibration with hydrogen gas takes place in the presence of a platinum catalyst (Hokko Beads) at 40°C (Coplen et al. 1991). The precision using this method is +/- 1.5‰. Since many of the groundwater samples were sulfidic (based on smell), the samples were treated with native copper for 5 days prior to exposure to the Hokko beads. It has been found that sulfides poison the catalyst and that this method effectively removes the sulfide from the water sample. Both oxygen and hydrogen isotopic data are calibrated using the V-SMOW-GISP-SLAP scale and are reported in ‰ according to the conventional notation. The latest calibration was performed in February 2009. The stable isotope laboratory at MGG/RSMAS has also participated in two previous IAEA inter-laboratory calibration exercises involving over 100 stable isotope laboratories worldwide. Carbon isotopes were measured using a method of acidification and extraction of the CO_2 under a flowing stream of He. The gas was analyzed using a Europa 20-20 and referenced to the V-PDB scale using a NaHCO_3 standard calibrated against NBS-19 using a Finnigan-MAT 251 stable isotope mass spectrometer.

Results

All $\delta^{18}\text{O}$, $\delta^{13}\text{C}$, and δD values are shown in Tables 1 & 2. Oxygen and hydrogen isotopic data are also shown in Figures 2 and 3 and the DH excess in Figure 4.

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Surface Water

The surface water can be separated into several groups based on stable O, C, and H isotopic values (See Figure 5). The cooling canals have salinity values between 65 and 74 gm/kg, $\delta^{18}\text{O}$ values between +5.74 and +6.34 ‰, $\delta^{13}\text{C}$ between -4.03 and -4.4‰, and δD between +34 and +41 ‰. In contrast, the waters from Biscayne Bay have much lower salinity values, similar to normal marine waters, 35-37 gm/kg, with $\delta^{18}\text{O}$ values of +2 to +2.5‰ (Figure 6) and δD values between 18 and 21‰. The low salinity surface waters have $\delta^{18}\text{O}$ values which range from -0.7 to +2.5, and δD ‰ values from -1.31 to +20.3‰.

Groundwater

The groundwater ranges in salinity from values of 57 gm/kg to less than 1 gm/kg. The highest salinity samples (L-3GW and L-5GW) also have elevated $\delta^{18}\text{O}$ and δD (+4.5 to +5.8‰; +25 to +36‰), while the lowest salinity samples have the most depleted $\delta^{18}\text{O}$ and δD values. The $\delta^{13}\text{C}$ of the groundwater are highly depleted (-10 to -13‰)

A contour map of the $\delta^{18}\text{O}$ and δD data from both the groundwater and surface water samples is shown in Figure 2 and 3. The location of the elevated $\delta^{18}\text{O}$ values in the cooling ponds can be clearly seen. The groundwater data is represented by as the contour lines. Figure 4 shows the DH excess.

Discussion

Cooling Ponds: The elevated salinity in the cooling canals arises from the evaporation. This evaporation also accounts for the enrichment of the $\delta^{18}\text{O}$ and δD . The extent of the enrichment can be approximated using the Craig and Gordon (1965) model as modified by Gonfiantini (1986). This model links the extent of the enrichment in $\delta^{18}\text{O}$ and δD to the relative humidity of the atmosphere, the $\delta^{18}\text{O}$ and δD of the water vapor in the atmosphere, and the chemical composition of the water evaporating. For example, Figure 7 shows the sensitivity of the $\delta^{18}\text{O}$ to changing relative humidity. The lower the relative humidity, the higher the $\delta^{18}\text{O}$ and δD values that can be attained during evaporation. These patterns are also reflected in Figure 8 which shows the relationship between $\delta^{18}\text{O}$ and δD during evaporation. The negative $\delta^{13}\text{C}$ values in the cooling canals (~ -4 ‰) reflect the oxidation of organic material, while the highly depleted values of the groundwater show the influence of the oxidation of organic material by sulfate (Figure 9).

Groundwater: The salinity and $\delta^{18}\text{O}$ of the surface and groundwater samples are shown in Figure 5 (See also Figure 8). In Figure 5 it can be clearly seen that the $\delta^{18}\text{O}$ of the cooling ponds can be explained as a result of evaporation of Biscayne Bay water. The groundwater in wells L-3 and L-5 can only be explained through mixing between the cooling ponds and groundwater. The groundwater in turn is produced through mixing between Bay water, Floridian aquifer water, and surface water. Further to the west the origin of the water in the wells G-21 and G-28 is more equivocal. The stable O and H isotopic data suggest that the well water could have either (i) formed from mixing with the cooling water and groundwater, or (ii) formed from the mixing of seawater and

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groundwater. In the case of these two wells it is clear that an additional tracer needs to be used in order to confirm the origin. The negative $\delta^{13}\text{C}$ values in L-3 and L-5 can be explained by mixing between groundwater and cooling canal water, while G-21 and G-28 are best explained by mixing between a fluid formed by a combination of cooling canal water and Biscayne Bay water and groundwater (See Figure 9).

Biscayne Bay: Biscayne Bay is a semi-enclosed body of water situated between peninsular Florida and a series of barrier islands in the north and some Pleistocene age coral reef islands in the south. The Bay is subjected to varying salinity as freshwater is contributed from rainfall, runoff, and groundwater. At the same time, seawater enters into the bay between the Barrier Islands. Starting in March 1997, samples from a series of stations were routinely analyzed for their stable O and H isotopic compositions. The average oxygen isotopic values for Biscayne Bay are shown in Figure 6. The station closest to Turkey Point, is Convoy Point. A time series of the data from this station shows a wide range of values. The variability at this station is probably unrelated to its proximity to Turkey Point, but is probably a result of its position relative to the shoreline where it is subject to evaporation and inundation by fresh water both from precipitation and runoff. The carbon isotopic composition of the waters in Biscayne Bay varies between -2 and 0‰, and has been decreasing over the past 15 years.

History of the Apparent Contamination of Groundwater: The Turkey Point Facility began commercial operation on December 14th, 1972. The 62 miles cooling canal system (CCS) takes seawater, which is used to cool the reactor, and exchange heat with the atmosphere. During this process evaporation takes place, the salinity increases, and additional water enters the CCS from Biscayne Bay (by groundwater seepage) and the Floridan aquifer. Unfortunately, there were no initial studies that characterized the groundwater in this area. However, in 1986-88 a study supported by the SFWMD (Contract C89-0254) investigated the oxygen isotopic composition of a transect of wells in southern Dade County, the most eastern cluster of which was positioned on the L-31E canal (Swart and Meyers, 1988). The geology of these wells drilled by the USGS have been described by Fish and Stewart (1991) and the fluid geochemistry by Sonntag (1987). The oxygen isotopic data of a sample collected from a screened interval between 20-23 ft from G-3321 located on the L-31E canal just to the north of the cooling canals showed values between -0.11 and -0.46 ‰, and the surface waters in the canal were measured at -0.01 and -0.06. These surface values compare with the measurements in this study of between -0.70 and +3.36 ‰. The groundwater values measured at L-3 and L-5 are considerably heavier than those reported at G-3321 in 1988.

Relationship between $\delta^{18}\text{O}$ and δD : The relationship between the $\delta^{18}\text{O}$ and δD is also controlled by evaporation and relative humidity (Figure 8). Samples evaporated into atmospheres with high relative humidity fall close to the meteoric water line (MWL) and therefore have a DH excess close to 10. In contrast, samples which are evaporated, particularly under conditions of low relative humidity, have lower DH excess values. The contour map of the DH excess values shows this effect extremely well (Figure 4). The cooling ponds all have negative DH excesses, while these values increase to those typical of rainwater as one progresses towards the west. The $\delta^{18}\text{O}$ and δD of surface

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waters of south Dade are not as positive as surface waters in the Everglades proper, as there is less standing water and the precipitation rapidly penetrates the bed rock, thereby protecting the water from evaporation. The various lines on Figure 8 show how fluids with an initial $\delta^{18}\text{O}$ of -3 might behave during evaporation. These lines are similar to straightforward mixing lines between the various end members and evaporation pathways.

Summary

- The cooling canal waters have the most positive oxygen and hydrogen isotopic values of any waters found in southern Florida. These positive values can be explained by evaporation and serve as a distinctive signature for the cooling canals.
- When mixed with fresh groundwater, the resultant fluids fall on a line that passes through Biscayne Bay water (Figure 5); therefore, it is impossible to identify the origin of waters with salinities less than that of Biscayne Bay, as having been derived from the cooling ponds using O and H isotopes alone. In particular the $\delta^{18}\text{O}$ of waters from G-21 and G-28 could have been produced in this way.
- As fluids in L-3 and L-5 have salinities higher than that in Biscayne Bay water they could ONLY have originated from the cooling canals.
- Using the $\delta^{18}\text{O}$ (or δD) in combination with $\delta^{13}\text{C}$ clearly identifies that the waters in G-21 and G-28 could not have been produced by mixing between Biscayne Bay water and groundwater alone (Figure 9). Rather, these fluids had to be produced by mixing between a fluid with a composition intermediary between Biscayne Bay and the cooling ponds and some groundwater end member.
- The absence of adequate well control surrounding the CCS precludes the rigorous use of any geochemical tracer in understanding the origin of the groundwater (See recommendation) at the present time.

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Recommendations

- In order to better define possible contamination of groundwater from the CCS, a number of nested wells should be installed symmetrically and at progressively increasing distances around and away from the Turkey Point facility. The nested wells should be screened at a number of intervals within the Biscayne Aquifer likely to represent probably flow paths. These intervals should be chosen in consultation with USGS geologists and after an examination of the core material.
- The groundwater well should be sampled seasonally together with surface waters and the waters analyzed for a number of relevant isotopes and minor element parameters.
- An additional isotopic indicator which might be useful is the ratio of ^6Li to ^7Li . During relatively low fluxes of neutrons, ^6Li undergoes a n,α reaction producing ^3H and ^4He . This will be evident in the concentration of Li, which will be lower than expected, and an unusual $^6\text{Li}/^7\text{Li}$ ratio. As neither of the isotopes of Li are radioactive and there is no signal derived from rainwater the $^6\text{Li}/^7\text{Li}$ ratio may be a diagnostic tracer of processes originating in CCS.

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References

- COPLEN, T.B., WILDMAN, J.D., and CHEN, J., 1991, Improvements in the gaseous hydrogen-water equilibration technique for hydrogen isotope ratio analysis: *Analytical Chemistry*, v. 63, p. 910-912.
- CRAIG, H., and GORDON, L.I., 1965, Deuterium and oxygen-18 variations in the ocean and the marine atmosphere: *Stable Isotopes in Oceanographic Studies and Paleotemperatures Consiglio Nazionales delle Ricerche, Lab. Di Geo. Nucleare, Pisa*, p. 9p.
- EPSTEIN, S., and MAYEDA, T., 1953, Variations in O¹⁸ content of waters from natural sources: *Geochimica Cosmochimica Acta*, v. 4, p. 213-224.
- FISH, J.E., and STEWART, M., 1991, Hydrogeology of the surficial aquifer system, Dade County, Florida, *in* USGS, ed., *Water-Resources Investigations Report 90-4108*, US Department of the Interior, p. 50.
- GONFIANTINI, R., 1986, Environmental Isotopes in Lake Studies, *in* Fritz, P., and Fontes, J., eds., *Handbook of Environmental Isotope Geochemistry*: Amsterdam, Elsevier, p. 113-168.
- LLOYD, M.R., 1964, Variations in the oxygen and carbon isotope ratios of Florida Bay mollusks and their environmental significance: *Journal of Geology*, v. 72:84.
- MEYERS J.B., 1990. Stable isotope hydrology and diagenesis in the surficial aquifer system, Southern Florida Everglades, Unpublished MS thesis, University of Miami, 92 p.
- MEYERS, J.B., SWART, P.K., and MEYERS, J.L., 1993, Geochemical evidence for groundwater behavior in an unconfined aquifer, south Florida: *Journal of Hydrology*, v. 148, p. 249-272.
- PRICE, R.M., 2001. Geochemical determinations of groundwater flow in Everglades National Park, Unpublished PhD Dissertation, University of Miami, 307 p.
- PRICE, R.M., and SWART, P.K., 2006, Geochemical indicators of groundwater recharge in the surficial aquifer system, Everglades National Park, Florida, USA, *Geological Society of America Special Paper*, p. 251-266.
- PRICE, R.M., SWART, P.K., and H.E., W., 2008, Seasonal and spatial variation in the stable isotopic composition ($\delta^{18}\text{O}$ and δD) of precipitation in south Florida: *Journal of Hydrology*, v. 358, p. 193-205.
- PRICE, R.M., TOP, Z., HAPPELL, J.D., and SWART, P.K., 2003, Use of tritium and helium to define groundwater flow conditions in Everglades National Park: *Water Resources Research*, v. 39.

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SONNTAG, W., 1987, Chemical Characteristics of water in the superficial aquifer system, Dade County Florida: Water-Resources Investigations Report, v. 87-4080.

STERNBERG, D.S.L., and SWART, P.K., 1987, Utilization of ocean water and fresh water by coastal plants of Southern Florida: Ecology, v. 68, p. 1888-1905.

SWART, P.K. AND MEYERS, J. 1988. Stable oxygen and hydrogen isotope hydrology of surficial aquifers of Dade and Broward Counties, Final Report for SFWMD Contract Number C89-0254.

SWART, P.K., STERNBERG, L.S., STEINEN, R., and HARRISON, S.A., 1989, Controls on the oxygen and hydrogen isotopic composition of the waters of Florida Bay, USA: Chemical Geology (Isotope Geoscience Section), v. 79, p. 113-123.

SWART, P.K., 1991, The oxygen and hydrogen isotopic composition of the Black Sea: Deep-Sea Research, v. 38, p. s761-s772.

SWART, P.K., 2000, The Oxygen Isotopic Composition of Interstitial Waters: Evidence for Fluid Flow and Recrystallization in the Margin of Great Bahama Bank, *in* Swart, P., Eberli, G., and Malone, M., eds., Scientific Results: College Station, p. 91-98.

SWART, P.K., and PRICE, K., 2002, Origin of salinity variations in Florida Bay: Limnology and Oceanography, v. 47, p. 1234-1241.

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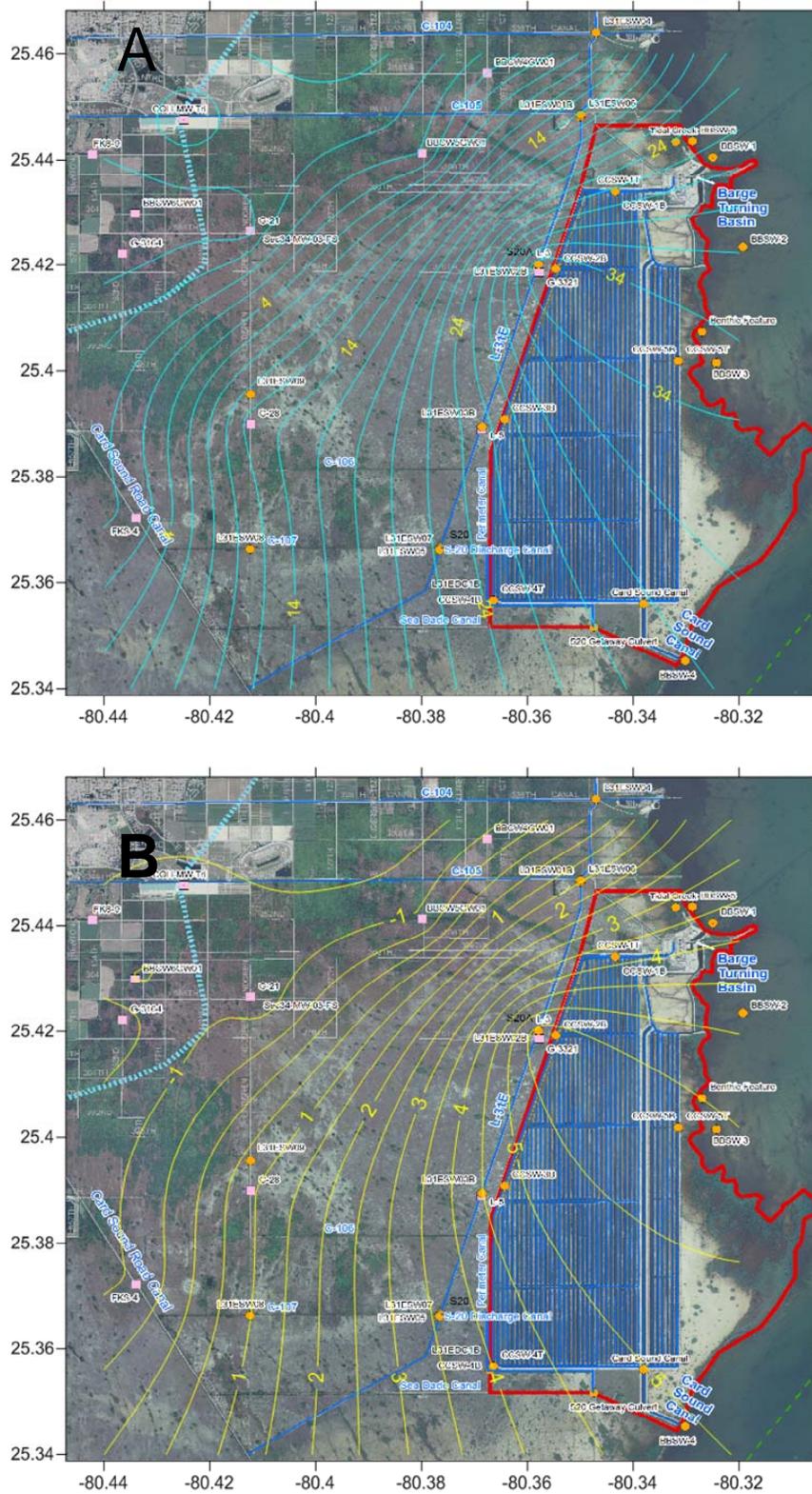


Figure 3: Contour of the $\delta^{18}\text{O}$ (A) and δD (B) groundwater samples.

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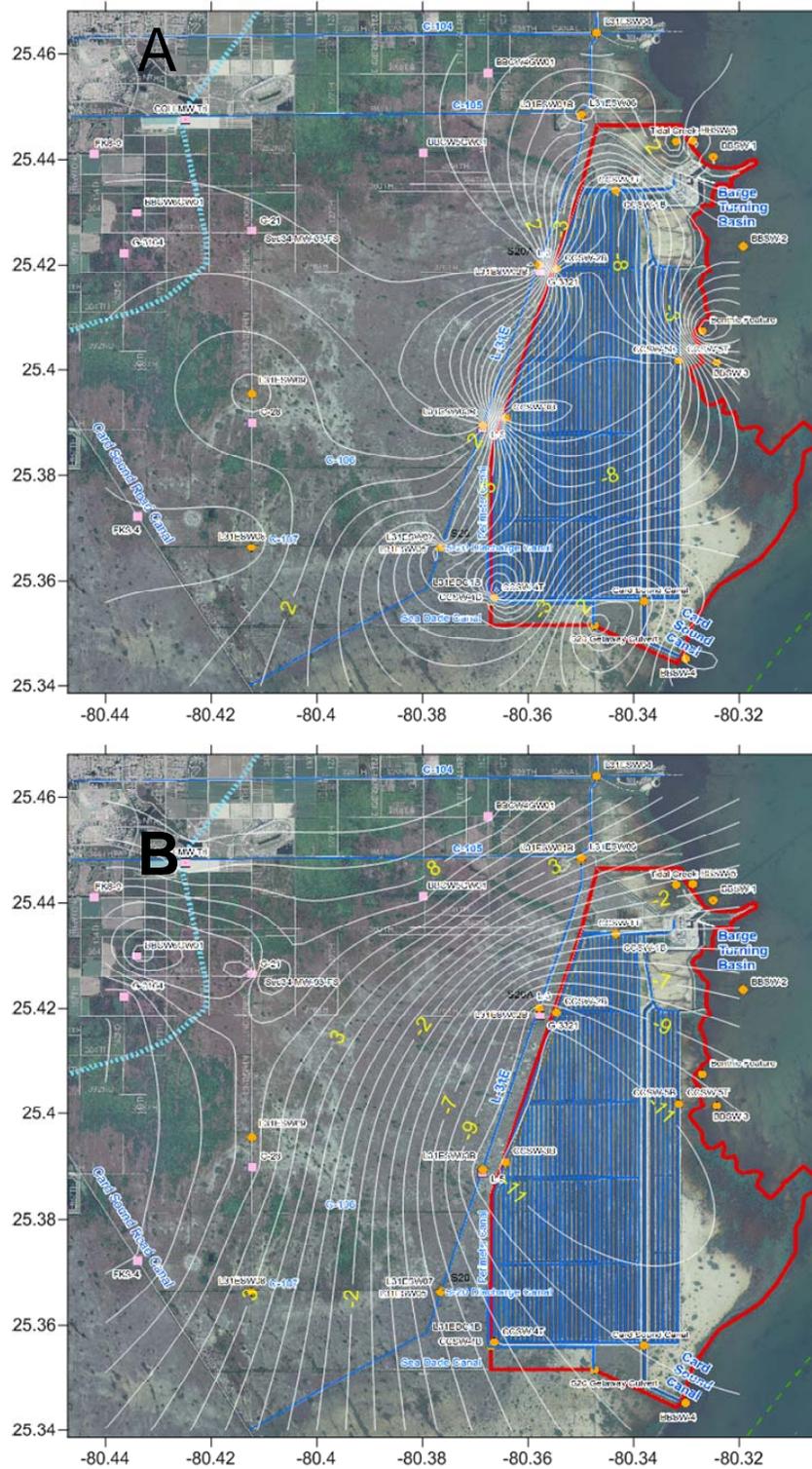


Figure 4: DH Excess for surface water (A) and groundwater (B).. Samples to the west show a normal DH of 10, while the DH excess in the cooling ponds have negative values. Samples from the CCS show much more negative DH excesses than samples from any other source.

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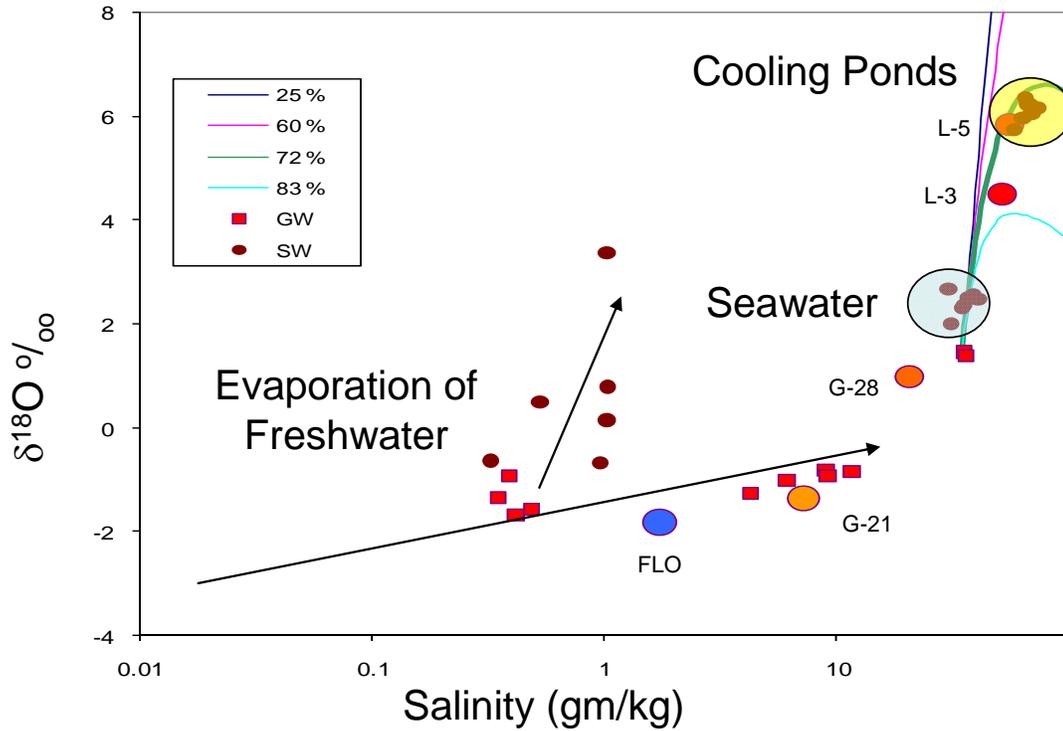


Figure 5: Salinity and $\delta^{18}O$ data from samples measured in this study. Samples from Biscayne Bay are shown by the area covered by the light- blue circle. The various theoretical evaporation lines are shown (Figure 5). The wells L-3, L-5, (red symbols) G-21, and G-28 (orange symbols) are indicated. The blue symbol indicates the composition of water from the Floridian aquifer.

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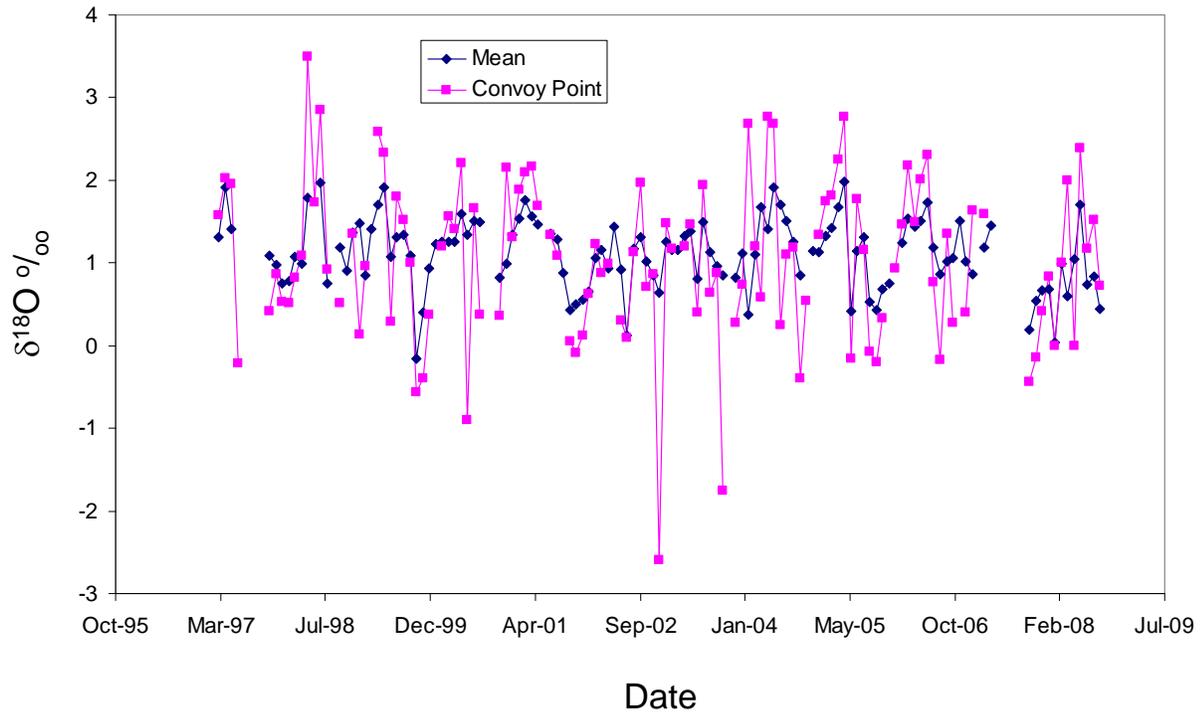


Figure 6: Comparison of the oxygen isotopic data (Swart, unpublished) from Convoy Point and the mean values from Biscayne Bay from 1997 to 2008. No samples are available after September 2008. The samples were collected by FIU and analyzed at the University of Miami.

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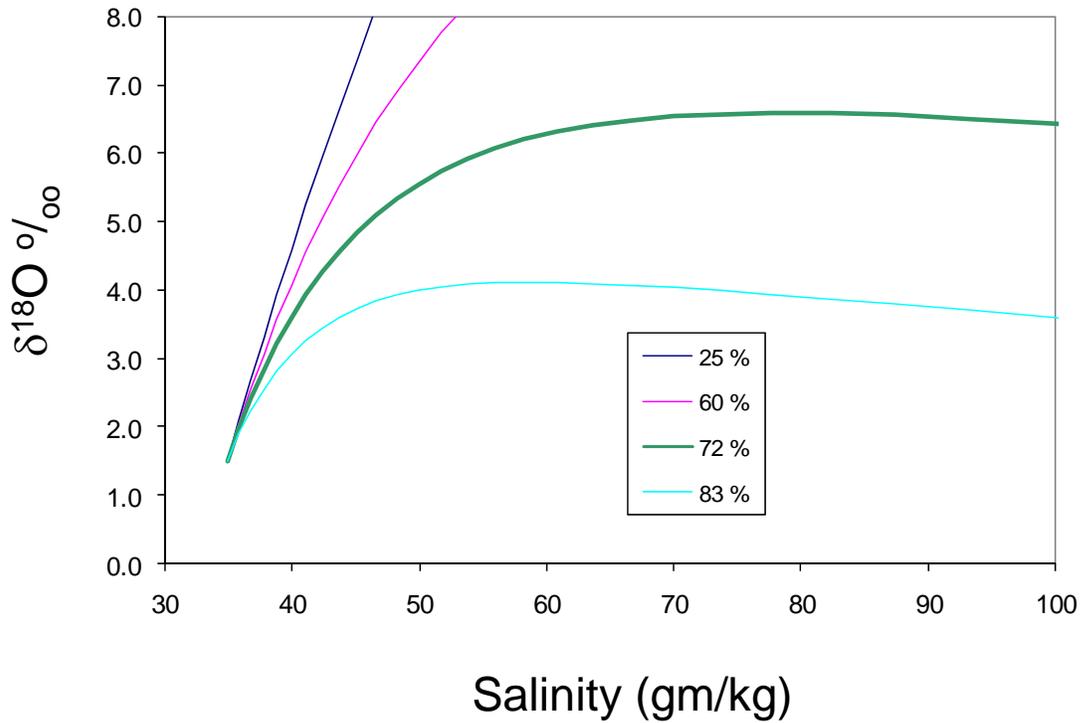


Figure 7: The theoretical relationship between salinity and $\delta^{18}\text{O}$. This model assumes the initial $\delta^{18}\text{O}$ of a water body with a salinity of 35 has a $\delta^{18}\text{O}$ of +1‰. The different lines show the behavior for evaporation into atmospheres of differing relative humidity.

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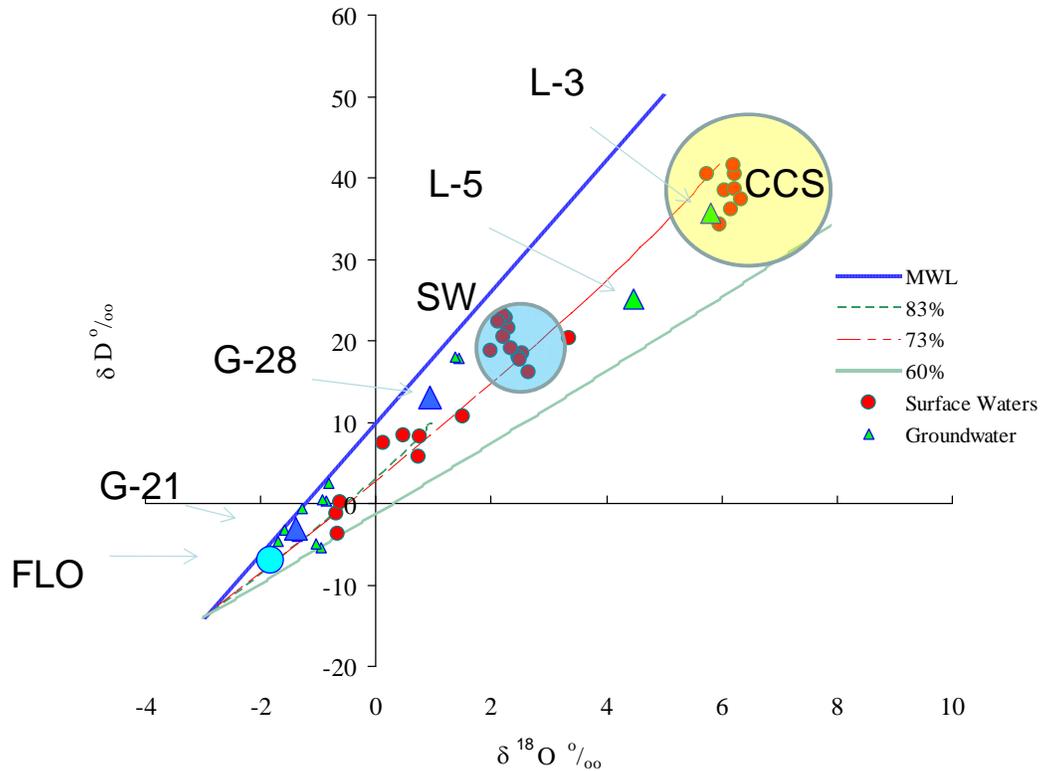


Figure 8: Relationship between $\delta^{18}\text{O}$ and δD with respect to the MWL (blue line). Other lines show the behavior of $\delta^{18}\text{O}$ and δD with respect to evaporation into atmospheres of different relative humidities. The seawater samples are shown by the light-blue circle and the CCS by the yellow circle. The round blue symbol near the MWL labeled FLO represents water from the Floridan aquifer and is similar to that reported for the Florida aquifer (Walsh, unpublished).

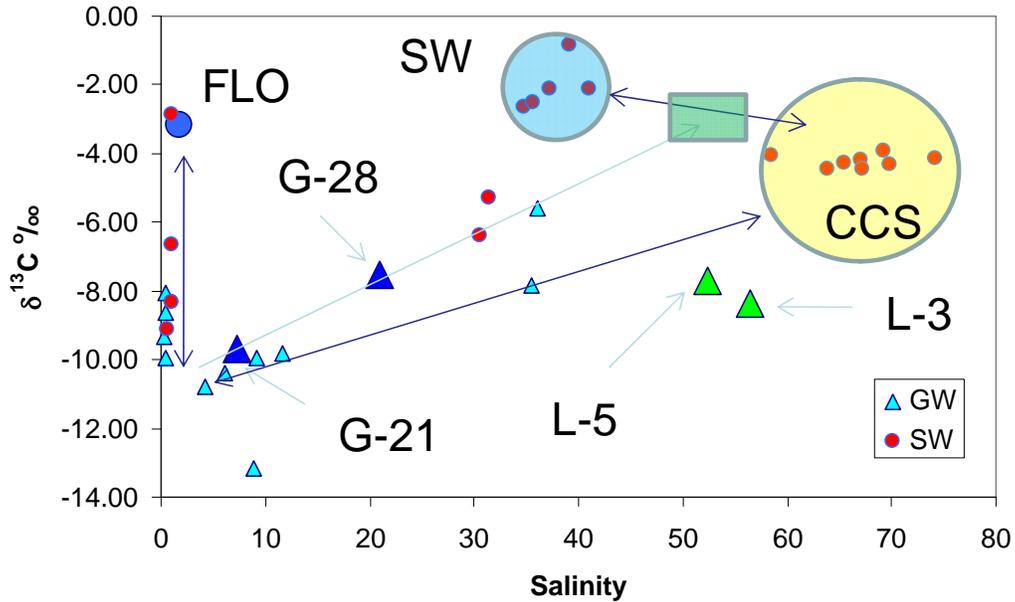


Figure9: The relationship between salinity and $\delta^{13}C$. The data can be defined by mixing between three different end members. These are the CCS ($S=74$, $\delta^{13}C = -4.4$), Floridian aquifer water ($S \sim 0$, $\delta^{13}C = -2$), and freshwater groundwater ($S \sim 0$, $\delta^{13}C = -10$). The CCS is shown by the yellow circle and Biscayne Bay by the light-blue circle. Water from Biscayne Bay falls on a mixing line between Floridian water and the Cooling ponds. Water from G-21 and G-28 falls on a mixing line between groundwater and a fluid which is best represented by a mixture of seawater and CCS water (Green Box). The Floridian aquifer is shown by the round blue symbol.

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Location	Sampling Depth (ft)	C ‰	s.d.	O ‰	s.d.	H ‰	s.d.
BBCW10GW1	9-12	-7.82	0.03	1.45	0.19	17.80	1.53
BBCW10GW2	31-41	-5.58	0.02	1.37	0.17	18.01	2.77
BBCW4GW01	32-35	-13.18	0.10	-0.83	0.16	2.45	3.50
BBCW5GW01	42	-9.84	0.15	-0.86	0.01	0.27	1.55
BBCW6GW01	45	-9.97	0.20	-0.95	0.17	-5.45	1.79
BBCW9GW01	27-30	-8.64	0.04	-1.59	0.10	-3.22	1.11
COH-MW-Tri	87	-10.79	0.03	-1.27	0.09	-0.58	3.98
FKS4GW01	35	-9.93	0.05	-0.94	0.19	0.49	1.91
FKS9GW01	75	-9.34	0.12	-1.37	0.04	-4.02	0.86
FLOGW01	1000	-3.16	0.11	-1.84	0.09	-7.00	1.46
G-21GW01	67	-9.69	0.02	-1.39	0.03	-3.05	1.31
G-28GW01	67	-7.52	0.12	0.95	0.13	12.98	2.81
G3164GW01	83	-8.06	0.23	-1.70	0.04	-4.72	0.29
L-3GW01	67	-8.37	0.11	5.81	0.04	35.69	4.51
L-5GW01	67	-7.73	0.06	4.48	0.17	25.13	3.68
Sec34-MW-0	83	-10.40	0.02	-1.03	0.33	-4.99	2.87

Table 1: Stable C, O, and H data of the water components from groundwater wells (See Figure 1). s.d. = standard deviation. The sampling depth is the screened interval in the wells from which the water was pumped.

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Location	C ‰	s.d.	O ‰	s.d.	H ‰	s.d.
BBCW10SW01	-5.27	0.03	1.99	0.04	18.72	0.27
BBSW01	-2.63	0.13	2.30	0.07	21.59	3.99
BBSW02	-0.83	0.04	2.54	0.19	18.42	1.94
BBSW03	-2.12	0.04	2.47	0.11	18.02	3.06
BBSW04	-2.11	0.17	2.49	0.25	17.74	3.40
BBSW05	-2.49	0.33	2.34	0.18	19.06	1.85
CCSSW01B	-4.18	0.19	6.22	0.15	40.41	5.48
CCSSW01T	-4.30	0.17	6.05	0.14	38.40	4.32
CCSSW02B	-3.92	0.09	6.21	0.09	41.49	4.16
CCSSW03B	-4.14	0.19	6.15	0.03	36.15	0.35
CCSSW04B	-4.47	0.04	5.95	0.14	34.34	1.06
CCSSW04T	-4.03	0.09	5.74	0.16	40.44	3.38
CCSSW05B	-4.43	0.03	6.23	0.16	38.68	0.49
CCSSW05T	-4.28	0.13	6.34	0.11	37.34	1.61
L-31EESW07	-2.88	0.04	3.36		20.34	
L-31EESW09		0.04	-0.66		-3.77	
L-31EEDC01B	-6.40	0.17	2.65	0.03	16.16	0.11
L-31EESW01B		0.33	0.77	0.01	8.23	0.03
L-31EESW02B	-6.65	0.17	0.12	0.08	7.37	1.87
L-31EESW03B	-8.33	0.01	-0.70	0.16	-1.31	1.99
L-31EESW08	-9.11	0.04	0.48	0.21	8.37	0.37
L-31ESW04	-7.36	0.09	-0.63	0.07	0.23	2.76
L-31ESW05	-8.26	0.03	0.74		5.71	
L-31ESW06	-5.66	0.13	1.52	0.13	10.76	2.02
S20	-5.92	0.04	2.25	0.08	22.79	1.58
Tidal Creek	-4.47	0.04	2.21		23.16	
Benthic Feature	-3.07	0.17	2.12	0.17	22.31	1.28
Card Sound Canal	-2.22	0.33	2.21	0.01	20.44	4.24

Table 2: Stable C, O, and H data of the water components from surface water sites (See Figure 1). s.d. = standard deviation.

Appendix E

TRITIUM

**Use of Tritium as a Tracer of Cooling Canal System Water
Movement into the Surficial Aquifer System Surrounding the
Turkey Point Nuclear Power Plant in Southeastern Miami-Dade
County, Florida**

August 27, 2009

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I. Introduction to Local Hydrology

Southeastern Florida coastal hydrology is characterized by a highly permeable and transmissive Surficial Aquifer System (SAS) that interacts with a complex series of man-made drainage canals that have direct contact with the aquifer system. The SAS is separated from the deeper Floridan aquifer system by the thick confining siliclastic unit of the Hawthorn Group (Fish and Stewart, 1991; Reese and Cunningham, 1999; Kohout, 1960). The SAS consists of a karstified and highly transmissive upper limestone aquifer named Biscayne aquifer, as well as a middle clastic unit, the Grey Limestone aquifer, and another clastic layer that terminates at the confining Hawthorn Group (Reese and Cunningham, 1999; Fish and Stewart, 1991). The Biscayne aquifer has been shown to underlie the terrestrial extent of both Miami-Dade County and Biscayne Bay, and consists of the Miami Limestone, the Ft. Thompson Formation, the Key Largo Limestone, and other minor units. The Biscayne aquifer is comprised of fresh water in its terrestrial extent, with the exception of saltwater intrusion near the coast, and is the sole source aquifer for much of Miami-Dade, Broward, and Monroe counties (Fish and Stewart, 1991; Kohout, 1960). The majority of drainage canals in Miami-Dade County are finished in the Upper Biscayne aquifer in the Miami Limestone and Ft. Thompson Formations. The system cooling canals (CCS) at Turkey Point consists mostly of shallow (0.3 to 1 meter deep) canals that sit on top of the limestone of the aquifer. In addition to the shallow canals of the CCS there are also three (Feeder, Collector and Card Sound) 6 meter deep canals that are cut into the limestone of the aquifer. Therefore the CCS is in direct contact with the Biscayne aquifer. Modeling of the hypersaline water in the CCS has shown that at first the dense water from the CCS sinks to the bottom of the aquifer and then spreads laterally, and that during the 25 year modeling period that neither salt content nor the position of the saltwater/freshwater interface have reached equilibrium (Hughes et al., 2009).

II. Introduction to Tritium

Hydrogen consists of three isotopes, Normal hydrogen (protium or H), deuterium (^2H or D), and Tritium (^3H , H-3, or T). An isotope is a form of an element that has the same number of protons in the nucleus, but a different number of neutrons. Tritium has two additional neutrons when compared to hydrogen. Normal hydrogen makes up 99.98% of naturally occurring hydrogen, 0.02% is deuterium, and tritium is present at about 1 atom per 10^{18} regular hydrogen atoms (Figure 1).

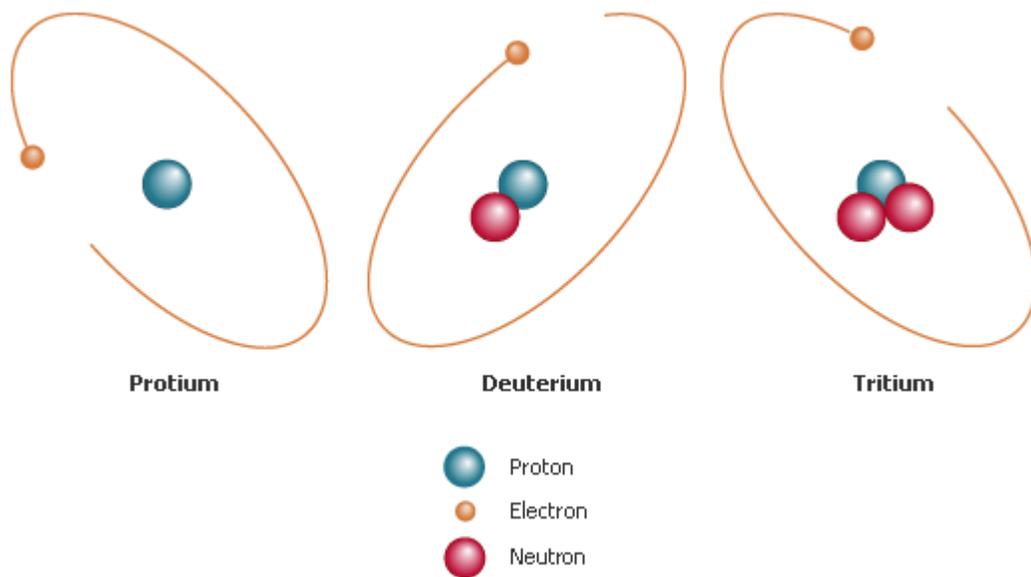


Figure 1) Isotopes of hydrogen

Hydrogen and deuterium are stable isotopes. Tritium is radioactive and undergoes radioactive decay with a half life of 12.32 years to form stable helium-3 (³He) (Figure 2). During radioactive decay, ³H emits a low energy beta particle.

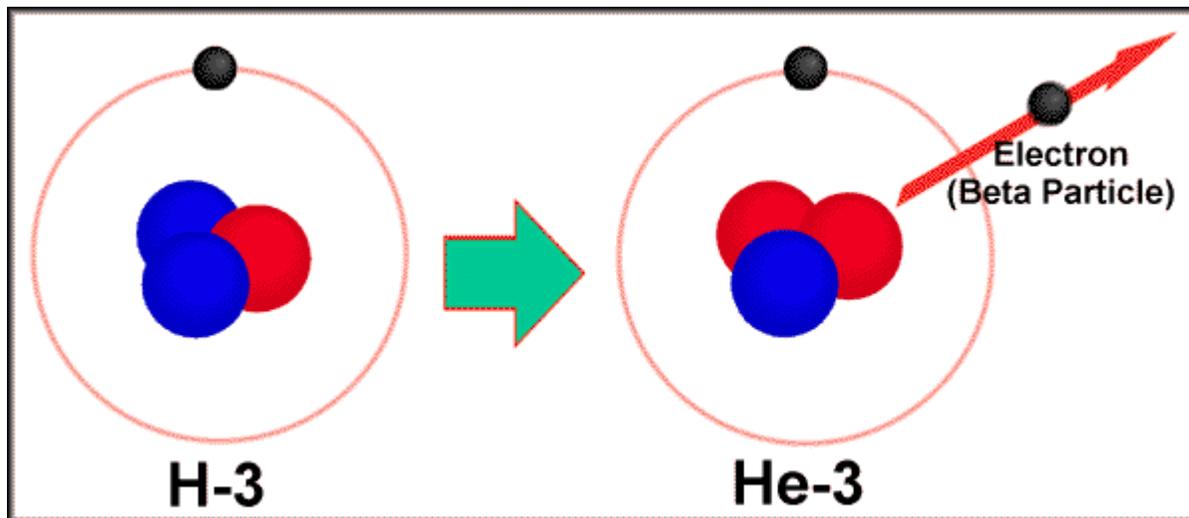
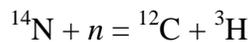


Figure 2) Radioactive decay of tritium. Blue = neutrons. Red = protons. Black = electrons.

Tritium is produced naturally in the upper atmosphere mainly by the interaction of cosmic ray neutrons with nitrogen through the following reaction:



Where n is a neutron, ^{14}N is the common isotope of nitrogen, and ^{12}C is the common isotope of carbon.

Most tritium produced in the atmosphere is oxidized or exchanges with normal hydrogen to form tritiated water (HTO). Because tritium is part of the water molecule, it is nearly the ideal tracer of water's pathway through the hydrological cycle (Michel, 2005). The remaining tritium is found in the form of tritium gas (HT). The pre-nuclear steady state global inventory of tritium has been estimated at between 3.5 and 4.5 kg (Lal and Peters, 1967, O'Brien et al., 1992). Tritium was first detected in nature as HT in the early 1950s (Faltings and Harteck, 1950; Grosse et al., 1951), and in the form of HTO several years later (Kaufman and Libby, 1954; Begemann and Libby, 1957)

Tritium is also produced by humans in nuclear reactors and during nuclear detonations. Tritium was first produced in large quantities in production reactors designed to produce ^3H because it was used to increase the yield of both fission and fusion nuclear weapons. During the testing of nuclear weapons in the atmosphere from 1954 to the mid-1970's, comparatively large amounts of ^3H were injected into the atmosphere in the form of HTO. Most of this tritium was released during a series of tests conducted by the USA and USSR during the periods of 1957-1958 and 1961-1963, with minor amounts being released by tests conducted by China and France in the mid 1970s. It is estimated that a total of 527 Kg of ^3H was released during atmospheric bomb testing (UNSCEAR, 2000). Nearly all of this HTO was deposited as rain into the earth's surface and groundwater within a few years of its release. **Currently no significant amount of bomb-produced tritium exists in the earth's atmosphere**, although there is about double the amount of pre-nuclear background ^3H due to the production and release of ^3H associated with nuclear power production and fuel reprocessing. Many of these patterns can be seen in a plot of the time history of tritium in rain at Ottawa, Canada where the longest record exists. (Figure 3).

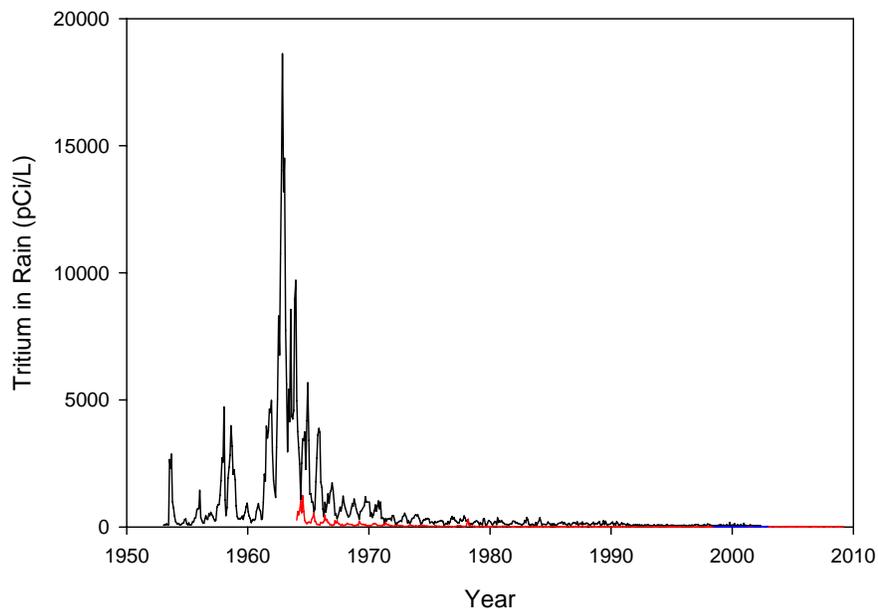


Figure 3) Monthly averages of tritium in rain for Ottawa, Canada (black), RSMAS, Florida (red) and Perrine, Florida (blue). Data from all three data sets through 2002 are from the International Atomic Energy Agency's (IAEA) global network of isotopes in precipitation (GNIP) database (IAEA/WMO 2006). Data from RSMAS from 2003 to the present are from the RSMAS Tritium Laboratory.

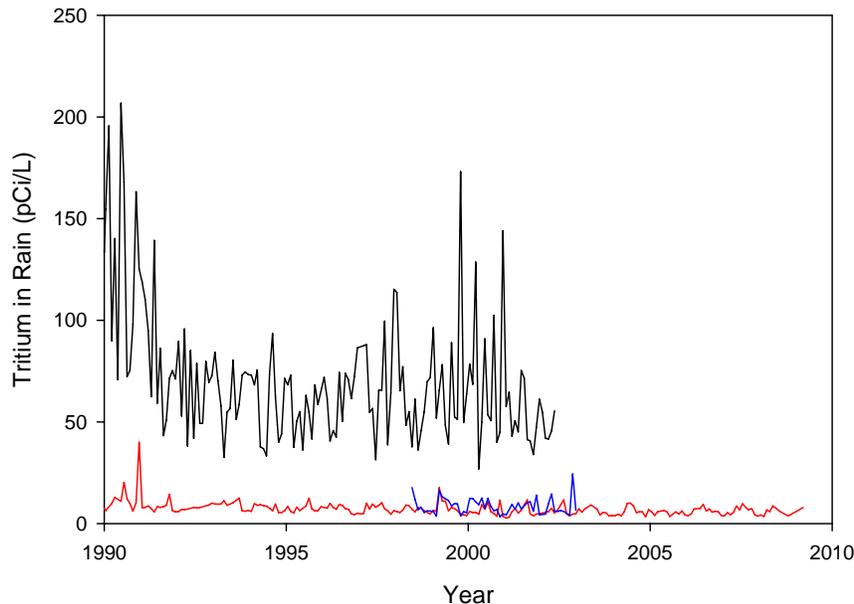


Figure 4) Monthly averages of tritium in rain for Ottawa, Canada (black), RSMAS, Florida (red) and Perrine, Florida (blue) from 1990 to 2009. Data from all three data sets through 2002 are from the International Atomic Energy Agency's (IAEA) global network of isotopes in precipitation (GNIP) database (IAEA/WMO 2006). Data from RSMAS from 2003 to the present are from the RSMAS Tritium Laboratory.

Included in Figures 3 and 4 are ^3H values in rain collected at the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS) on Virginia Key from 1964 to the present and in the Perrine area (8805 SW 178 Terrace, Palmetto Bay FL) from 1998 to 2002. All relatively heavy isotopes are concentrated in rain as one moves toward the poles and away from the oceans. This is the main reason ^3H is more concentrated in Ottawa, Canada rain, compared to South Florida rain. Similar patterns are observed in other isotopes such as ^2H and ^{18}O . A more detailed plot of ^3H in rain from 1990 to the present is shown in Figure 4 and as can be seen the amount of ^3H in rain in South Florida has been relatively constant over that time period.

It was quickly realized during and after the bomb-produced tritium transient that ^3H would be very useful for studying hydrologic processes (IAEA, 1962). Since that time, ^3H has been widely used to study physical mixing processes in oceanographic and hydrologic systems (Michel, 2005). Tritium has been used in hydrology to study the movement of water through the unsaturated zone, physical processes in surface and groundwaters, and interactions between surface and groundwaters (Michel, 2005). Most ^3H studies in hydrology have used the transient atmospheric levels of ^3H , rather than deliberate injections of ^3H as an added tracer. However there have been some studies employing deliberate additions of tritium. Kaufman and Todd (1962) used introduced tritium to study the seepage and loss of water from unlined canals. Quay et al (1980) used ^3H to study the movement of ^3H injected into a lake thermocline. Houle et al. (2004) used excess added ^3H and ^{35}S to trace the movement of sulfur relative to water in a forested watershed. Tritium contaminant sites or sites with ^3H -elevated industrial water can be

considered equivalent to tracer injections (Michel, 2005). Several studies have used the elevated tritium signal in the Savannah River below the Savannah River Department of Energy Site to estimate the flushing rate of the estuary at the river mouth (Hayes, 1979) and the influence of river water on the coastal shelf (Bush, 1988). An accidental release of ^3H into a river in Switzerland was used to study the infiltration of river water into the aquifer (Hoehn and Santschi, 1987; Santschi et al., 1987). Tritium from accidental and planned releases has been used to extensively study the movement of water and associated contaminants at Los Alamos National Laboratory (LANL, 2007). Releases of tritium have been used to trace groundwater movement at the Hanford Site 200 Area Land Disposal site (Barnett et al., 2003). Brookhaven National Laboratory has used ^3H in groundwater to track the extent of a tritium leak from the research reactor and associated spent fuel storage pool (BNL, 2000; 2009). Accidental ^3H releases have all been traced by monitoring the groundwater ^3H concentration at the following nuclear power plant sites: Indian Point, Braidwood, Callaway, Dresden, Byron, Palo Verde, and Quad Cities (<http://www.nrc.gov/reactors/operating/ops-experience/tritium/sites-grndwtr-contam.html>).

Since ^3H is part of the water molecule, tracing it effectively traces groundwater movement. It is not possible to “treat tritium as tritium,” as has been suggested by FPL (2009b), and ignore the fact that it is part of the water molecule. Tritium is ideal for tracing groundwater because it is part of the water molecule, not something dissolved in the water. Tracing elevated levels of ^3H in groundwater is by default tracing groundwater movement. In report prepared for FPL, monthly ^3H data was collected from a series of wells surrounding the CCS from October 1975 to August of 1976 (Dames and Moore, 1978). This report states ^3H can be used as a reliable tracer of CCS water seepage into the groundwater. Therefore the assertion made by FPL (FPL 2009b) that “no evidence that tritium has been used as a tracer of groundwater movement in close proximity to a nuclear power plant” is false.

III. Choosing the appropriate tracer(s) to detect CCS water in the groundwater surrounding the Turkey Point Power Plant (TPPP)

Determining how much hypersaline CCS water has penetrated into the groundwater surrounding the plant has been treated as a three-end member mixing problem. The three end members are CCS water, Biscayne Bay Surface Water (BBSW), and fresh groundwater. Tritium will be a very useful tracer of CCS water seeping into the groundwater because the concentration of ^3H in the cooling canals is several hundred times elevated over the other end members and any other potential sources of ^3H . Tritium will be discussed in detail following the discussion of other potential tracers. A suite of potential tracers was sampled in February and March 2009 (Synoptic Sampling Survey). A total of 42 samples were obtained (Figure 5). The following parameters were analyzed in all samples: Alkalinity, salinity, chloride (Cl^-), sulfate (SO_4^{-2}), fluoride (F^-), bromide (Br^-), sodium (Na^+), potassium (K^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), strontium (Sr^{+2}), barium (Ba^{+2}), boron (B^{+3}), stable oxygen isotopes ($\delta^{18}\text{O}$), deuterium (δD), and stable carbon isotopes ($\delta^{13}\text{C}$). Tritium was only analyzed from water not found on FPL property because of a prohibition by FPL.

Stalker et al. (2009) used the ionic data in binary and ternary mixing models. Most of the ions (Ca^{+2} , Na^+ , Br^- , Mg^{+2} , K^+ , SO_4^{-2} , and Sr^{+2}) had a linear relationship with Cl^- with fresh groundwater at one end, CCS water at the other end and BBSW along the mixing/evaporation line in the middle (see Figure 6 for an example). They concluded that high ion concentrations greater than in seawater in some samples could be used to identify CCS water in one of the canals (L31DCSW01B) and two groundwater wells (L3GW01, L5GW01) in close proximity to the cooling canals. The binary mixing models that they developed yielded low errors, but they could not be used in most cases to distinguish between the mixing of fresh groundwater and either BBSW or CCS water. Therefore, the source of the salinization of the groundwater could not be determined. Stalker et al. (2009) also used Ba^{+2} in a ternary mixing model because the three end members of interest had differing Ba^{+2} concentrations. While this ternary model was more useful in differentiating between the two saline end members, it did have some problems (Figure7). Only one well was used as the fresh groundwater end member, which increases the uncertainty, and this model could not describe the saline waters in many groundwater samples.

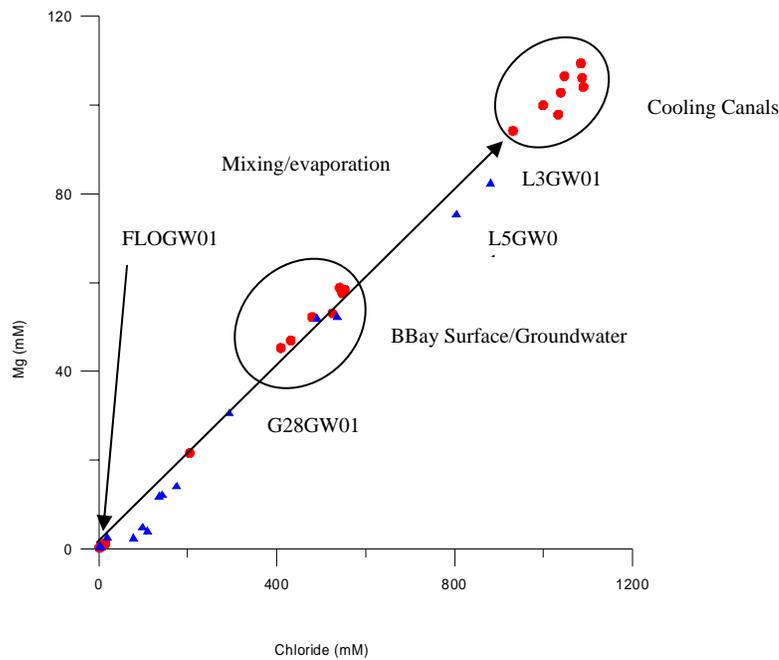


Figure 6) Plot of chloride concentration (mM) against magnesium (mM). This plot shows a strong linear relationship between the two ions in both surface water and groundwater (Stalker et al., 2009).

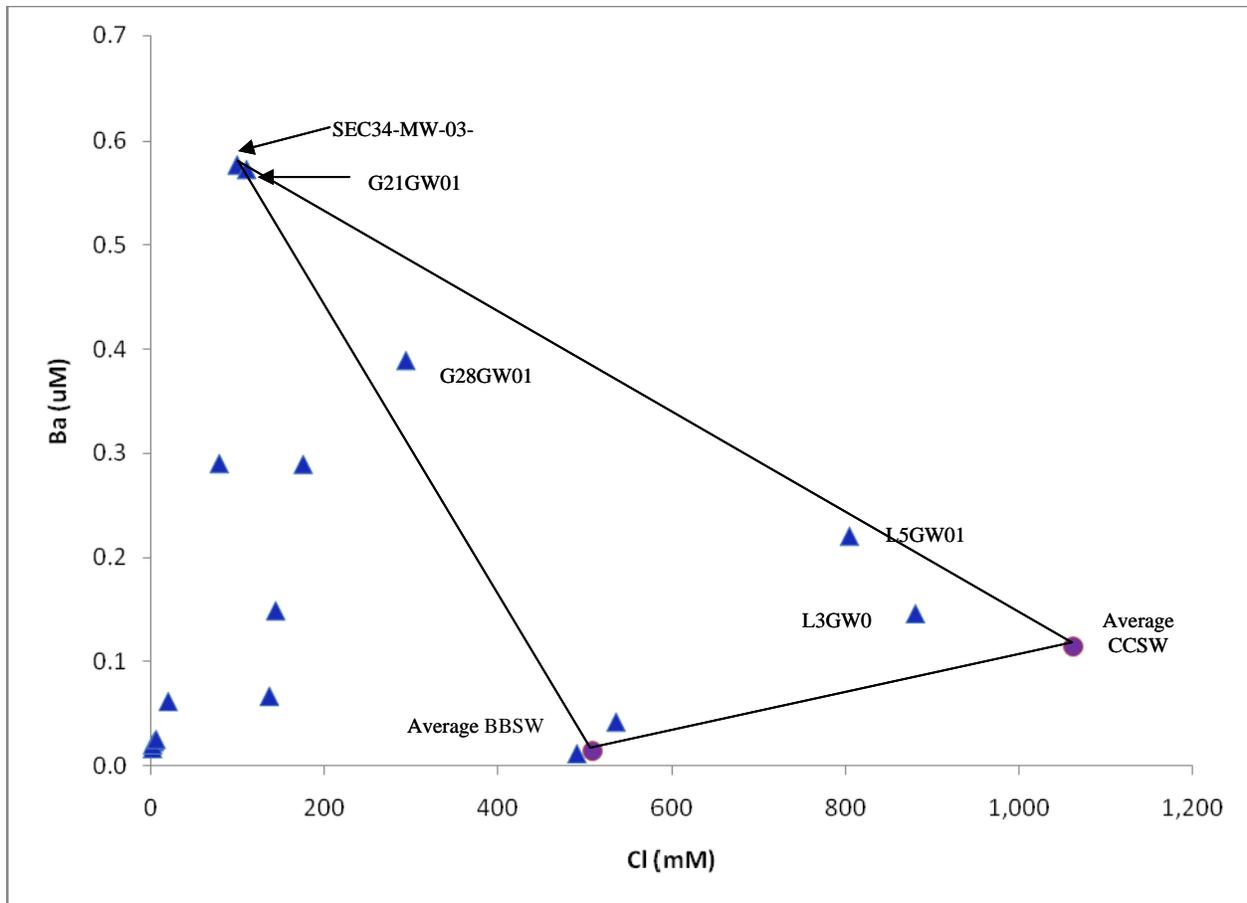


Figure 7) Ternary Tie-Line Mixing diagram of Dissolved Barium and Chloride concentrations. Purple circles are average surface water end members. Blue triangles are groundwater samples. The triangle represents the mixing area of these three end-members, and sample points that fall within the boundaries are a mixture of the three (Stalker et al., 2009).

Swart (2009) analyzed the same samples in the Stalker et al. (2009) for $\delta^{18}\text{O}$, δD and $\delta^{13}\text{C}$. He concluded that when CCS water is mixed with fresh groundwater, the resultant fluids fall on a line that passes through Biscayne Bay water when using $\delta^{18}\text{O}$ and δD as a tracer. (Figure 8). Therefore, it is impossible to distinguish waters with salinities less than that of BBSW, as having been derived from mixtures of fresh groundwater with either CCS water or BBSW, using $\delta^{18}\text{O}$ and δD alone. Using the $\delta^{18}\text{O}$ or δD in combination with $\delta^{13}\text{C}$ clearly identifies that the waters in G-21 and G-28 could not have been produced by mixing BBSW and fresh groundwater alone. Rather, these fluids had to be produced by mixing between a fluid with a composition intermediary between BBSW and CCS water, and some fresh groundwater (Figure 9).

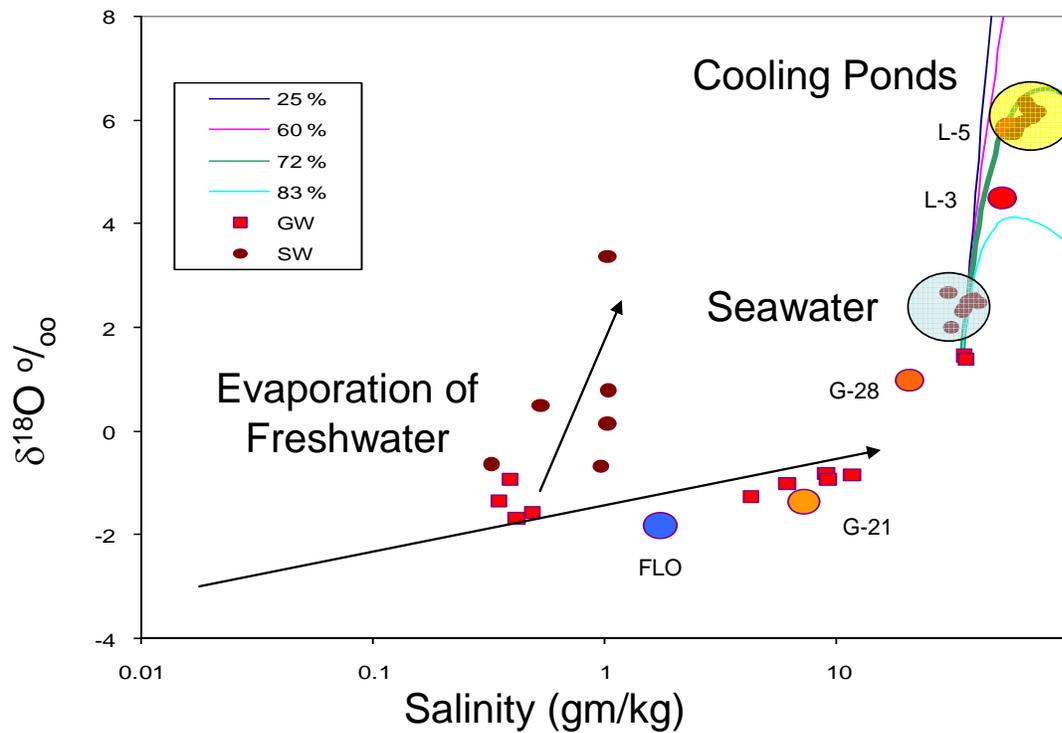


Figure 8) Salinity and $\delta^{18}\text{O}$ data from samples measured in the March 2009 sampling. Samples from Biscayne Bay are shown by the area covered by the light- blue circle. The various theoretical evaporation lines are shown. The wells L-3, L-5, (red symbols) G-21, and G-28 (orange symbols) are indicated. The blue symbol indicates the composition of water from the Floridian aquifer. Figure from Swart (2009).

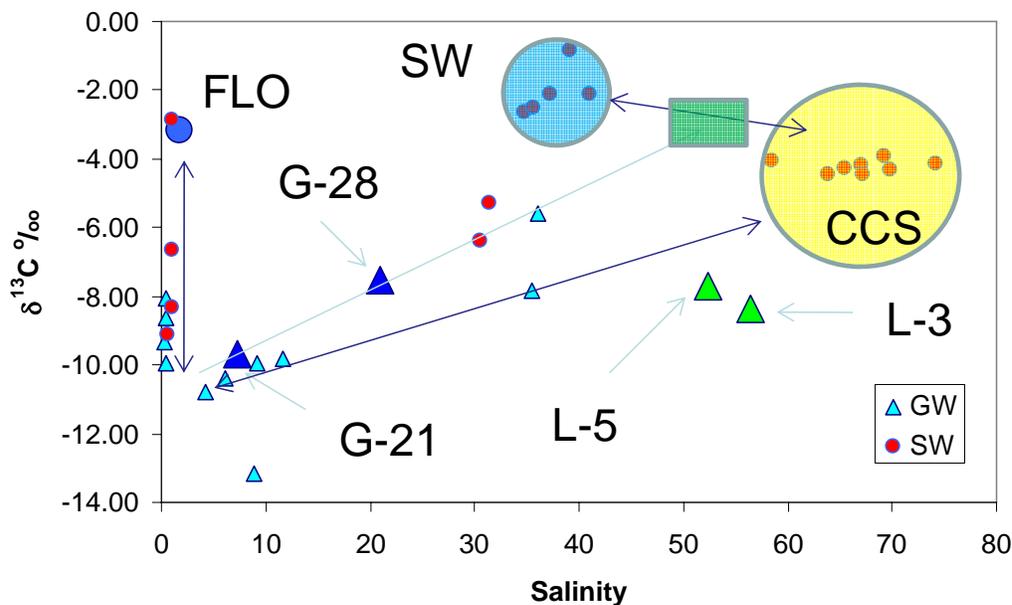
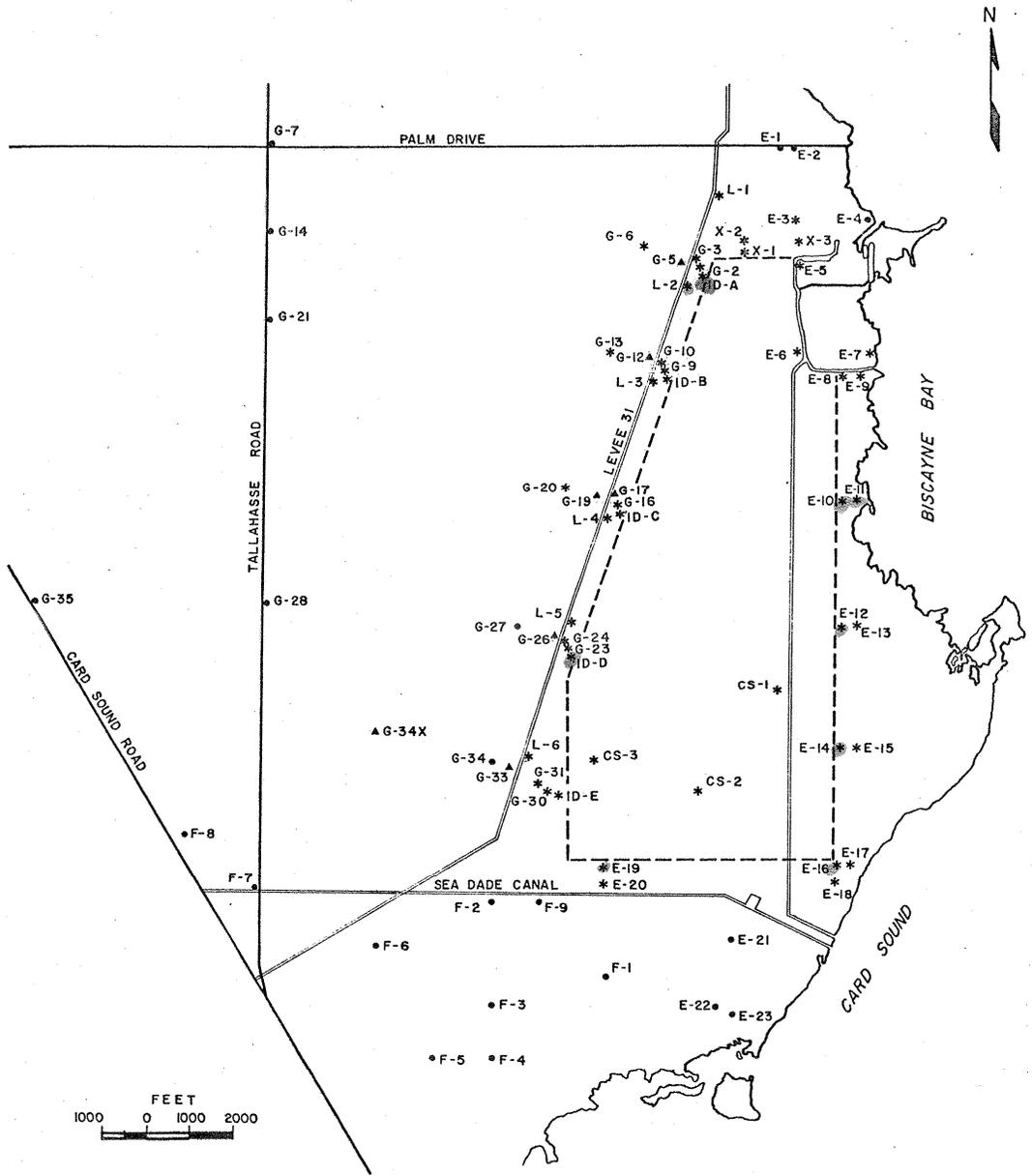


Figure 9) The relationship between salinity and $\delta^{13}\text{C}$ from Swart (2009). The data can be defined by mixing three different end members. These are the cooling canals (CCS, $S=74$, $\delta^{13}\text{C} = -4.4$), Floridan aquifer water ($S \sim 0$, $\delta^{13}\text{C} = -2$), and fresh groundwater ($S \sim 0$, $\delta^{13}\text{C} = -10$). The CCS water is shown by the yellow circle and Biscayne Bay (SW) by the light-blue circle. Water from Biscayne Bay falls on a mixing line between Floridian water and the cooling canals. Water from G-21 and G-28 (orange symbols) falls on a mixing line between groundwater and a fluid which is best represented by a mixture of seawater and CCS water (Green Box). The Floridan aquifer is represented by the round blue symbol.

Groundwater surrounding the Turkey Point site could be a mixture of any combination of rainwater, groundwater, BBSW or CCS water. In order for ^3H to be a useful tracer of CCS water, the amount of ^3H in the CCS must be significantly different than the other end-members. FPL reported that the average concentration of ^3H in the CCS water was 5000 pCi/L over the time period of 1990 to 2008 (FPL, 2009b). An average of 4000 pCi/L was reported to the Nuclear Regulatory Commission in FPL (2008a). Using the rainfall ^3H values from south Florida shown in Figure 4 the average value at RSMAS was 7.2 ± 3.4 pCi/L, ($n=212$) over the same time period and from Perrine it was 8.7 ± 4.1 pCi/L ($n = 51$) from 1998-2002, where the uncertainty is one standard deviation and n is the number of measurements. The background average of ^3H values in groundwater and surface water from south Florida is presented in Table 1. All of these averages are less than 15 pCi/L. Therefore, CCS water contains 333 times more ^3H than background BBSW and groundwater (assuming a 15 pCi/L average in BBSW and groundwater and 5000 pCi/L in CCS water) and should prove to be a very useful tracer of CCS water movement into the groundwater and surface water surrounding Turkey Point. Tritium has been used as a tracer of CCS seepage into the aquifer surrounding Turkey Point by FPL in the mid-1970s (Dames and Moore, 1978). This report states that “The presence of tritium in association with an increase in chlorinity would be evidence that cooling canal system waters contributed to

a portion of the chlorinity increase.” While actual tritium concentrations are not given (Dames and Moore, 1978), values above the detection limit of 500 pCi/L were reported in 34 wells at least once during the monthly sampling from October, 1975 to August 1976 (Figure 10). All wells with above detection limit values for ^3H were located close to the CCS. This report suggested that there was not enough ^3H data to calculate the proportion of CCS water in the aquifer, but that the presence of ^3H in the groundwater beneath and surrounding the CCS was evidence that CCS water was found in the aquifer.



LEGEND :

- * WELLS WITH TRITIUM IN GROUND WATER WITH CONCENTRATIONS IN EXCESS OF 0.5 pCi / mi .
- ▲ WELLS IN WHICH TRITIUM WAS NOT FOUND.

DAMES & MOORE

WELLS WITH TRITIUM
IN GROUND WATER
OCTOBER 1975 - AUGUST 1976

FIGURE 5.1

Figure 10) Wells where ^3H was >500 pCi/L

IV. Potential additional pathways of ³H into the Biscayne Aquifer surrounding Turkey Point

FPL has suggested that alternative sources (other than CCS water entering the Biscayne Aquifer) would render ³H not useful as a tracer. They have suggested that weapons testing could explain some of the elevated ³H found surrounding Turkey Point. As shown in Figures 1 and 2 no significant bomb produced ³H remains in the atmosphere or rainfall. Nearly all of the bomb-produced ³H was rained out of the atmosphere and deposited into surface or groundwater within several years of being introduced. The peak concentration of ³H in the atmosphere and rainwater occurred in 1963 (Figure 1). Measurements of ³H in Miami rain did not begin until 1964, but it is possible to estimate the 1963 average in Miami rain by scaling it to the Ottawa rain record (Price et al., 2003). In 1964, the yearly averaged ³H in rain in Ottawa was ~9.5 times greater than the corresponding Miami value. Using this scaling factor the average ³H value in Miami rain would have been 980 pCi/L in 1963. If one were to sample south Florida groundwater in 2009 that was recharged in 1963, there could be ~74 pCi/L of ³H remaining after radioactive decay. However, over that time period there is significant dispersion of the bomb peak ³H and a more realistic estimate of maximum bomb-peak ³H that would be found in south Florida groundwater would be ~ 15 to 20 pCi/L. This means that the maximum bomb peak ³H is nearly indistinguishable from background ³H values and could not significantly contribute to elevated levels of ³H found in groundwater surrounding Turkey Point.

Table 1) Average ³H values in ground and surface water from the South Florida area.

Location	Reference	Sampling years	³ H in groundwater (pCi/L)	³ H in surface water (pCi/L)
ENP	Price (2001)	1997-1999	5.2 ± 4.8 (n=120)	
WCA-3B	Happell et al. (2002)	2002	13.4 ± 7.7 (n=12)	7.2 ± 0.1 (n=2)
L31N	Happell et al. (2004)	2004	4.9 ± 2.9 (n=8)	6.7 ± 0.4 (n=3)
Lox Mit. Bank	Happell et al. (2005)	2004	6.0 ± 0.3 (n=3)	6.7 ± 0.4 (n=7)
Biscayne Bay	Happell (2003)	2003	8.2 ± 3.9 (n=10)	
Biscayne Bay	Happell (2005)	2005	8.7 ± 3.2 (n=12)	13.6 ± 5.1 (n=4)
Biscayne Bay	Synoptic Sampling	2009	6.0 ± 3.3 (n=2)	13.7 ± 5.8 (n=12)

ENP = Everglades National Park. WCA-3B = water conservation area 3B. L31N = L31N canal. Uncertainties are one standard deviation and n is the number of samples

Another potential additional source of ³H to the groundwater is HTO vapor scavenging by rainwater and deposition on the surface. This is usually referred to as tritium recapture. It is important to note that only a small portion of the released HTO vapor is scavenged by rain. Several studies have reported that ³H in rainfall is elevated near nuclear power plants (Harris et al, 2008; Tokuyama and Oonishi, 1997; Papadopoulos et al., 1986). The Harris et al. (2008) study was conducted at the Cook Nuclear Power Plant in response to elevated levels of tritium discovered in a storm drain outfall. While elevated ³H in rainfall was detected within 300 meters of the gaseous effluent vent, they concluded that rainfall was only a minor component to the elevated ³H seen in the storm drain outfall. Most of the elevated ³H in the storm drain came from

air conditioner condensate that was routed into the storm drain. This suggests that most of the HTO vapor remains in vapor form rather than being transferred to rain.

Tritium is released from Turkey Point in both liquid and gaseous forms. In liquid form all ^3H is in the form of HTO, and all is released into the CCS. In 2007, a total of 589.4 curies of ^3H was released in liquid form to the CCS (FPL 2008a). During gaseous releases both HTO and HT are released. The total of both these gaseous forms released in 2007 was 18.8 curies (FPL 2008a). Assuming all gaseous releases are in the form of HTO these releases only account for 3% of the total amount of ^3H released from Turkey Point. This suggests that recapture of gaseous emissions will not contribute significant amounts of ^3H to the environment surrounding Turkey Point when compared to liquid emissions. Possible pathways of gaseous HTO to the groundwater will be discussed below.

HTO vapor emissions to the atmosphere can also originate from evaporation of CCS water. This suggests that water vapor surrounding the cooling canals could be enriched in HTO. The only known measurements of HTO vapor surrounding Turkey Point vapor occurred in the mid-1970s (Ostlund and Dorsey, 1976). Four samples collected just to the west (downwind) of the cooling canals had an average ^3H concentration of 216 ± 45 pCi/L compared to two samples taken upwind of the cooling canals that had a average ^3H concentration of 118 ± 41 pCi/L. Ostlund and Dorsey (1976) also estimated that during the mid-1970s the flux of ^3H from the cooling canals via evaporation was 600 to 1100×10^{12} picocuries per year (pCi/y). This suggests that most of the ^3H released to the atmosphere via CCS water evaporation is greatly diluted by backgroundwater vapor and/or mixed into the atmosphere and quickly transported away from the Turkey Point site.

If there were significant amounts of HTO vapor deposited on the surface, the most likely place to detect this ^3H would be in surface water surrounding Turkey Point. In 2007, four out of 36 surface water samples collected had ^3H above the LLD of 147 pCi/L, while in 2008 two out of 36 samples had detectable ^3H (FPL 2008b, 2009a). According to FPL “These results are consistent with the known subsurface interchange that occurs between the closed cooling canal and its surrounding waters, and the hydraulic head pressure gradients caused by the flow of aquifer subsurface waters in south Florida.” (FPL 2008b, 2009a). Deposition of evaporated HTO was not considered in the report. Appendix D of this report is part of the voluntary industry initiative to monitor ^3H in groundwater, and 4 wells (L-3, L-5, G-21 and G-28) to the west of the cooling canals were sampled as part of this initiative. These wells have long screen zones (> 40 feet) and samples were collected from the top and bottom of the screen. If HTO vapor deposition were significant, one would expect to see detectable ^3H in the top of the wells, but all samples collected from the top of the wells were below the LLD of 350 pCi/L. In contrast, some samples collected from the bottom of the wells had detectable levels of ^3H , ranging from 440 to 4380 pCi/L (FPL 2008b, 2009a). According to FPL (2008b, 2009a), “Wells L-3 and L-5 are adjacent to the west border of the cooling canal system; the tritium levels seen in the 'bottom' samples is consistent with the known and understood interface between the canal system and underlying salt to brackish-water aquifer. As expected, tritium is not seen in the 'top' sample.”

Evapotranspiration of rain scavenged HTO vapor also needs to be considered when determining if this transport mechanism is able to move significant amounts of ^3H into the groundwater surrounding Turkey Point. Abteu (2004) estimates that the annual evapotranspiration rate in south Florida to be 134.5 cm/yr. The estimate was based on a review of the literature, as well as measurements. The average annual rainfall for Homestead, Florida is

140 cm/yr. This means that most of the HTO vapor scavenged by rainfall will be returned to the atmosphere via evapotranspiration and will not end up in the groundwater.

In conclusion, the only likely significant source of elevated over background ^3H in the groundwater surrounding Turkey Point is the subsurface connection between CCS water and the underlying Biscayne aquifer.

V. Tritium as a tracer of CCS water surrounding Turkey Point.

Stalker et al. (2009) developed a ternary mixing model using Ba^{+2} with BBSW, CCS water and fresh groundwater as the three end members (Figure 7). A similar approach will be used here for ^3H . A plot of specific conductance versus ^3H for all samples where both parameters were measured clearly indicates three distinct end member groups (Figure 11). One group is the relatively high conductivity/high ^3H set of samples from the CCS, the second is the group of moderate conductivity/low ^3H set of samples from surface and groundwater in Biscayne Bay, and a third group of relatively low conductivity/low ^3H set of samples from surface and groundwater on land surrounding the CCS. These groups are circled in light yellow in Figure 11. It is very clear from this plot that ^3H does not suffer the limitation of the other proposed tracers where it is not possible to distinguish between BBSW/fresh water and CCS water/freshwater mixtures. These are a set of groundwater (L3GW01, L5GW01, G28GW01, G21GW01, COH-MW-Trig-BS, and BBCW4GW01) and surface water (S20 and L31ESW05) samples that appear to be mainly mixtures of CCS water and fresh groundwater. There is a set of surface water samples (Pond, Eastbay, Benthic, and BBSW04) that appear to be a mixture of BBSW and CCS water. There are 3 groundwater samples (BBCW5GW01, FKS4GW01, and Sec34-MW-03-FS) that appear to be mainly mixtures of fresh groundwater and Biscayne Bay water, with a portion of very low ^3H groundwater (possibly Floridan aquifer).

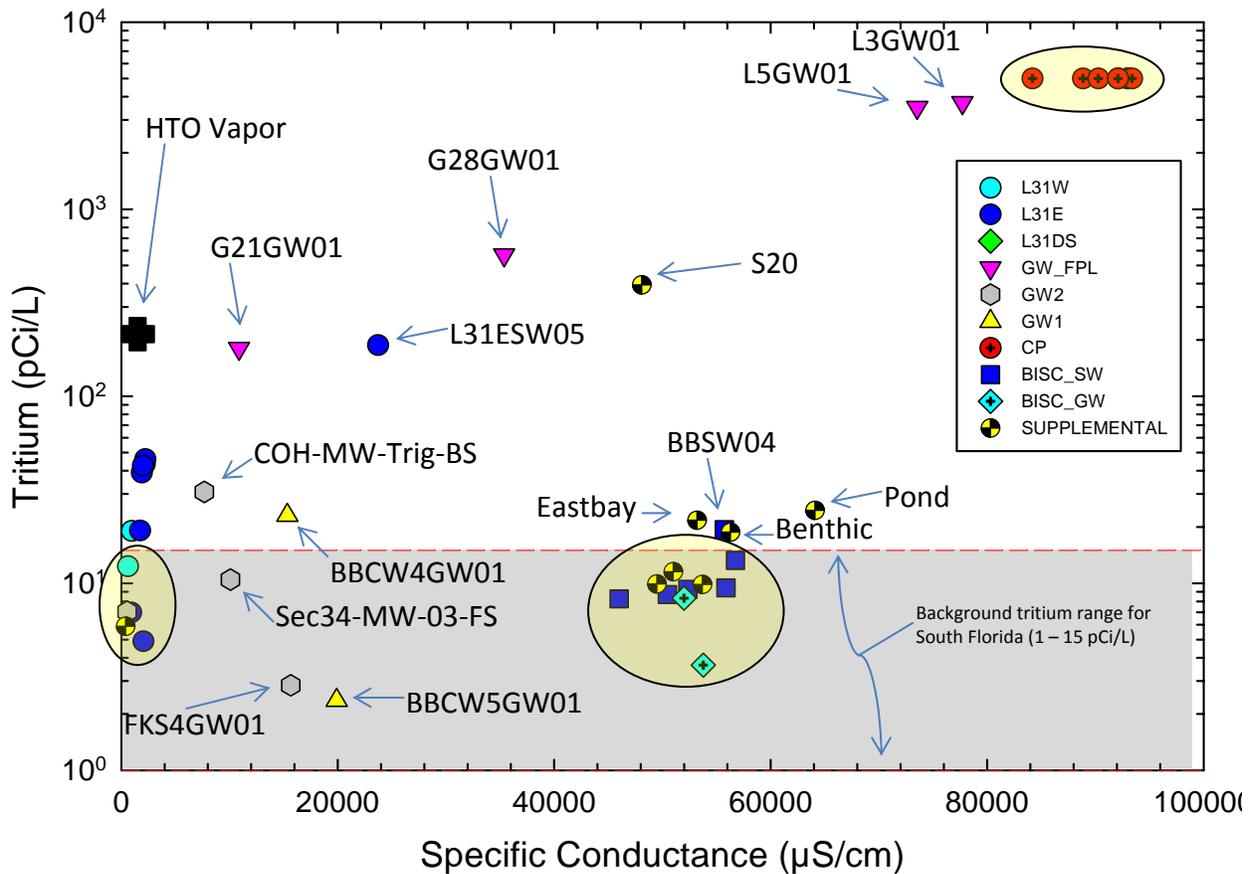


Figure 11) A plot of tritium versus specific conductivity. Tritium values in the GW_FPL and CP groups were obtained from FPL (2008a, 2008b, 2009a, 2009b). All other tritium values were measured as part of the February and March 2009 sampling events. Conductivity was measured in the field for most samples, except for the supplemental group where conductivity was measured in the lab from remaining samples. Light yellow circles represent the three known end members.

Included in Figure 11 as a black cross is the average ^3H value of HTO vapor measured in the Ostlund and Dorsey (1976) study. A conductivity of $500 \mu\text{S}/\text{cm}$ is assumed for this potential elevated HTO input. Only a portion of this HTO could be potentially deposited as rainfall into the local surface water, so the ^3H given for this potential input is probably less than shown in Figure 11. There does appear to be a set of surface water samples from the L31 canal that could be slightly affected by deposition of elevated HTO rain. A better knowledge of the ^3H concentration in the water vapor and rainfall close to the cooling and SFWMD canals would allow one to also see mixtures of fresh groundwater/elevated over local background rain HTO, which would be easily distinguishable from fresh groundwater/CCS water mixtures.

Swart (2009) reported that $\delta^{13}\text{C}$ might also be useful in differentiating between CCS water and seawater in mixtures. Making a 3D plot of $\delta^{13}\text{C}$, ^3H and conductivity shows how the addition of the $\delta^{13}\text{C}$ data compliments the ^3H versus conductivity plot (Figure 12).

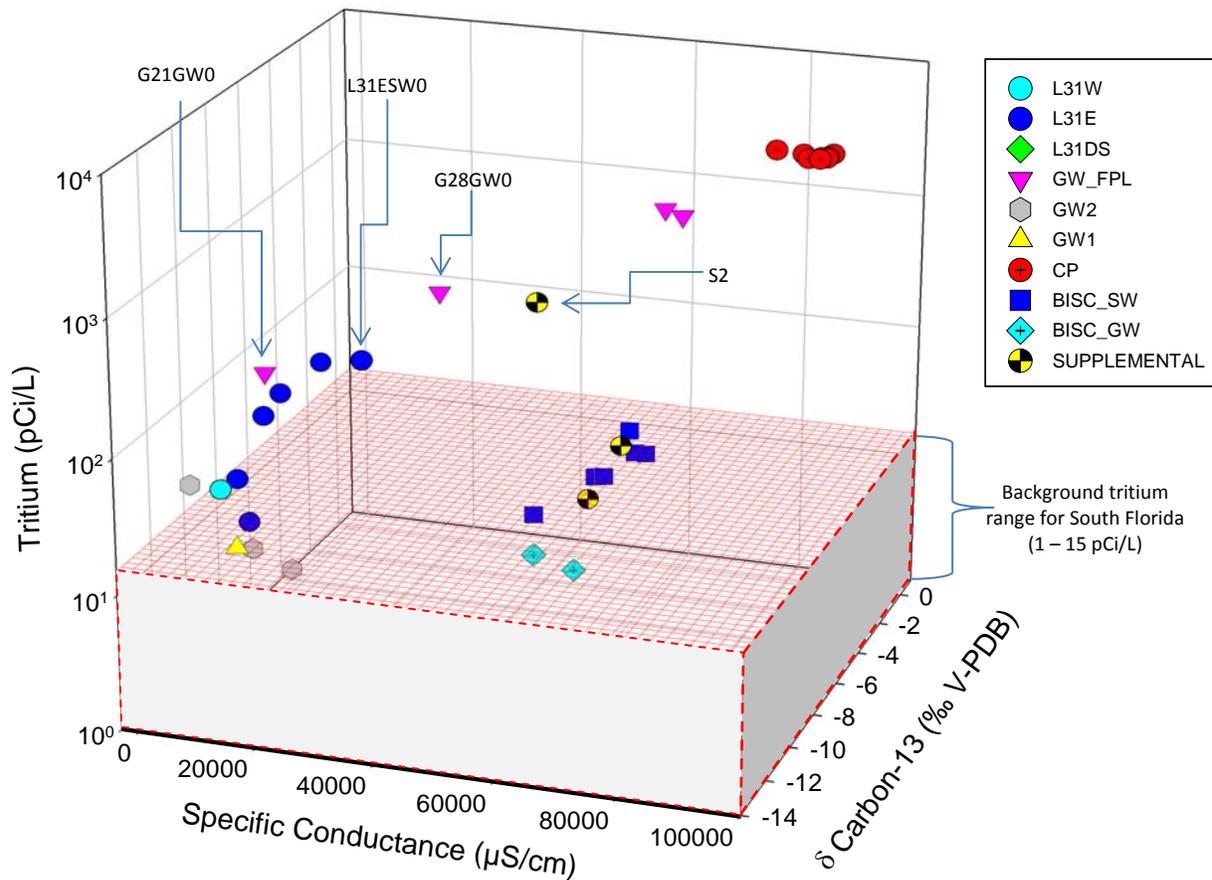


Figure 12) A 3D plot of tritium, specific conductance and $\delta^{13}\text{C}$. There are less supplemental points in this plot compared to Figure 11 because $\delta^{13}\text{C}$ was not measured in all samples.

It is premature to make estimates of the fraction of CCS water in mixtures at this time until better depth and spatial control on the groundwater sampling points is obtained. However it can be clearly seen from Figures 11 and 12 that including ^3H as a tracer allows one to differentiate between the relative amounts of CCS water, BBSW, and fresh groundwater (and elevated HTO rain if it is occurring) in the waters surrounding the Turkey Point cooling canals. It should also be pointed out that radioactive decay will decrease the amount of ^3H in groundwater as it moves away from the cooling canals. Unless time information is known any estimates of the fraction of CCS water in mixtures should be considered a minimum value. The underestimation will be larger at the edge of the CCS water plume. The age of the edge of the CCS water plume in the aquifer could be estimated by measuring other parameters such as helium-3 (^3He , in combination with ^3H), chlorofluorocarbons (CFCs), or sulfur hexafluoride (SF_6)

VI. Conclusions

- 1) The proposed alternative tracers to ^3H , that were measured in the synoptic survey, do not allow one to determine the source (BBSW or CCS) of fresh groundwater salinization when salinities are below that of BBSW. Ba^{+2} and $\delta^{13}\text{C}$ can be useful in some cases.

- 2) Tritium is a very useful tracer of groundwater movement because it is part of the water molecule. Tracing tritium in groundwater is by default tracing groundwater flow. Groundwater flow has been traced at many nuclear power plants and facilities, including Turkey Point, by using tritium measurements.
- 3) While it was not the intent of FPL, they have, in effect, carried out a relatively long term (~ 35 years) deliberate tracer experiment surrounding the Turkey Point cooling canals, by carefully controlling and monitoring the addition of ^3H to the cooling canals.
- 4) Tritium is a very useful tracer of CCS water surrounding Turkey Point. A ^3H versus specific conductivity plot (Figure 11) clearly shows how ^3H can be used to distinguish CCS water inputs even when mixture salinities are below BBSW salinity. Taking into account the possibility of a small source of elevated ^3H rainfall into the mix, all samples obtained to date can be explained by mixtures of CCS water/BBSW/fresh groundwater/ ^3H elevated rain. Estimates of the fractions of these various end members can be determined by the following recommendations.

Recommendations

- 1) A series of well clusters with multiple screen depths surrounding the cooling canals on all sides (including Biscayne Bay) is needed to obtain a better idea of the horizontal and vertical extent of CCS water movement into the aquifer.
- 2) Tritium measurements in samples from these well clusters, as well as in surface water, water vapor, and rainfall in the vicinity of Turkey Point, are needed to accurately characterize the extent and amount of the CCS water influence in the groundwater surrounding Turkey Point.
- 3) At a minimum, in addition to the ^3H measurements, Ba^{+2} , $\delta^{13}\text{C}$ and conductivity (or a proxy such as salinity or Cl^-) should be measured in surface and groundwater surrounding the plant. Measurements of all of the major ions and stable isotopes measured in the synoptic survey would complement the above tracers. The addition of components such as ^3He , CFCs and SF_6 would help determine the age of the CCS water in the Biscayne aquifer and would make the determination of the fraction of CCS water more robust because radioactive decay of ^3H could be accounted for.

References

- Abteu, W. 2004. Evapotranspiration in the Everglades: comparison of Bowen Ratio measurements and model estimations. *South Florida Water Management District Technical Paper* **417**, 16 pp.
- Barnett, D.B., Reiger, J.T. and Thornton E.C. 2003. Results of tritium tracking and groundwater monitoring at the Hanford Site 200 Area state-approved land disposal site—fiscal year 2003. *PNNL Report*, **PNNL-14449**, 30 pp.
- Begemann, F. and Libby, W. F. 1957. Continental water balance, groundwater inventory and storage times, surface ocean mixing rates and world wide water circulation patterns from cosmic-ray and bomb tritium. *Geochim. Cosmochim. Acta* **12**, 277-296.
- BNL. 2000. Operable Unit III Record of Decision. Environmental Restoration Division, Brookhaven National Laboratory.
- BNL. 2009. Final Record of Decision for Area of Concern 31 High Flux Beam Reactor. Environmental Restoration Division, Brookhaven National Laboratory.
- Bush, K.A. 1988. Identification of Savannah River water on the South Atlantic Bight Shelf using tritium. *J. Geophys. Res.* **93**, 9315-9331.
- Dames and Moore. 1978. Salinity evaluation Turkey Point cooling canal system, Florida Power and Light Company.
- Faltings, V. and Harteck, P. 1950. Der tritium gehalt der atmosphäre. *Z. Naturforsch* **52**, 438-439.
- Fish, J.E. and Stewart, M. 1991. Hydrogeology of the Surficial Aquifer System, Dade County, Florida. *U.S. Geological Survey Water-Resources Investigations Report* **90-4108**.
- FPL. 2008a. Annual radioactive effluent release report, January 2007 through December 2007.
- FPL. 2008b. Annual radiological environmental operating report, January 2007 through December 2007.
- FPL. 2009a. Annual radiological environmental operating report, January 2008 through December 2008.
- FPL. 2009b Report to the SFMWD on June 23, 2009.
- Grosse, A. V., Johnston, W. M. and Wolfgang, R. L. 1951. Tritium in nature. *Science* **113**, 1-2.
- Happell, J.D. 2003. Tritium Laboratory data release 03-24, University of Miami.
- Happell, J.D. 2005. Tritium Laboratory data release 05-69, University of Miami.

- Happell, J.D., Top, Z. and Swart P.K. 2002. Tree island preliminary isotope study. SFWMD report. 10 pp.
- Happell, J.D., Top, Z. and Swart P.K. 2004. L31N isotope study. SFWMD report. 12 pp.
- Happell, J.D., Top, Z. and Swart P.K. 2005. Loxahatchee Mitigation Bank/Boca Chase Isotope Study. SFWMD report. 12 pp.
- Hariss, J.T., Miller, D.W. and Foster D.W. 2008. Tritium recapture behavior at a nuclear power reactor due to airborne releases. *Health Phys.* **92**, 203-212.
- Hayes, D.W. 1979. Tritium in the Savannah River estuary and adjacent marine waters. *Behaviour of Tritium in the Environment*. IAEA, 271-281.
- Hoehn, E. and Santschi, P.H. 1987. Interpretation of tracer displacement during infiltration of river water to groundwater. *Water. Resour. Res.* **23**, 633-640.
- Houle, D. Carigan, R. and Roberge, R. 2004. The transit of $^{35}\text{SO}_4^{-2}$ and $^3\text{H}_2\text{O}$ added in situ to soil on a boreal coniferous forest. *Water, Air and Soil Poll.* **4**, 501-517.
- Hughes, J.D., Langevin, C.D, and Brakefield-Goswami, L. 2009. Effect of hypersaline cooling canals on aquifer salinization. *Hydrogeol. J.* DOI 10.1007/s10040-009-0502-7.
- International Atomic Energy Agency (IAEA) 1962, *Tritium in the Physical and Biological Sciences*. Vol. 1. IAEA, 369 pp.
- IAEA/WMO. 2006. Global Network of Isotopes in Precipitation. The GNIP Database. Accessible at: <http://isohis.iaea.org>
- Kaufman, S. and Libby, W. F. 1954. The natural distribution of tritium. *Phys. Rev.* **93**, 1337-1344.
- Kaufmann, W.J. and Todd, D.K. 1962. Application of tritium tracer to canal seepage measurements. *Tritium in the Physical and Biological Sciences* **1**, 83-94.
- Kohout. F.A..1960. Cyclic Flow of Salt Water in the Biscayne Aquifer of South-eastern Florida. *Journal of Geophysical Research* **65**, 2133-2141.
- Lal, D. and Peters, B. 1967. Cosmic ray produced radioactivity on earth. *Encyclopedia of Physics* **46**, 407-434.
- LANL 2007. Plans and Practices for Groundwater Protection at Los Alamos National Laboratory: Final Report, ISBN: 0-309-10620-6, National Academies Press, 104 pp.
- Michel, R.L. 2005. Tritium in the hydrologic cycle. In: *Isotopes in the Water Cycle: Past, Present, and Future of a Developing Science*, 53-66.

O'Brien, K., Lerner, A.D., Shea, M.A. and Smart, D.F. 1992. The production of cosmogenic isotopes in the Earth's atmosphere and their inventories, In: *The Sun in Time*, Univ. Arizona Press, 317-342.

Ostlund, H. G. and Dorsey, H.G. 1976. Turkey Point Tritium. *University of Miami/Rosenstiel School of Marine and Atmospheric Science Report 76005*. 13pp.

Papadopoulos D, Konig LA, Langguth KG and Fark S. 1986. Contamination of precipitation due to tritium release into the atmosphere. *Radiat Protect Dosim.* **16**, 95–100.

Price, R.M. 2001. Geochemical determinations of groundwater flow in Everglades National Park. PhD. Dissertation. Univ. of Miami, 307 pp.

Price, R.M., Top, Z., Happell, J.D. and Swart, P.K. 2003. Use of tritium and helium to define groundwater flow conditions in Everglades National Park. *Water Resour. Res.* **39**, 1267-1278.

Quay, P.D., Broecker, W.S., Hesslein, R.H. and Schindler, D.W. 1980. Vertical diffusion rates determined by tritium tracer experiments in the thermocline and hypolimnion of two lakes. *Limnol. Oceanogr.* **25**, 201-218.

Reese, R. S. and Cunningham, K. J. 1999. Hydrogeology of the Gray Limestone Aquifer in South Florida. *USGS Water Resources Investigation Report, 99-4213*.

Santschi, P.H., Hoehn, E., Lueck, A. and Farrenkothén, K. 1987. Tritium as a tracer of the movement of surface water and groundwater in the Glatt Valley, Switzerland. *Environ. Sci. Technol.* **21**, 910-916.

Stalker, J.C., Price R.M. and McFarlane, A. 2009. Geochemical Investigation of the surface water and groundwater in the immediate Vicinity of Florida Power and Light Turkey Point Cooling Canals. SFWMD report. 42 pp.

Swart, P.K. 2009. Analysis of the Stable H, O, and C Isotopic Composition of Waters in the Vicinity of Turkey Point Power Plant, South Florida. SFWMD report. 22 pp.

Tokuyama H and Oonishi M. 1997. Precipitation washout of tritiated water vapor from a nuclear reactor. *J Environ Radioact.* **34**, 59–68.

UNSCEAR 2000. Sources and effects of ionizing radiation, In: *United Nations Scientific Committee on the Effects of Atomic Radiation, Volume I: Sources*, 654 pp.

Appendix F

L-31E SPECIFIC CONDUCTANCE AND TEMPERATURE

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

L-31E CANAL SPECIFIC CONDUCTANCE AND TEMPERATURE PROFILING

Miami-Dade County, Florida



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Introduction

On February 4, 2009, South Florida Water Management District (SFWMD) staff ran 28 water temperature and specific conductance profiles in the L-31E Canal (see locations in **Table 1**). Staff ran the profiles on a 6.5-mile reach of the canal south from the starting point at S.W. 344th Street (Palm Drive) as shown in **Figure 1**. Each of the 28 profiles was run at approximately 0.25-mile intervals from the beginning of the canal segment. A dirt road intersects the canal six miles south of the starting point. At this location, staff ran a profile on either side of the culvert that connected the canal segments under the road, then continued south for another 0.5 miles until the L-31E Canal turned to the southwest. At each location, SFWMD staff collected a specific conductance and water temperature profile from the surface of the canal to the bottom.

Table 1. Locations of profile sites.

Site	Latitude	Longitude	Site	Latitude	Longitude
1	25° 26' 52.4"	80° 20' 59.2"	15	25° 24' 03.1"	80° 21' 53.3"
2	25° 26' 40.0"	80° 20' 59.3"	16	25° 23' 51.2"	80° 21' 57.2"
3	25° 26' 27.8"	80° 21' 01.5"	17	25° 23' 38.7"	80° 22' 01.8"
4	25° 26' 15.7"	80° 21' 05.9"	18	25° 23' 26.9"	80° 22' 06.1"
5	25° 26' 03.8"	80° 21' 10.2"	19	25° 23' 14.5"	80° 22' 10.5"
6	25° 25' 51.0"	80° 21' 14.7"	20	25° 23' 02.8"	80° 22' 14.6"
7	25° 25' 39.3"	80° 21' 18.9"	21	25° 22' 51.2"	80° 22' 18.7"
8	25° 25' 27.9"	80° 21' 23.0"	22	25° 22' 38.5"	80° 22' 23.2"
9	25° 25' 15.8"	80° 21' 27.2"	23	25° 22' 26.3"	80° 22' 27.7"
10	25° 25' 03.4"	80° 21' 31.6"	24	25° 22' 14.0"	80° 22' 31.9"
11	25° 24' 51.3"	80° 21' 36.1"	25	25° 22' 02.1"	80° 22' 36.2"
12	25° 24' 39.1"	80° 21' 40.4"	26	25° 22' 00.3"	80° 22' 36.6"
13	25° 24' 26.7"	80° 21' 44.8"	27	25° 21' 48.2"	80° 22' 40.9"
14	25° 24' 14.7"	80° 21' 49.0"	28	25° 21' 34.2"	80° 22' 45.9"

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Methodology

SFWMD staff used a YSI 600 XL multi-parameter probe to collect the water temperature and specific conductance profiles in the L-31E canal. The unit collected pressure (converted to depth in feet), water temperature, and specific conductance readings. Before using the unit, SFWMD staff calibrated the specific conductance sensor with a 2,000 microsiemens per centimeter ($\mu\text{S}/\text{cm}$) standard, the standard closest to the anticipated specific conductance values in the canal. A hand-held global positioning system (GPS) unit (Garmin GPSmap 60CS) was used to collect the latitude and longitude of each profile location. The profile locations started in the L-31E adjacent to S.W. 344th Street and were numbered successively from locations 1 through 28. Staff used the trip function on the GPS to measure 0.25 miles between subsequent sampling points. At each location, staff reset the depth sensor on the YSI unit to zero feet, corresponding to the surface level of the canal. The logging function was set to collect data every 0.5 seconds as the unit was lowered to the bottom of the canal. Staff stopped the logging function on the YSI when the unit rested on the bottom of the canal. This method allowed the multi-parameter probe to collect data from the surface to the base of the canal.

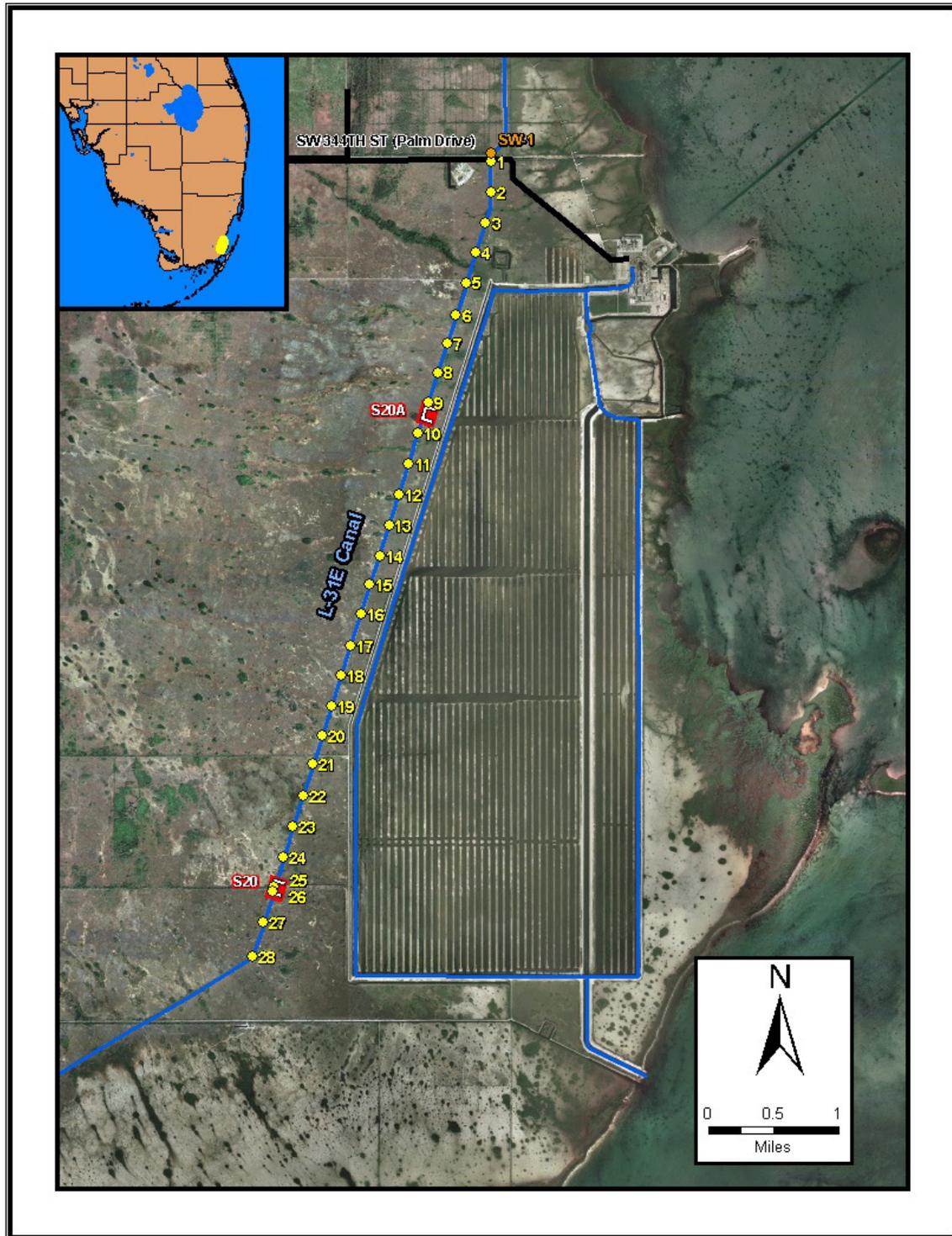


Figure 1. Locations of the profiles in the L-31E Canal, Miami-Dade County.

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Results

The following sections describe the results of the specific conductance and water temperature profiling. Appendix A includes full profiles for both specific conductance and water temperature at each location. Table 2 provides a summary of the specific conductance and water temperature data at the water surface and canal bottom for each location. The table also includes the distance of each profile from the starting location adjacent to S.W. 344th Street and the canal bottom depth. As a reference, the surface water elevation in the L-31E Canal during the profiling event was 1.26 feet referenced to the 1929 National Geodetic Vertical Datum (NGVD 1929). Note that the canal bottom depth is not referenced to NGVD and is a measured depth below the water surface in the canal.

Table 2. Surface and canal bottom profile data.

Sample Location	Approximate Distance from Start (miles)	Specific Conductance at Top ($\mu\text{S}/\text{cm}$)	Specific Conductance at Bottom ($\mu\text{S}/\text{cm}$)	Water Temperature at Surface (°C)	Water Temperature at Bottom (°C)	Bottom Depth (feet)
1	0.00	2,173	2,161	19.72	19.62	10.1
2	0.25	2,137	2,091	19.76	19.58	8.8
3	0.50	2,123	2,090	19.89	19.78	11.1
4	0.75	2,094	2,089	20.28	19.89	7.8
5	1.00	2,065	2,053	20.06	19.70	8.8
6	1.25	2,029	2,028	19.79	19.63	8.0
7	1.50	1,999	1,980	20.15	19.67	10.2
8	1.75	1,971	1,967	20.25	19.84	10.4
9	2.00	1,937	1,900	20.15	19.66	7.9
10	2.25	1,905	1,910	20.07	19.55	9.6
11	2.50	1,880	1,742	20.09	19.73	10.1
12	2.75	1,855	1,847	20.14	19.67	10.4
13	3.00	1,831	1,821	20.22	19.81	10.2
14	3.25	1,807	1,790	20.07	19.61	9.1
15	3.50	1,770	1,767	19.90	19.64	7.9
16	3.75	1,750	1,741	20.03	19.67	8.9
17	4.00	1,720	1,721	20.29	19.68	9.3
18	4.25	1,707	1,699	20.11	19.73	10.6
19	4.50	1,683	1,601	20.33	19.71	11.2
20	4.75	1,682	1,674	20.31	19.73	10.2
21	5.00	1,737	1,787	20.58	19.93	9.9
22	5.25	1,691	1,683	20.93	19.93	9.6
23	5.50	1,682	1,653	20.67	19.90	11.2
24	5.75	1,673	1,668	20.69	20.00	9.5
25	6.00	1,671	1,664	20.88	20.51	8.7
26	6.00	1,775	1,767	20.22	19.64	11.7
27	6.25	1,773	1,768	20.46	19.72	8.1
28	6.50	1,789	1,791	21.52	19.71	9.1

3.1 SPECIFIC CONDUCTANCE PROFILES

The profiling showed that the specific conductance in the L-31E Canal decreased as SFWMD staff proceeded south for the first 4.5 miles. After 4.5 miles, the specific conductance readings remained somewhat similar until the canal intersected the dirt road at 6 miles from the starting location. On the south side of the dirt road, the specific conductance readings in the canal were approximately 100 $\mu\text{S}/\text{cm}$ higher than the north side of the road. Generally, the specific conductance values at the canal surface were higher and showed less variability than the values at the bottom of the canal. The only major discrepancy was the reading collected at five miles south of the starting location (Site 21). At Site 21, the specific conductance from the bottom of the canal was higher than the surface value. This site is located south of an unnamed canal running west from the L-31E Canal. This unnamed canal does not appear to be directly connected (i.e., not connected by culvert or control structure) to the canals and cooling ponds on Florida Power and Light's property. This canal may have some influence on the specific conductance reading collected at Site 21. No profile locations were planned for the unnamed canal; therefore, its specific conductance is unknown. At Site 17, 4 miles from the starting point, the water was slightly (1 $\mu\text{S}/\text{cm}$) higher at the bottom of the canal than at the surface. There was generally only a slight variability between the surface and bottom specific conductance values, except at the locations collected 2.0, 2.5, and 4.5 miles from the starting location (Sites 9, 11, and 19, respectively). At these locations, the specific conductance of the water had a difference greater than 50 $\mu\text{S}/\text{cm}$ between the surface and the bottom of the canal.

Figure 2 is a chart showing the changes in specific conductance at the surface and bottom of the canal moving south from location Site 1. Each grid line on the X-axis corresponds to a sample location shown in **Figure 1**, as the grid lines are spaced every 0.25 miles. Site 1 starts at 0 miles on the X-axis, and each subsequent site is located on each gridline along the axis. Sites 25 and 26 both occur at 6 miles from the start, on either side of a culvert, hence the vertical line on the chart, as two values (one for each site) are plotted at this point. **Figure 3** shows the contoured specific conductance values for the entire profile at each site. Please note that the apparent oscillation at a distance of 5.75 to 6.25 miles is an artifact of contouring two sample locations at this distance.

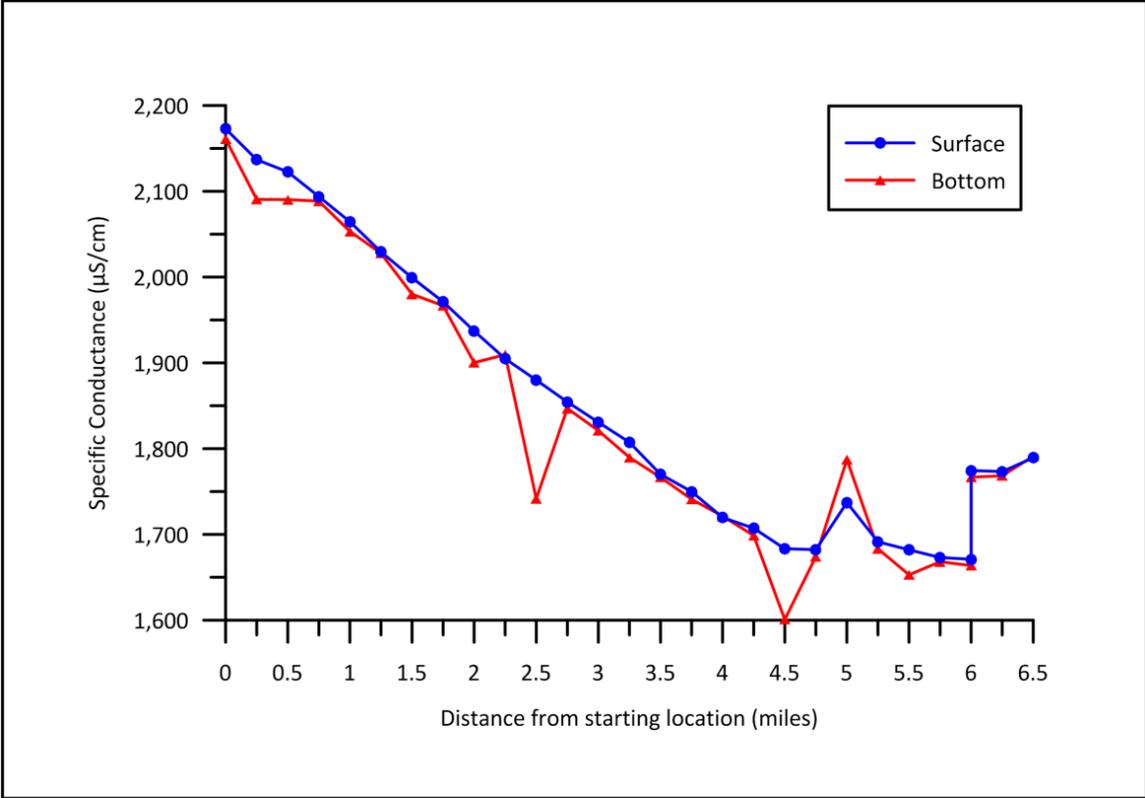


Figure 2. Specific conductance values based on distance from the starting location.

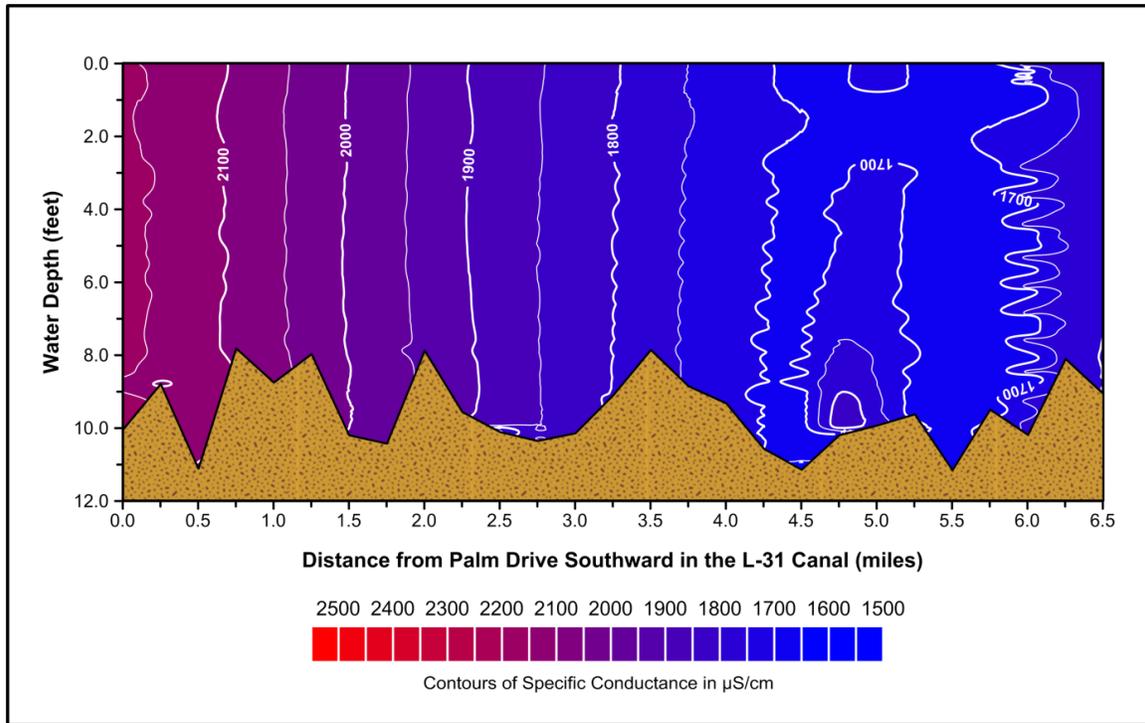


Figure 3. Contoured specific conductance values with depth based on distance from the starting location.

At the end of the day, SFWMD staff took one of the calibrated YSI units to the section of the L-31E Canal located north of Site 1 (labeled SW-1 in **Figure 1**). This section of the canal is located on the north side of S.W. 344th Street and is not directly connected (i.e., not connected by culvert or control structure) to the section of canal where the staff conducted the profiling. The specific conductance at the bottom of the northern section of the L-31E adjacent to the north side of S.W. 344th Street was 569 $\mu\text{S}/\text{cm}$. There was also a noticeable difference in the appearance of the canal water here. On the north side of S.W. 344th Street, the water was colorless and clear, while on the south side, where the profiles were run, the water was light brown and turbid.

3.2 WATER TEMPERATURE PROFILES

The profiling showed that the water temperature in the L-31E Canal remained fairly constant as SFWMD staff proceeded south for the first 4.75 miles. After 4.75 miles, the water temperature readings increased, at both the surface and bottom of the canal. The increases in surface water temperature may be due to the fact that these reading were collected around the middle of the day when the water had been warmed by the sun. However, between 4.75 and 5 miles, the bottom water temperature reading increased slightly. This increase could be due to influence from the unnamed canal running west of the L-31E Canal. The water temperature increase seen at 6 miles on the north side of the

culvert may be due to warmer water seeping under or around the S-20 structure. One can reach this conclusion because the surface and bottom water temperature dropped significantly on the south side of the culvert. **Figure 4** is a chart showing the changes in water temperature moving south from Site 1 at the surface and bottom of the canal. Each grid line on the X-axis corresponds to a sample location shown in **Figure 1**, as the grid lines are spaced every 0.25 miles on the axis. **Figure 5** shows the contoured water temperature values for the entire profile at each site. One should note that the unusual pattern at a distance 6 miles (the vertical line) is due to collecting two samples at this distance on either side of a culvert. [SFWMD1]

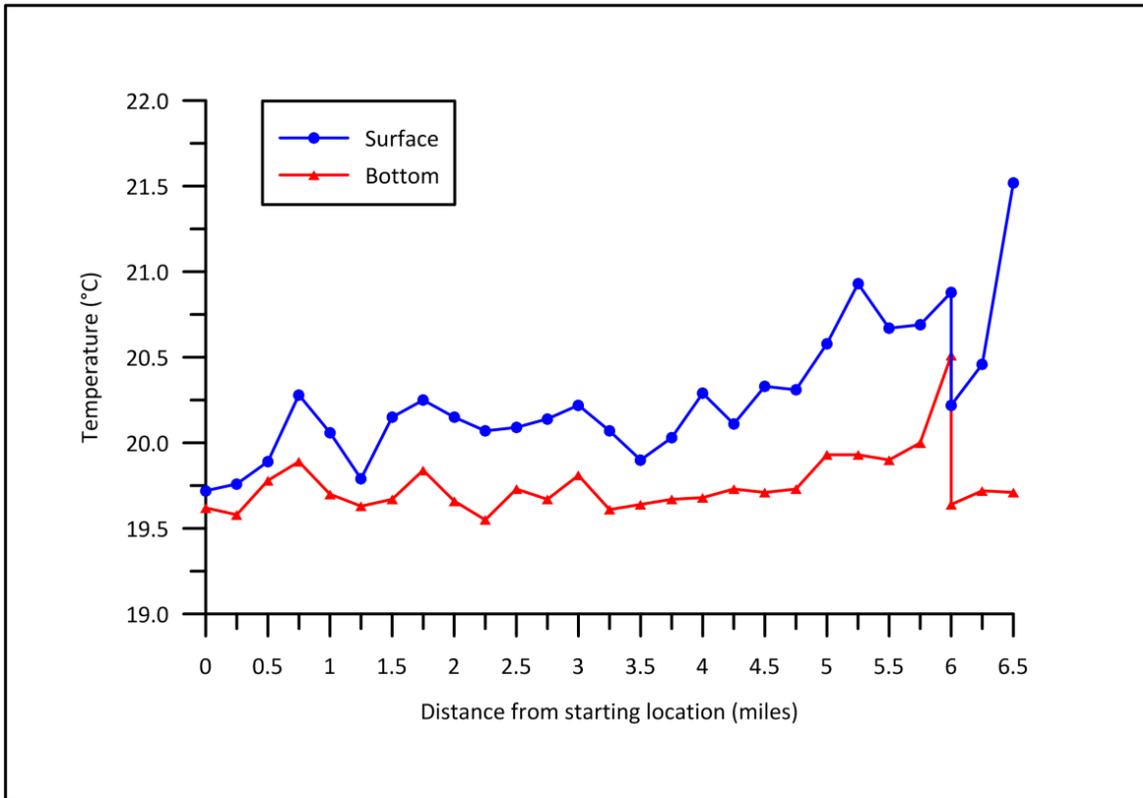


Figure 4. Water temperature values based on distance from the starting location.

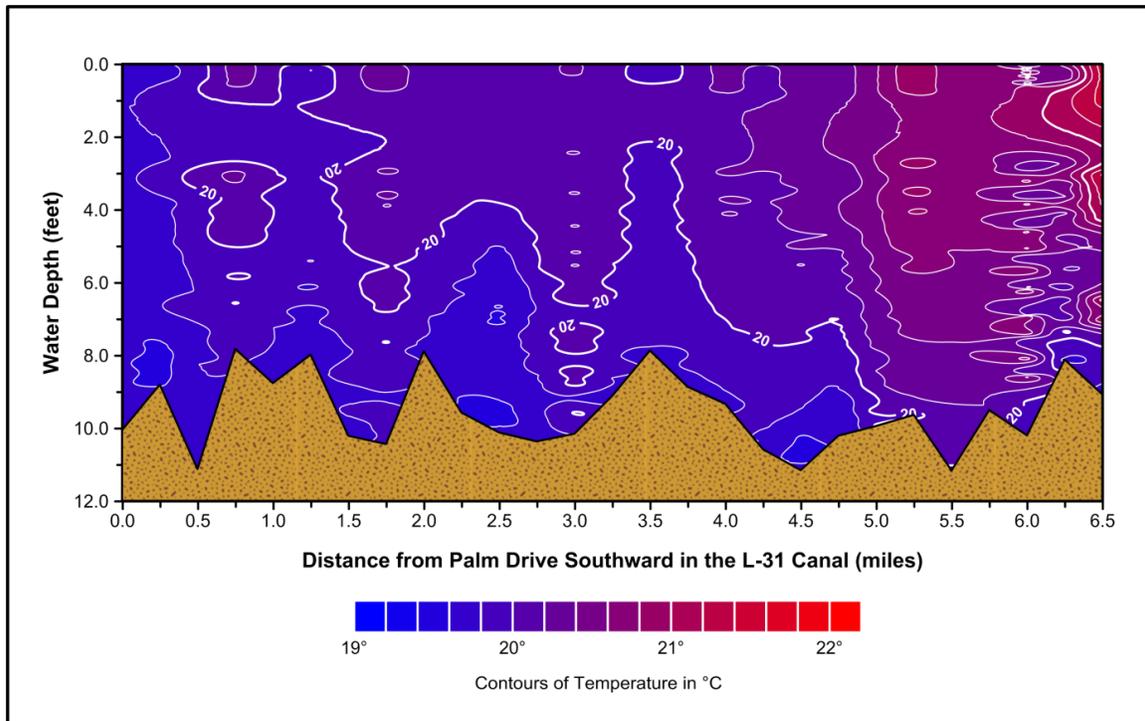


Figure 5. Contoured water temperature values with depth based on distance from the starting location.

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Conclusions and Recommendations

Based on the data collected for this investigation, there is a significant change in the specific conductance in the L-31E Canal as one proceeds south. Water temperature variations are more subtle and water temperatures may be affected by the time of day they were measured. It may be worthwhile collecting future profiles in the afternoon when peak air temperatures are reached to determine how much ambient temperature affects the water temperature readings at the surface.

Based on this investigation, additional profiles should be run in the L-31E Canal at the same locations to see if these readings vary temporally. Future readings should be collected in the wet and dry seasons to see if the time of year also affects the profiles. As previously mentioned, profiles should be collected after noon to see if ambient temperature effects can be reduced. Another idea could be to collect profile samples running north to south and then collect profiles later in the day for the first mile to see if variations in water temperature are due to ambient conditions.

Additional profiles should be collected in the unnamed canal that runs west of the L-31E and on the opposite side of S-20 to ascertain the water conditions at these locations and determine if water from these locations could be influencing conditions in the L-31E Canal.

Appendix A

SPECIFIC CONDUCTANCE AND TEMPERATURE PROFILE DATA

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 01	0.00	2/4/2009	10:05:10	0.226	19.72	2172.9
Site 01	0.00	2/4/2009	10:05:11	0.446	19.73	2172.5
Site 01	0.00	2/4/2009	10:05:11	2.855	19.73	2172.0
Site 01	0.00	2/4/2009	10:05:12	3.411	19.73	2171.3
Site 01	0.00	2/4/2009	10:05:12	4.082	19.73	2171.0
Site 01	0.00	2/4/2009	10:05:13	4.563	19.73	2170.6
Site 01	0.00	2/4/2009	10:05:13	5.229	19.73	2170.2
Site 01	0.00	2/4/2009	10:05:14	5.699	19.73	2169.7
Site 01	0.00	2/4/2009	10:05:14	6.019	19.72	2169.5
Site 01	0.00	2/4/2009	10:05:15	6.296	19.72	2169.4
Site 01	0.00	2/4/2009	10:05:15	7.101	19.71	2168.9
Site 01	0.00	2/4/2009	10:05:16	7.902	19.70	2168.1
Site 01	0.00	2/4/2009	10:05:16	8.473	19.69	2167.7
Site 01	0.00	2/4/2009	10:05:17	9.191	19.68	2166.8
Site 01	0.00	2/4/2009	10:05:17	9.961	19.66	2165.9
Site 01	0.00	2/4/2009	10:05:18	9.981	19.65	2164.3
Site 01	0.00	2/4/2009	10:05:18	10.037	19.63	2162.8
Site 01	0.00	2/4/2009	10:05:19	10.056	19.62	2161.1
Site 02	0.25	2/4/2009	10:18:11	0.011	19.76	2136.9
Site 02	0.25	2/4/2009	10:18:12	0.028	19.76	2136.8
Site 02	0.25	2/4/2009	10:18:12	0.124	19.76	2136.8
Site 02	0.25	2/4/2009	10:18:13	0.246	19.76	2136.8
Site 02	0.25	2/4/2009	10:18:13	0.413	19.76	2136.7
Site 02	0.25	2/4/2009	10:18:14	2.585	19.76	2136.8
Site 02	0.25	2/4/2009	10:18:14	3.756	19.75	2136.6
Site 02	0.25	2/4/2009	10:18:15	3.829	19.74	2136.7
Site 02	0.25	2/4/2009	10:18:15	4.450	19.73	2136.6
Site 02	0.25	2/4/2009	10:18:16	4.682	19.72	2136.9
Site 02	0.25	2/4/2009	10:18:16	5.223	19.71	2137.1
Site 02	0.25	2/4/2009	10:18:17	5.758	19.70	2137.2
Site 02	0.25	2/4/2009	10:18:17	6.015	19.69	2137.4
Site 02	0.25	2/4/2009	10:18:18	7.085	19.68	2137.8
Site 02	0.25	2/4/2009	10:18:18	7.088	19.66	2137.9
Site 02	0.25	2/4/2009	10:18:19	7.199	19.65	2138.2
Site 02	0.25	2/4/2009	10:18:19	7.312	19.63	2138.5
Site 02	0.25	2/4/2009	10:18:20	7.437	19.61	2139.0
Site 02	0.25	2/4/2009	10:18:20	7.594	19.60	2139.4
Site 02	0.25	2/4/2009	10:18:21	7.711	19.58	2139.9
Site 02	0.25	2/4/2009	10:18:21	7.899	19.56	2140.4
Site 02	0.25	2/4/2009	10:18:22	8.036	19.55	2139.9
Site 02	0.25	2/4/2009	10:18:22	8.202	19.54	2135.0
Site 02	0.25	2/4/2009	10:18:23	8.359	19.54	2125.4
Site 02	0.25	2/4/2009	10:18:23	8.493	19.54	2115.9
Site 02	0.25	2/4/2009	10:18:24	8.611	19.55	2106.9
Site 02	0.25	2/4/2009	10:18:24	8.715	19.57	2098.5
Site 02	0.25	2/4/2009	10:18:25	8.804	19.58	2090.6
Site 03	0.50	2/4/2009	10:25:56	0.037	19.89	2122.7
Site 03	0.50	2/4/2009	10:25:57	0.074	19.89	2122.9
Site 03	0.50	2/4/2009	10:25:57	0.179	19.88	2122.8
Site 03	0.50	2/4/2009	10:25:58	0.358	19.88	2122.7
Site 03	0.50	2/4/2009	10:25:58	2.357	19.88	2122.7
Site 03	0.50	2/4/2009	10:25:59	3.820	19.88	2122.6
Site 03	0.50	2/4/2009	10:25:59	4.226	19.88	2122.4
Site 03	0.50	2/4/2009	10:26:00	5.041	19.87	2122.0
Site 03	0.50	2/4/2009	10:26:00	5.215	19.87	2121.8

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 03	0.50	2/4/2009	10:26:01	5.238	19.86	2122.0
Site 03	0.50	2/4/2009	10:26:01	5.392	19.85	2121.8
Site 03	0.50	2/4/2009	10:26:02	5.529	19.84	2121.6
Site 03	0.50	2/4/2009	10:26:02	5.680	19.84	2121.4
Site 03	0.50	2/4/2009	10:26:03	5.889	19.83	2121.3
Site 03	0.50	2/4/2009	10:26:03	6.074	19.82	2121.2
Site 03	0.50	2/4/2009	10:26:04	6.234	19.81	2121.2
Site 03	0.50	2/4/2009	10:26:04	8.239	19.80	2121.2
Site 03	0.50	2/4/2009	10:26:05	8.376	19.79	2121.6
Site 03	0.50	2/4/2009	10:26:05	8.535	19.79	2121.6
Site 03	0.50	2/4/2009	10:26:06	8.534	19.78	2121.6
Site 03	0.50	2/4/2009	10:26:06	8.752	19.77	2121.5
Site 03	0.50	2/4/2009	10:26:07	8.958	19.77	2121.4
Site 03	0.50	2/4/2009	10:26:07	9.117	19.76	2121.5
Site 03	0.50	2/4/2009	10:26:08	9.317	19.76	2121.4
Site 03	0.50	2/4/2009	10:26:08	9.507	19.75	2121.5
Site 03	0.50	2/4/2009	10:26:09	9.616	19.75	2121.9
Site 03	0.50	2/4/2009	10:26:09	9.809	19.74	2121.8
Site 03	0.50	2/4/2009	10:26:10	10.044	19.74	2121.6
Site 03	0.50	2/4/2009	10:26:10	10.226	19.74	2121.4
Site 03	0.50	2/4/2009	10:26:11	10.344	19.74	2119.8
Site 03	0.50	2/4/2009	10:26:11	10.521	19.74	2115.2
Site 03	0.50	2/4/2009	10:26:12	10.668	19.74	2111.7
Site 03	0.50	2/4/2009	10:26:12	10.758	19.74	2106.3
Site 03	0.50	2/4/2009	10:26:13	10.860	19.75	2102.2
Site 03	0.50	2/4/2009	10:26:13	10.946	19.75	2099.5
Site 03	0.50	2/4/2009	10:26:14	11.018	19.76	2096.6
Site 03	0.50	2/4/2009	10:26:14	11.077	19.77	2093.4
Site 03	0.50	2/4/2009	10:26:15	11.127	19.78	2090.3
Site 04	0.75	2/4/2009	10:33:20	0.008	20.28	2093.9
Site 04	0.75	2/4/2009	10:33:21	0.008	20.28	2093.7
Site 04	0.75	2/4/2009	10:33:21	0.008	20.28	2093.6
Site 04	0.75	2/4/2009	10:33:22	0.068	20.28	2093.6
Site 04	0.75	2/4/2009	10:33:22	0.163	20.28	2093.2
Site 04	0.75	2/4/2009	10:33:23	0.322	20.27	2092.6
Site 04	0.75	2/4/2009	10:33:23	0.549	20.26	2091.7
Site 04	0.75	2/4/2009	10:33:24	2.981	20.25	2090.7
Site 04	0.75	2/4/2009	10:33:24	3.221	20.22	2090.0
Site 04	0.75	2/4/2009	10:33:25	3.987	20.20	2089.2
Site 04	0.75	2/4/2009	10:33:25	4.389	20.16	2088.6
Site 04	0.75	2/4/2009	10:33:26	4.666	20.13	2088.2
Site 04	0.75	2/4/2009	10:33:26	4.884	20.09	2088.2
Site 04	0.75	2/4/2009	10:33:27	5.826	20.05	2088.2
Site 04	0.75	2/4/2009	10:33:27	6.549	20.01	2088.1
Site 04	0.75	2/4/2009	10:33:28	6.943	19.97	2088.8
Site 04	0.75	2/4/2009	10:33:28	7.589	19.93	2089.0
Site 04	0.75	2/4/2009	10:33:29	7.827	19.89	2088.6
Site 05	1.00	2/4/2009	10:40:43	0.066	20.06	2064.6
Site 05	1.00	2/4/2009	10:40:44	0.121	20.06	2064.4
Site 05	1.00	2/4/2009	10:40:44	0.239	20.06	2064.1
Site 05	1.00	2/4/2009	10:40:45	0.433	20.06	2063.0
Site 05	1.00	2/4/2009	10:40:45	0.572	20.05	2062.1
Site 05	1.00	2/4/2009	10:40:46	0.790	20.03	2061.9
Site 05	1.00	2/4/2009	10:40:46	3.023	20.01	2061.8
Site 05	1.00	2/4/2009	10:40:47	3.829	19.98	2061.7

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 05	1.00	2/4/2009	10:40:47	4.522	19.95	2061.8
Site 05	1.00	2/4/2009	10:40:48	5.065	19.92	2062.2
Site 05	1.00	2/4/2009	10:40:48	5.431	19.89	2062.6
Site 05	1.00	2/4/2009	10:40:49	6.137	19.85	2063.2
Site 05	1.00	2/4/2009	10:40:49	6.769	19.83	2063.8
Site 05	1.00	2/4/2009	10:40:50	7.232	19.80	2064.8
Site 05	1.00	2/4/2009	10:40:50	7.912	19.77	2065.5
Site 05	1.00	2/4/2009	10:40:51	8.435	19.75	2066.1
Site 05	1.00	2/4/2009	10:40:51	8.667	19.73	2066.2
Site 05	1.00	2/4/2009	10:40:52	8.719	19.71	2063.9
Site 05	1.00	2/4/2009	10:40:52	8.744	19.70	2060.8
Site 05	1.00	2/4/2009	10:40:53	8.757	19.70	2057.1
Site 05	1.00	2/4/2009	10:40:53	8.766	19.70	2053.3
Site 06	1.25	2/4/2009	10:48:38	0.164	19.79	2029.4
Site 06	1.25	2/4/2009	10:48:39	0.172	19.80	2029.5
Site 06	1.25	2/4/2009	10:48:39	0.230	19.81	2029.6
Site 06	1.25	2/4/2009	10:48:40	0.361	19.81	2029.4
Site 06	1.25	2/4/2009	10:48:40	0.515	19.82	2029.3
Site 06	1.25	2/4/2009	10:48:41	0.696	19.83	2029.0
Site 06	1.25	2/4/2009	10:48:41	2.700	19.83	2028.7
Site 06	1.25	2/4/2009	10:48:42	3.446	19.84	2028.3
Site 06	1.25	2/4/2009	10:48:42	4.030	19.83	2027.1
Site 06	1.25	2/4/2009	10:48:43	4.421	19.83	2026.3
Site 06	1.25	2/4/2009	10:48:43	4.890	19.81	2025.6
Site 06	1.25	2/4/2009	10:48:44	5.397	19.79	2025.1
Site 06	1.25	2/4/2009	10:48:44	6.098	19.77	2024.8
Site 06	1.25	2/4/2009	10:48:45	6.749	19.75	2024.8
Site 06	1.25	2/4/2009	10:48:45	7.465	19.72	2025.0
Site 06	1.25	2/4/2009	10:48:46	7.807	19.70	2025.9
Site 06	1.25	2/4/2009	10:48:46	7.770	19.67	2026.4
Site 06	1.25	2/4/2009	10:48:47	7.760	19.65	2026.7
Site 06	1.25	2/4/2009	10:48:47	7.843	19.63	2027.2
Site 06	1.25	2/4/2009	10:48:48	7.898	19.62	2027.7
Site 06	1.25	2/4/2009	10:48:48	7.938	19.61	2028.0
Site 06	1.25	2/4/2009	10:48:49	7.962	19.61	2028.0
Site 06	1.25	2/4/2009	10:48:49	7.979	19.62	2027.7
Site 06	1.25	2/4/2009	10:48:50	7.985	19.63	2027.7
Site 07	1.50	2/4/2009	10:55:58	0.001	20.15	1999.3
Site 07	1.50	2/4/2009	10:55:58	0.042	20.15	1999.2
Site 07	1.50	2/4/2009	10:55:59	0.102	20.14	1999.1
Site 07	1.50	2/4/2009	10:55:59	0.193	20.14	1998.9
Site 07	1.50	2/4/2009	10:56:00	0.281	20.14	1998.7
Site 07	1.50	2/4/2009	10:56:00	0.383	20.14	1998.5
Site 07	1.50	2/4/2009	10:56:01	0.569	20.13	1998.2
Site 07	1.50	2/4/2009	10:56:01	0.805	20.12	1997.0
Site 07	1.50	2/4/2009	10:56:02	3.152	20.10	1996.2
Site 07	1.50	2/4/2009	10:56:02	3.579	20.09	1995.5
Site 07	1.50	2/4/2009	10:56:03	4.208	20.06	1994.9
Site 07	1.50	2/4/2009	10:56:03	4.882	20.03	1994.5
Site 07	1.50	2/4/2009	10:56:04	5.031	20.00	1994.5
Site 07	1.50	2/4/2009	10:56:04	5.803	19.97	1994.6
Site 07	1.50	2/4/2009	10:56:05	5.824	19.93	1995.0
Site 07	1.50	2/4/2009	10:56:05	6.499	19.90	1995.5
Site 07	1.50	2/4/2009	10:56:06	6.826	19.86	1996.0
Site 07	1.50	2/4/2009	10:56:06	7.580	19.83	1996.6

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 07	1.50	2/4/2009	10:56:07	7.770	19.80	1997.3
Site 07	1.50	2/4/2009	10:56:07	7.871	19.78	1997.9
Site 07	1.50	2/4/2009	10:56:08	9.006	19.75	1998.6
Site 07	1.50	2/4/2009	10:56:08	8.919	19.73	1999.4
Site 07	1.50	2/4/2009	10:56:09	8.976	19.71	2000.1
Site 07	1.50	2/4/2009	10:56:09	9.913	19.69	2000.6
Site 07	1.50	2/4/2009	10:56:10	9.988	19.67	2000.2
Site 07	1.50	2/4/2009	10:56:10	10.077	19.66	1998.5
Site 07	1.50	2/4/2009	10:56:11	10.129	19.65	1995.4
Site 07	1.50	2/4/2009	10:56:11	10.166	19.65	1991.5
Site 07	1.50	2/4/2009	10:56:12	10.180	19.66	1987.7
Site 07	1.50	2/4/2009	10:56:12	10.202	19.66	1983.8
Site 07	1.50	2/4/2009	10:56:13	10.212	19.67	1980.1
Site 08	1.75	2/4/2009	11:03:08	0.121	20.25	1971.2
Site 08	1.75	2/4/2009	11:03:09	0.246	20.25	1971.2
Site 08	1.75	2/4/2009	11:03:09	0.401	20.25	1970.9
Site 08	1.75	2/4/2009	11:03:10	0.623	20.25	1970.1
Site 08	1.75	2/4/2009	11:03:10	2.905	20.24	1969.2
Site 08	1.75	2/4/2009	11:03:11	3.554	20.23	1968.3
Site 08	1.75	2/4/2009	11:03:11	3.896	20.21	1967.7
Site 08	1.75	2/4/2009	11:03:12	4.603	20.18	1967.5
Site 08	1.75	2/4/2009	11:03:12	5.093	20.15	1967.6
Site 08	1.75	2/4/2009	11:03:13	5.978	20.12	1968.0
Site 08	1.75	2/4/2009	11:03:13	6.337	20.09	1968.3
Site 08	1.75	2/4/2009	11:03:14	6.742	20.05	1968.8
Site 08	1.75	2/4/2009	11:03:14	7.628	20.02	1969.3
Site 08	1.75	2/4/2009	11:03:15	8.104	19.98	1970.0
Site 08	1.75	2/4/2009	11:03:15	8.738	19.95	1970.5
Site 08	1.75	2/4/2009	11:03:16	9.584	19.92	1971.2
Site 08	1.75	2/4/2009	11:03:16	10.012	19.89	1971.9
Site 08	1.75	2/4/2009	11:03:17	10.384	19.86	1970.1
Site 08	1.75	2/4/2009	11:03:17	10.439	19.84	1966.7
Site 09	2.00	2/4/2009	11:10:16	0.009	20.15	1937.2
Site 09	2.00	2/4/2009	11:10:17	0.033	20.15	1937.3
Site 09	2.00	2/4/2009	11:10:17	0.113	20.15	1937.4
Site 09	2.00	2/4/2009	11:10:18	0.235	20.15	1937.2
Site 09	2.00	2/4/2009	11:10:18	0.359	20.14	1937.0
Site 09	2.00	2/4/2009	11:10:19	0.580	20.14	1936.0
Site 09	2.00	2/4/2009	11:10:19	0.808	20.12	1935.5
Site 09	2.00	2/4/2009	11:10:20	2.936	20.11	1934.4
Site 09	2.00	2/4/2009	11:10:20	3.393	20.09	1934.0
Site 09	2.00	2/4/2009	11:10:21	4.001	20.06	1933.7
Site 09	2.00	2/4/2009	11:10:21	4.361	20.03	1933.8
Site 09	2.00	2/4/2009	11:10:22	4.920	20.00	1934.2
Site 09	2.00	2/4/2009	11:10:22	5.096	19.96	1935.0
Site 09	2.00	2/4/2009	11:10:23	5.932	19.92	1936.1
Site 09	2.00	2/4/2009	11:10:23	6.113	19.88	1937.2
Site 09	2.00	2/4/2009	11:10:24	6.757	19.85	1937.9
Site 09	2.00	2/4/2009	11:10:24	6.909	19.81	1938.9
Site 09	2.00	2/4/2009	11:10:25	7.686	19.78	1939.9
Site 09	2.00	2/4/2009	11:10:25	7.646	19.74	1940.1
Site 09	2.00	2/4/2009	11:10:26	7.778	19.72	1939.4
Site 09	2.00	2/4/2009	11:10:26	7.849	19.70	1936.6
Site 09	2.00	2/4/2009	11:10:27	7.895	19.68	1933.2
Site 09	2.00	2/4/2009	11:10:27	7.848	19.67	1930.6

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 09	2.00	2/4/2009	11:10:28	7.822	19.66	1928.3
Site 09	2.00	2/4/2009	11:10:28	7.832	19.66	1922.9
Site 09	2.00	2/4/2009	11:10:29	7.839	19.66	1917.8
Site 09	2.00	2/4/2009	11:10:29	7.847	19.66	1913.0
Site 09	2.00	2/4/2009	11:10:30	7.860	19.66	1908.5
Site 09	2.00	2/4/2009	11:10:30	7.869	19.66	1904.4
Site 09	2.00	2/4/2009	11:10:31	7.887	19.66	1900.3
Site 10	2.25	2/4/2009	11:17:20	0.015	20.07	1904.8
Site 10	2.25	2/4/2009	11:17:20	0.079	20.07	1904.6
Site 10	2.25	2/4/2009	11:17:21	0.201	20.06	1904.0
Site 10	2.25	2/4/2009	11:17:21	0.337	20.05	1903.8
Site 10	2.25	2/4/2009	11:17:22	0.489	20.04	1903.7
Site 10	2.25	2/4/2009	11:17:22	2.448	20.02	1903.4
Site 10	2.25	2/4/2009	11:17:23	3.689	20.01	1903.4
Site 10	2.25	2/4/2009	11:17:23	4.168	19.99	1903.3
Site 10	2.25	2/4/2009	11:17:24	4.785	19.96	1903.6
Site 10	2.25	2/4/2009	11:17:24	5.213	19.93	1904.2
Site 10	2.25	2/4/2009	11:17:25	5.734	19.90	1905.2
Site 10	2.25	2/4/2009	11:17:25	5.799	19.86	1906.3
Site 10	2.25	2/4/2009	11:17:26	6.313	19.82	1907.4
Site 10	2.25	2/4/2009	11:17:26	6.856	19.78	1908.5
Site 10	2.25	2/4/2009	11:17:27	7.273	19.74	1910.1
Site 10	2.25	2/4/2009	11:17:27	7.624	19.71	1911.1
Site 10	2.25	2/4/2009	11:17:28	8.161	19.68	1912.1
Site 10	2.25	2/4/2009	11:17:28	8.496	19.65	1913.1
Site 10	2.25	2/4/2009	11:17:29	8.652	19.62	1913.9
Site 10	2.25	2/4/2009	11:17:29	9.149	19.59	1914.7
Site 10	2.25	2/4/2009	11:17:30	9.536	19.57	1912.2
Site 10	2.25	2/4/2009	11:17:30	9.573	19.55	1909.5
Site 11	2.50	2/4/2009	11:25:30	0.049	20.09	1880.0
Site 11	2.50	2/4/2009	11:25:31	0.050	20.09	1880.1
Site 11	2.50	2/4/2009	11:25:31	0.075	20.09	1880.1
Site 11	2.50	2/4/2009	11:25:32	0.137	20.09	1880.1
Site 11	2.50	2/4/2009	11:25:32	0.253	20.09	1880.0
Site 11	2.50	2/4/2009	11:25:33	0.393	20.08	1879.5
Site 11	2.50	2/4/2009	11:25:33	0.576	20.08	1878.9
Site 11	2.50	2/4/2009	11:25:34	0.780	20.06	1878.4
Site 11	2.50	2/4/2009	11:25:34	1.008	20.04	1877.7
Site 11	2.50	2/4/2009	11:25:35	3.046	20.02	1877.1
Site 11	2.50	2/4/2009	11:25:35	3.366	20.00	1876.6
Site 11	2.50	2/4/2009	11:25:36	3.966	19.97	1875.9
Site 11	2.50	2/4/2009	11:25:36	4.185	19.94	1875.5
Site 11	2.50	2/4/2009	11:25:37	4.400	19.90	1874.8
Site 11	2.50	2/4/2009	11:25:37	4.536	19.87	1874.9
Site 11	2.50	2/4/2009	11:25:38	4.723	19.84	1875.2
Site 11	2.50	2/4/2009	11:25:38	4.883	19.81	1875.6
Site 11	2.50	2/4/2009	11:25:39	5.046	19.78	1875.9
Site 11	2.50	2/4/2009	11:25:39	5.238	19.75	1876.1
Site 11	2.50	2/4/2009	11:25:40	5.400	19.73	1876.4
Site 11	2.50	2/4/2009	11:25:40	5.575	19.70	1876.7
Site 11	2.50	2/4/2009	11:25:41	5.774	19.68	1876.6
Site 11	2.50	2/4/2009	11:25:41	5.933	19.65	1876.9
Site 11	2.50	2/4/2009	11:25:42	6.085	19.64	1877.1
Site 11	2.50	2/4/2009	11:25:42	6.257	19.62	1877.5
Site 11	2.50	2/4/2009	11:25:43	6.425	19.60	1877.6

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 11	2.50	2/4/2009	11:25:43	6.643	19.59	1877.8
Site 11	2.50	2/4/2009	11:25:44	6.857	19.57	1878.0
Site 11	2.50	2/4/2009	11:25:44	7.098	19.56	1878.2
Site 11	2.50	2/4/2009	11:25:45	9.373	19.55	1878.3
Site 11	2.50	2/4/2009	11:25:45	9.392	19.54	1878.9
Site 11	2.50	2/4/2009	11:25:46	9.628	19.53	1879.5
Site 11	2.50	2/4/2009	11:25:46	9.754	19.52	1879.4
Site 11	2.50	2/4/2009	11:25:47	9.838	19.52	1878.6
Site 11	2.50	2/4/2009	11:25:47	9.865	19.52	1876.7
Site 11	2.50	2/4/2009	11:25:48	9.903	19.52	1874.7
Site 11	2.50	2/4/2009	11:25:48	9.925	19.52	1872.6
Site 11	2.50	2/4/2009	11:25:49	9.932	19.53	1869.6
Site 11	2.50	2/4/2009	11:25:49	9.927	19.54	1862.5
Site 11	2.50	2/4/2009	11:25:50	9.926	19.55	1854.6
Site 11	2.50	2/4/2009	11:25:50	9.952	19.56	1844.2
Site 11	2.50	2/4/2009	11:25:51	9.961	19.57	1834.5
Site 11	2.50	2/4/2009	11:25:51	9.984	19.58	1825.9
Site 11	2.50	2/4/2009	11:25:52	9.996	19.59	1818.1
Site 11	2.50	2/4/2009	11:25:52	9.994	19.61	1810.9
Site 11	2.50	2/4/2009	11:25:53	9.992	19.62	1804.1
Site 11	2.50	2/4/2009	11:25:53	9.988	19.63	1798.3
Site 11	2.50	2/4/2009	11:25:54	9.988	19.64	1793.0
Site 11	2.50	2/4/2009	11:25:54	9.972	19.65	1788.1
Site 11	2.50	2/4/2009	11:25:55	9.954	19.66	1783.5
Site 11	2.50	2/4/2009	11:25:55	9.938	19.67	1779.5
Site 11	2.50	2/4/2009	11:25:56	9.955	19.68	1775.9
Site 11	2.50	2/4/2009	11:25:56	9.975	19.68	1772.2
Site 11	2.50	2/4/2009	11:25:57	9.989	19.69	1768.2
Site 11	2.50	2/4/2009	11:25:57	10.006	19.70	1765.1
Site 11	2.50	2/4/2009	11:25:58	10.015	19.70	1762.3
Site 11	2.50	2/4/2009	11:25:58	10.024	19.71	1759.8
Site 11	2.50	2/4/2009	11:25:59	10.032	19.71	1757.5
Site 11	2.50	2/4/2009	11:25:59	10.041	19.71	1755.5
Site 11	2.50	2/4/2009	11:26:00	10.047	19.71	1753.7
Site 11	2.50	2/4/2009	11:26:00	10.052	19.72	1752.1
Site 11	2.50	2/4/2009	11:26:01	10.065	19.72	1750.3
Site 11	2.50	2/4/2009	11:26:01	10.075	19.72	1749.2
Site 11	2.50	2/4/2009	11:26:02	10.085	19.72	1747.9
Site 11	2.50	2/4/2009	11:26:02	10.092	19.72	1746.9
Site 11	2.50	2/4/2009	11:26:03	10.096	19.72	1746.0
Site 11	2.50	2/4/2009	11:26:03	10.103	19.72	1745.3
Site 11	2.50	2/4/2009	11:26:04	10.109	19.72	1744.5
Site 11	2.50	2/4/2009	11:26:04	10.111	19.73	1743.9
Site 11	2.50	2/4/2009	11:26:05	10.114	19.73	1742.9
Site 11	2.50	2/4/2009	11:26:05	10.114	19.73	1742.5
Site 11	2.50	2/4/2009	11:26:06	10.118	19.73	1742.1
Site 11	2.50	2/4/2009	11:26:06	10.122	19.73	1741.6
Site 12	2.75	2/4/2009	11:32:37	0.107	20.14	1854.5
Site 12	2.75	2/4/2009	11:32:38	0.163	20.14	1854.4
Site 12	2.75	2/4/2009	11:32:38	0.282	20.14	1854.3
Site 12	2.75	2/4/2009	11:32:39	0.483	20.14	1853.7
Site 12	2.75	2/4/2009	11:32:39	2.433	20.13	1852.8
Site 12	2.75	2/4/2009	11:32:40	3.161	20.11	1851.3
Site 12	2.75	2/4/2009	11:32:40	3.566	20.09	1850.6
Site 12	2.75	2/4/2009	11:32:41	4.260	20.06	1850.0

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 12	2.75	2/4/2009	11:32:41	4.943	20.03	1849.5
Site 12	2.75	2/4/2009	11:32:42	5.576	19.99	1849.5
Site 12	2.75	2/4/2009	11:32:42	5.695	19.96	1849.6
Site 12	2.75	2/4/2009	11:32:43	5.926	19.92	1850.0
Site 12	2.75	2/4/2009	11:32:43	6.947	19.89	1850.4
Site 12	2.75	2/4/2009	11:32:44	7.592	19.85	1850.7
Site 12	2.75	2/4/2009	11:32:44	7.939	19.82	1851.2
Site 12	2.75	2/4/2009	11:32:45	8.536	19.79	1851.7
Site 12	2.75	2/4/2009	11:32:45	8.776	19.76	1852.1
Site 12	2.75	2/4/2009	11:32:46	9.287	19.74	1852.5
Site 12	2.75	2/4/2009	11:32:46	9.736	19.72	1853.0
Site 12	2.75	2/4/2009	11:32:47	10.039	19.70	1853.3
Site 12	2.75	2/4/2009	11:32:47	10.271	19.68	1852.2
Site 12	2.75	2/4/2009	11:32:48	10.312	19.67	1850.9
Site 12	2.75	2/4/2009	11:32:48	10.328	19.66	1849.7
Site 12	2.75	2/4/2009	11:32:49	10.348	19.66	1848.3
Site 12	2.75	2/4/2009	11:32:49	10.366	19.67	1846.9
Site 13	3.00	2/4/2009	11:39:06	0.025	20.22	1830.7
Site 13	3.00	2/4/2009	11:39:07	0.095	20.22	1831.2
Site 13	3.00	2/4/2009	11:39:07	0.258	20.22	1831.2
Site 13	3.00	2/4/2009	11:39:08	2.427	20.22	1830.8
Site 13	3.00	2/4/2009	11:39:08	3.536	20.22	1830.5
Site 13	3.00	2/4/2009	11:39:09	4.437	20.22	1830.1
Site 13	3.00	2/4/2009	11:39:09	5.153	20.22	1829.4
Site 13	3.00	2/4/2009	11:39:10	5.526	20.22	1828.4
Site 13	3.00	2/4/2009	11:39:10	6.374	20.20	1826.8
Site 13	3.00	2/4/2009	11:39:11	7.354	20.18	1825.8
Site 13	3.00	2/4/2009	11:39:11	7.789	20.15	1824.9
Site 13	3.00	2/4/2009	11:39:12	8.436	20.11	1824.3
Site 13	3.00	2/4/2009	11:39:12	8.775	20.07	1824.1
Site 13	3.00	2/4/2009	11:39:13	9.560	20.02	1824.5
Site 13	3.00	2/4/2009	11:39:13	9.802	19.97	1825.0
Site 13	3.00	2/4/2009	11:39:14	9.997	19.93	1824.6
Site 13	3.00	2/4/2009	11:39:14	10.058	19.88	1823.5
Site 13	3.00	2/4/2009	11:39:15	10.120	19.84	1822.4
Site 13	3.00	2/4/2009	11:39:15	10.155	19.81	1821.0
Site 14	3.25	2/4/2009	11:46:08	0.037	20.07	1807.4
Site 14	3.25	2/4/2009	11:46:09	0.038	20.07	1807.3
Site 14	3.25	2/4/2009	11:46:09	0.142	20.07	1807.2
Site 14	3.25	2/4/2009	11:46:10	0.297	20.06	1807.1
Site 14	3.25	2/4/2009	11:46:10	0.525	20.06	1806.9
Site 14	3.25	2/4/2009	11:46:11	3.048	20.05	1806.5
Site 14	3.25	2/4/2009	11:46:11	3.758	20.04	1805.4
Site 14	3.25	2/4/2009	11:46:12	4.549	20.03	1804.5
Site 14	3.25	2/4/2009	11:46:12	5.477	20.00	1804.0
Site 14	3.25	2/4/2009	11:46:13	6.113	19.98	1803.4
Site 14	3.25	2/4/2009	11:46:13	6.602	19.95	1802.7
Site 14	3.25	2/4/2009	11:46:14	7.134	19.91	1801.8
Site 14	3.25	2/4/2009	11:46:14	7.561	19.87	1801.4
Site 14	3.25	2/4/2009	11:46:15	8.017	19.83	1800.7
Site 14	3.25	2/4/2009	11:46:15	8.618	19.79	1799.7
Site 14	3.25	2/4/2009	11:46:16	8.902	19.75	1799.0
Site 14	3.25	2/4/2009	11:46:16	9.072	19.71	1797.3
Site 14	3.25	2/4/2009	11:46:17	9.094	19.67	1795.8
Site 14	3.25	2/4/2009	11:46:17	9.104	19.64	1794.0

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 14	3.25	2/4/2009	11:46:18	9.110	19.62	1792.0
Site 14	3.25	2/4/2009	11:46:18	9.115	19.61	1789.8
Site 15	3.50	2/4/2009	11:53:00	0.059	19.90	1770.1
Site 15	3.50	2/4/2009	11:53:01	0.096	19.91	1770.2
Site 15	3.50	2/4/2009	11:53:01	0.175	19.91	1770.3
Site 15	3.50	2/4/2009	11:53:02	0.338	19.92	1770.3
Site 15	3.50	2/4/2009	11:53:02	2.348	19.92	1770.2
Site 15	3.50	2/4/2009	11:53:03	2.930	19.92	1770.0
Site 15	3.50	2/4/2009	11:53:03	3.379	19.92	1769.4
Site 15	3.50	2/4/2009	11:53:04	4.067	19.92	1768.4
Site 15	3.50	2/4/2009	11:53:04	4.684	19.92	1767.7
Site 15	3.50	2/4/2009	11:53:05	5.272	19.90	1767.0
Site 15	3.50	2/4/2009	11:53:05	5.786	19.88	1766.5
Site 15	3.50	2/4/2009	11:53:06	6.495	19.85	1766.2
Site 15	3.50	2/4/2009	11:53:06	7.162	19.82	1766.1
Site 15	3.50	2/4/2009	11:53:07	7.820	19.78	1766.0
Site 15	3.50	2/4/2009	11:53:07	7.844	19.74	1766.0
Site 15	3.50	2/4/2009	11:53:08	7.852	19.71	1766.1
Site 15	3.50	2/4/2009	11:53:08	7.863	19.67	1766.3
Site 15	3.50	2/4/2009	11:53:09	7.871	19.64	1766.6
Site 16	3.75	2/4/2009	11:59:49	0.002	20.03	1749.9
Site 16	3.75	2/4/2009	11:59:49	0.013	20.03	1750.0
Site 16	3.75	2/4/2009	11:59:50	0.092	20.03	1750.0
Site 16	3.75	2/4/2009	11:59:50	0.246	20.03	1750.0
Site 16	3.75	2/4/2009	11:59:51	0.448	20.03	1749.7
Site 16	3.75	2/4/2009	11:59:51	2.538	20.03	1749.2
Site 16	3.75	2/4/2009	11:59:52	3.058	20.03	1748.8
Site 16	3.75	2/4/2009	11:59:52	3.716	20.02	1748.6
Site 16	3.75	2/4/2009	11:59:53	4.291	20.01	1748.3
Site 16	3.75	2/4/2009	11:59:53	4.861	19.99	1748.0
Site 16	3.75	2/4/2009	11:59:54	5.461	19.97	1747.5
Site 16	3.75	2/4/2009	11:59:54	5.962	19.95	1747.0
Site 16	3.75	2/4/2009	11:59:55	6.509	19.92	1746.3
Site 16	3.75	2/4/2009	11:59:55	7.106	19.89	1745.9
Site 16	3.75	2/4/2009	11:59:56	7.572	19.86	1745.6
Site 16	3.75	2/4/2009	11:59:56	8.174	19.82	1745.3
Site 16	3.75	2/4/2009	11:59:57	8.509	19.78	1744.8
Site 16	3.75	2/4/2009	11:59:57	8.791	19.75	1744.8
Site 16	3.75	2/4/2009	11:59:58	8.861	19.71	1743.8
Site 16	3.75	2/4/2009	11:59:58	8.865	19.69	1742.4
Site 16	3.75	2/4/2009	11:59:59	8.866	19.67	1741.0
Site 17	4.00	2/4/2009	12:06:53	0.002	20.29	1719.7
Site 17	4.00	2/4/2009	12:06:53	0.077	20.28	1719.8
Site 17	4.00	2/4/2009	12:06:54	0.202	20.28	1719.9
Site 17	4.00	2/4/2009	12:06:54	0.402	20.27	1719.7
Site 17	4.00	2/4/2009	12:06:55	0.642	20.27	1719.1
Site 17	4.00	2/4/2009	12:06:55	2.971	20.26	1718.5
Site 17	4.00	2/4/2009	12:06:56	3.690	20.24	1717.9
Site 17	4.00	2/4/2009	12:06:56	4.104	20.22	1717.4
Site 17	4.00	2/4/2009	12:06:57	4.514	20.20	1716.9
Site 17	4.00	2/4/2009	12:06:57	4.907	20.18	1716.4
Site 17	4.00	2/4/2009	12:06:58	5.542	20.15	1715.7
Site 17	4.00	2/4/2009	12:06:58	5.961	20.11	1715.1
Site 17	4.00	2/4/2009	12:06:59	6.452	20.07	1714.8

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 17	4.00	2/4/2009	12:06:59	6.794	20.03	1714.8
Site 17	4.00	2/4/2009	12:07:00	7.259	19.99	1715.0
Site 17	4.00	2/4/2009	12:07:00	7.727	19.94	1715.4
Site 17	4.00	2/4/2009	12:07:01	8.198	19.90	1716.0
Site 17	4.00	2/4/2009	12:07:01	8.544	19.85	1716.8
Site 17	4.00	2/4/2009	12:07:02	8.924	19.81	1717.9
Site 17	4.00	2/4/2009	12:07:02	9.245	19.76	1719.1
Site 17	4.00	2/4/2009	12:07:03	9.330	19.72	1720.3
Site 17	4.00	2/4/2009	12:07:03	9.335	19.68	1721.3
Site 18	4.25	2/4/2009	12:14:01	0.125	20.11	1707.2
Site 18	4.25	2/4/2009	12:14:02	0.117	20.12	1707.3
Site 18	4.25	2/4/2009	12:14:02	0.114	20.12	1707.3
Site 18	4.25	2/4/2009	12:14:03	0.171	20.12	1707.3
Site 18	4.25	2/4/2009	12:14:03	0.293	20.12	1707.5
Site 18	4.25	2/4/2009	12:14:04	0.478	20.12	1707.6
Site 18	4.25	2/4/2009	12:14:04	0.712	20.13	1707.7
Site 18	4.25	2/4/2009	12:14:05	3.091	20.13	1707.8
Site 18	4.25	2/4/2009	12:14:05	3.517	20.13	1707.7
Site 18	4.25	2/4/2009	12:14:06	4.017	20.14	1707.5
Site 18	4.25	2/4/2009	12:14:06	4.481	20.13	1707.2
Site 18	4.25	2/4/2009	12:14:07	4.793	20.13	1706.6
Site 18	4.25	2/4/2009	12:14:07	5.400	20.12	1705.8
Site 18	4.25	2/4/2009	12:14:08	5.942	20.11	1704.9
Site 18	4.25	2/4/2009	12:14:08	6.410	20.08	1703.9
Site 18	4.25	2/4/2009	12:14:09	7.063	20.06	1703.5
Site 18	4.25	2/4/2009	12:14:09	7.268	20.02	1702.9
Site 18	4.25	2/4/2009	12:14:10	7.920	19.99	1702.3
Site 18	4.25	2/4/2009	12:14:10	8.392	19.96	1702.0
Site 18	4.25	2/4/2009	12:14:11	8.713	19.92	1701.8
Site 18	4.25	2/4/2009	12:14:11	9.406	19.89	1701.6
Site 18	4.25	2/4/2009	12:14:12	9.650	19.85	1701.3
Site 18	4.25	2/4/2009	12:14:12	9.949	19.82	1701.3
Site 18	4.25	2/4/2009	12:14:13	10.353	19.79	1701.2
Site 18	4.25	2/4/2009	12:14:13	10.505	19.77	1700.7
Site 18	4.25	2/4/2009	12:14:14	10.553	19.74	1699.7
Site 18	4.25	2/4/2009	12:14:14	10.583	19.73	1698.7
Site 19	4.50	2/4/2009	12:21:04	0.030	20.33	1683.3
Site 19	4.50	2/4/2009	12:21:05	0.082	20.33	1683.2
Site 19	4.50	2/4/2009	12:21:05	0.202	20.33	1682.9
Site 19	4.50	2/4/2009	12:21:06	0.359	20.33	1682.5
Site 19	4.50	2/4/2009	12:21:06	0.572	20.32	1682.2
Site 19	4.50	2/4/2009	12:21:07	2.621	20.31	1682.0
Site 19	4.50	2/4/2009	12:21:07	3.172	20.30	1681.6
Site 19	4.50	2/4/2009	12:21:08	3.847	20.28	1681.3
Site 19	4.50	2/4/2009	12:21:08	4.448	20.26	1681.1
Site 19	4.50	2/4/2009	12:21:09	4.970	20.24	1680.7
Site 19	4.50	2/4/2009	12:21:09	5.503	20.21	1680.1
Site 19	4.50	2/4/2009	12:21:10	5.992	20.17	1679.4
Site 19	4.50	2/4/2009	12:21:10	6.544	20.13	1678.8
Site 19	4.50	2/4/2009	12:21:11	7.065	20.08	1678.5
Site 19	4.50	2/4/2009	12:21:11	7.535	20.04	1678.3
Site 19	4.50	2/4/2009	12:21:12	7.979	19.99	1678.4
Site 19	4.50	2/4/2009	12:21:12	8.481	19.94	1678.6
Site 19	4.50	2/4/2009	12:21:13	9.011	19.89	1678.8
Site 19	4.50	2/4/2009	12:21:13	9.212	19.85	1679.4

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 19	4.50	2/4/2009	12:21:14	9.416	19.81	1679.9
Site 19	4.50	2/4/2009	12:21:14	9.599	19.77	1680.5
Site 19	4.50	2/4/2009	12:21:15	9.755	19.73	1681.1
Site 19	4.50	2/4/2009	12:21:15	9.901	19.70	1681.6
Site 19	4.50	2/4/2009	12:21:16	10.027	19.67	1682.1
Site 19	4.50	2/4/2009	12:21:16	10.100	19.65	1682.6
Site 19	4.50	2/4/2009	12:21:17	10.124	19.63	1682.9
Site 19	4.50	2/4/2009	12:21:17	10.145	19.61	1682.9
Site 19	4.50	2/4/2009	12:21:18	10.225	19.59	1683.1
Site 19	4.50	2/4/2009	12:21:18	10.297	19.58	1683.1
Site 19	4.50	2/4/2009	12:21:19	10.386	19.57	1682.6
Site 19	4.50	2/4/2009	12:21:19	10.455	19.56	1681.8
Site 19	4.50	2/4/2009	12:21:20	10.507	19.55	1680.5
Site 19	4.50	2/4/2009	12:21:20	10.517	19.54	1679.0
Site 19	4.50	2/4/2009	12:21:21	10.519	19.54	1676.6
Site 19	4.50	2/4/2009	12:21:21	10.528	19.53	1676.4
Site 19	4.50	2/4/2009	12:21:22	10.540	19.53	1677.0
Site 19	4.50	2/4/2009	12:21:22	10.553	19.53	1677.4
Site 19	4.50	2/4/2009	12:21:23	10.587	19.53	1677.7
Site 19	4.50	2/4/2009	12:21:23	10.669	19.53	1676.4
Site 19	4.50	2/4/2009	12:21:24	10.739	19.53	1675.8
Site 19	4.50	2/4/2009	12:21:24	10.806	19.53	1674.5
Site 19	4.50	2/4/2009	12:21:25	10.874	19.53	1672.3
Site 19	4.50	2/4/2009	12:21:25	10.936	19.53	1669.7
Site 19	4.50	2/4/2009	12:21:26	10.919	19.53	1667.6
Site 19	4.50	2/4/2009	12:21:26	10.912	19.53	1663.3
Site 19	4.50	2/4/2009	12:21:27	10.923	19.54	1656.9
Site 19	4.50	2/4/2009	12:21:27	10.930	19.55	1650.8
Site 19	4.50	2/4/2009	12:21:28	10.919	19.56	1644.5
Site 19	4.50	2/4/2009	12:21:28	10.904	19.57	1638.6
Site 19	4.50	2/4/2009	12:21:29	10.900	19.59	1633.0
Site 19	4.50	2/4/2009	12:21:29	10.904	19.60	1628.2
Site 19	4.50	2/4/2009	12:21:30	10.908	19.61	1623.7
Site 19	4.50	2/4/2009	12:21:30	10.910	19.63	1620.0
Site 19	4.50	2/4/2009	12:21:31	10.914	19.64	1616.7
Site 19	4.50	2/4/2009	12:21:31	10.935	19.65	1613.6
Site 19	4.50	2/4/2009	12:21:32	10.979	19.66	1611.0
Site 19	4.50	2/4/2009	12:21:32	11.018	19.67	1608.9
Site 19	4.50	2/4/2009	12:21:33	11.052	19.68	1606.8
Site 19	4.50	2/4/2009	12:21:33	11.081	19.69	1605.2
Site 19	4.50	2/4/2009	12:21:34	11.109	19.70	1603.6
Site 19	4.50	2/4/2009	12:21:34	11.133	19.70	1602.1
Site 19	4.50	2/4/2009	12:21:35	11.156	19.71	1600.8
Site 20	4.75	2/4/2009	12:27:29	0.007	20.31	1682.3
Site 20	4.75	2/4/2009	12:27:29	0.063	20.31	1683.5
Site 20	4.75	2/4/2009	12:27:30	0.195	20.30	1684.0
Site 20	4.75	2/4/2009	12:27:30	0.360	20.30	1685.1
Site 20	4.75	2/4/2009	12:27:31	0.562	20.29	1686.2
Site 20	4.75	2/4/2009	12:27:31	0.768	20.28	1687.1
Site 20	4.75	2/4/2009	12:27:32	2.764	20.28	1687.9
Site 20	4.75	2/4/2009	12:27:32	2.906	20.27	1689.0
Site 20	4.75	2/4/2009	12:27:33	3.032	20.26	1691.2
Site 20	4.75	2/4/2009	12:27:33	3.207	20.24	1693.5
Site 20	4.75	2/4/2009	12:27:34	3.387	20.22	1695.4
Site 20	4.75	2/4/2009	12:27:34	4.655	20.20	1697.8

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 20	4.75	2/4/2009	12:27:35	5.133	20.17	1701.9
Site 20	4.75	2/4/2009	12:27:35	5.468	20.13	1706.7
Site 20	4.75	2/4/2009	12:27:36	5.905	20.10	1712.6
Site 20	4.75	2/4/2009	12:27:36	6.397	20.06	1718.1
Site 20	4.75	2/4/2009	12:27:37	6.548	20.04	1723.1
Site 20	4.75	2/4/2009	12:27:37	6.775	20.01	1727.9
Site 20	4.75	2/4/2009	12:27:38	6.991	20.00	1733.7
Site 20	4.75	2/4/2009	12:27:38	7.198	19.98	1739.5
Site 20	4.75	2/4/2009	12:27:39	7.401	19.96	1745.2
Site 20	4.75	2/4/2009	12:27:39	7.605	19.94	1751.5
Site 20	4.75	2/4/2009	12:27:40	7.824	19.92	1758.7
Site 20	4.75	2/4/2009	12:27:40	8.025	19.90	1765.9
Site 20	4.75	2/4/2009	12:27:41	8.252	19.87	1773.6
Site 20	4.75	2/4/2009	12:27:41	8.468	19.85	1780.6
Site 20	4.75	2/4/2009	12:27:42	8.670	19.82	1787.1
Site 20	4.75	2/4/2009	12:27:42	8.850	19.80	1793.1
Site 20	4.75	2/4/2009	12:27:43	8.999	19.77	1798.2
Site 20	4.75	2/4/2009	12:27:43	9.084	19.75	1803.2
Site 20	4.75	2/4/2009	12:27:44	9.168	19.73	1807.5
Site 20	4.75	2/4/2009	12:27:44	9.248	19.72	1810.7
Site 20	4.75	2/4/2009	12:27:45	9.314	19.70	1813.4
Site 20	4.75	2/4/2009	12:27:45	9.376	19.69	1815.9
Site 20	4.75	2/4/2009	12:27:46	9.439	19.68	1817.9
Site 20	4.75	2/4/2009	12:27:46	9.513	19.67	1819.6
Site 20	4.75	2/4/2009	12:27:47	9.582	19.66	1821.3
Site 20	4.75	2/4/2009	12:27:47	9.647	19.65	1822.7
Site 20	4.75	2/4/2009	12:27:48	9.704	19.64	1824.1
Site 20	4.75	2/4/2009	12:27:48	9.756	19.64	1824.8
Site 20	4.75	2/4/2009	12:27:49	9.801	19.63	1825.3
Site 20	4.75	2/4/2009	12:27:49	9.840	19.63	1825.4
Site 20	4.75	2/4/2009	12:27:50	9.875	19.63	1825.3
Site 20	4.75	2/4/2009	12:27:50	9.911	19.63	1824.7
Site 20	4.75	2/4/2009	12:27:51	9.944	19.63	1823.7
Site 20	4.75	2/4/2009	12:27:51	9.971	19.64	1822.7
Site 20	4.75	2/4/2009	12:27:52	9.988	19.64	1822.5
Site 20	4.75	2/4/2009	12:27:52	9.990	19.64	1822.3
Site 20	4.75	2/4/2009	12:27:53	9.991	19.65	1821.6
Site 20	4.75	2/4/2009	12:27:53	9.992	19.65	1816.7
Site 20	4.75	2/4/2009	12:27:54	9.989	19.66	1812.3
Site 20	4.75	2/4/2009	12:27:54	9.990	19.66	1806.8
Site 20	4.75	2/4/2009	12:27:55	9.995	19.67	1796.8
Site 20	4.75	2/4/2009	12:27:55	9.999	19.67	1789.0
Site 20	4.75	2/4/2009	12:27:56	10.002	19.68	1781.0
Site 20	4.75	2/4/2009	12:27:56	10.011	19.68	1773.4
Site 20	4.75	2/4/2009	12:27:57	10.045	19.69	1760.6
Site 20	4.75	2/4/2009	12:27:57	10.078	19.69	1748.5
Site 20	4.75	2/4/2009	12:27:58	10.105	19.69	1737.3
Site 20	4.75	2/4/2009	12:27:58	10.127	19.70	1727.3
Site 20	4.75	2/4/2009	12:27:59	10.140	19.70	1718.4
Site 20	4.75	2/4/2009	12:27:59	10.151	19.71	1710.2
Site 20	4.75	2/4/2009	12:28:00	10.166	19.71	1702.7
Site 20	4.75	2/4/2009	12:28:00	10.179	19.71	1695.9
Site 20	4.75	2/4/2009	12:28:01	10.189	19.72	1689.6
Site 20	4.75	2/4/2009	12:28:01	10.201	19.72	1683.7
Site 20	4.75	2/4/2009	12:28:02	10.208	19.72	1678.5

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 20	4.75	2/4/2009	12:28:02	10.208	19.73	1674.0
Site 21	5.00	2/4/2009	12:34:29	0.018	20.58	1737.2
Site 21	5.00	2/4/2009	12:34:30	0.051	20.58	1737.1
Site 21	5.00	2/4/2009	12:34:30	0.146	20.58	1737.1
Site 21	5.00	2/4/2009	12:34:31	0.317	20.58	1736.9
Site 21	5.00	2/4/2009	12:34:31	0.543	20.58	1735.8
Site 21	5.00	2/4/2009	12:34:32	2.915	20.58	1733.8
Site 21	5.00	2/4/2009	12:34:32	3.466	20.57	1732.1
Site 21	5.00	2/4/2009	12:34:33	4.043	20.55	1730.6
Site 21	5.00	2/4/2009	12:34:33	4.617	20.53	1728.5
Site 21	5.00	2/4/2009	12:34:34	5.013	20.50	1726.3
Site 21	5.00	2/4/2009	12:34:34	5.552	20.46	1724.8
Site 21	5.00	2/4/2009	12:34:35	6.212	20.41	1724.7
Site 21	5.00	2/4/2009	12:34:35	6.914	20.37	1726.6
Site 21	5.00	2/4/2009	12:34:36	7.386	20.32	1729.9
Site 21	5.00	2/4/2009	12:34:36	7.749	20.26	1735.3
Site 21	5.00	2/4/2009	12:34:37	8.416	20.21	1742.3
Site 21	5.00	2/4/2009	12:34:37	8.827	20.16	1750.7
Site 21	5.00	2/4/2009	12:34:38	9.514	20.10	1759.8
Site 21	5.00	2/4/2009	12:34:38	9.921	20.04	1769.5
Site 21	5.00	2/4/2009	12:34:39	9.941	19.99	1778.6
Site 21	5.00	2/4/2009	12:34:39	9.943	19.93	1787.3
Site 22	5.25	2/4/2009	12:41:36	0.012	20.93	1691.4
Site 22	5.25	2/4/2009	12:41:37	0.012	20.93	1691.5
Site 22	5.25	2/4/2009	12:41:37	0.020	20.93	1691.5
Site 22	5.25	2/4/2009	12:41:38	0.055	20.94	1691.3
Site 22	5.25	2/4/2009	12:41:38	0.133	20.94	1691.1
Site 22	5.25	2/4/2009	12:41:39	0.270	20.94	1690.8
Site 22	5.25	2/4/2009	12:41:39	0.461	20.94	1689.9
Site 22	5.25	2/4/2009	12:41:40	0.701	20.93	1688.8
Site 22	5.25	2/4/2009	12:41:40	2.720	20.91	1688.4
Site 22	5.25	2/4/2009	12:41:41	3.476	20.89	1686.3
Site 22	5.25	2/4/2009	12:41:41	4.056	20.84	1685.2
Site 22	5.25	2/4/2009	12:41:42	4.598	20.79	1684.0
Site 22	5.25	2/4/2009	12:41:42	4.991	20.73	1682.7
Site 22	5.25	2/4/2009	12:41:43	5.608	20.67	1682.0
Site 22	5.25	2/4/2009	12:41:43	6.274	20.60	1681.6
Site 22	5.25	2/4/2009	12:41:44	6.603	20.52	1681.1
Site 22	5.25	2/4/2009	12:41:44	7.347	20.45	1680.8
Site 22	5.25	2/4/2009	12:41:45	8.449	20.38	1680.6
Site 22	5.25	2/4/2009	12:41:45	8.989	20.31	1680.7
Site 22	5.25	2/4/2009	12:41:46	9.026	20.24	1680.9
Site 22	5.25	2/4/2009	12:41:46	9.193	20.18	1681.2
Site 22	5.25	2/4/2009	12:41:47	9.411	20.12	1681.5
Site 22	5.25	2/4/2009	12:41:47	9.523	20.06	1682.1
Site 22	5.25	2/4/2009	12:41:48	9.536	20.01	1682.5
Site 22	5.25	2/4/2009	12:41:48	9.594	19.97	1682.8
Site 22	5.25	2/4/2009	12:41:49	9.637	19.93	1683.3
Site 23	5.50	2/4/2009	12:48:00	0.044	20.67	1682.1
Site 23	5.50	2/4/2009	12:48:01	0.043	20.67	1682.1
Site 23	5.50	2/4/2009	12:48:01	0.038	20.67	1682.0
Site 23	5.50	2/4/2009	12:48:02	0.051	20.67	1682.0
Site 23	5.50	2/4/2009	12:48:02	0.065	20.67	1682.0
Site 23	5.50	2/4/2009	12:48:03	0.217	20.67	1682.1

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 23	5.50	2/4/2009	12:48:04	0.409	20.67	1681.9
Site 23	5.50	2/4/2009	12:48:04	0.612	20.67	1681.7
Site 23	5.50	2/4/2009	12:48:05	2.835	20.67	1681.2
Site 23	5.50	2/4/2009	12:48:05	3.492	20.66	1680.7
Site 23	5.50	2/4/2009	12:48:06	4.200	20.65	1680.1
Site 23	5.50	2/4/2009	12:48:06	4.617	20.62	1679.1
Site 23	5.50	2/4/2009	12:48:07	5.122	20.59	1678.0
Site 23	5.50	2/4/2009	12:48:07	5.739	20.55	1677.1
Site 23	5.50	2/4/2009	12:48:08	6.387	20.50	1676.3
Site 23	5.50	2/4/2009	12:48:08	7.084	20.45	1675.7
Site 23	5.50	2/4/2009	12:48:09	7.653	20.39	1675.2
Site 23	5.50	2/4/2009	12:48:09	8.219	20.33	1674.9
Site 23	5.50	2/4/2009	12:48:10	8.719	20.28	1674.6
Site 23	5.50	2/4/2009	12:48:10	9.216	20.23	1674.5
Site 23	5.50	2/4/2009	12:48:11	9.776	20.17	1674.4
Site 23	5.50	2/4/2009	12:48:11	10.330	20.12	1674.6
Site 23	5.50	2/4/2009	12:48:12	10.729	20.08	1674.8
Site 23	5.50	2/4/2009	12:48:12	10.930	20.04	1674.3
Site 23	5.50	2/4/2009	12:48:13	11.015	20.00	1671.7
Site 23	5.50	2/4/2009	12:48:13	11.058	19.97	1668.6
Site 23	5.50	2/4/2009	12:48:14	11.086	19.95	1665.6
Site 23	5.50	2/4/2009	12:48:14	11.109	19.93	1662.9
Site 23	5.50	2/4/2009	12:48:15	11.133	19.92	1660.3
Site 23	5.50	2/4/2009	12:48:15	11.152	19.91	1657.8
Site 23	5.50	2/4/2009	12:48:16	11.164	19.90	1655.5
Site 23	5.50	2/4/2009	12:48:16	11.165	19.90	1652.9
Site 24	5.75	2/4/2009	12:54:43	0.078	20.69	1673.1
Site 24	5.75	2/4/2009	12:54:44	0.163	20.69	1673.2
Site 24	5.75	2/4/2009	12:54:45	0.297	20.70	1673.3
Site 24	5.75	2/4/2009	12:54:45	0.376	20.69	1673.2
Site 24	5.75	2/4/2009	12:54:46	0.454	20.69	1673.1
Site 24	5.75	2/4/2009	12:54:46	0.533	20.69	1673.1
Site 24	5.75	2/4/2009	12:54:47	0.717	20.68	1672.8
Site 24	5.75	2/4/2009	12:54:47	2.784	20.67	1672.9
Site 24	5.75	2/4/2009	12:54:48	3.254	20.66	1672.6
Site 24	5.75	2/4/2009	12:54:48	3.817	20.65	1672.0
Site 24	5.75	2/4/2009	12:54:49	4.068	20.64	1671.7
Site 24	5.75	2/4/2009	12:54:49	4.418	20.62	1670.9
Site 24	5.75	2/4/2009	12:54:50	5.080	20.60	1669.7
Site 24	5.75	2/4/2009	12:54:50	5.301	20.57	1668.6
Site 24	5.75	2/4/2009	12:54:51	5.488	20.53	1667.5
Site 24	5.75	2/4/2009	12:54:51	6.214	20.49	1666.8
Site 24	5.75	2/4/2009	12:54:52	6.363	20.44	1666.1
Site 24	5.75	2/4/2009	12:54:52	6.556	20.40	1665.9
Site 24	5.75	2/4/2009	12:54:53	7.672	20.35	1665.9
Site 24	5.75	2/4/2009	12:54:53	8.290	20.29	1665.9
Site 24	5.75	2/4/2009	12:54:54	8.759	20.25	1666.1
Site 24	5.75	2/4/2009	12:54:54	9.408	20.20	1666.3
Site 24	5.75	2/4/2009	12:54:55	9.522	20.15	1666.5
Site 24	5.75	2/4/2009	12:54:55	9.524	20.11	1666.9
Site 24	5.75	2/4/2009	12:54:56	9.492	20.07	1667.2
Site 24	5.75	2/4/2009	12:54:56	9.502	20.03	1667.6
Site 24	5.75	2/4/2009	12:54:57	9.507	20.00	1668.2
Site 25	6.00	2/4/2009	13:02:19	0.099	20.88	1671.0
Site 25	6.00	2/4/2009	13:02:20	0.171	20.87	1670.8

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 25	6.00	2/4/2009	13:02:20	0.256	20.87	1670.9
Site 25	6.00	2/4/2009	13:02:21	0.382	20.87	1670.9
Site 25	6.00	2/4/2009	13:02:21	0.577	20.86	1671.0
Site 25	6.00	2/4/2009	13:02:22	0.786	20.86	1671.0
Site 25	6.00	2/4/2009	13:02:22	1.014	20.85	1671.0
Site 25	6.00	2/4/2009	13:02:23	3.210	20.85	1670.9
Site 25	6.00	2/4/2009	13:02:23	3.836	20.84	1670.4
Site 25	6.00	2/4/2009	13:02:24	4.593	20.83	1669.6
Site 25	6.00	2/4/2009	13:02:24	5.060	20.82	1668.9
Site 25	6.00	2/4/2009	13:02:25	5.656	20.80	1668.5
Site 25	6.00	2/4/2009	13:02:25	6.213	20.77	1667.7
Site 25	6.00	2/4/2009	13:02:26	6.916	20.74	1666.6
Site 25	6.00	2/4/2009	13:02:26	7.379	20.71	1665.5
Site 25	6.00	2/4/2009	13:02:27	8.082	20.67	1664.5
Site 25	6.00	2/4/2009	13:02:27	8.581	20.62	1664.0
Site 25	6.00	2/4/2009	13:02:28	8.651	20.56	1663.7
Site 25	6.00	2/4/2009	13:02:28	8.652	20.51	1663.7
Site 26	6.00	2/4/2009	14:26:12	0.069	20.22	1774.5
Site 26	6.00	2/4/2009	14:26:13	0.162	20.23	1773.9
Site 26	6.00	2/4/2009	14:26:13	0.303	20.25	1773.3
Site 26	6.00	2/4/2009	14:26:14	0.517	20.26	1772.1
Site 26	6.00	2/4/2009	14:26:14	2.841	20.26	1770.8
Site 26	6.00	2/4/2009	14:26:15	3.637	20.25	1769.4
Site 26	6.00	2/4/2009	14:26:15	4.429	20.24	1767.9
Site 26	6.00	2/4/2009	14:26:16	5.319	20.21	1766.8
Site 26	6.00	2/4/2009	14:26:16	6.135	20.18	1765.5
Site 26	6.00	2/4/2009	14:26:17	6.879	20.14	1764.2
Site 26	6.00	2/4/2009	14:26:17	7.573	20.09	1762.8
Site 26	6.00	2/4/2009	14:26:18	8.466	20.04	1762.2
Site 26	6.00	2/4/2009	14:26:18	9.263	19.98	1761.5
Site 26	6.00	2/4/2009	14:26:19	9.855	19.92	1761.0
Site 26	6.00	2/4/2009	14:26:19	10.442	19.86	1761.0
Site 26	6.00	2/4/2009	14:26:20	10.967	19.80	1760.6
Site 26	6.00	2/4/2009	14:26:20	11.351	19.74	1762.1
Site 26	6.00	2/4/2009	14:26:21	11.599	19.68	1764.2
Site 26	6.00	2/4/2009	14:26:21	11.652	19.64	1766.8
Site 27	6.25	2/4/2009	14:34:25	0.153	20.46	1773.3
Site 27	6.25	2/4/2009	14:34:26	0.156	20.45	1773.5
Site 27	6.25	2/4/2009	14:34:26	0.249	20.44	1773.6
Site 27	6.25	2/4/2009	14:34:27	0.387	20.44	1773.5
Site 27	6.25	2/4/2009	14:34:28	2.728	20.42	1772.1
Site 27	6.25	2/4/2009	14:34:28	3.275	20.41	1770.6
Site 27	6.25	2/4/2009	14:34:29	3.624	20.39	1769.4
Site 27	6.25	2/4/2009	14:34:29	4.086	20.36	1768.3
Site 27	6.25	2/4/2009	14:34:30	4.763	20.28	1766.9
Site 27	6.25	2/4/2009	14:34:31	5.384	20.23	1766.5
Site 27	6.25	2/4/2009	14:34:31	5.625	20.18	1766.6
Site 27	6.25	2/4/2009	14:34:32	6.146	20.13	1766.7
Site 27	6.25	2/4/2009	14:34:32	6.468	20.07	1767.0
Site 27	6.25	2/4/2009	14:34:33	6.947	20.02	1767.4
Site 27	6.25	2/4/2009	14:34:33	7.328	19.97	1768.0
Site 27	6.25	2/4/2009	14:34:34	7.690	19.92	1768.5
Site 27	6.25	2/4/2009	14:34:34	7.820	19.87	1769.2
Site 27	6.25	2/4/2009	14:34:35	7.988	19.83	1769.2
Site 27	6.25	2/4/2009	14:34:35	8.051	19.80	1769.1

Site	Distance from Starting Point (miles)	Date	Time	Depth (feet)	Temperature (°C)	Specific Conductance (µS/cm)
Site 27	6.25	2/4/2009	14:34:36	8.079	19.77	1768.9
Site 27	6.25	2/4/2009	14:34:36	8.101	19.74	1768.7
Site 27	6.25	2/4/2009	14:34:37	8.119	19.72	1768.3
Site 28	6.50	2/4/2009	14:43:16	0.027	21.52	1789.4
Site 28	6.50	2/4/2009	14:43:17	0.081	21.52	1789.3
Site 28	6.50	2/4/2009	14:43:17	0.196	21.51	1789.3
Site 28	6.50	2/4/2009	14:43:18	0.331	21.50	1789.0
Site 28	6.50	2/4/2009	14:43:18	0.486	21.50	1788.4
Site 28	6.50	2/4/2009	14:43:19	0.674	21.49	1787.6
Site 28	6.50	2/4/2009	14:43:19	0.864	21.47	1787.3
Site 28	6.50	2/4/2009	14:43:20	1.072	21.46	1786.9
Site 28	6.50	2/4/2009	14:43:20	3.021	21.44	1786.1
Site 28	6.50	2/4/2009	14:43:21	3.233	21.42	1784.9
Site 28	6.50	2/4/2009	14:43:21	3.253	21.39	1783.2
Site 28	6.50	2/4/2009	14:43:22	3.319	21.35	1781.9
Site 28	6.50	2/4/2009	14:43:22	3.466	21.32	1781.2
Site 28	6.50	2/4/2009	14:43:23	3.643	21.28	1781.0
Site 28	6.50	2/4/2009	14:43:23	3.817	21.24	1781.0
Site 28	6.50	2/4/2009	14:43:24	4.020	21.20	1779.4
Site 28	6.50	2/4/2009	14:43:24	4.230	21.14	1777.3
Site 28	6.50	2/4/2009	14:43:25	6.464	21.07	1775.3
Site 28	6.50	2/4/2009	14:43:25	7.022	20.99	1774.1
Site 28	6.50	2/4/2009	14:43:26	7.398	20.20	1799.0
Site 28	6.50	2/4/2009	14:43:26	7.687	20.05	1801.0
Site 28	6.50	2/4/2009	14:43:27	8.093	19.91	1802.5
Site 28	6.50	2/4/2009	14:43:27	8.594	19.81	1802.1
Site 28	6.50	2/4/2009	14:43:28	8.904	19.74	1801.6
Site 28	6.50	2/4/2009	14:43:28	8.993	19.73	1799.6
Site 28	6.50	2/4/2009	14:43:29	9.020	19.72	1797.8
Site 28	6.50	2/4/2009	14:43:29	9.036	19.71	1796.2
Site 28	6.50	2/4/2009	14:43:30	9.041	19.71	1794.8
Site 28	6.50	2/4/2009	14:43:30	9.059	19.71	1793.7
Site 28	6.50	2/4/2009	14:43:31	9.060	19.71	1792.7
Site 28	6.50	2/4/2009	14:43:31	9.066	19.71	1792.2
Site 28	6.50	2/4/2009	14:43:32	9.071	19.71	1791.7
Site 28	6.50	2/4/2009	14:43:32	9.075	19.71	1791.3

