Saltwater Interface Monitoring and Mapping Program Update 2024

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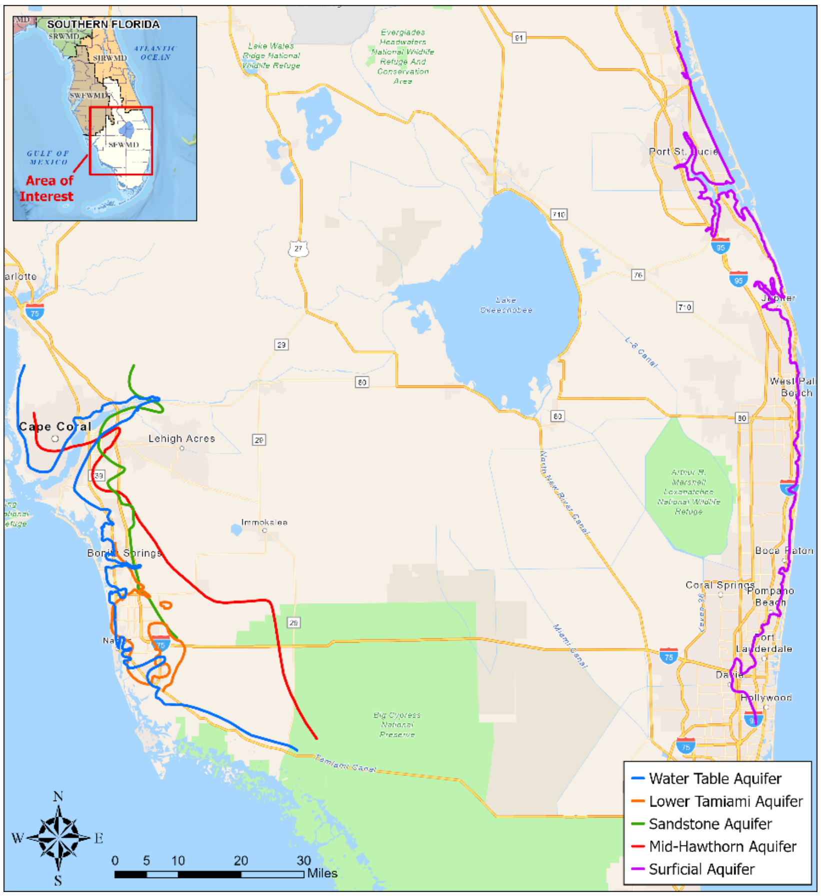

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ACRONYMS AND ABBREVIATIONS

bls	below land surface
District	South Florida Water Management District
ECSM	East Coast Surficial Model
ft	foot or feet
IAS	intermediate aquifer system
LTA	Lower Tamiami aquifer
m	meter or meters
mg/L	milligrams per liter
MHA	Mid-Hawthorn aquifer
PS	public supply
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
SMCL	secondary maximum contaminant level
SSA	Sandstone aquifer
TDS	total dissolved solids
USGS	United States Geological Survey
WTA	Water Table aquifer

1 INTRODUCTION

The South Florida Water Management District (SFWMD or District) began mapping the approximate location of the saltwater interface in 2009 and has produced updated maps every 5 years since 2009. Due to the ongoing effects of sea level rise, this monitoring and mapping program is an essential part of the District's resiliency and adaptation strategies.

In 2024, the District mapped the approximate extent of the saltwater interface in the surficial aquifer system (SAS) within St. Lucie, Martin, Palm Beach, Broward, Collier, Lee, and Charlotte counties (**Figure 1**). The United States Geological Survey (USGS) conducts saltwater interface mapping for Miami-Dade and Monroe counties (Zhang and Renshaw 2024).

In the Lower West Coast Planning Area, the District developed saltwater interface maps for the Water Table aquifer (WTA), Lower Tamiami aquifer (LTA), Sandstone aquifer (SSA), and the Mid-Hawthorn aquifer (MHA).

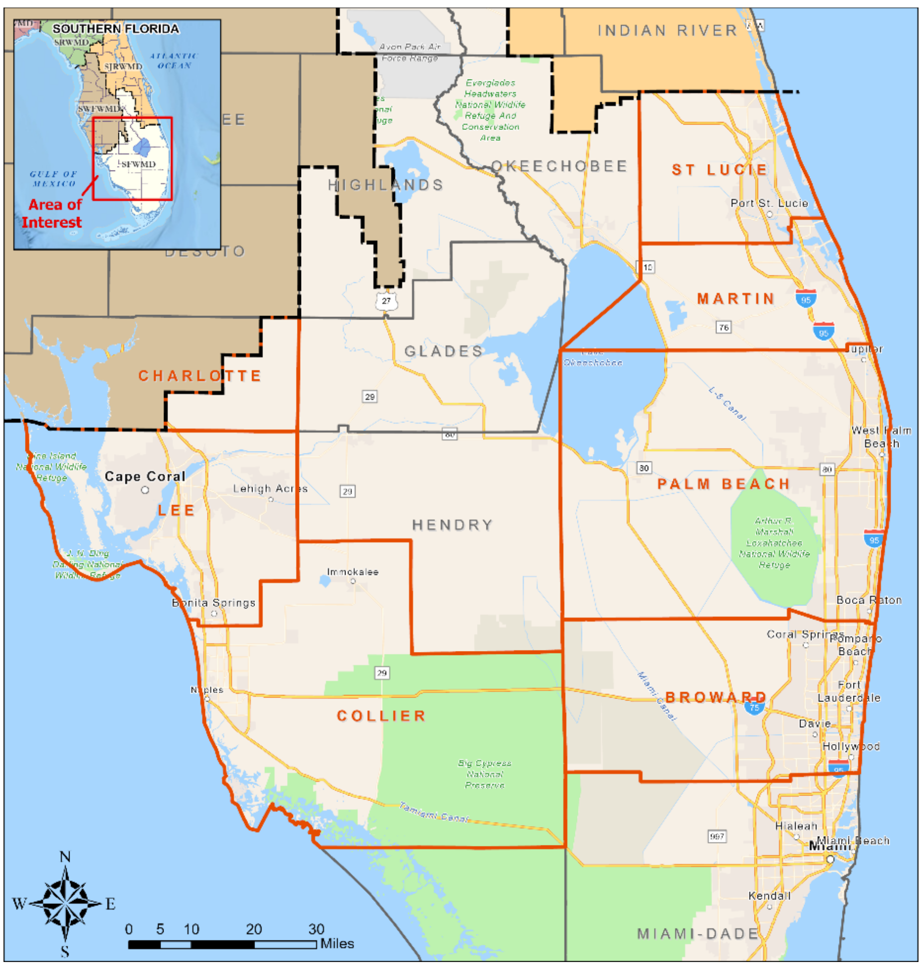

Figure 1. Counties included in the SFWMD's saltwater interface mapping program.

This report documents the data gathering, tabulation, and synthesis methods that were used to produce the 2024 saltwater interface maps presented and discussed in this report. The 2024 maps include the 2009, 2014, and 2019 saltwater interface locations, allowing the reader to see where the saltwater interface has migrated inland, or in some cases, retreated seaward.

2 BACKGROUND AND PURPOSE

2.1 Project Introduction

The District established the saltwater interface monitoring and mapping program to evaluate the extent of seawater encroachment into the SAS along the eastern and western coastlines of South Florida. Water quality data (e.g., chlorides, total dissolved solids [TDS], specific conductance) collected during the dry season (March 1 through May 31) by the District, stakeholders, counties, and other entities are compiled by the District every 5 years and used to update the location of the SAS saltwater interface maps (including the Biscayne aquifer) on the east coast of Florida, and the WTA, LTA, SSA, and MHA on the west coast of Florida within the District's boundaries. The District's regulatory staff use the mapped position of the saltwater interface as part of the water use permitting review process. Coastal utilities also use these maps to monitor for potential impacts to public supply (PS) wellfields.

Water quality data are obtained and compiled from multiple sources (refer to Section 3.3) to generate the saltwater interface maps. Chloride concentration data from 1,135 wells were used to create the 2024 saltwater interface maps.

2.2 Planning and Permitting

District water supply plans for each planning area within the District are updated every 5 years, as required by Chapters 373 and 187, Florida Statutes. Saltwater intrusion monitoring is an important component of water management, and the location and movement of the saltwater interface is an important component of water supply planning. For example, if coastal wellfields are overpumped, saltwater can be drawn into wells either laterally or vertically from deeper aquifers, causing PS wells to be shut down, resulting in the need for new wells to be installed farther inland or for an alternative water supply source to be identified and developed.

The District's regulatory staff use the saltwater interface maps when evaluating applications for water use permits. Projects located in areas vulnerable to saltwater intrusion are required to implement a saline water monitoring program and periodically report chloride concentrations from groundwater samples collected from their wells to the District. Chloride data from sampled wells can vary between the dry and wet seasons.

2.3 Project Objectives

The main objective of this monitoring and mapping effort is to evaluate the changes in the location of the saltwater interface every 5 years. The saltwater interface is defined as the 250 milligrams per liter (mg/L) isochlor (i.e., a line of equal chloride values) in this report and on the associated maps. Saltwater intrusion is considered harmful when the chloride concentrations consistently remain above 250 mg/L, above and beyond seasonal fluctuations in chloride concentrations (SFWMD 2022b). A chloride concentration of 250 mg/L is the United States Environmental Protection Agency's secondary maximum contaminant level (SMCL) for chloride. The collected chloride concentration data are used to map the location and extent of saltwater intrusion, show the changes in the position of the saltwater interface that have occurred over the past 5 years, and help determine the causes of those changes. Chloride data from sampled wells can vary between the dry and wet seasons. This mapping effort is focused on the location of the saltwater interface during the dry season as it will reflect the farthest inland extent of the interface.

2.4 Common Sources of Saltwater Intrusion

2.4.1 Lateral Intrusion from the Coast

Lateral (inland) intrusion from the coast is the most common type of saltwater intrusion, particularly along Florida's coastline (**Figure 2**). The boundary between fresh groundwater and saltwater is known as the saltwater interface. Fresh groundwater discharging toward the coast prevents landward encroachment of saltwater. If too much fresh water is pumped from the aquifer, the heads (i.e., water levels) in the aquifer can decline to a point where saltwater can migrate laterally inland. If pumping wells are too close to the saltwater interface, saltwater may be drawn into the wells and contaminate the water supply. For example, production wells in the cities of Dania Beach and Hallandale Beach PS wellfields in Broward County were negatively affected by lateral saltwater intrusion and had to be abandoned.

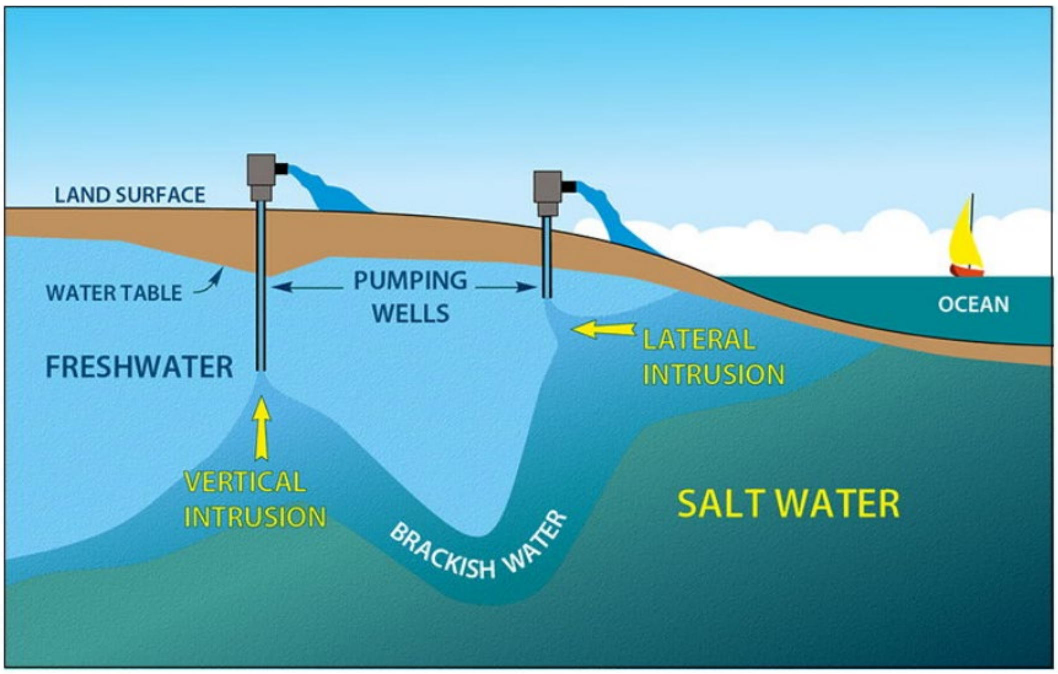

Figure 2. Conceptual drawing of lateral and vertical saltwater intrusion within coastal aquifers (Feltgen 2015).

2.4.2 Vertical Intrusion

Vertical intrusion is caused by the lowering of the freshwater head due to overpumping, which can allow the upward migration (sometimes referred to as upconing) of saline or brackish water into shallower aquifers or production zones used for public water supply (**Figure 2**). This may occur more frequently during droughts when the water table is lowered due to increased pumpage. In some cases, "natural" vertical intrusion can occur if strong upward vertical hydraulic gradients are present between aquifers separated by a leaky aquitard.

2.4.3 Surface Infiltration

Infiltration of saltwater into shallow freshwater aquifers can originate from saltwater canals, quarries, pits, ponds, or lagoons that are hydraulically connected to the shallow aquifer. The relatively denser saltwater can flow and "sink" into the freshwater aquifer from these surface features, causing local saltwater intrusion. Some canals in Broward County were designed to allow boat access to the ocean and do not have salinity control structures, or the canals have salinity control structures located farther inland to allow boat access to the ocean. Because these canals were excavated through the freshwater aquifer, they can cause saltwater intrusion of the freshwater aquifer.

2.4.4 Relict (Connate) Seawater

Relict seawater is found in various parts of Florida. As sea level fell during previous ice ages, saltwater was locally trapped within impermeable sediments or rock and is referred to as connate water. In contrast, relatively more permeable sediments or rock are recharged by freshwater infiltration from rainfall, flushing out any saline water.

Historically, the higher salinity LTA groundwater in inland Collier County was interpreted to be connate water (i.e., higher salinity water that was not flushed out of the aquifer during previous sea level high stands). More recently, geochemical data (Shoemaker et al. 2003) suggested an alternate theory that vertical movement of water from the underlying Floridan aquifer system is responsible for these areas of higher salinity groundwater. This theory is challenged by the approximately 250 to 425 feet (ft) of low-permeability Hawthorn Group sediments that tend to provide hydraulic separation between these aquifers in inland Collier County. Regardless of the exact origin of the higher salinity LTA groundwater, it is neither the result of lateral intrusion from the coast nor upconing due to wellfield withdrawals. This higher salinity groundwater is designated on the Collier County LTA saltwater intrusion maps by cross-hatched shapes.

2.4.5 Other Mechanisms

Saltwater contamination may also occur along open boreholes and within abandoned, improperly constructed, or corroded wells that can provide pathways for vertical migration of saline water between interconnected aquifers.

2.5 Importance of Saltwater Monitoring

Saltwater intrusion has been understood as a threat to fresh groundwater supplies for almost a century. Saltwater intrusion monitoring of the Biscayne aquifer began in 1939 (Prinos et al. 2014). Saltwater intrusion has continued since that time, forcing water managers to implement long-term mitigation efforts. The Ghyben–Herzberg relation (Drabbe and Ghijben 1889, Herzberg 1901) explains how changes in freshwater head (water level elevation) can change the depth to the saltwater interface. This relation assumed simple hydrostatic conditions in a homogeneous, unconfined coastal aquifer and showed that the interface separating saltwater of a density ρ_s and fresh water with a density of ρ_f must project into the aquifer at an angle less than 90° (Freeze and Cherry 1979). The weight of a unit column of fresh water extending from the water table to the saltwater interface is balanced by a unit column of saltwater extending from sea level to the same depth as the point on the interface (Freeze and Cherry 1979). The formula for calculating the depth of fresh water below sea level is as follows:

$$Z_s = \rho_f / (\rho_s - \rho_f) \cdot Z_w \qquad \text{Equation (1)}$$

Where:

Z_s = depth of fresh water below sea level (meters [m])
Z_w = thickness of fresh water above sea level (m)
ρ_f = density of fresh water (1.000 grams per cubic centimeter [g/cm^3])
ρ_s = density of saltwater (1.025 g/cm^3)

Substituting the values of ρ_f and ρ_s into Equation 1 results in Equation 2, which is called the Ghyben–Herzberg relation:

$$Z_s = 40 \cdot Z_w \qquad \text{Equation (2)}$$

The Ghyben–Herzberg relation shows that if the water table in an unconfined coastal aquifer is lowered by 1 m, the saltwater interface will rise 40 m (Freeze and Cherry 1979).

Freshwater heads in coastal areas must be maintained at high enough elevations to prevent saltwater encroachment into the fresh groundwater system. To help protect wellfields and prevent inland movement of saltwater through coastal canals, salinity control structures have been constructed near the coast in some, but not all canals (refer to Section 2.4.3). These control structures allow the District to raise the upstream canal stage and the groundwater elevation in the surrounding water table (particularly during the dry season), in order to raise the inland freshwater head to prevent saltwater intrusion.

Over time, some coastal wellfields have been replaced by wellfields farther inland as the saltwater interface has moved landward and impacted wellfield operations and water quality. Significant ongoing population increases in South Florida and the associated increase in water use present challenges for water supply and require careful monitoring of the location of the saltwater interface. Ongoing sea level rise also requires continued saltwater interface monitoring and mapping so that adaptation strategies can be developed and implemented to protect the freshwater aquifers and the water supply of South Florida.

3 SALTWATER INTERFACE MAPPING

3.1 Strategy

Due to the relatively slow movement of groundwater, and after reviewing the historical movement of the saltwater interface in South Florida, it was determined that the appropriate interval for the preparation of saltwater interface maps would be every 5 years. Including the saltwater intrusion maps produced in 2024 and discussed in this report, the District has produced four sets of saltwater intrusion maps for the years 2009, 2014, 2019, and 2024. The changes of the locations of the saltwater interfaces over this time frame confirm that the 5-year monitoring interval is appropriate for showing the movement of the saltwater interface over time, identifying areas of concern, and adjusting the groundwater monitoring network.

The District maps the farthest inland extent of the saltwater interface, which typically occurs at the end of the dry season (March through May of each year). The largest chloride concentration reported at each well during the 3-month dry season was plotted on each map and used to define the farthest inland extent of the interface. In certain areas where data were sparse, and monitoring wells in the area were not sampled during the March through May time frame, chloride concentration data reported for those wells for the months before or after the dry season were used to help constrain the interface location. These data are indicated on the data summary tables on the saltwater interface maps produced for this report.

3.2 Limitations and Other Considerations

There are several challenges to mapping the 250 mg/L isochlor. First, the saltwater interface is a three-dimensional surface that must be represented on a two-dimensional plan-view map. Second, the interface is a dynamic surface, moving due to changes in hydraulic head and chloride concentration differentials within the aquifer as well as rising sea levels. Third, a fixed point in time must be selected to represent the isochlor location. Fourth, the saltwater interface is a diffuse saltwater-freshwater mixing zone that must be represented by a single line on plan-view maps. Lastly, different pathways for saltwater intrusion or pathways along the top of confining units may complicate mapping of the isochlor. It is important to note that there may be one or more mechanisms (see Section 2.4) contributing to the movement or location of the saltwater interface.

Data limitations also affect saltwater interface mapping. Wells used in previous years' maps are not always available 5 years later (due to being destroyed during urban development or road construction) or have not been sampled in the last 3 to 5 years, making comparisons between mapping efforts more challenging. In some cases, monitor wells are no longer required to be sampled for chlorides if the sampling was a condition of a water use permit.

Conversely, new wells may be installed between mapping efforts, providing data in areas previously lacking data. New wells and the chloride concentration data collected from those wells can alter the position of the saltwater interface and change the interpretation from previous maps. These changes in the saltwater interface position may not represent actual movement of the interface because no data were available in that area during previous saltwater interface mapping. Finally, monitor wells that were appropriately designed and constructed to detect the saltwater interface are not always available or do not exist in certain areas. The most logical interpretations for the saltwater interface location must be made based on hydrogeologic principles and the open intervals of the monitor wells used to map the interface. Reclaimed water use, wellfield pumping, domestic water usage, and infiltration from canals and surface water bodies can all affect the movement and location of the saltwater interface.

Proper well construction is an important factor for detection of the saltwater interface. Monitor wells consist of both blank casing (solid casing with no slots in the casing) installed above either a well screen consisting of machined slots or, in some instances, an uncased, open section of the borehole to allow water to enter the well. Whether or not a groundwater sample collected from a monitor well "detects" the saltwater interface can be directly related to the total well depth and the length and location of the open or screened interval of the well. If a well is installed too shallow in the aquifer, groundwater samples collected from that well may not indicate the presence of salt water. However, a well screened just above the base of the aquifer in the same location as the shallow well described above will provide groundwater samples containing elevated chloride concentrations, assuming for the sake of argument that the saltwater interface has passed beneath both wells. In an ideal saltwater monitoring program, all saltwater intrusion wells would be installed with short (5- to 10-ft-long) well screens at the base of the aquifer, eliminating groundwater mixing between aquifer flow zones of differing salinities. Because a Districtwide saltwater intrusion monitoring well network consisting of hundreds of perfectly designed saltwater intrusion monitoring wells does not exist, the District uses, where possible, the best available groundwater quality sample data available from the most reliable wells.

The Florida Department of Environmental Protection has standard methods for sampling monitor wells; however, the methods for saltwater intrusion monitoring may not be consistently implemented. This is unavoidable due to the challenges mentioned earlier. Well construction and sampling methods affect the quality of groundwater samples. Additionally, not all samples are analyzed for chloride concentrations. Instead, some surface and groundwater samples are analyzed for specific conductance, TDS, or salinity. These data were converted to chloride concentrations so that they could be used for mapping purposes. The details of the specific conductance to chloride conversion methodology are discussed in Section 3.3.

For the 2024 mapping, 16 surface water samples on the west coast as well as 25 surface water samples and 18 groundwater samples on the east coast were converted from the reported specific conductance values to chloride concentrations. On the west coast, 28 surface water samples and 2 groundwater samples were reported as salinity, and 7 surface water samples on the east coast were also reported as salinity. These 37 salinity samples were converted to chloride concentrations. All chloride groundwater concentrations used in this report are reported in units of mg/L.

Finally, there is the issue of the timing of groundwater sample collection. Ideally, all wells to be used for saltwater interface mapping would be sampled every 5 years during the dry season when freshwater heads in the aquifer are lowest (March 1 through May 31). However, not all wells were sampled during this preferred time frame. In some cases, particularly in an area lacking data or near PS wellfields, a chloride concentration reported from outside this time frame, but as close to the time frame as possible, was used. This often occurs due to regulatory requirements that specify when certain facilities must collect and submit sampling data to the District or other agencies. On the 2024 saltwater interface maps, chloride concentration data from outside the dry season time frame are denoted using an asterisk in the well data tables at the bottom of each map.

3.3 Data Gathering and Evaluation Process

Figure 3 is a flow chart showing the data gathering and evaluation process for the 2024 saltwater interface mapping effort. The following data sources were used for the 2024 saltwater interface maps:

- SFWMD DBHYDRO database – surface water data, groundwater data, well construction data
- SFWMD groundwater sampling programs
- SFWMD Regulation database
- USGS National Water Information System (NWIS)
- Broward County
- Collier County
- City of Naples
- City of Pompano Beach
- City of Fort Lauderdale
- Town of Jupiter Water Utilities
- Martin County
- Loxahatchee River District

During the 2014 and 2019 isochlor mapping, the District identified spatial gaps in the saltwater intrusion monitoring network. To supplement the existing groundwater data, seven wells were selected for groundwater sample collection to bolster the District's monitoring network before the 2024 mapping effort. (**Table 1**). These seven new wells that were sampled included two new saltwater intrusion monitor wells that were recently installed by the District. These two wells, named BS-2 (located along the C-10 Canal spur in the City of Hollywood) and BS-3 (located along the G-16 Canal in the City of Pompano Beach) were installed within spatial gaps in the existing saltwater intrusion monitoring network prior to the 2024 isochlor mapping effort. An initial set of dual induction logs were collected from these two wells shortly after installation. Future dual induction logs will help bolster the monitoring network. District hydrogeologists purged and sampled all seven monitor wells listed in **Table 1** before the 2024 isochlor mapping started. These groundwater samples were submitted to the District's West Palm Beach laboratory for chloride concentration analyses and the resultant chloride concentration data were added to the maps.

Surface water and groundwater data used for this project were scrutinized for duplicates, consistency of parameters, reporting units, qualifiers, and missing information. All external sources were inspected to eliminate possible duplication of records and data inconsistencies. Records with potential data quality issues were identified and removed. All data variables, such as station names, water quality parameters, reporting units, county name, aquifer name, and sample type (groundwater or surface water), were unified under a single attribute name. Geographic coordinates were converted to state plane coordinates as needed. All cased depth and depth drilled information are reported in feet below land surface (ft bls). Subsequently, all data sources were merged into a single database to include the entire period of record.

The processed 2024 groundwater data, including surface water data, were formatted and split into two different files for the west coast and east coast to include all necessary fields for spatial analyses. These steps are illustrated in **Figure 3**. All data processing, analyses, and well time-series plots were performed using R programming language version 4.4.1 (R Development Core Team 2018).

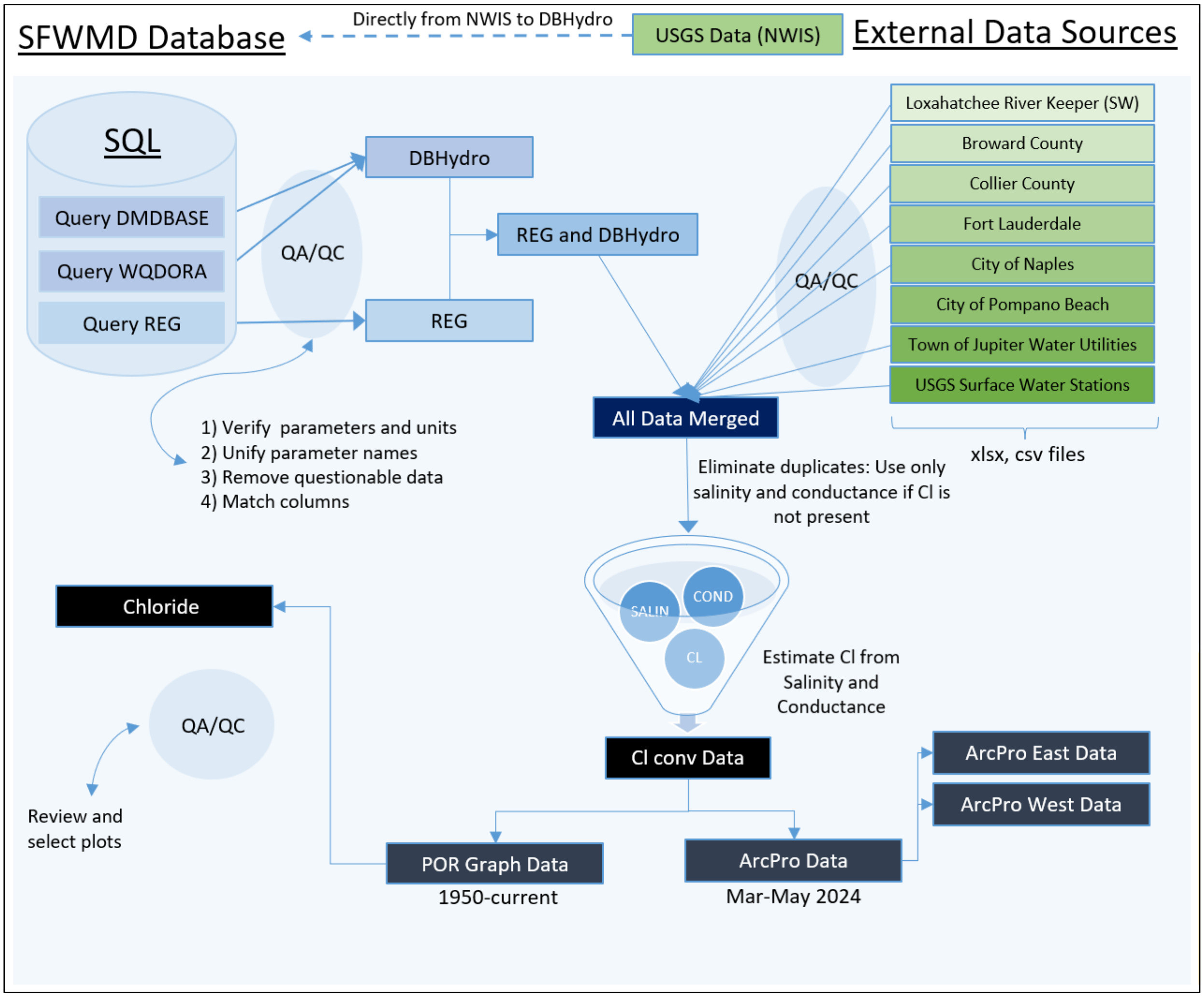

Figure 3. The data gathering and evaluation process for the saltwater intrusion evaluation conducted by the SFWMD.

Table 1. Additional monitor wells sampled by the SFWMD in 2024.

Well ID	X Coordinate	Y Coordinate	County
BS-2	801124.3	260212.7	Broward
BS-3	800813.6	261337.5	Broward
C-2064	448461.2	616313.4	Collier
C-391	396263.6	675583.5	Collier
L-2644	317097.9	817487.6	Lee
PB-1772	958599.2	763977.1	Palm Beach
PBS-S44	955922.9	903787.7	Palm Beach

The data collection and evaluation efforts focused primarily on groundwater chloride concentrations. However, not all groundwater samples were analyzed for chloride since specific conductance or salinity data were sometimes available. Therefore, specific conductance and salinity had to be converted to chloride concentrations to increase the number of chloride data points available for saltwater interface mapping. Three different methods for converting to chloride concentrations were evaluated: the method used in the 2019 saltwater interface mapping update, the method used for the development of the East Coast Surficial Model (ECSM), and the method given in Appendix I of *Map of an Approximate Inland Extent of Saltwater at the Base of the Biscayne Aquifer in the Model Land Area of Miami-Dade County, Florida, 2016* (Prinos 2017). These methods will be referred to as the 2019 saltwater interface mapping update method, the ECSM method, and the Prinos method, respectively.

In the 2019 saltwater interface mapping update specific conductance and salinity measurements were converted to chloride concentration using Equations 4 and 5 below (Iricanin 2017). Using Equation 4, specific conductance was converted to practical salinity assuming a water temperature of 25°C.

$$S_{PSS} = 0.0123 - 0.2174R_t^{1/2} + 25.3283R_t + 13.7714R_t^{3/2} - 6.4788R_t^2 + 2.5842R_t^{5/2} \quad \text{Equation (4)}$$

Where:

S_{PSS} = practical salinity
R_t = ratio between sample specific conductance and the reference conductance of seawater (53,064 microsiemens per centimeter [µS/cm])

The chloride concentration was then derived from the resulting practical salinity value based on the relationship between chlorinity and salinity as described by Wooster et al. (1969) and Iricanin (2017) shown in Equation 5. The derived chloride concentration was adjusted for density using the approximate density of seawater (1.02 g/cm^3 at 25°C). The final chloride concentrations obtained from this conversion scheme were approximations considered suitable for this application.

$$Cl = S_{PSS} \times \frac{1.005}{1.80655} \times 1{,}020 \quad \text{Equation (5)}$$

Where:

Cl = chloride concentration (mg/L)
S_{PSS} = practical salinity

The development of the ECSM by the District required converting chloride concentrations and specific conductance values to TDS concentrations. The conversion equations for the ECSM were determined empirically by using linear regression to establish a relationship between chloride and specific conductance based on samples that have both values. There are various regression equations for different ranges of chlorides (i.e., less than 250 mg/L, more than 250 mg/L and less than 8,300 mg/L, more than 8,300 mg/L). The conversion of specific conductance to TDS uses bins of ratios, where different "bins" (ranges of specific conductance values) use different ratios that range from 0.57 to 0.68.

The Prinos method came from a linear regression of chloride concentration and specific conductance of 16,184 water samples collected between 1940 and 2016 from 178 monitoring sites in South Florida. The relationship is given in Equation 6:

$$Cl = 0.3458SpCond - 176.32 \qquad \text{Equation (6)}$$

Where:

Cl = chloride concentration (mg/L)
SpCond = specific conductance (µS/cm)

To evaluate if the chloride conversion method used in the 2019 saltwater interface mapping update was still the best method to use, the District's water quality databases were queried for water samples that had reported chloride and specific conductance values and were collected within the WTA, SAS, LTA, SSA, or MHA. The data set was comprised of 2,175 samples collected between August 9, 1984 and April 16, 2024. Each specific conductance measurement was converted to a chloride concentration using the three different conversion methods: the 2019 saltwater interface mapping update method, the ECSM method, and the Prinos method. The results from these methods were then compared against each other and to the laboratory-measured chloride concentrations. Both the ECSM and Prinos methods resulted in negative chloride values when reported laboratory chloride concentrations were low. The ECSM and Prinos methods were more accurate in the range of about 100 to 250 mg/L chlorides but were less accurate than the 2019 saltwater interface mapping update method for very low or very high specific conductance values. When the 2019 saltwater interface mapping update method was inaccurate, the inaccuracies erred on the side of higher chlorides, which resulted in a more conservative saltwater intrusion map. Therefore, the chloride conversion method used for the 2019 saltwater interface mapping update was used for the 2024 saltwater interface mapping update.

For the 2024 saltwater interface mapping update, active monitor wells were selected by querying various databases for all wells from which chloride groundwater samples were collected and analyzed between March 1, 2024 and May 31, 2024. However, as discussed earlier, some wells were not sampled between March 1 and May 31. Instead, those wells were sampled just outside of the preferred March 1 through May 31 dry season time frame, so those chloride concentration data were used to fill areas that would otherwise be spatial data gaps. Chloride groundwater concentrations were available for the March through May 2024 time frame for most monitor wells used in 2019 or identified in 2024. Because the objective of the saltwater interface mapping is to map the farthest of the inland extent of saltwater intrusion, the highest chloride concentration reported during the March 1 through May 31, 2024 period was used for mapping whenever possible.

Time-series plots of the entire periods of record of chloride concentration data were created for each monitor well. Each time-series plot has a horizontal dashed line representing a chloride concentration of 250 mg/L to help show when chloride concentrations have reached the SMCL. In addition, the color of the chloride concentration data points changes from green (for samples with concentrations less than or equal to 100 mg/L) to yellow (for samples with concentrations between 101 and 250 mg/L) to orange (for samples with concentrations between 251 and 1,000 mg/L) and then to red (samples with concentrations greater than 1,000 mg/L). These time-series plots show trends in chloride concentrations over time, which can indicate when the saltwater interface began to migrate past a particular well. An example of this is illustrated by the time-series plot for a 200-ft-deep monitor well G-2478 (Well 7 monitor) ID 136574 located near the City of Hallandale Beach (**Figure 4**). **Figure 4** shows that the chloride concentrations at this well were less than 250 mg/L from the late 1980s until the early 2000s when concentrations slowly increased to greater than 250 mg/L (orange dots) as the saltwater interface began to pass through the monitor well. From 2010 to 2019 to 2024, the chloride concentrations increased sharply from about 790 mg/L to 6,750 mg/L, to 8,747 mg/L, respectively.

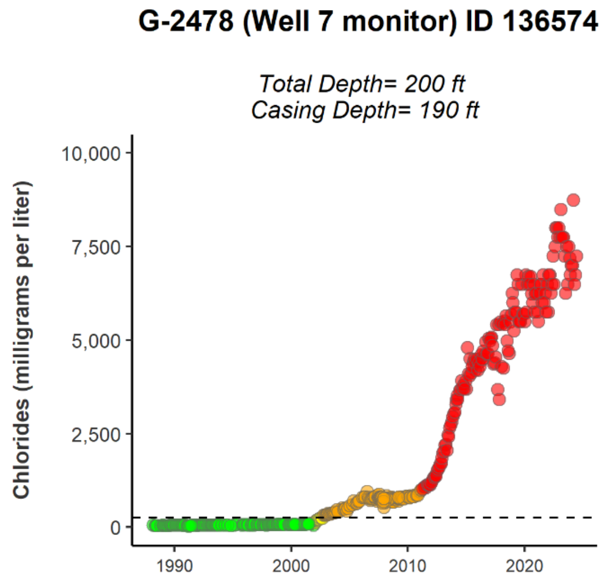

Figure 4. Chloride time-series plot for G-2478 (Well 7 monitor) ID 136574 near the City of Hallandale Beach in Broward County.

Time-series plots can also show improvements in groundwater quality (i.e., decreases in chloride concentration) in areas where groundwater pumpage has been reduced, where demand has shifted to alternative water supplies, or where reclaimed water projects have been implemented, causing reductions in groundwater pumpage. **Figure 5** shows that the chloride concentrations exceeded 250 mg/L at G-2445 for most of its period of record. Since 1999, the water quality has gradually improved, and the saltwater interface in the area has retreated toward the coast. Select time-series plots are inserted along the borders of the saltwater interface maps to provide a different, nonspatial perspective regarding movement of the interface.

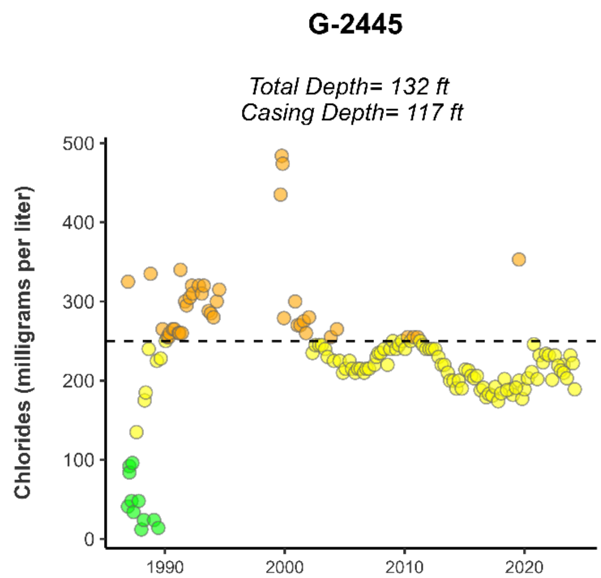

Figure 5. Chloride time-series plot for G-2445 in the City of Pompano Beach in Broward County.

3.4 Mapping Process

The saltwater interface mapping process used in 2024 is shown in **Figure 6**. The 2024 processed chloride concentration data were imported into ArcPro for map creation and manual editing of the saltwater interface. West coast chloride concentration data were further divided into their source SAS aquifer (WTA, LTA, SSA, and MHA).

Surface water stations with chloride data, specific conductance data, or salinity data were converted to chloride concentrations and were used to enhance or constrain the saltwater interface line, but only in areas where groundwater data were absent, such as in upstream portions of drainages, canals, or estuaries. These surface water samples were collected at established monitoring stations in canals, streams, estuaries, and control structures near coastal areas. Coastal salinity control structures were plotted on each map and used as reference points for the location of the saltwater interface along selected coastal canals.

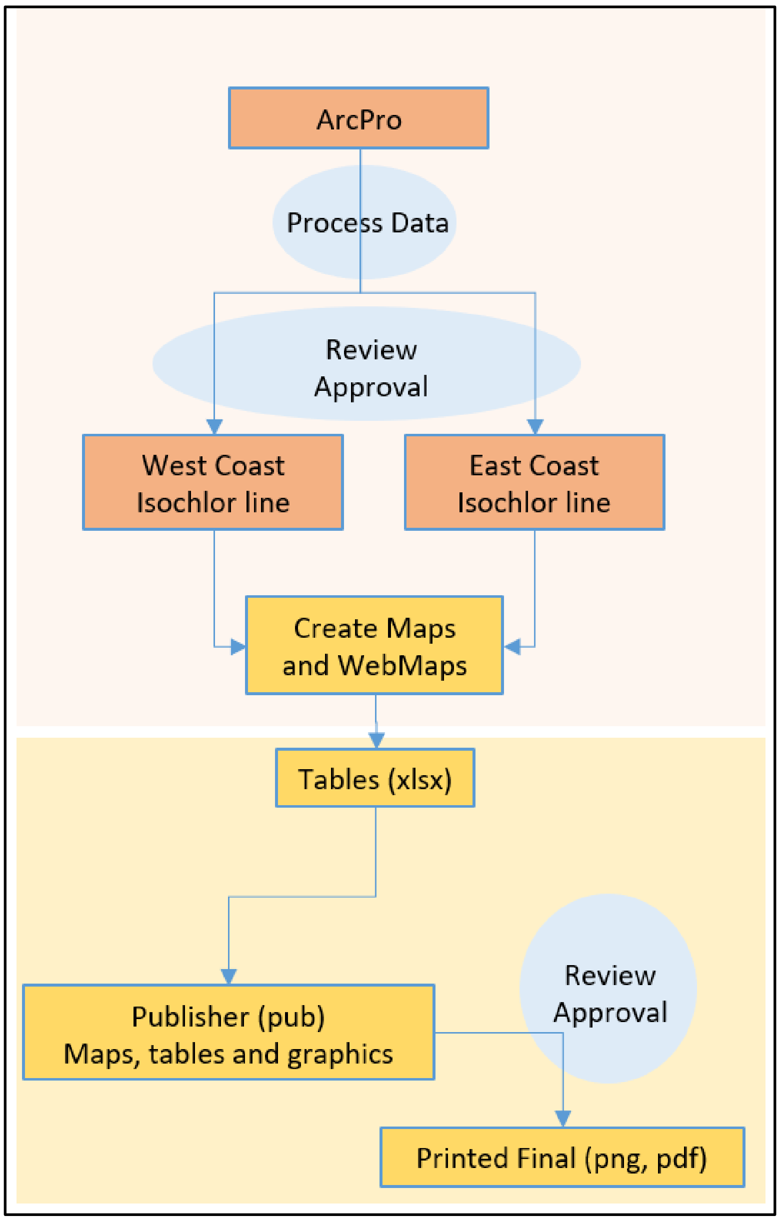

Figure 6. Saltwater interface mapping flow chart.

Subsequently, chloride concentration maps were created showing the 2019 isochlors and the 2024 chloride concentration data. To modify the 2019 isochlor, the 2019 isochlor was copied in ArcPro, renamed the 2024 isochlor, and was then manually modified in ArcPro to match the 2024 chloride data, while retaining the original 2019 isochlor. Each chloride concentration that changed the location of the isochlor was manually checked for data accuracy. The movement of the isochlor was based not only on the chloride concentration at each well but also on site-specific information from neighboring wells, including the total depths and open intervals for nearby wells along with their chloride concentrations.

The 250 mg/L chloride isochlor was drawn for the SAS in all the east coast counties (Martin, St. Lucie, Palm Beach, and Broward), and one isochlor was drawn for each of the SAS and intermediate aquifer system (IAS) aquifers along the west coast (Lee and Collier counties) for the 2024 dry season. Individual maps were created for each county and corresponding aquifer, showing the previous (2009 through 2019) and current (2024) isochlors, and all wells and surface water samples used for the 2024 isochlor, locations of all PS wellfields, county lines, coastal control structures, and canals as well as roadways and cities. Descriptions of individual areas of isochlor movement are provided in Section 5.

3.5 Map Creation

Once all the chloride data were gathered and evaluated, they were added to the maps for review and development of the 2024 interface positions. **Table 2** summarizes the saltwater intrusion maps by county, aquifer, and year of publication. Starting in 2019, the Lee County and Collier County MHA maps were combined into one map, resulting in a total of eight maps covering five aquifers in six District coastal counties starting in 2019.

Table 2. Saltwater interface maps produced by year.

County	Aquifer	2009	2014	2019	2024
Martin and St. Lucie	Surficial	X	X	X	X
Palm Beach	Surficial	X	X	X	X
Broward	Surficial	X	X	X	X
Lee	Water Table	X	X	X	X
Lee	Mid-Hawthorn	X	X		
Lee and Collier	Sandstone	X	X	X	X
Lee and Collier	Lower Tamiami	X	X	X	X
Collier	Water Table	X	X	X	X
Collier	Mid-Hawthorn	X	X		
Lee and Collier	Mid-Hawthorn			X	X

Note: Miami-Dade County saltwater interface mapping is performed by the USGS.

These maps also include selected chloride concentration time-series plots, a reference table of all the wells plotted on each map, and the approximate locations of the 2009, 2014, 2019, and 2024 isochlors, so relative movement of the isochlor over time can be evaluated.

Figure 7 is the legend for the 2024 saltwater intrusion maps. The well symbols on the maps are color coded based on the following 2024 dry season chloride concentration ranges (shown in **Figure 7**):

- Green represents chloride concentrations less than or equal to 100 mg/L.
- Yellow represents chloride concentrations between 101 and 250 mg/L.
- Orange represents chloride concentrations between 251 and 1,000 mg/L.
- Red represents chloride concentrations greater than 1,000 mg/L.

These are the same color codes and chloride concentration divisions used for the data plotted on the chloride time-series plots. The chloride concentrations plotted on the maps are the highest chloride concentrations analyzed between March 1, 2024 and May 31, 2024, except for those wells indicated by an asterisk in the map's data tables. Wells denoted with an asterisk in the map tables used the closest available chloride concentration data to the dry season time frame, usually from January through April 2024 and, in a few cases, December 2023 because data were not available for the dry season time frame. The legend shows that each colored dot on the map is a well that is labeled with a number followed by another number in parentheses, followed by a third number in smaller gray font. The first number next to the well symbol is a Map ID number (assigned in numerical order from north to south on each map), and the second number in parentheses is the 2024 chloride concentration in mg/L. To aid the reader in seeing why changes in the saltwater interface location were made, the 2019 chloride concentration is the third number in gray font on each label.

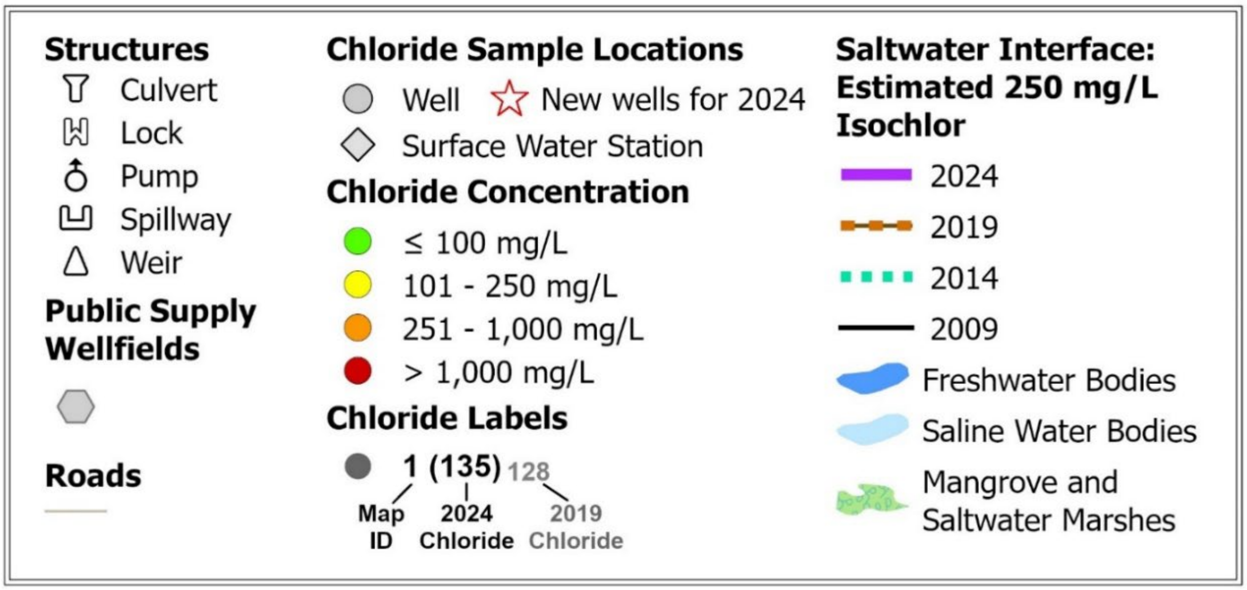

Figure 7. Legend for the 2024 SFWMD saltwater interface maps.

Along the bottom of each saltwater interface map is a reference table, which serves as a key to identifying the wells on each map using a map identification number (Map ID number shown in **Figure 7**). These reference tables provide well information including the District Facility ID for each well, the project name associated with each well, the well name or station name, the well coordinates, the facility type (i.e., well, canal, or estuary), the cased depth and total depth for each well, and the 2019 and 2024 chloride concentrations. A total of 1,120 wells and 79 surface water samples were plotted on the eight 2024 saltwater interface maps.

All map layouts were created using ArcPro version 3.1.2 (ESRI 2023). The final maps, including data tables and time-series plots, were prepared using Microsoft Publisher and converted to Adobe portable document format (PDF) files for final review, management approval, and distribution. Following final review, the maps were saved as PDFs, which are designed to be plotted at sizes ranging from 36 inches wide by 48 inches tall to 36 inches wide by 60 inches tall.

The PDF maps are available on the District's website at https://www.sfwmd.gov/documents-by-tag/saltwaterinterface. An interactive GIS-based version of the maps is also available at https://geoportal.sfwmd.gov/portal/apps/instant/minimalist/index.html?appid=f3c4bb609fb64a56bd4c9ba067396600.

This GIS map allows stakeholders and the public to zoom in to areas of interest and see in better detail how the interface relates to specific wells and/or facilities. All the data for each well and surface water sampling location are available to view by clicking on individual wells or surface water locations in the GIS map. Users can turn on and off different layers, such as PS wellfields, water reuse areas, and interface lines from previous years or only view interface lines and chloride data for specific aquifers. Finally, the District has also made the data available for users to download as feature classes from the Geospatial Open Data Portal (at https://geo-sfwmd.hub.arcgis.com/) to use in their own maps and reports.

4 WATER SUPPLY PLANNING

The saltwater interface monitoring and mapping program is an important component of water supplying planning, particularly in coastal areas. The District water supply planning areas applicable to this mapping effort are named the Upper East Coast, Lower East Coast, and Lower West Coast. The District publishes water supply plans which recognize that declining inland groundwater elevations may induce saltwater intrusion in coastal areas. Installation of coastal canal salinity control structures has helped stabilize the saltwater interface in some areas, but there is evidence of inland migration in other areas, particularly coastal Broward and Miami-Dade counties. A few coastal PS wellfields located seaward of salinity control structures are no longer operating due to saltwater intrusion (SFWMD 2024).

Sea level rise can increase landward movement of the saltwater interface. As sea level continues to rise, some coastal wellfields may have to relocate farther inland, decrease pumpage, change water treatment processes, or be replaced with alternative water sources (SFWMD 2024). The continued collection of groundwater elevation and groundwater chloride concentration data is critical to understanding the location and extent of saltwater intrusion, particular in areas near PS wellfields.

4.1 Upper East Coast

The *2021 Upper East Coast Water Supply Plan Update* (SFWMD 2021) was approved in November 2021. The plan update recognized that the saltwater interface maps can be used to track the location of the saltwater interface over time, identify areas of concern that require additional monitoring, and suggest changes in wellfield operations. The saltwater interface is regionally dynamic, with inland movement in some areas and seaward movement in other areas. Local-scale investigations of the approximate position of the saltwater interface could be warranted in areas of concern, depending on the network of available monitor wells, the proximity of saltwater sources to wellfields, and wellfield groundwater withdrawal rates. The plan update concluded that the SAS historically has served as the primary source of water for urban demands in the Upper East Coast Planning Area, and expansion of SAS withdrawals is limited due to wetland impacts and the increased potential for saltwater intrusion. Development of alternative water sources, such as the Floridan aquifer system, may be required to reduce demand on the SAS, which will reduce the potential for saltwater intrusion (SFWMD 2021).

4.2 Lower East Coast

The *2023–2024 Lower East Coast Water Supply Plan Update* (SFWMD 2024) was approved in September 2024, while the 2024 saltwater interface maps were drafted but not yet finalized. The plan update compared the 2009, 2014, and 2019 saltwater interface maps. The analyses indicated there were a few locations where noticeable inland movement of the saltwater interface occurred in Broward and Miami-Dade counties. These data, in addition to the 2024 saltwater mapping results, are important to calibrate groundwater models designed to simulate future saltwater movement.

With increased impacts of sea level rise, local governments, utilities, and private entities may be required to develop adaptive strategies to combat further saltwater intrusion (as well as regional flood protection). Strategies include construction of defensive barriers and pumping systems, improvement of infrastructure, and changes to land use. With the inland movement of the saltwater interface, local investigations of the interface position could be warranted in some areas, depending on the network of monitor wells available, land available for installing new monitor wells, the proximity of saltwater sources to wellfield locations, and withdrawal rates.

The plan update recommended that utilities design wellfield locations, configurations, and pumping regimes to avoid saltwater intrusion. Implementation of groundwater recharge systems could help prevent inland movement of the saltwater interface. The SFWMD, USGS, and local governments should continue to coordinate saltwater intrusion monitoring efforts to delineate the location and movement of the saltwater interface and identify areas of concern. Meanwhile, the SFWMD should periodically review existing groundwater monitoring networks and enhance them as appropriate (SFWMD 2024).

4.3 Lower West Coast

The *2022 Lower West Coast Water Supply Plan Update* (SFWMD 2022a) was approved in December 2022. The plan update noted that the monitoring networks used for saltwater intrusion, aquifer assessment, and groundwater modeling are a hybrid of regional programs and monitoring required or performed by water use permittees. Efforts should be made to identify locations considered critical to long-term monitoring and modeling to ensure wells are constructed, maintained, and replaced as necessary. SAS and IAS wellfield operating plans should be reviewed and revised by utilities to maximize withdrawals while avoiding harm to natural systems and potential aquifer impacts due to saltwater intrusion.

The plan update recognized that future increases in SAS and IAS withdrawals are limited by, among other issues, the potential for saltwater intrusion. In the Lower West Coast Planning Area, monitoring of groundwater chloride concentrations is crucial for the protection of fresh groundwater due to inland migration of the saltwater interface and upward movement (upconing) of saline groundwater. Another potential source of saltwater cross-contamination between aquifers is improperly abandoned wells. As noted in other water supply plans, local-scale investigation of the saltwater interface position could be warranted in some areas, depending on the network of available monitor wells, the proximity of saltwater sources to wellfield locations, and withdrawal rates. By tracking the movement of the saltwater interface every 5 years, areas of concern may be identified that require additional monitoring and/or may need changes in wellfield operations (SFWMD 2022a).

5 2024 SALTWATER INTERFACE INTERPRETATION

5.1 St. Lucie and Martin Counties – Surficial Aquifer System

Chloride concentration data from 183 SAS groundwater samples and 30 surface water samples were used to draw the 2024 saltwater interface in St. Lucie and Martin counties. There has been little movement of the interface in this region. The coastal area north of the City of Fort Pierce lacks monitor well data. However, the chloride concentrations in the four SAS wells in this area are all well below 250 mg/L, and the chloride concentrations in three of these four wells have decreased since 2019.

Between the City of Fort Pierce and Jensen Beach, there is only one monitor well located close to the coastline, and no monitor wells are located seaward of the City of Fort Pierce–Lawnwood PS wellfield in St. Lucie County. The sections below discuss movement of the interface, particularly near PS wellfields.

The 2024 interface near the South Martin Regional Utility–South PS wellfield in Hobe Sound has migrated approximately 500 ft inland since 2019 but is farther seaward than it was in 2014 and 2009 (**Figure 8**). This result is based primarily on the chloride concentration of 2,350 mg/L reported at Well-R4 ID 280521 (Map ID 176 in **Figure 8**) in May 2024 as well as the chloride concentration at SW-13D ID 156278 (Map ID 169 in **Figure 8**), which increased from 42 mg/L in 2019 to 282 mg/L in 2024. Review of monthly total pumpage data from this wellfield showed that the total pumpage for the January 1 through May 31 period was 190.82 million gallons greater in 2024 than it was in 2019 and 170.10 million gallons greater than in 2014. In addition, the total yearly pumpage from the wellfield has increased each year since 2014. The total reported pumpage was approximately 560.92 million gallons in 2014, 626.39 million gallons in 2020, 763.87 million gallons in 2021, 786.24 million gallons in 2022, and 795.07 million gallons in 2023. These increased pumping volumes likely caused reduced freshwater heads near the wellfield and inland movement of the saltwater interface from 2019 to 2024 and could continue to do so in the future.

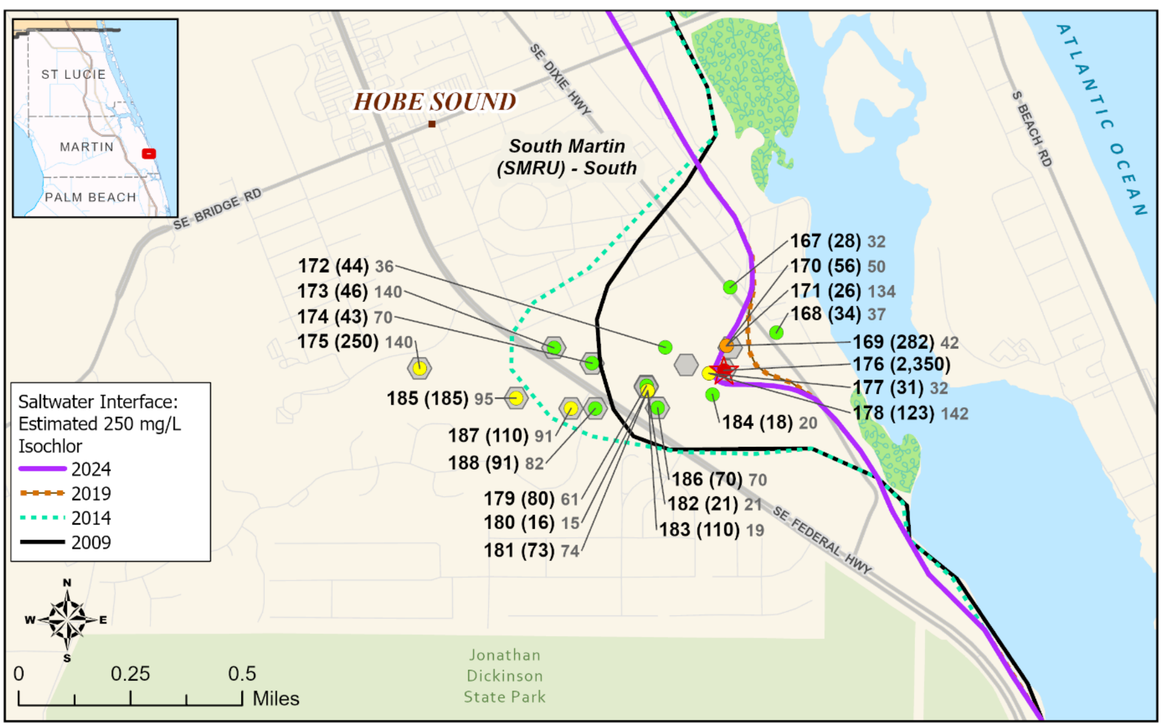

Figure 8. Position of the 2024 saltwater interface in the SAS at the South Martin Regional Utility–South PS wellfield in Hobe Sound in Martin County.

As shown in the time-series plot for Well-R4 ID 280521 (**Figure 9**), chloride concentrations have remained well above 250 mg/L since December 21, 2021 and began to significantly increase starting in April 2023 when chloride concentrations increased to 1,100 mg/L from the March 2023 concentration of 749 mg/L. Chloride concentrations reached their maximum concentration of 2,790 mg/L at Well-R4 ID 280521 on December 31, 2023, with the May 2024 concentration decreasing slightly to 2,350 mg/L.

Further evidence of slow inland migration of the interface at this wellfield is shown on the time-series chloride plot for SW-13D ID 156278 mentioned above (**Figure 10**). This well has reported low chloride concentrations in the 20 to 40 mg/L range for years until December 2023 when the chloride concentrations began to slowly increase, exceeding the 250 mg/L threshold on April 30, 2024, with a chloride concentration of 282 mg/L and a May 31, 2024 chloride concentration of 262 mg/L (**Figure 10**). SW-13D ID 156278 is reported to be 35 ft shallower than Well-R4 ID 280521 and may be starting to detect the relatively shallower leading edge of the saltwater interface.

The remaining wells inland from Well-R4 ID 280521 have been reporting low chloride concentrations for their entire history and appear fairly stable, except for SW-3DR ID 156038 (Map ID 178 in **Figure 8**), located about 180 ft west-southwest of Well-R4 ID 280521. At SW-3DR ID 156038, chloride concentrations have exceeded the 250 mg/L limit between August 2012 and February 2021 and again between April 2021 and June 2022 (**Figure 11**). Since October 2022, the chloride concentrations at SW-3DR ID 156038 have remained below 250 mg/L with a dry season chloride concentration of 123 mg/L reported in May 2024.

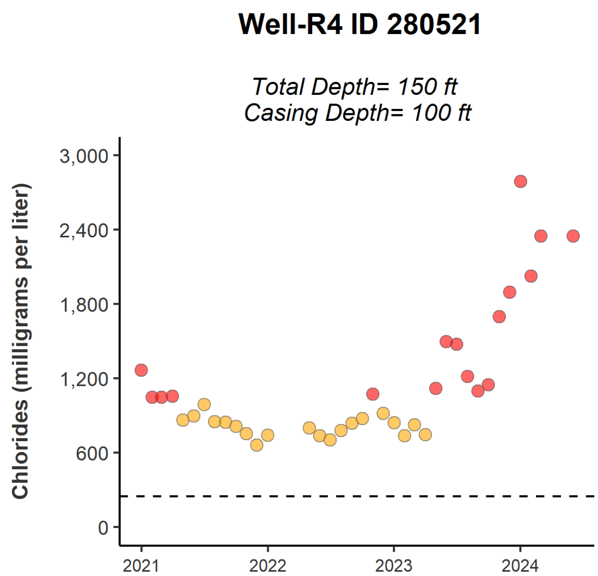

Figure 9. Chloride time-series plot for Well-R4 ID 280521 at the South Martin Regional Utility–South PS wellfield in Martin County showing increasing chloride concentration trend. The May 2024 chloride concentration was 2,350 mg/L.

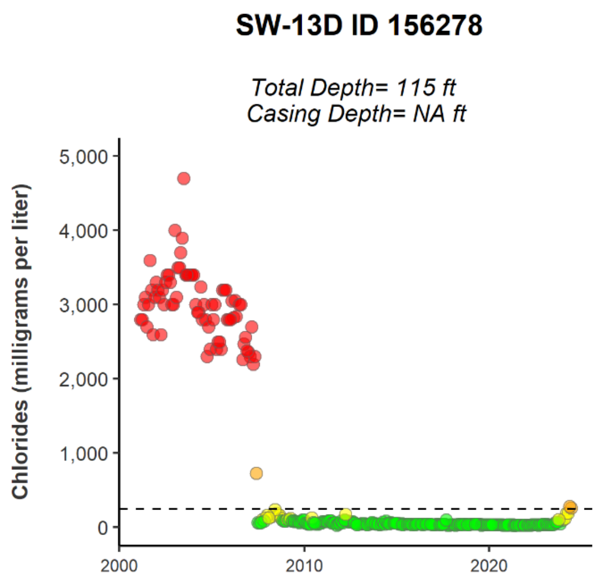

Figure 10. Chloride time-series plot for SW-13D ID 156278 at the South Martin Regional Utility–South PS wellfield in Martin County. The May 2024 chloride concentration was 262 mg/L.

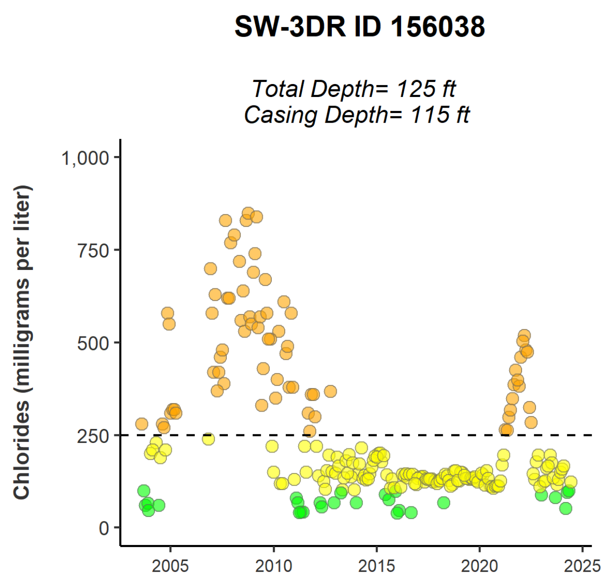

Figure 11. Chloride time-series plot for SW-3DR ID 156038 at the South Martin Regional Utility–South PS wellfield in Martin County. The May 2024 chloride concentration was 123 mg/L.

5.2 Palm Beach County – Surficial Aquifer System

Chloride concentration data from 306 SAS groundwater samples and two surface water samples were used to draw the 2024 saltwater interface in Palm Beach County. Due to the clustering of monitor wells in certain areas, the Palm Beach County map has insets to enlarge the scale for closer examination of the saltwater interface location.

New groundwater chloride concentrations were obtained from three monitor wells in Jonathan's Landing Golf Club (**Figure 12**). The three wells in Jonathan's Landing Golf Club appear to be replacement monitor wells for historical wells with long periods of record that are in approximately the same locations as the three wells shown in **Figure 12**. The 2024 chloride concentrations for these wells were 1,005 mg/L (JLOW-08R, Map ID 30), 340 mg/L (JLOW-04R, Map ID 38), and 336 mg/L (JLOW-5R, Map ID 43), from north to south, respectively.

The time-series chloride concentration plots for all three original monitor wells show increasing chloride concentration trends prior to being replaced by new monitor wells. For example, JLOW-08 ID 137201 (**Figure 13**) contained low groundwater chloride concentrations ranging from approximately 20 to 70 mg/L between 2001 and 2021. Then, starting in December 2021, chloride concentrations at JLOW-08 ID 137201 increased to 660 mg/L and varied between 264 mg/L and 819 mg/L until the well was replaced by JLOW-08R ID 262694. JLOW-08R ID 262694 has a total of three chloride concentrations reported for samples collected in November 2023 (900 mg/L), January 2024 (551 mg/L), and April 2024 (1,005 mg/L). JLOW-08 ID 137201 and JLOW-08R ID 262694 have identical total depths, but the well screen intervals are not known. These data indicate that saltwater intrusion continues at this location (**Figure 14**).

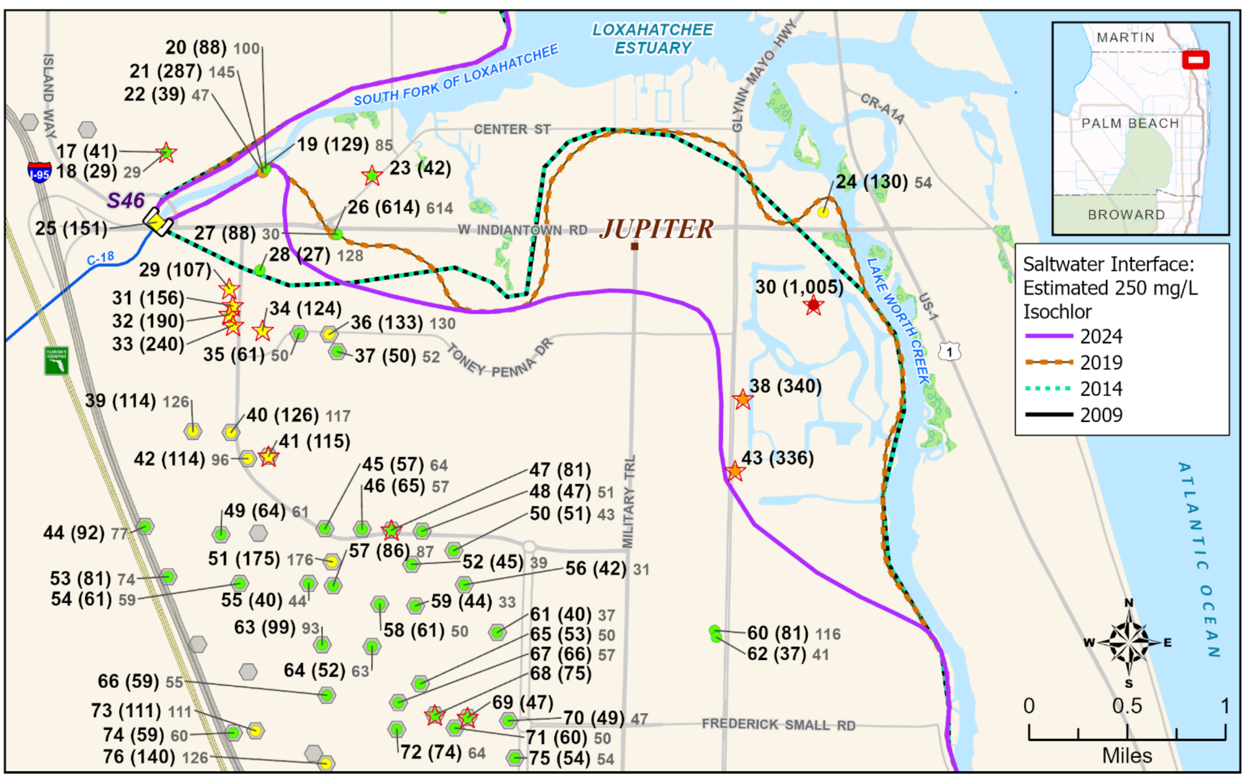

Figure 12. Position of the 2024 saltwater interface in the SAS near Jonathan's Landing Golf Club in the Town of Jupiter in Palm Beach County. Map IDs 30, 38, and 43 are the monitor wells at the golf club.

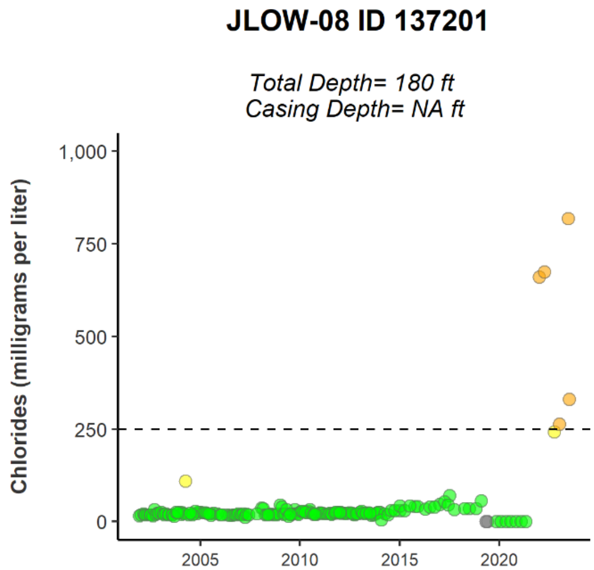

Figure 13. Chloride time-series plot for JLOW-08 ID 137201 at Jonathan's Landing Golf Club in the Town of Jupiter in Palm Beach County.

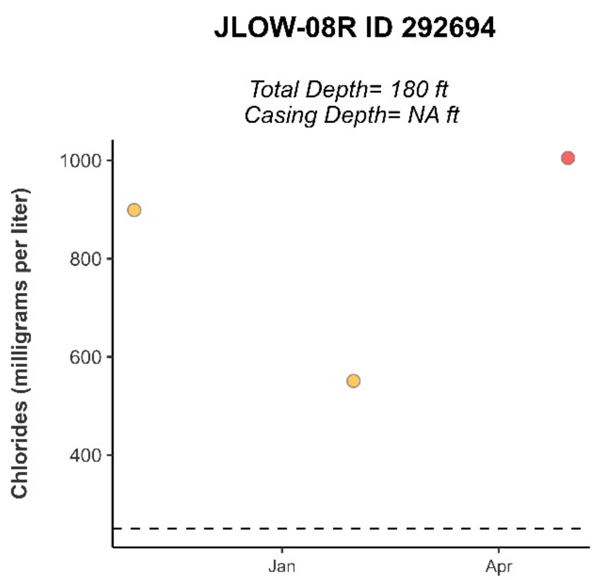

Figure 14. Chloride time-series plot for JLOW-08R ID 262694 at Jonathan's Landing Golf Club in the Town of Jupiter in Palm Beach County. Date range shown is 2023 to 2024.

Moving southwest in Jonathan's Landing Golf Club, the next well with 2024 chloride concentration data is JLOW-04R ID 27067 (Map ID 38 in **Figure 12**). Once chloride monitoring began at replacement well JLOW-04R ID 27067, chloride concentrations were 342, 341, and 340 mg/L in October 2023, January 2024, and April 30, 2024, respectively (**Figure 15**), indicating that elevated chloride concentrations are present about 640 ft southwest and inland of JLOW-9 ID 137202. JLOW-04R ID 27067 is a replacement of Well 4 (South Gate Well); however, Well 4 (South Gate Well) does not have any chloride data associated with it. JLOW-09 ID 137202 is the closest well to JLOW-04R ID 2706 that has groundwater chloride concentration data. The well screen interval for JLOW-04R ID 2706 is 60 to 120 ft bls. JLOW-9 ID 137202 has a well depth of 180 ft and an unknown screen interval. Chloride concentration data for JLOW-9 ID 137202 extends back to 1985 (**Figure 16**), when chloride concentrations were generally less than 100 mg/L until they increased dramatically and exceeded 250 mg/L in 2003 and 2005. After 2005, chloride concentrations decreased at JLOW-9 ID 137202 to less than 150 mg/L until October 2019 when concentrations began to increase, approaching 250 mg/L. Numerous Town of Jupiter Water Utilities PS wells are located as close as 1.5 miles to the southwest of Jonathan's Landing Golf Club and completed at similar depths as the Jonathan's Landing Golf Club wells yet are still reporting fresh groundwater in 2024 with chloride concentrations generally in the 40 to 75 mg/L range. Ongoing monitoring is warranted in the Jonathan's Landing Golf Club wells and surrounding areas.

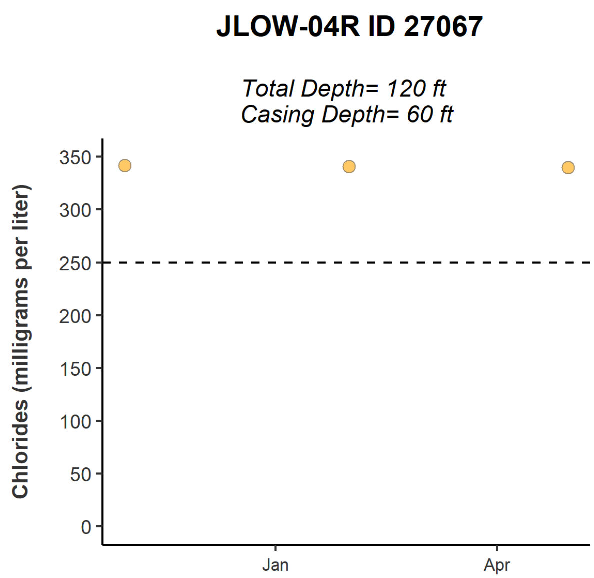

Figure 15. Chloride time-series plot for JLOW-04R ID 27067 at Jonathan's Landing Golf Club in the Town of Jupiter in Palm Beach County during October 2023, January 2024, and April 2024.

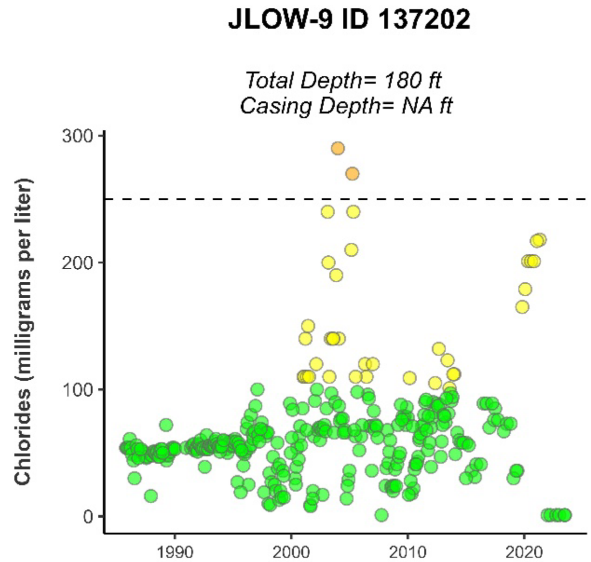

Figure 16. Chloride time-series plot for JLOW-09 ID 137202 at Jonathan's Landing Golf Club in the Town of Jupiter in Palm Beach County.

Jonathan's Landing Golf Club is designated as a reclaimed water user, but this does not appear to be improving the chloride concentrations in its monitor wells. The Town of Jupiter Water Utilities PS wells to the west are completed at similar depths as the wells at the golf course, but are all reporting chloride concentrations below 250 mg/L. The golf course is bordered on the east by the Intracoastal Waterway, which could be a source of lateral intrusion of saltwater into the aquifer.

South of Jonathan's Landing Golf Club, the saltwater interface moved inland beneath the Good Samaritan Medical Center in the City of West Palm Beach between 2019 and 2024 (**Figure 17**). The chloride concentrations at two of the three monitor wells in this area have increased since 2019, increasing from 9,510 mg/L in 2019 to 11,000 mg/L in 2024 at the well closest to the Intracoastal Waterway (PBV ID 155268 [Map ID 106]). The saltwater interface likely extends beneath the two monitoring wells to the west of PBV ID 155268 due to the differences in total well depths and the depths of the open intervals in these three monitor wells as well as the elevated chloride concentration at PBV ID 155268 (**Figure 17**). PBV ID 155268 is open from 192 to 212 ft bls, whereas the two wells with lower concentrations to the west have significantly shallower open intervals of 45 to 65 ft bls at the northern well (PB3 ID 17073 [Map ID 105], chloride concentration of 62 mg/L), and 60 to 80 ft bls at the southern well (PB2R ID 45047 [Map ID 107], chloride concentration of 37 mg/L).

The chloride time-series plot for the shallow monitor well east of the leading edge of the 2024 saltwater interface (PB2R ID 45047) has been stable for its entire history since October 2013 with chloride concentrations ranging between 29 and 37 mg/L (**Figure 18**) as compared to the other shallow well to the northeast (PB-3 ID 17073) whose chloride time-series plot shows higher chloride concentrations and more variation in chloride concentrations. Chloride concentrations at PB-3 ID 17073 (**Figure 19**) started to increase in January 2013 and peaked in October 2017 at a concentration of 153 mg/L before declining to 62 mg/L, which is higher than all the concentrations reported between 1981 and 2002. PB-3 ID 17073 may be starting to intercept and detect the shallow, diffuse, leading edge of the saltwater interface and should continue to be monitored along with the other two wells at this site. Unfortunately, no other monitor wells exist in the vicinity of the Good Samaritan Medical Center that could help refine the location of the saltwater interface. Installation of additional monitor wells in the area would help better constrain the lateral extent of saltwater intrusion in this area.

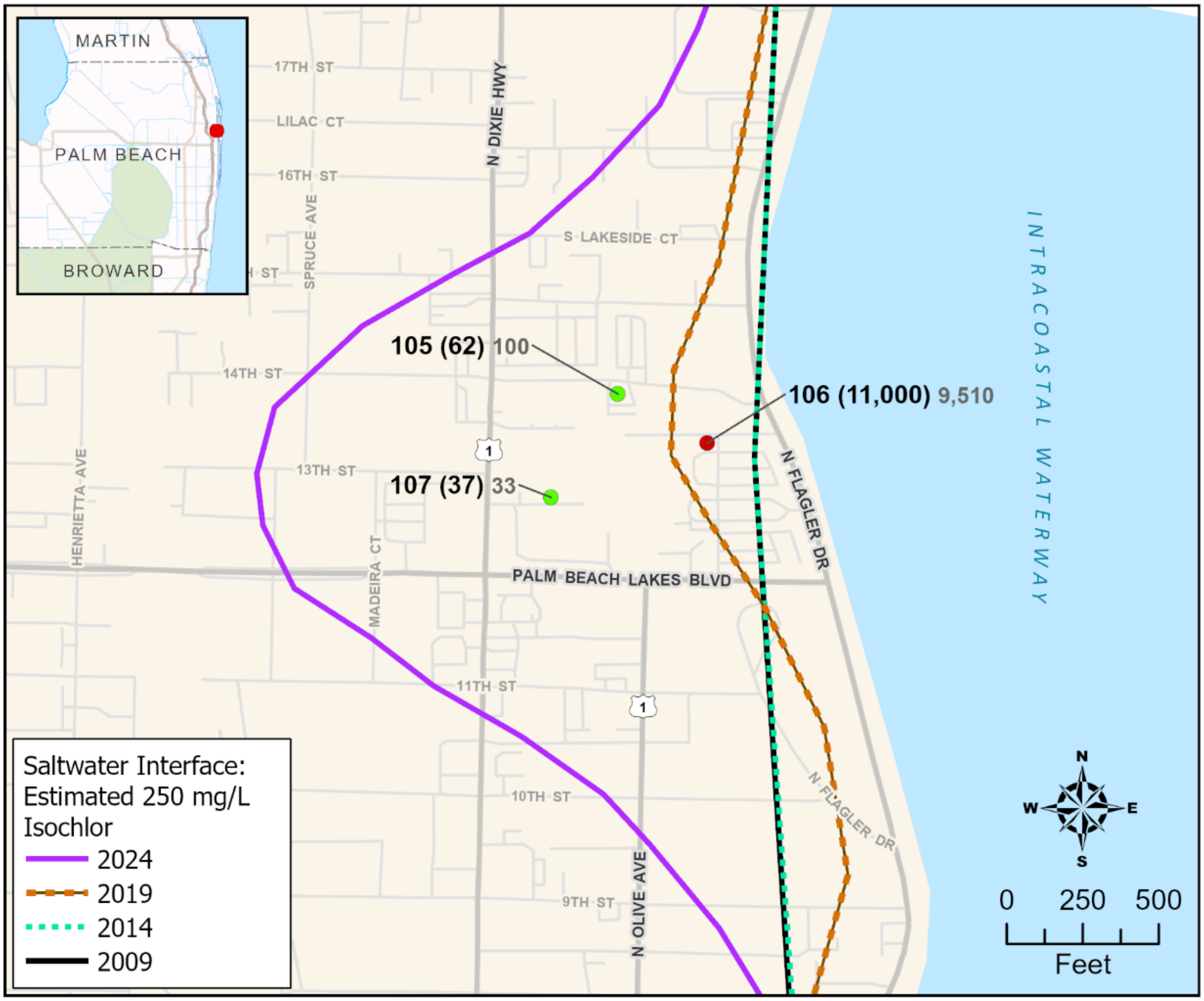

Figure 17. Position of the 2024 saltwater interface in the SAS beneath the Good Samaritan Medical Center in the City of West Palm Beach in Palm Beach County.

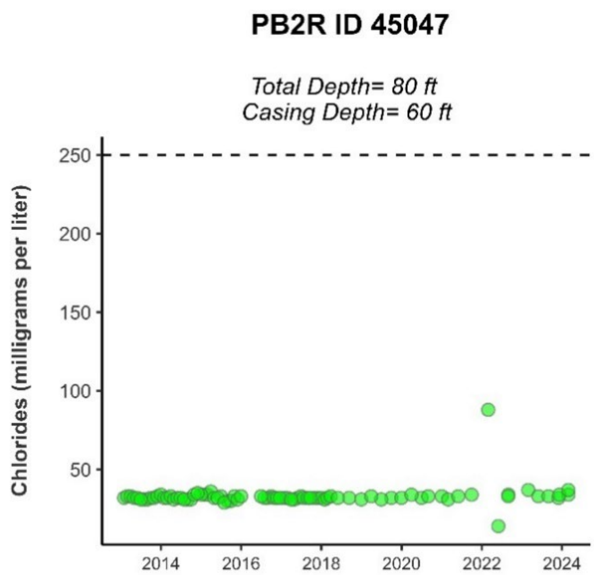

Figure 18. Chloride time-series plot for shallow monitor well PB2R ID 45047 near Good Samaritan Medical Center, inland of the 2024 saltwater interface.

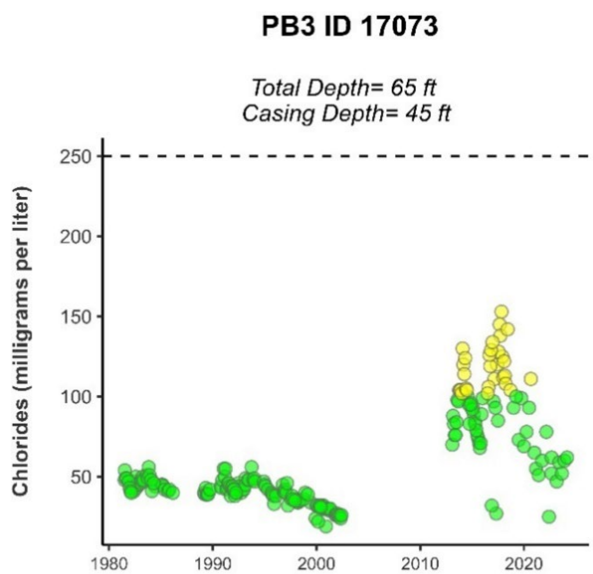

Figure 19. Chloride time-series plot for shallow monitor well PB3 ID 17073 near Good Samaritan Medical Center, close to the northeastern edge of the 2024 saltwater interface.

No notable changes were made to the saltwater interface between the Good Samaritan Medical Center and the City of Lake Worth Beach, primarily due to the lack of monitor wells along the coastline in this area. Near the City of Lake Worth Beach Utilities PS wellfield, inland movement of the saltwater interface was mapped southwest of LWMW-9 ID 192495 (Map ID 127), where chloride concentrations increased from 1,880 mg/L to 2,000 mg/L between 2019 and 2024 (**Figure 20**). The total depth of LWMW-9 ID 192495 is 328 ft bls, with no open interval information. The monitor wells to the southwest of the 2024 isochlor have 2024 chloride concentrations in the 17 to 31 mg/L range and have slightly shallower total depths and open intervals. To the south in **Figure 20**, the saltwater interface moved slightly seaward due to decreasing chloride concentrations in most of the wells on either side of the 2019 isochlor.

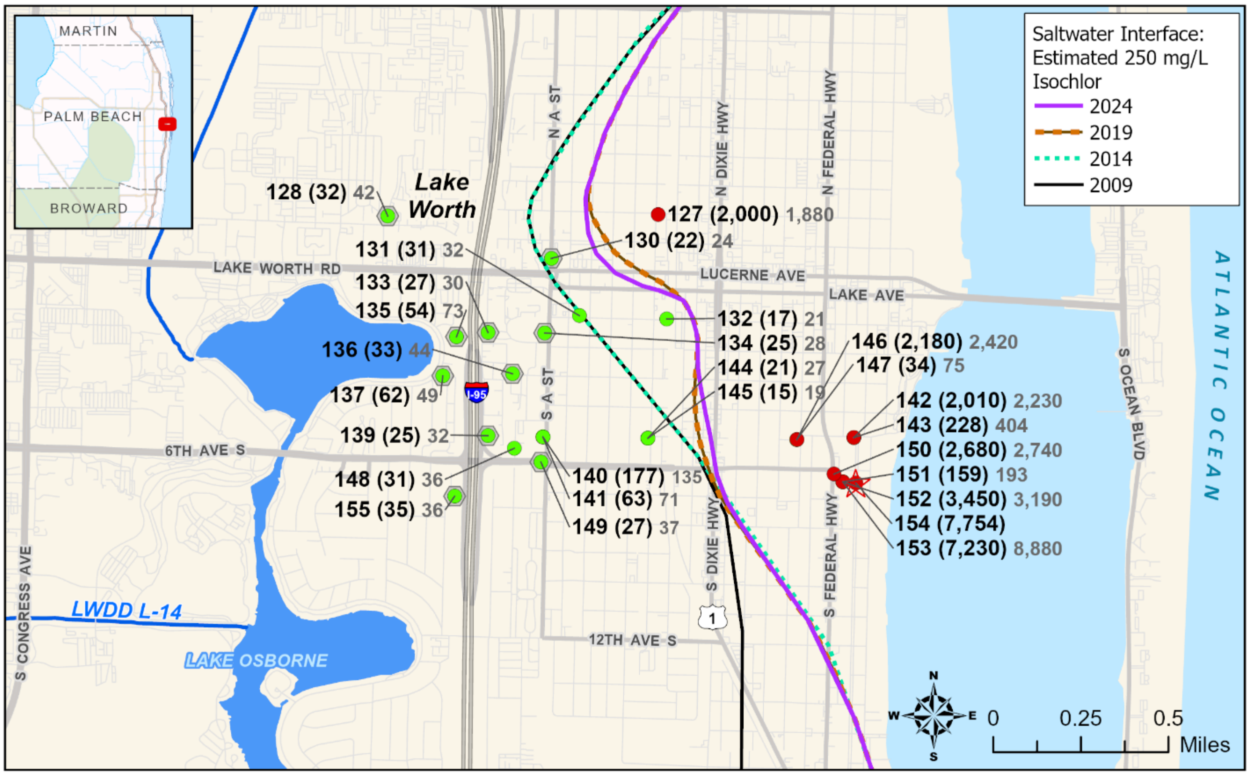

Figure 20. Position of the 2024 saltwater interface in the SAS near the City of Lake Worth Beach Utilities PS wellfield in Palm Beach County.

The leading edge of the 2024 interface extends beneath the Town of Lantana PS wellfield (**Figure 21)** but does not extend as far inland as it did in 2009. LT4-C ID 137788 (Map ID 174) is adjacent to Dixie Highway/U.S. Route 1. At this well, chloride concentrations increased from 1,715 mg/L in 2019 to 2,160 mg/L in 2024 (**Figure 21**). This well has an open interval extending from 150 to 160 ft bls. The chloride time-series plot for LT4-C ID 137788 (**Figure 22**) shows that chloride concentrations began increasing in the early 1990s, when chloride concentrations were just above 250 mg/L, until the chloride concentrations reached their maximum concentrations around 2009. Since 2009, the chloride concentrations in this well have declined and varied between approximately 1,100 and 2,800 mg/L.

Wells located between the 2019 and 2024 interface positions (**Figure 21**) are Town of Lantana PS wells that have total depths ranging from 75 to 108 ft deep, whereas the wells to the west of the 2024 interface are deeper PS wells in the towns of Lantana and Manalapan. Two of those wells have open intervals from 171 to 206 ft bls (2 ID 26028 [Map ID 177] and MN03 ID 137755 [Map ID 176]), and the third well has an open interval from 55 to 75 ft bls (MN12 ID 137759 [Map ID 179]). The chloride time-series plot for MN03 ID 137755 (**Figure 23**) shows that chloride concentrations in this well have clustered in the 30 to 60 mg/L range between 1985 and 2010, with an overall increasing trend in the maximum reported chloride concentrations visible until 2012, when the maximum chloride concentration was reported for this well (90 mg/L in August 2012). Since 2012, the trend of the maximum chloride concentrations has declined, reaching a minimum of 11 mg/L in February 2022. Since that time, the chloride concentrations have been increasing, reaching 49 mg/L in March 2024 and 44 mg/L in May 2024.

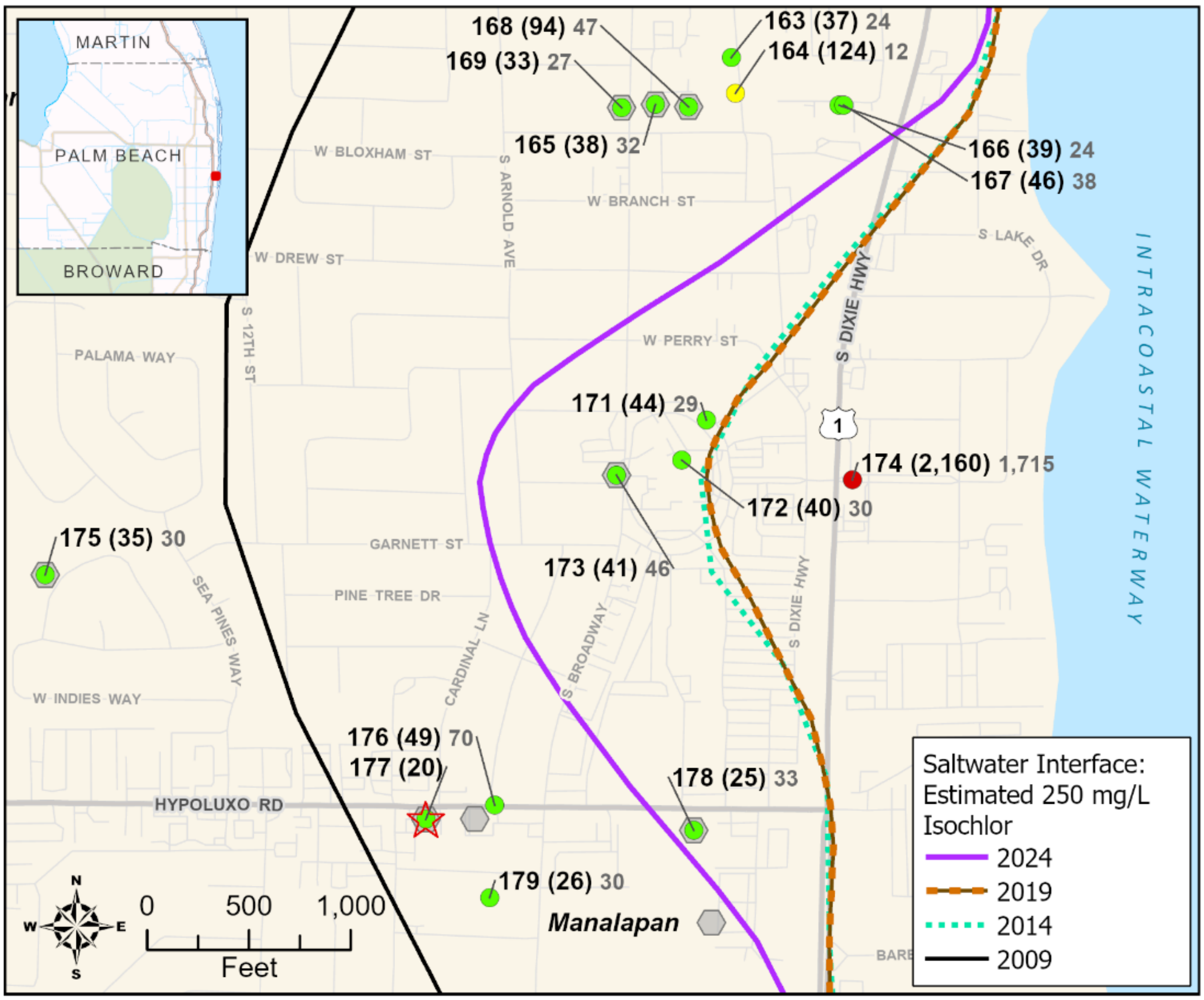

Figure 21. Position of the 2024 saltwater interface in the SAS near the Town of Lantana PS wellfield in Palm Beach County.

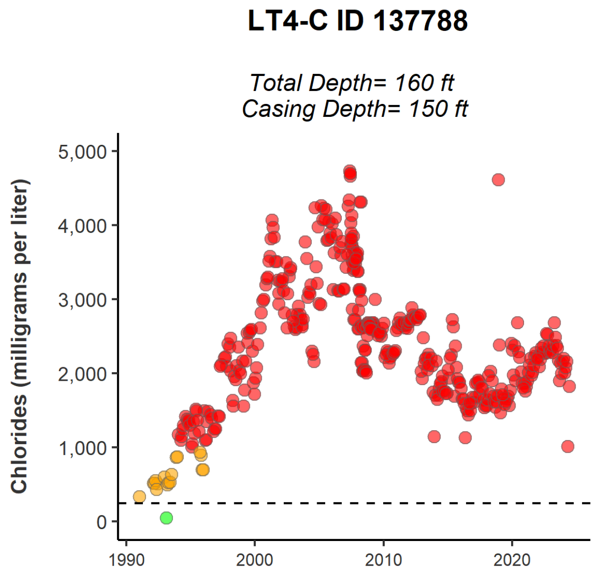

Figure 22. Chloride time-series plot for LT4-C ID 137788 in the Town of Lantana in Palm Beach County.

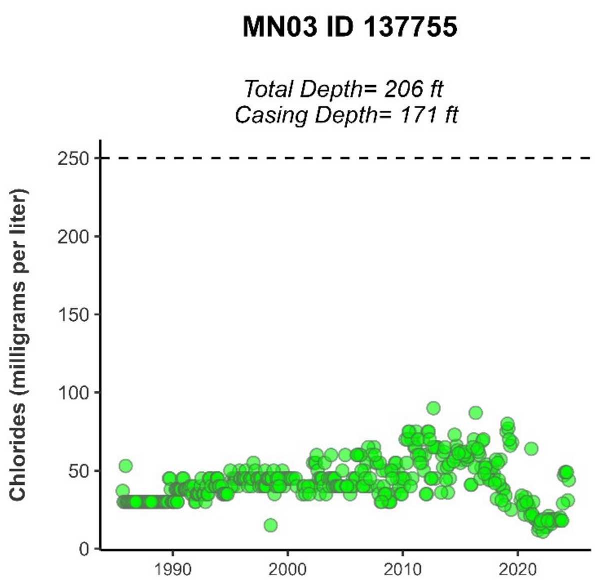

Figure 23. Chloride time-series plot for MN03 ID 137788 in the Town of Manalapan in Palm Beach County.

The leading edge of the 2024 saltwater interface beneath the City of Boynton Beach PS wellfield in **Figure 24** is defined by the 350-ft-deep BYHP1 ID 152794 (Map ID 202) which had a 2024 dry season chloride concentration of 1,520 mg/L. The PS wells in this area range in depth from 54 to 273 ft bls, with the deeper wells being located primarily west of Interstate 95. BYHP1 ID 152794 has an open interval extending from 340 to 350 ft bls. The chloride time-series plot for BYHP1 ID 152794 shows that since monitoring began in August 2003, chloride concentrations have exceeded 250 mg/L, with two decreases in concentrations recorded in 2006 and 2010 when chloride concentrations declined to concentrations close to 250 mg/L (**Figure 25**). Since 2010, however, the overall trend of chloride concentrations at BYHP1

ID 152794 has been gradually increasing, possibly indicating slow migration of the saltwater interface through this well. The production wells west of BYHP1 ID 152794 are about 117 to 150 ft shallower and reported 2024 dry season chloride concentrations in the 34 to 46 mg/L range.

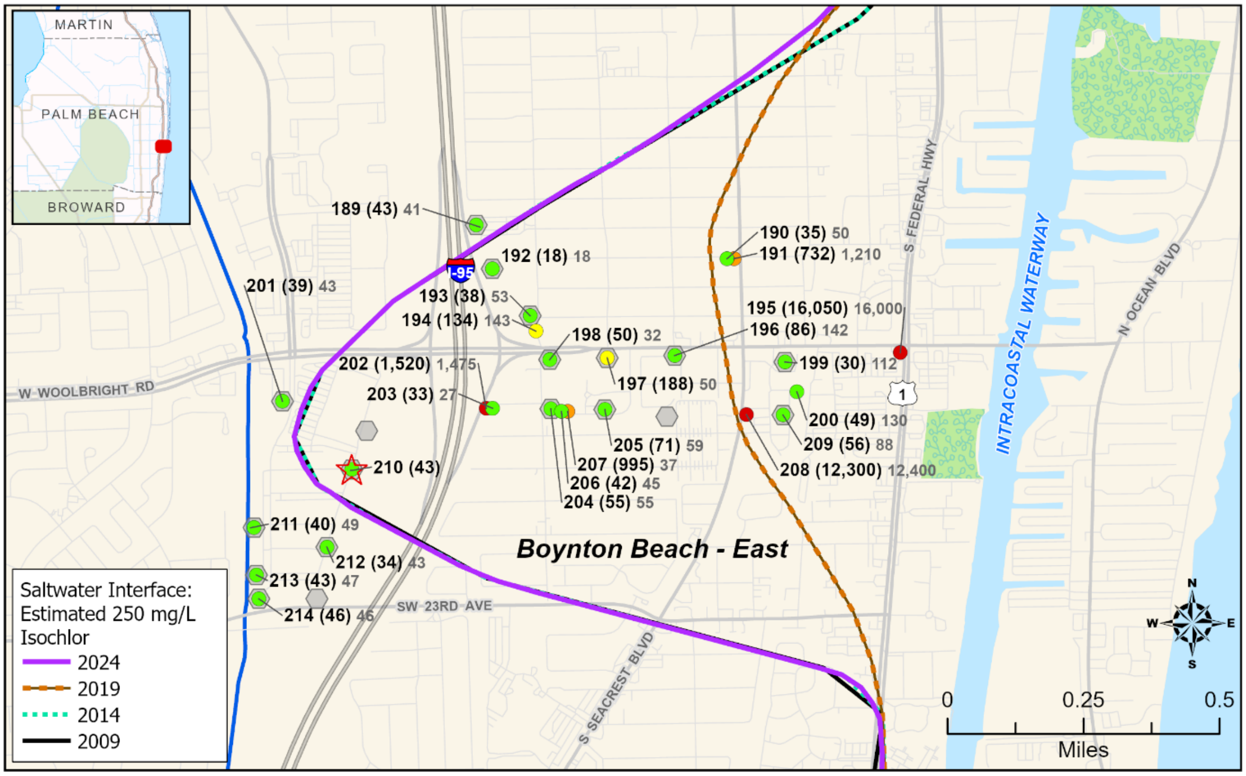

Figure 24. Position of the 2024 saltwater interface in the SAS near the City of Boynton Beach PS wellfield in Palm Beach County.

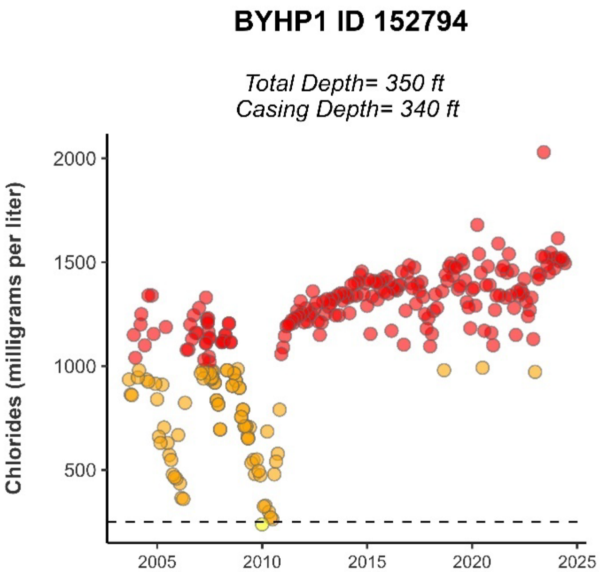

Figure 25. Chloride time-series plot for BYHP1 ID 152794 in the City of Boynton Beach in Palm Beach County.

Monitor well BYHP2 ID 152793 (Map ID 203), with a total depth of 280 ft bls (60 ft shallower than BYHP1 ID 152794), was installed north of and adjacent to BYHP1 ID 152794, apparently at the same time, and has recorded chloride concentrations below 40 mg/L since the start of monitoring in August 2003 (**Figure 26**). The 60 ft difference in total depths of these two wells and the significant difference in chloride concentrations between these two wells indicate that the leading edge/toe of the saltwater interface is thin near these two wells and has entered the open interval of the deeper well (BYHP1 ID 152794) but has not progressed far enough inland for the thicker portion of the saltwater wedge with higher chloride concentrations to be detected in the shallower well (BYHP2 ID 152793). The wells to the west of Interstate 95 all have had chloride concentrations below 60 mg/L since monitoring began in the 1980s; however, these wells are over 100 ft shallower than BYHP1 ID 152794, with total depths around 200 ft bls, and are not detecting the saltwater interface at these shallower depths.

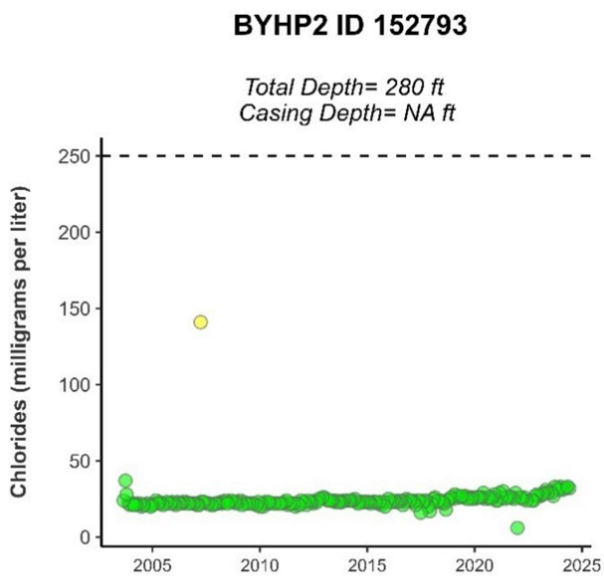

Figure 26. Chloride time-series plot for BYHP2 ID 152793 in the City of Boynton Beach in Palm Beach County.

Figure 27 shows that the 2024 interface has apparently moved inland beneath the easternmost City of Delray Beach PS wellfield. The 12 City of Delray Beach PS wells located adjacent to the 2024 interface are completed to depths ranging from 76 to 115 ft bls. The three wells to the west of the 2024 isochlor with elevated chloride concentrations are completed deeper in the aquifer than the shallow PS wells with low chloride concentrations. PB690D ID 136672 (**Figure 28**, Map ID 232), with an open interval from 182 to 185 ft bls, reported an increase in chloride concentrations from 7,650 mg/L in 2019 to 9,720 mg/L in 2024. To the north, two wells have high chloride concentrations combined with large increases in chloride concentrations since 2019. In PB692D ID 136666 (**Figure 29**, Map ID 219), which is reportedly screened from 182 to 185 ft bls, the chloride concentrations increased from 3,588 mg/L in 2019 to 14,400 mg/L in 2024, and in PB-1707 (**Figure 30**, Map ID 222), the chloride concentrations increased from 3,320 mg/L in 2019 to 14,134 mg/L in 2024. PB-1707 has a reported screen interval of 182.4 to 183 ft bls. Review of a recent video log of this well indicates that an unknown length of the well screen (consisting of round holes in the PVC casing) has filled with debris, leaving only about 6 inches of well screen exposed above the fill. No information is available about the construction of this USGS well. Because of the large increases in chloride concentrations between 2019 and 2024 at these three wells completed with short well screens at similar depths, and because these wells are significantly deeper than the PS wells to the west, the 2024 interface was moved inland from its 2019 position. Additional deeper monitor wells would be needed in this area and inland to more accurately locate the presence of saltwater along or close to the base of the aquifer. All three of these wells with elevated chloride concentrations show the same trends on the chloride time-series plots (**Figures 28, 29,** and **30**). Additionally, all three of these wells have contained saltwater for most of their periods of record, and all three show a similar trend of decreasing chloride concentrations until approximately 2019, followed by a steady increase in chloride concentrations until 2024.

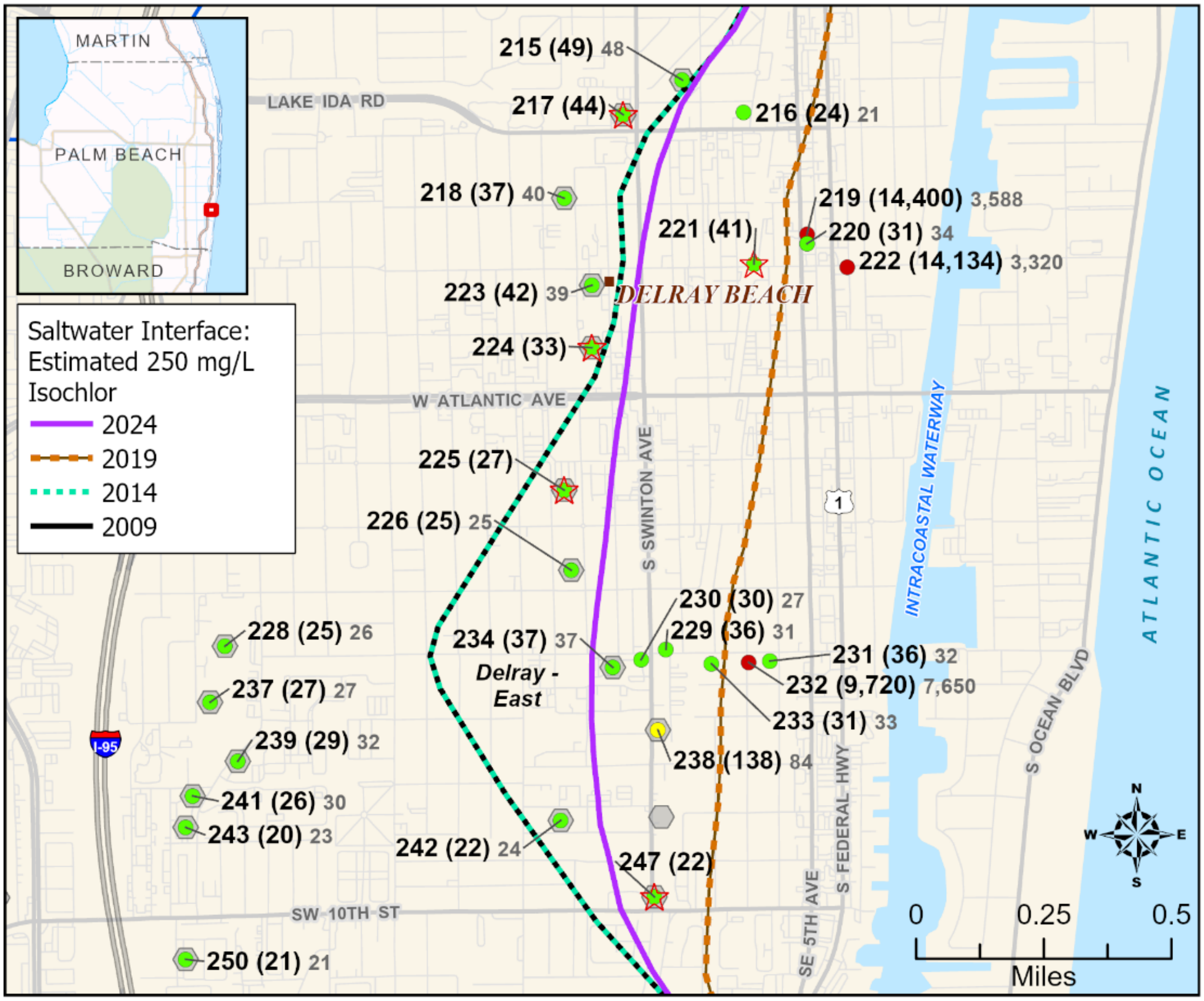

Figure 27. Position of the 2024 saltwater interface in the SAS near the City of Delray Beach Utilities PS wellfield in Palm Beach County.

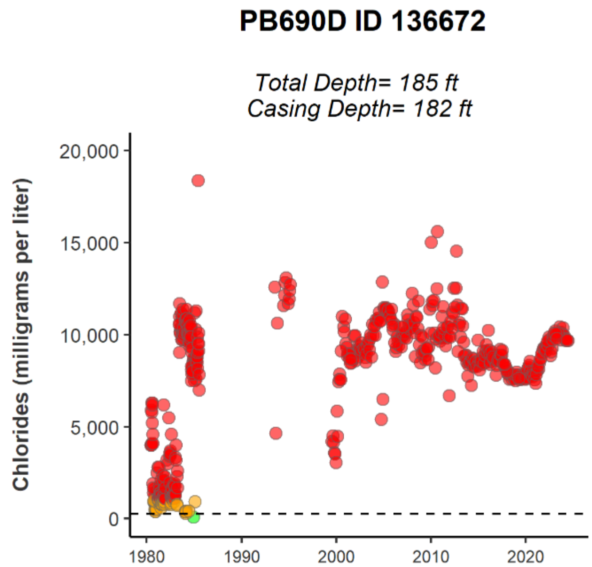

Figure 28. Chloride time-series plot for PB690D ID 136672 in the City of Delray Beach in Palm Beach County.

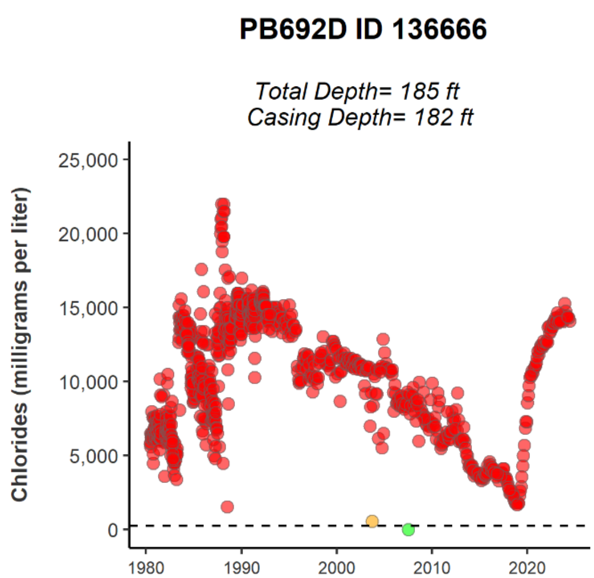

Figure 29. Chloride time-series plot for PB692D ID 136666 in the City of Delray Beach in Palm Beach County.

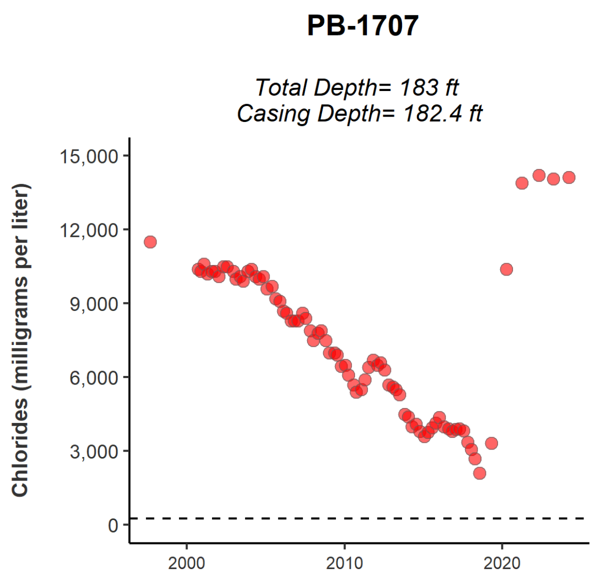

Figure 30. Chloride time-series plot for PB-1707 in the City of Delray Beach in Palm Beach County.

5.3 Broward County – Surficial Aquifer System

Chloride concentration data from 122 SAS groundwater samples and two surface water samples were used to draw the 2024 saltwater interface in Broward County. **Figure 31** shows that the saltwater interface has retreated approximately 1 mile seaward in the City of Pompano Beach since 2019 due to decreasing chloride concentrations at SWI9-S ID 136333 (130 ft deep, Map ID 46) and SWI9-D ID 136332 (140 ft deep, Map ID 45). **Figure 32** is a chloride time-series plot for SWI9-D ID 136332 showing that chloride concentrations in this well have fluctuated throughout its entire history but have predominantly been significantly greater than 250 mg/L. The last sample analyzed from this well in September 2020 had a chloride concentration of 318 mg/L. The next sample from this well was collected in October 2020, and the chloride concentration decreased to 219 mg/L. Since then, the overall trend of chloride concentrations at this well has been one of decreasing concentrations with a few small increases in chloride concentration. **Figure 33** is a plot of fluid specific conductance profiles that were logged in SWI9-D ID 136332 since 2017. Each line represents the average fluid specific conductance profile collected during the dry season of that year. There is a progressive reduction in the fluid specific conductance profiles each year, in agreement with the chloride time-series plot for the well, and the trend in this area of groundwater freshening and saltwater interface retreat. The fluid specific conductance profiles for the other City of Pompano Beach wells are presented in **Appendix A**.

Figure 31 also shows the location of newly installed saltwater intrusion monitoring well BS-3 (Map ID 43) located on the western bank of the G-16 Canal near the West Atlantic Boulevard southbound on-ramp to Interstate 95. This well was installed in February 2023 by the District to fill a spatial data gap where inland migration of the saltwater interface could be detected before it reaches the City of Pompano Beach PS wellfield to the west. This well was installed with a 10-ft-long screen at the base of the SAS with a 10-ft-long sump extending into the underlying Hawthorn Group sediments to allow for future dual induction geophysical logging of the entire aquifer and detection of the encroaching saltwater interface along the base of the SAS. A groundwater sample collected from this well in 2024 was fresh with a chloride concentration of 19 mg/L.

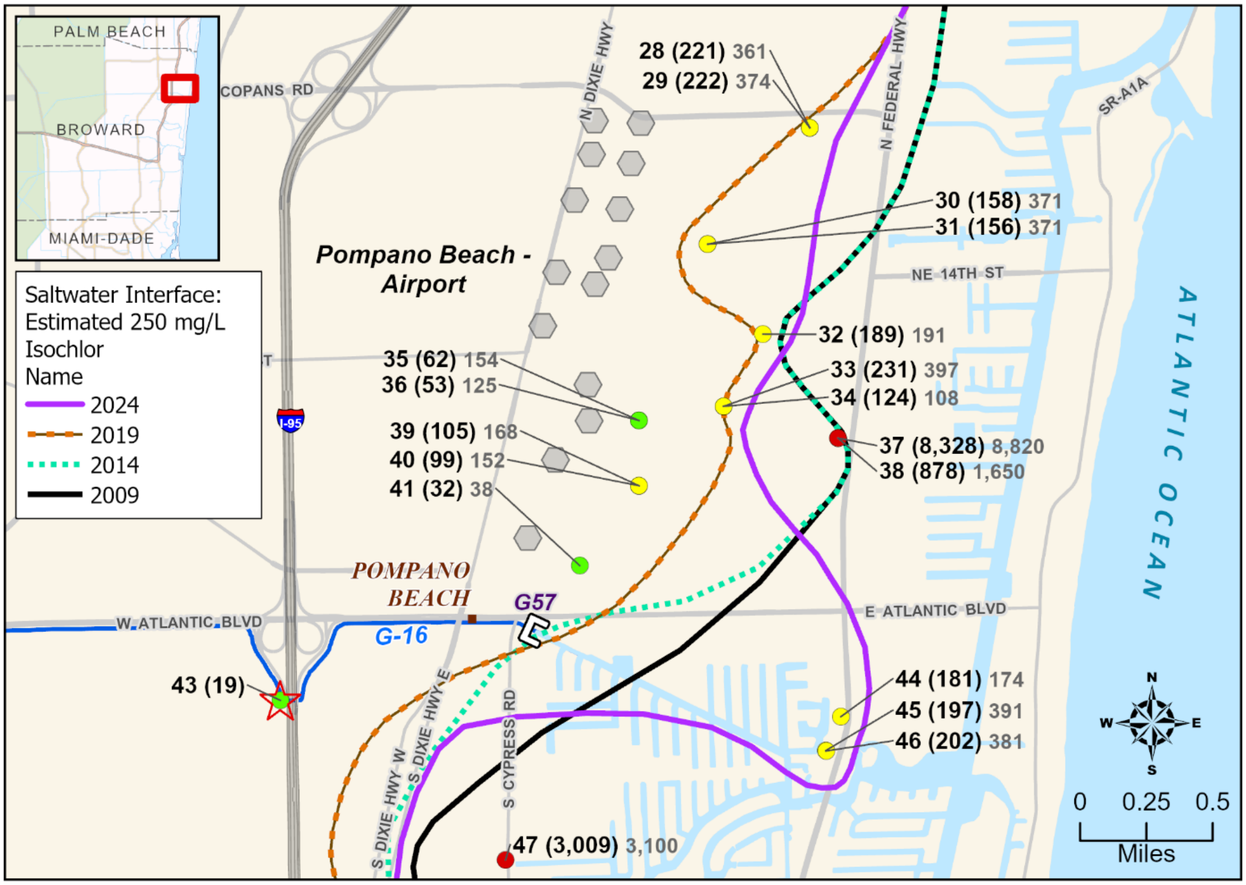

Figure 31. Position of the 2024 saltwater interface near the City of Pompano Beach Utilities Eastern PS wellfield in Broward County. Newly installed monitor well BS-3 (Map ID 43) had a 2024 chloride concentration of 19 mg/L.

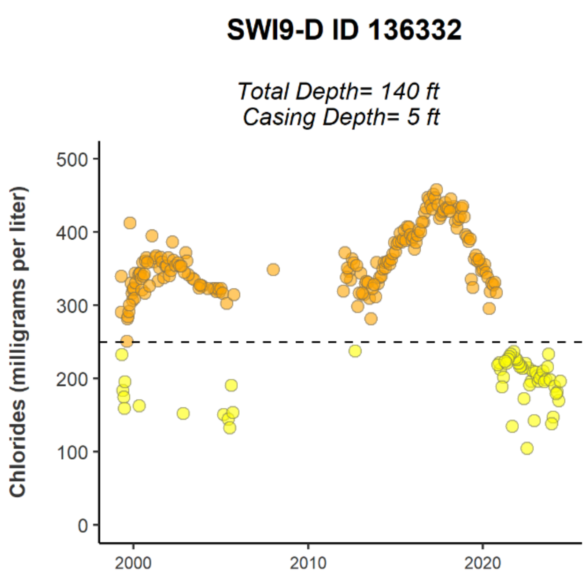

Figure 32. Chloride time-series plot for SWI9-D ID 136332, located at the southeastern edge of the 2024 interface in **Figure 31** (Map ID 45) in the City of Pompano Beach in Broward County.

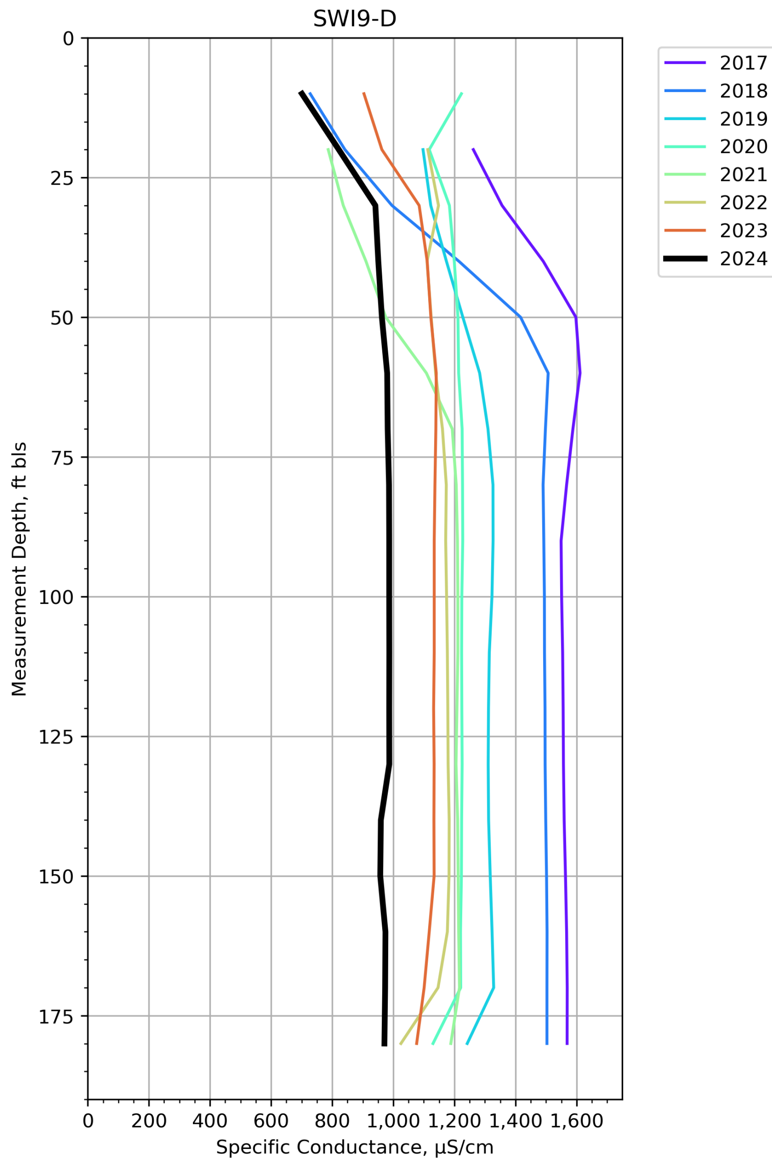

Figure 33. Fluid specific conductance versus depth plot for SWI9-D ID 136332 (Map ID 45), located at the southeastern edge of the 2024 interface in **Figure 31** in the City of Pompano Beach in Broward County.

Figure 34 shows the movement of the interface near the City of Fort Lauderdale Dixie PS wellfield since 2019. The Dixie PS wellfield production wells are Biscayne aquifer wells screened from 90 to 120 ft bls. The City of Fort Lauderdale has installed 10 saltwater intrusion monitor wells in the general vicinity of the Dixie PS wellfield (**Figure 34**). All 10 of these monitor wells have long well screens that start at a depth of 5 ft bls and extend to depths ranging from 200 to 280 ft bls. Rather than collecting groundwater samples from these wells for laboratory analyses, the City of Fort Lauderdale performs vertical, specific conductance profiling, once at the end of the wet season and once at the end of the dry season, at each of its 10 saltwater intrusion monitor wells. This is accomplished by slowly lowering a conductivity sonde down each well. The sonde measures and records specific conductance every 2 seconds as the sonde is lowered down each well. The city then summarizes these specific conductance data and reports them at 10-ft-depth intervals for each well (Alejandra Simon, personal communication, February 29, 2024). For this report, the largest specific conductance values recorded in each well (often at or near the bottom of the well) were converted to chloride concentrations using the methodology outlined in this report. Two fluid specific conductance versus depth plots for MW-10D ID 286505 (Map ID 62 in **Figure 34**) and MW-6A ID 282730 (Map ID 69 in **Figure 34**) are presented and discussed below.

Northeast of the Dixie PS wellfield, the 2024 interface has moved inland in the area between NW 19th Street to the north and Davie Boulevard to the south (**Figure 34**), primarily due to chloride concentrations increasing at G-2899 (Map ID 58). At this well, chloride concentrations increased from 1,020 mg/L in 2019 to 1,622 mg/L in 2024 (**Figure 35**). The 250 mg/L interface passed through G-2899 sometime between January 2005 and April 2005, when the chloride concentration reached 270 mg/L, and continued to increase until it reached a concentration of 1,622 mg/L in 2024 (**Figure 35**).

Closer to the Dixie PS wellfield, chloride concentrations reached 2,660 mg/L in 2024 at City of Fort Lauderdale monitor well MW-10D ID 286505 (**Figure 36**). **Figure 36** combines the chloride concentration data for wells MW-10C and MW-10D ID 28650. The data gap in **Figure 36** was caused because MW-10C was destroyed prior to 2019 and was replaced by MW-10D ID 286505 in August 2022, causing a 3-year-long gap in data. MW-10D ID 286505, the closest monitor well to the Dixie PS wellfield, is completed to a total depth of 280 ft bls and has a well screen installed from 5 to 280 ft bls. **Figure 36** shows that chloride concentrations collected between August 2005 and April 2018 ranged between 140 and 1,000 mg/L but began to increase in April 2017, exceeding 1,000 mg/L, before the original well (MW-10C) was destroyed in July of 2018. Once the replacement well MW-10D ID 286505 was installed at this location, the chloride concentrations were variable, but most of the chloride concentrations have been much higher than they were in MW-10C, with the 2024 dry season chloride concentration reaching 2,660 mg/L.

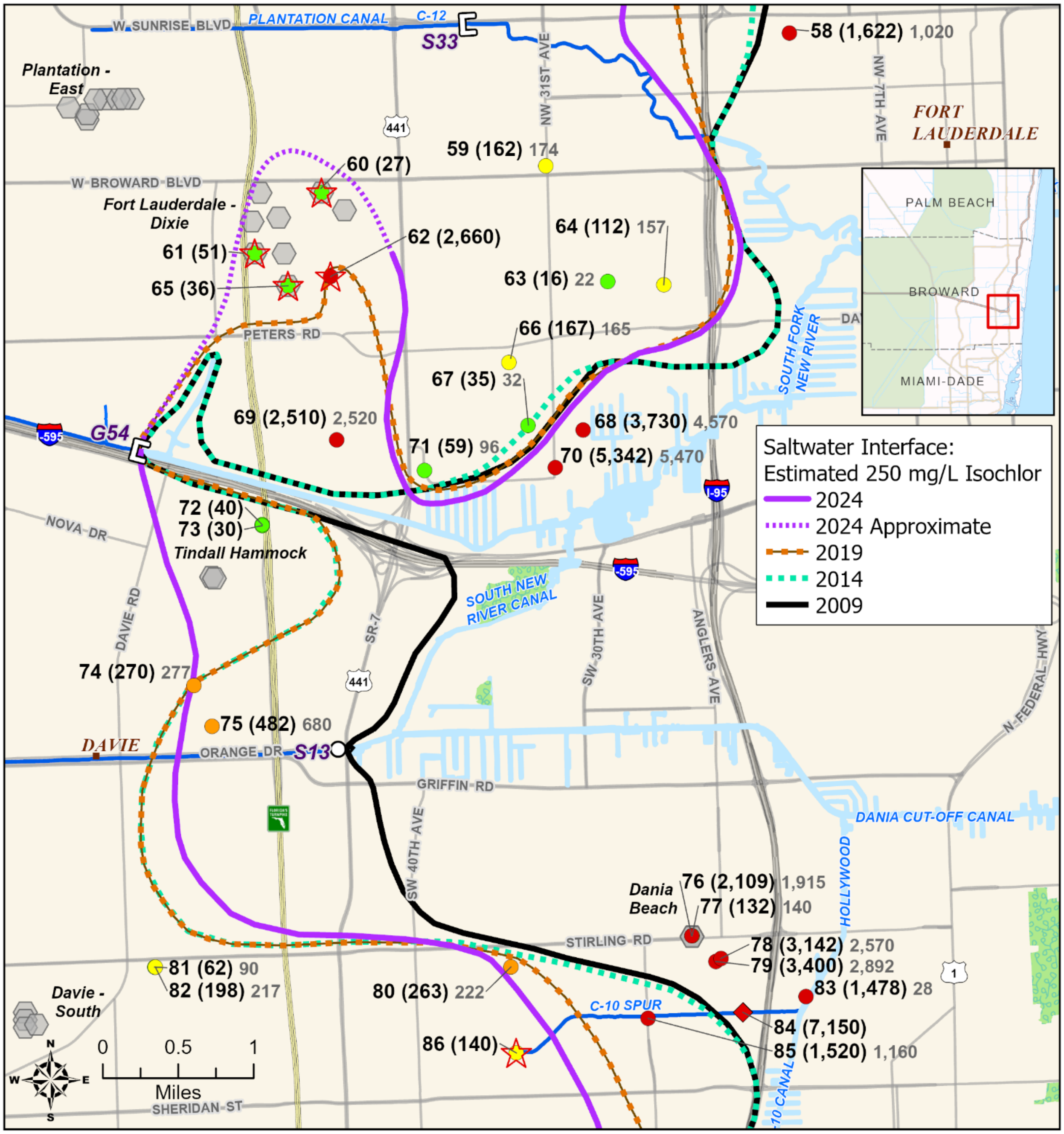

Figure 34. Position of the 2024 saltwater interface in the Biscayne Aquifer near the City of Fort Lauderdale Dixie PS wellfield in Broward County.

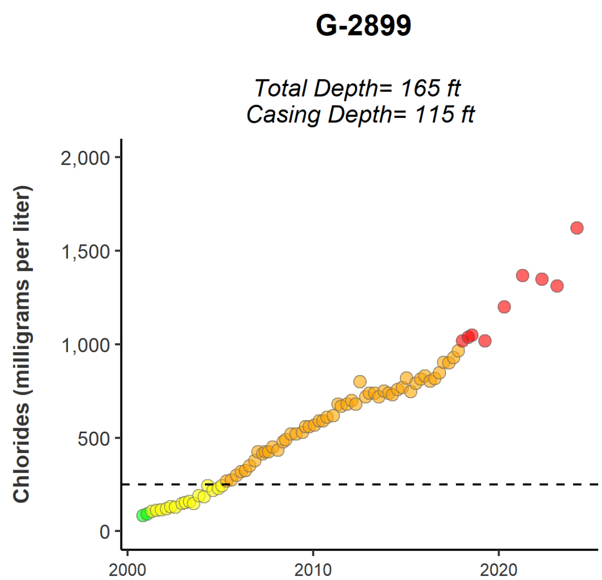

Figure 35. Chloride time-series plot for G-2899 near the Dixie PS wellfield in the City of Fort Lauderdale in Broward County.

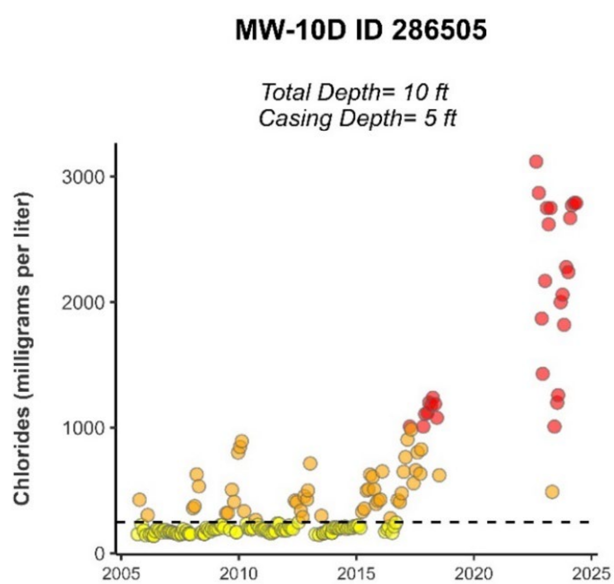

Figure 36. Chloride time-series plot for MW-10D ID 286505 and MW-10C near the Dixie PS wellfield in the City of Fort Lauderdale in Broward County.

In addition to chloride time-series plots, fluid specific conductance data collected by the City of Fort Lauderdale during each month of each dry season was averaged for each year and plotted against depth for each of the 10 City of Fort Lauderdale monitor wells (**Appendix B**). The fluid specific conductance profiles for the two monitor wells closest to the Dixie PS wellfield, MW-10D ID 286505 and MW6A ID 282730, are discussed in this report. **Figure 37** is a fluid specific conductance versus depth profile for MW-10C and MW-10D ID 286505. The thick black line is the data from May 2024. By comparing the inflections of each specific conductance profile line from each year in **Figure 37**, evidence of movement of the saltwater interface through this well can be deduced. The purple line shows that in 2005, the specific conductance began to increase at a depth of approximately 230 ft bls. In May 2023, the specific conductance also started increasing at a depth of 230 ft bls, whereas in 2024, the specific conductance increases dramatically at 200 ft bls and continues to increase with depth to concentrations far higher than in 2023 or any of the other years in **Figure 37**. These data indicate that the saltwater interface has moved through this well, is getting thicker, and is increasing in concentration with depth as the thicker portions of the saltwater wedge moves northwest along the base of the aquifer.

MW6A ID 282730 (Map ID 68 in **Figure 34**) is located southeast of MW-10D ID 286505 and the Dixie PS wellfield and is the southern-most City of Fort Lauderdale monitor well from the wellfield. The maximum chloride concentrations at this well have been greater than 250 mg/L and generally above 2,000 mg/L for the entire sampling history (**Figure 38**). The groundwater chloride concentrations increased significantly starting around 2012 at MW6A ID 282730.

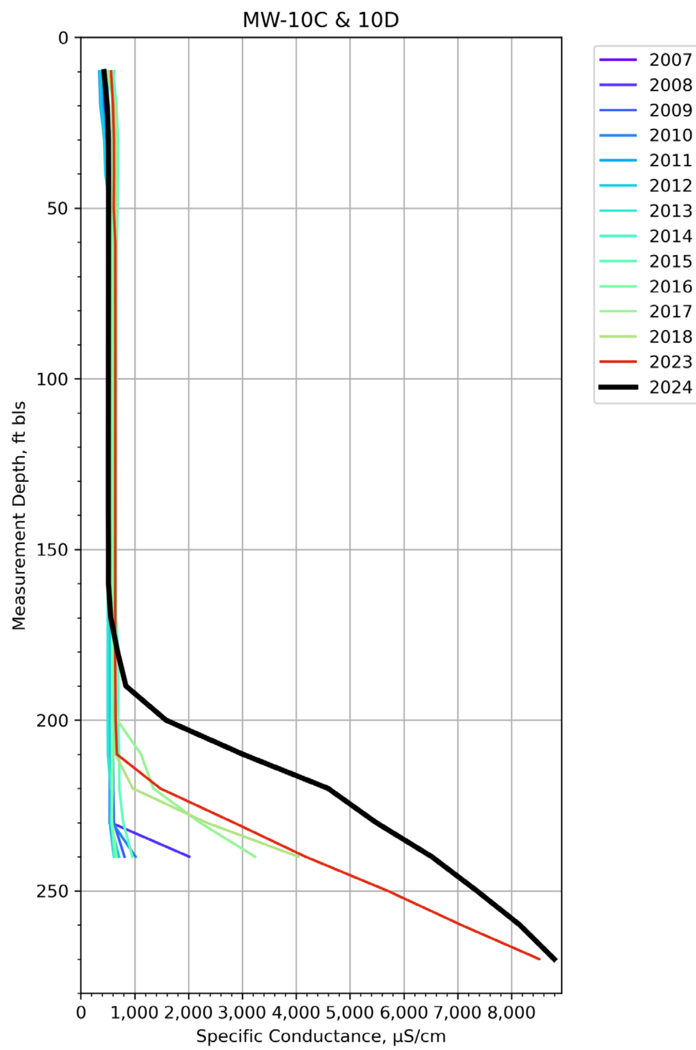

Figure 37. Fluid specific conductance plot for City of Fort Lauderdale monitor wells MW10C and MW10D ID 286505 near the Dixie PS wellfield in Broward County.

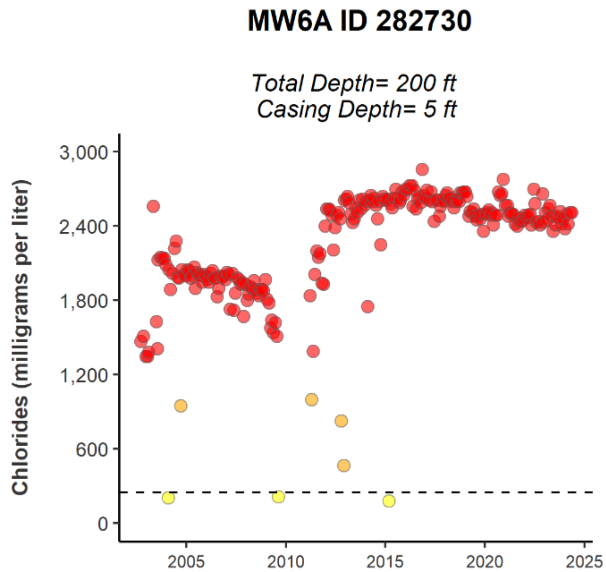

Figure 38. Chloride time-series plot for MW6A ID 282730 in the City of Fort Lauderdale in Broward County.

Like the fluid specific conductance versus depth plot for MW-10C and MW-10D ID 286505, **Figure 39** shows that the saltwater wedge is moving through and thickening at MW6A ID 282730. The purple and darker blue lines show that in between 2004 and 2009 the specific conductance values sharply increased at approximately 190 to 200 ft bls, whereas by 2024, the specific conductance values began increasing at a much shallower rate, at approximately 130 ft bls, with higher specific conductance values recorded between 150 and 200 ft bls during this same time frame than during the 2005 to 2009 time frame.

South of the Dixie PS wellfield, in the area south of Interstate 595 (**Figure 34**), the 2024 saltwater interface was adjusted inland compared to the 2019 interpretation because the two Ferncrest Water Treatment Plant wells (MW5 ID 136755 (Map ID 72) and MW6 ID 136756 [Map ID 73]) at the Tindall Hammock PS wellfield are shallow wells that are not completed at or near the base of the aquifer. Therefore, these wells are not detecting the saltwater interface that likely lies underneath them based on the other wells in the area. Well MW5 ID 136755 is open from 10 to 20 ft bls, and MW6 ID 136756 is open from 72 to 82 ft bls. Town of Davie well MW-4 (Veterans Park DW-4) ID 137073 (Map ID 74) farther to the south (**Figure 34**) helps bracket the location of the interface, as this well is completed with an open interval from 165 to 175 ft bls and has a 2024 chloride concentration of 270 mg/L.

As shown in **Figure 40**, the chloride concentrations at MW-4 (Veterans Park DW-4) ID 137073 first consistently exceeded 250 mg/L in September 2004, with most of the chloride concentrations reported since that time being greater than 250 mg/L.

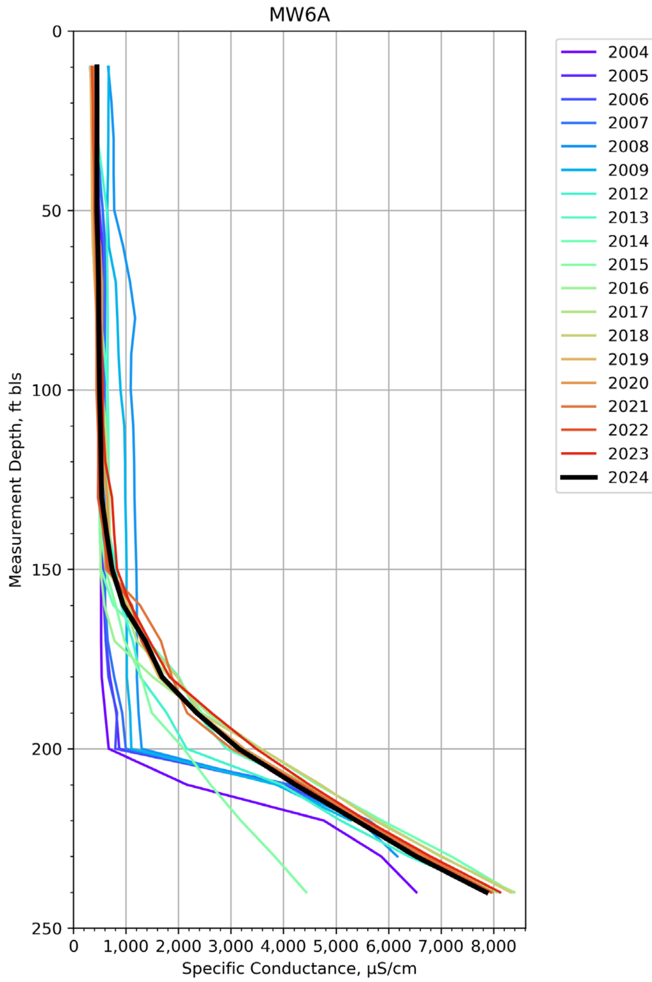

Figure 39. Fluid specific conductance plot for City of Fort Lauderdale monitor well MW6A ID 282730 in Broward County. Specific conductance data collected by the City of Fort Lauderdale during each month of the dry season of each year has been averaged and plotted. The thick black line is the data from May 2024.

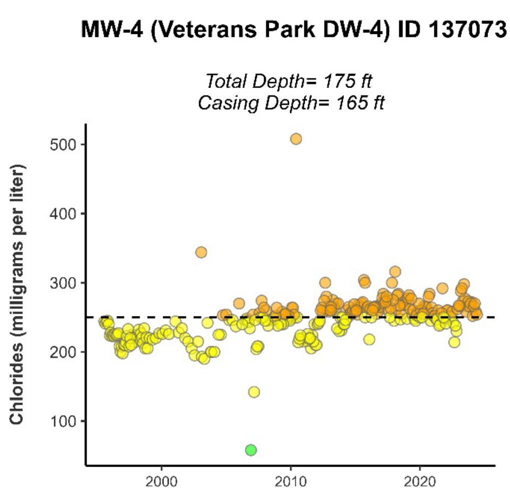

Figure 40. Chloride time-series plot for MW-4 (Veterans Park DW-4) ID 137073 in the Town of Davie in Broward County.

The 2024 interface has moved inland through the remainder of southern Broward County down to the Miami-Dade County line (**Figure 41**). Large increases in chloride concentrations have been reported in 2024 east of the 2024 interface. The chloride concentrations reported for the cities of Hollywood–Hallandale Beach and Hollywood–South PS wellfields, located west of the 2024 interface, show that chloride concentrations have decreased slightly in all the wells since 2019 (**Figure 41**).

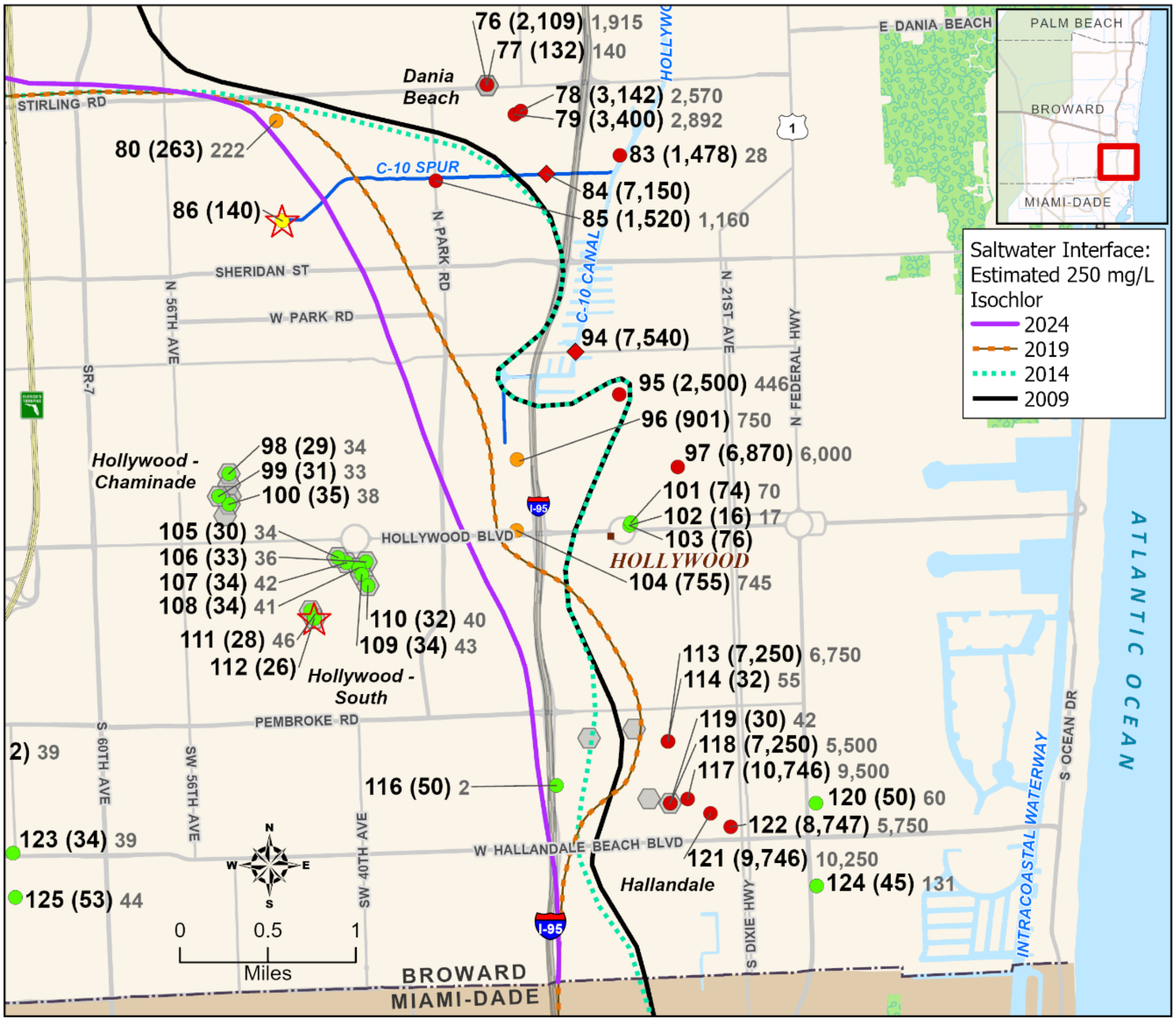

Figure 41. Position of the 2024 saltwater interface in the Biscayne aquifer near the cities of Dania Beach, Hollywood, and Hallandale Beach PS wellfields in Broward County. Map ID 86 is the newly installed saltwater intrusion monitor well BS-2 in the City of Hollywood.

5.4 Lee County – Water Table Aquifer

Chloride concentration data from 95 WTA groundwater samples and 14 surface water samples were used to draw the 2024 saltwater interface in Lee County. The 2024 interface has advanced landward in some areas and remained stable in others, compared to 2009, 2014, and 2019. The interface near the City of Cape Coral was previously drawn with boxy-shaped corners. For 2024, the WTA isochlor has been rounded out and moved closer to the coastline to more accurately reflect the shape and position of the interface (**Figure 42**).

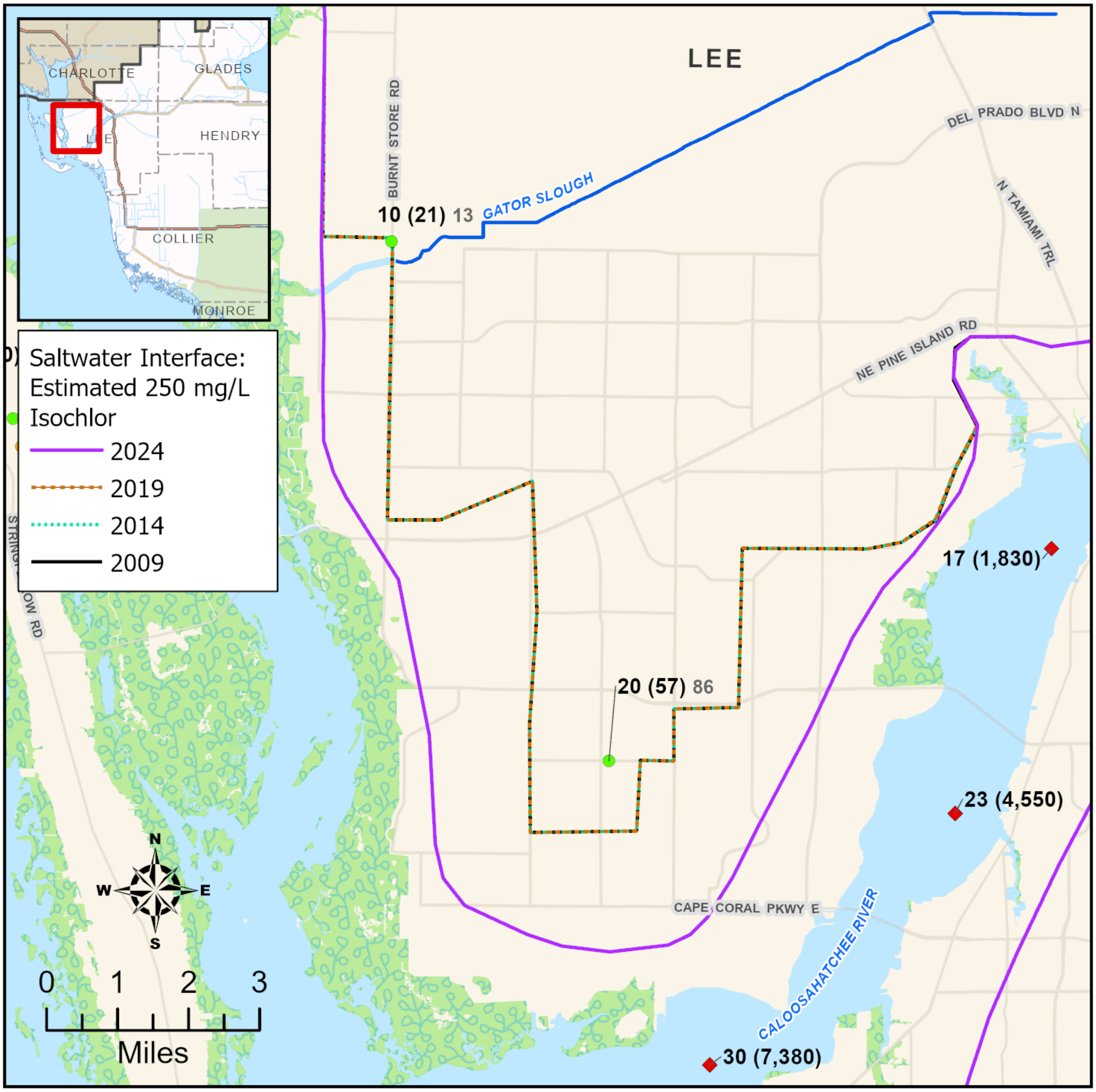

Figure 42. Position of the 2024 saltwater interface in the WTA in the City of Cape Coral in Lee County.

Between the Village of Estero and the City of Bonita Springs, the WTA interface has moved inland in two areas since 2019 (**Figure 43**). The wells in the region generally reported increasing chloride concentrations between 2019 and 2024. As the chloride time-series plot (**Figure 44**) for LM-3410 ID 141491 shows (Map ID 97, located between the Village of Estero and the City of Bonita Springs in **Figure 43**), chloride concentrations began to increase in 2009 and have varied from around 100 to 400 mg/L since that time. To the east of this area are the Lee County Corkscrew, Lee County Pinewoods, and the City of Bonita Springs–West PS wellfields, which pump from the WTA and LTA. This pumping may be affecting the movement of the interface.

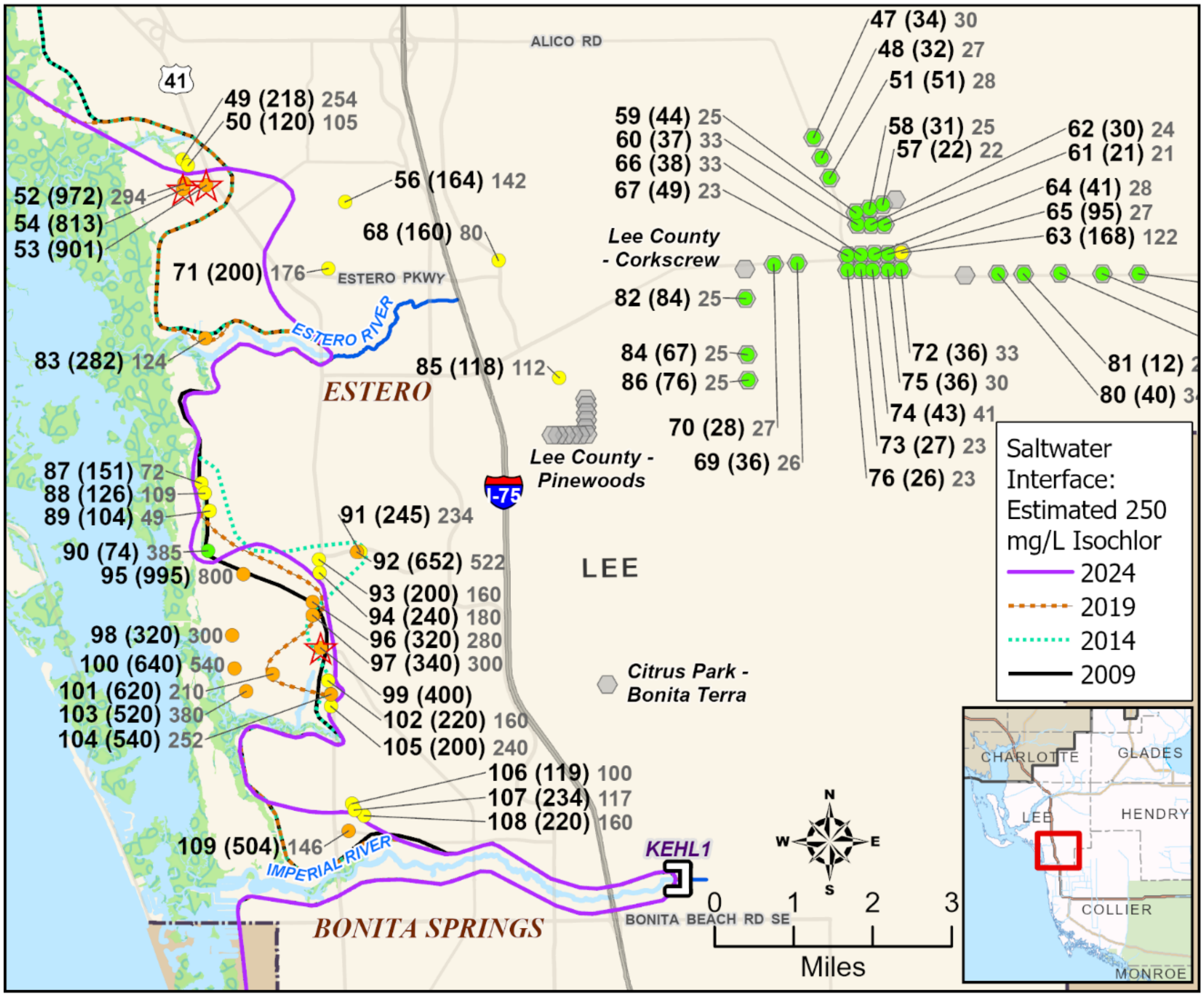

Figure 43. Position of the 2024 saltwater interface in the WTA in coastal Lee County.

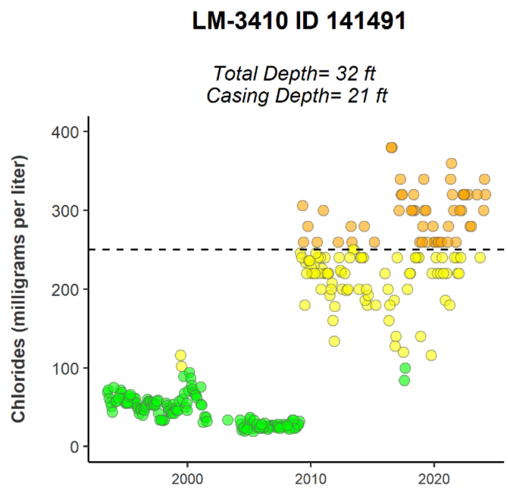

Figure 44. Chloride time-series plot for LM-3410 ID 141491 in Lee County.

5.5 Collier County – Water Table Aquifer

Chloride concentration data from 95 WTA groundwater samples and 31 surface water samples were used to draw the 2024 saltwater interface in Collier County. Unlike on the east coast of Florida where salinity control structures are present and often act as a divide to prevent saltwater from freely flowing inland, the Lower West Coast Planning Area typically does not have such structures. Thus, areas adjacent to freshwater creeks, such as Haldemen Creek, Lely Canal, and Henderson Strand, have indicated landward movement of the saltwater interface. **Figure 45** shows the Cocohatchee River and its control structure COCO1. The 2024 interface is farther inland than it was in 2009, 2014, and 2019, likely due to new chloride data from CCN5 (Map ID 12) and CCN11 (Map ID 26).

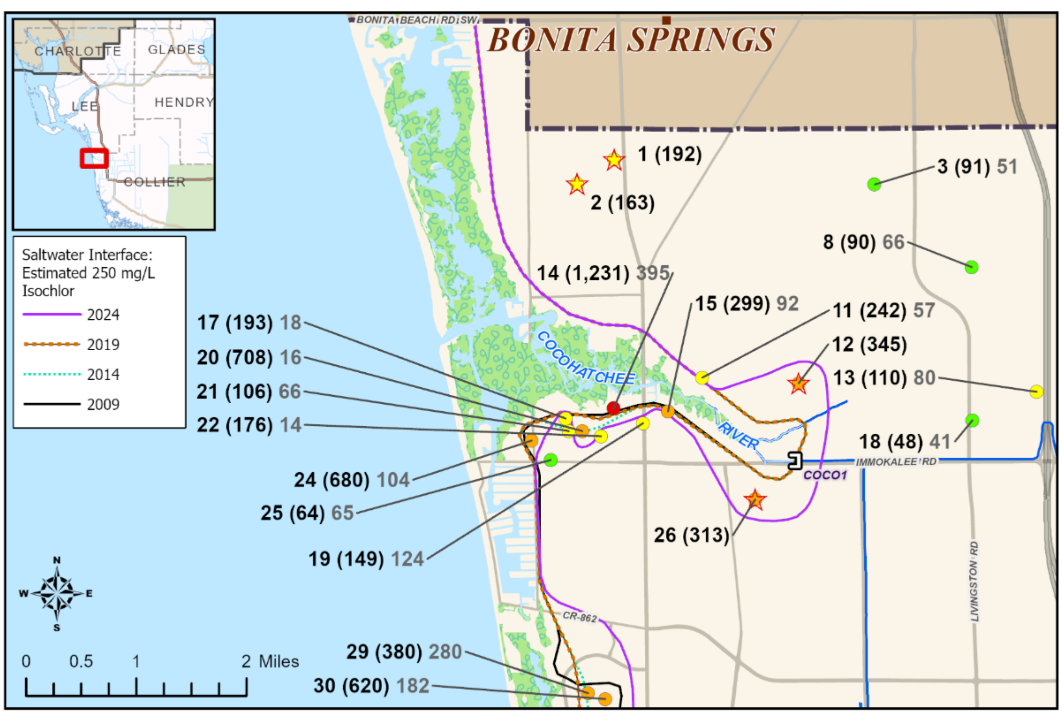

Figure 45. Position of the 2024 saltwater interface in the WTA near the Cocohatchee River in Collier County.

However, additional movement of the saltwater interface was noted in the Lely Canal area in Collier County (**Figure 46**). The area around the Lely Canal outfall is a coastal natural habitat influenced by tidal changes. Lely Canal lacks a control structure, so saltwater can flow inland through the canal. In 2019, the saltwater interface wrapped inland around Lely Canal, but a new inland data point from C-1276 (Map ID 60 in **Figure 46**) shows that elevated chloride concentrations (**Figure 47**) have been recorded at the Collier County South Hawthorn WTA PS wellfield, much farther inland than was mapped in 2019.

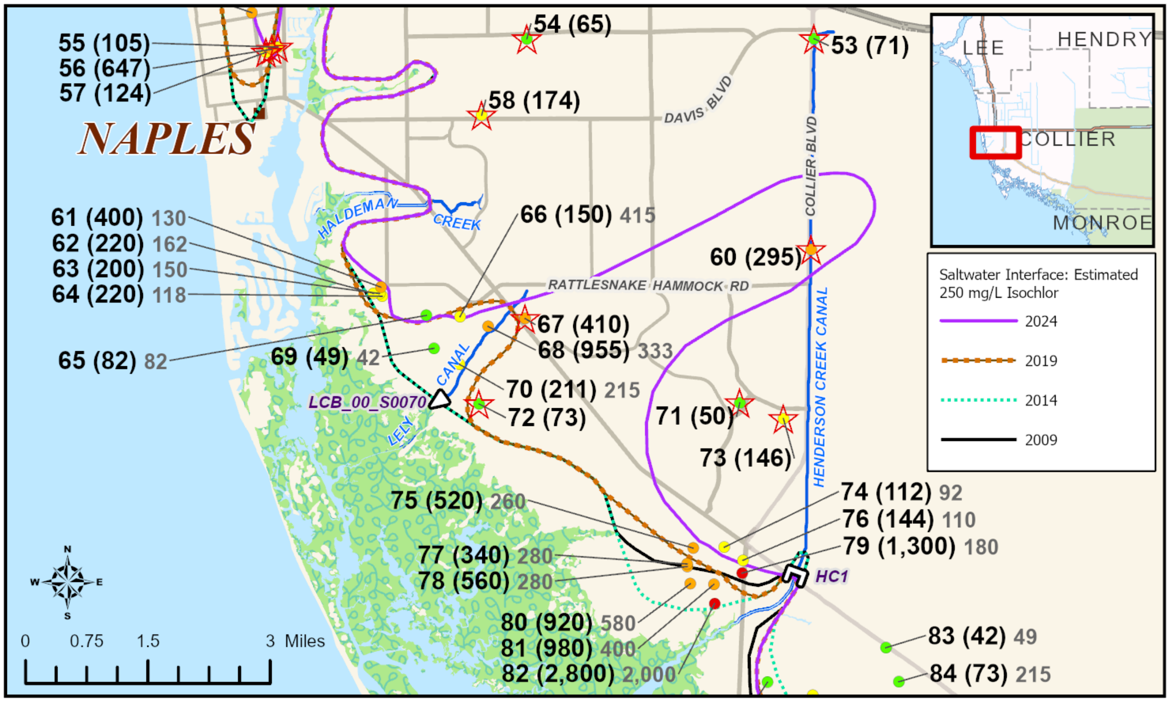

Figure 46. Position of the 2024 saltwater interface in the WTA near Henderson Creek Canal in central Collier County.

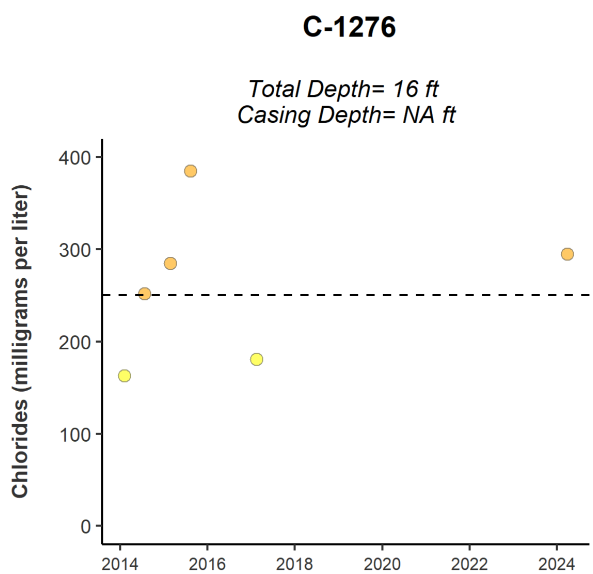

Figure 47. Chloride time-series plot for C-1276 in Collier County.

The WTA interface in southern Collier County moved both inland and seaward since 2019. Inland movement is seen on the western side of **Figure 48** due to the new surface water data point TMBR37 (Map ID 94). Seaward retreat/movement of the saltwater interface has occurred on the eastern side of **Figure 48** near the Port of the Islands. In this area, MW-1 ID 229836 (Map ID 95) freshened significantly since 2019, with chloride concentrations decreasing from 262 mg/L in 2019 to 93 mg/L in 2024.

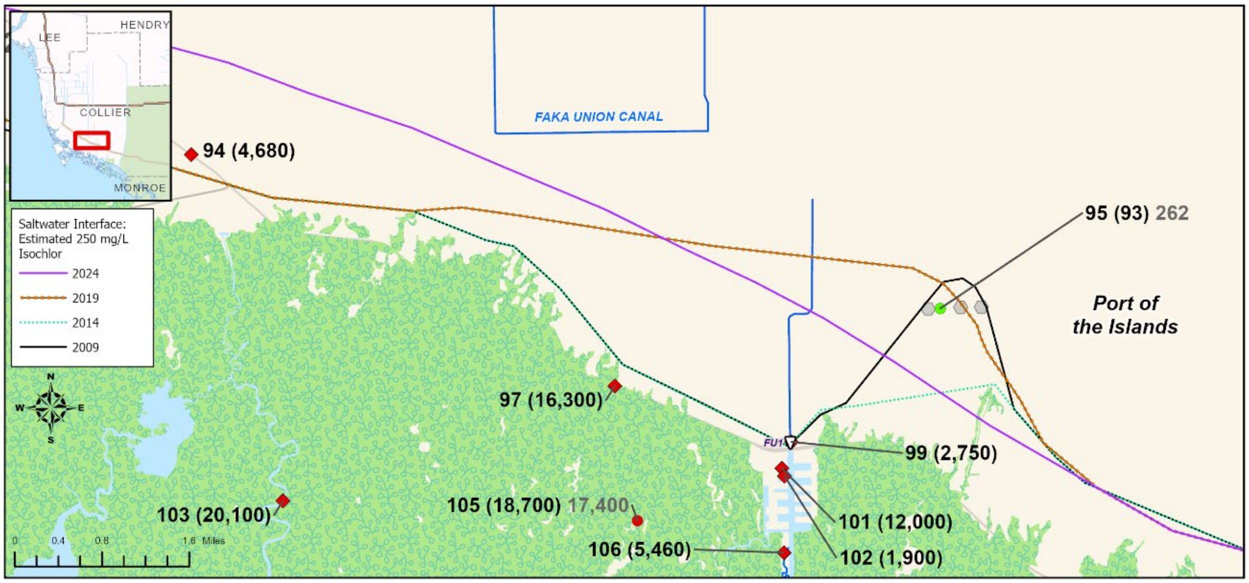

Figure 48. Position of the 2024 saltwater interface in the WTA east of Marco Island and the Ten Thousand Islands in southern Collier County.

5.6 Lee and Collier Counties – Lower Tamiami Aquifer

Chloride concentration data from 160 LTA groundwater samples were used to draw the 2024 saltwater interface in Lee and Collier counties. The LTA on the west coast experiences two sources of saltwater intrusion, lateral intrusion along the coast and upconing of connate water. The 2024 LTA interface in Lee and Collier counties exhibited some movement due to changes in chloride concentrations over time compared to previous years. Large changes in the 2024 LTA interface were due to new data points allowing for an updated interpretation to the location of the interface.

In north Collier County, near the Cocohatchee Canal, the saltwater interface showed some movement seaward and landward (**Figure 49**). Well 1 ID 104175 (Map ID 39), Well 2 ID 10946 (Map ID 40), and Well 3 ID 104186 (Map ID 44) are three new data points that allowed for a better understanding of the inland extent of the saltwater interface, resulting in the interface being farther inland from where it was in 2019. CO-14 ID 144235 (Map ID 32) freshened from a chloride concentration of 317 mg/L in 2019 to 153 mg/L in 2024. Near that well, the saltwater interface retreated toward the coast.

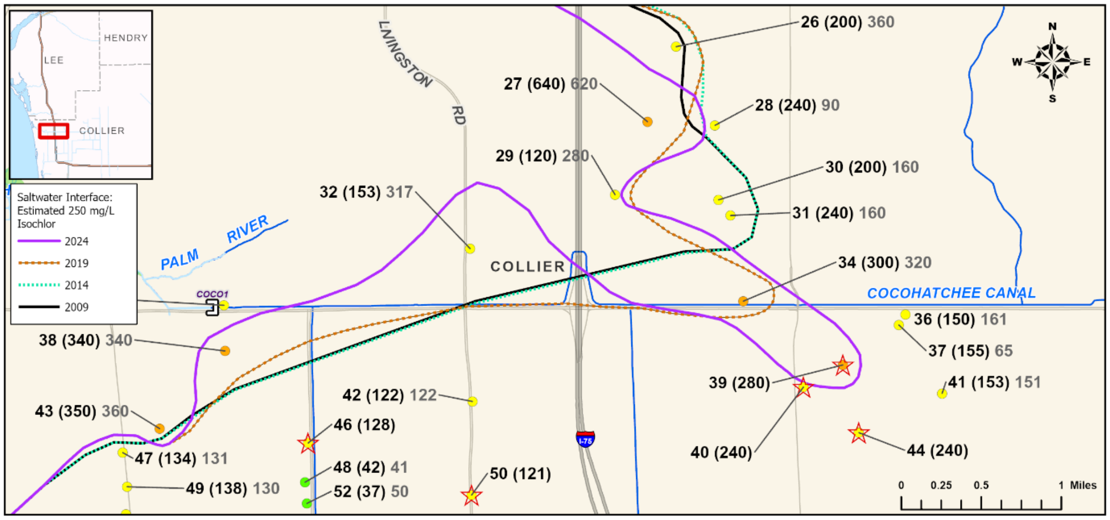

Figure 49. Position of the 2024 saltwater interface in the LTA near the Cocohatchee Canal in Collier County, primarily due to newly obtained data.

Based on new chloride concentration data, the 2024 interface near the City of Naples Coastal Ridge PS wellfield was interpreted to be closer to the coastline compared to 2019 (**Figure 50**). Monitor wells in this area that had 2019 chloride concentration data did not show significant changes in chloride concentrations.

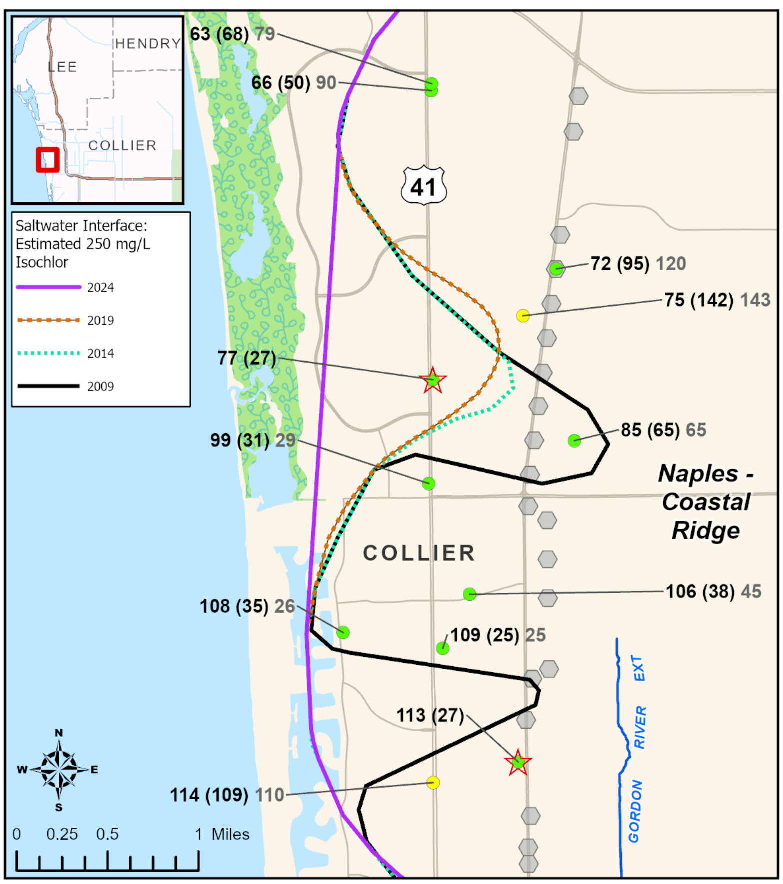

Figure 50. Position of the 2024 saltwater interface in the LTA in the City of Naples area in Collier County, primarily due to newly obtained data.

The 2024 LTA saltwater interface moved inland in the area east of the City of Naples and the Gordon River (**Figure 51**). The interface location was modified because the chloride concentrations at C3 ID 2997 (Map ID 122) increased from 119 mg/L in 2019 to 161 mg/L in 2024.

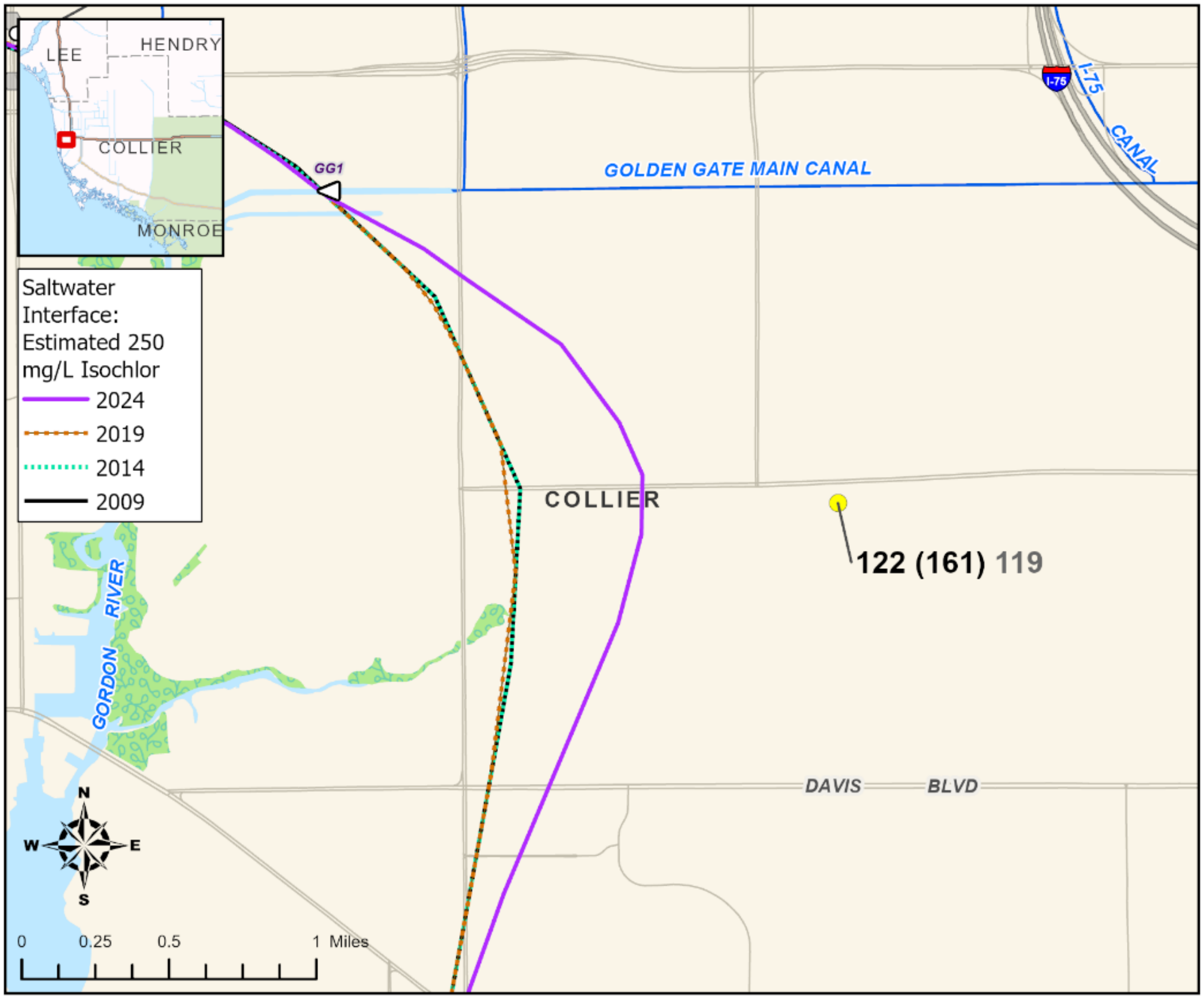

Figure 51. Position of the 2024 saltwater interface in the LTA east of the City of Naples and the Gordon River in Collier County, due to increasing chloride concentrations at C3 ID 2997 Map ID 122.

The LTA saltwater interface moved landward in the City of Bonita Springs area and northern Collier County. The area of connate seawater in Collier County has reduced in size since 2019 and has split into two distinct areas of connate water (**Figure 52**). Using the recently updated hydrostratigraphy for the Lower West Coast Planning Area (Zumbro et al. 2023) and 2024 water quality data to compare the extents of the connate water with the base of the LTA, the area of connate water as mapped in 2019 has reduced in total size and has now been divided into two separate areas based on both groundwater chloride concentrations and hydrostratigraphy (**Figure 52**). **Figure 53** shows the connate region and the elevation in feet using the North American Vertical Datum of 1988 (NAVD88) of the base of the LTA using the Lower West Coast updated hydrostratigraphy (Zumbro et al. 2023). Chloride concentrations reported for wells in the Collier County PS wellfield adjacent to and east of the connate water areas are predominantly fresh (chloride concentrations less than 100 mg/L), except for six wells that reported chloride concentrations ranging from 178 mg/L in 33 ID 148411 (Map ID 90 in **Figure 52**) to 230 mg/L in 1 ID 45421 (Map ID 89 in **Figure 52**).

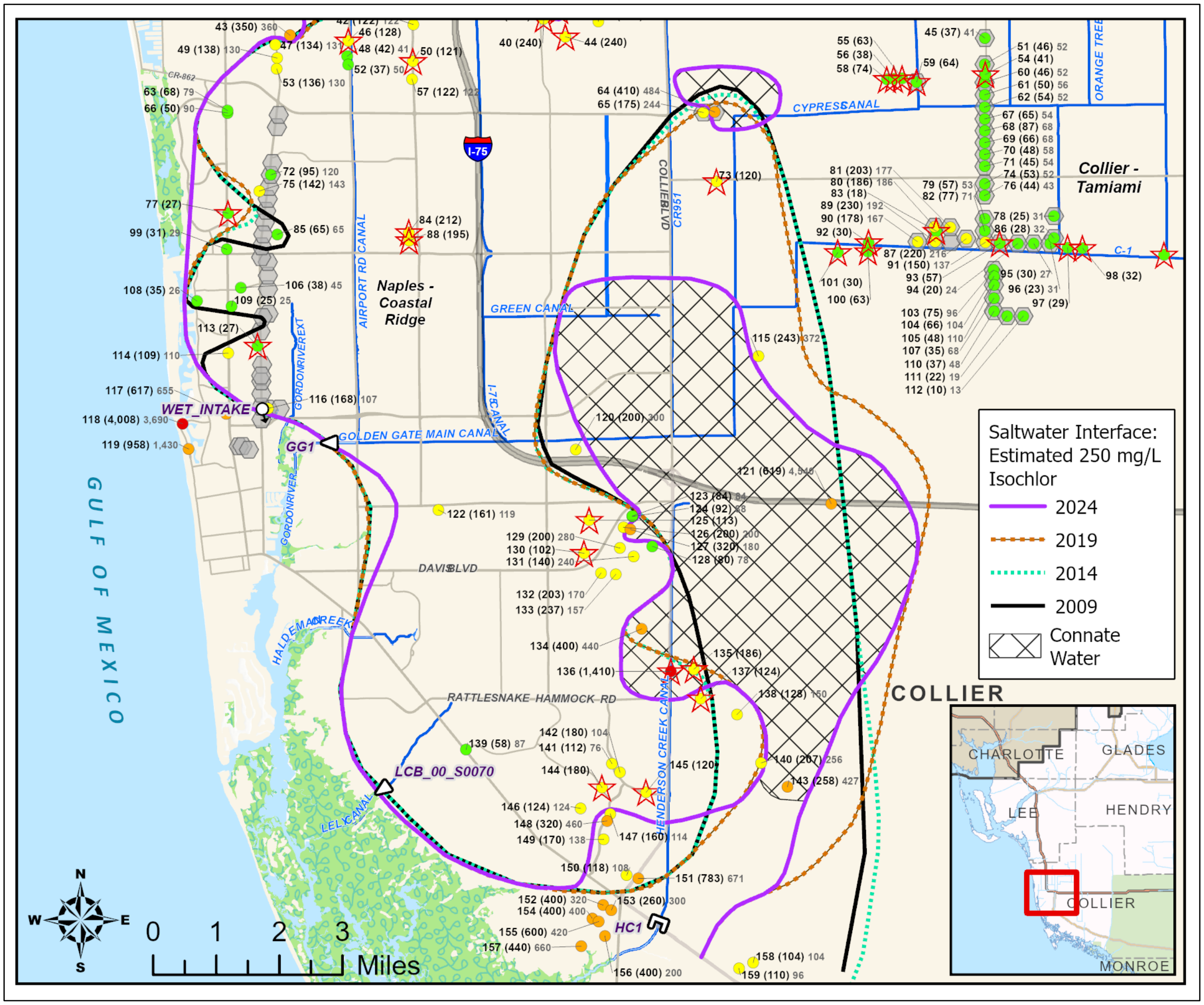

Figure 52. Position of the 2024 saltwater interface in the LTA indicating two areas of connate water in Collier County. Groundwater chloride concentrations in these connate water areas exceed 250 mg/L.

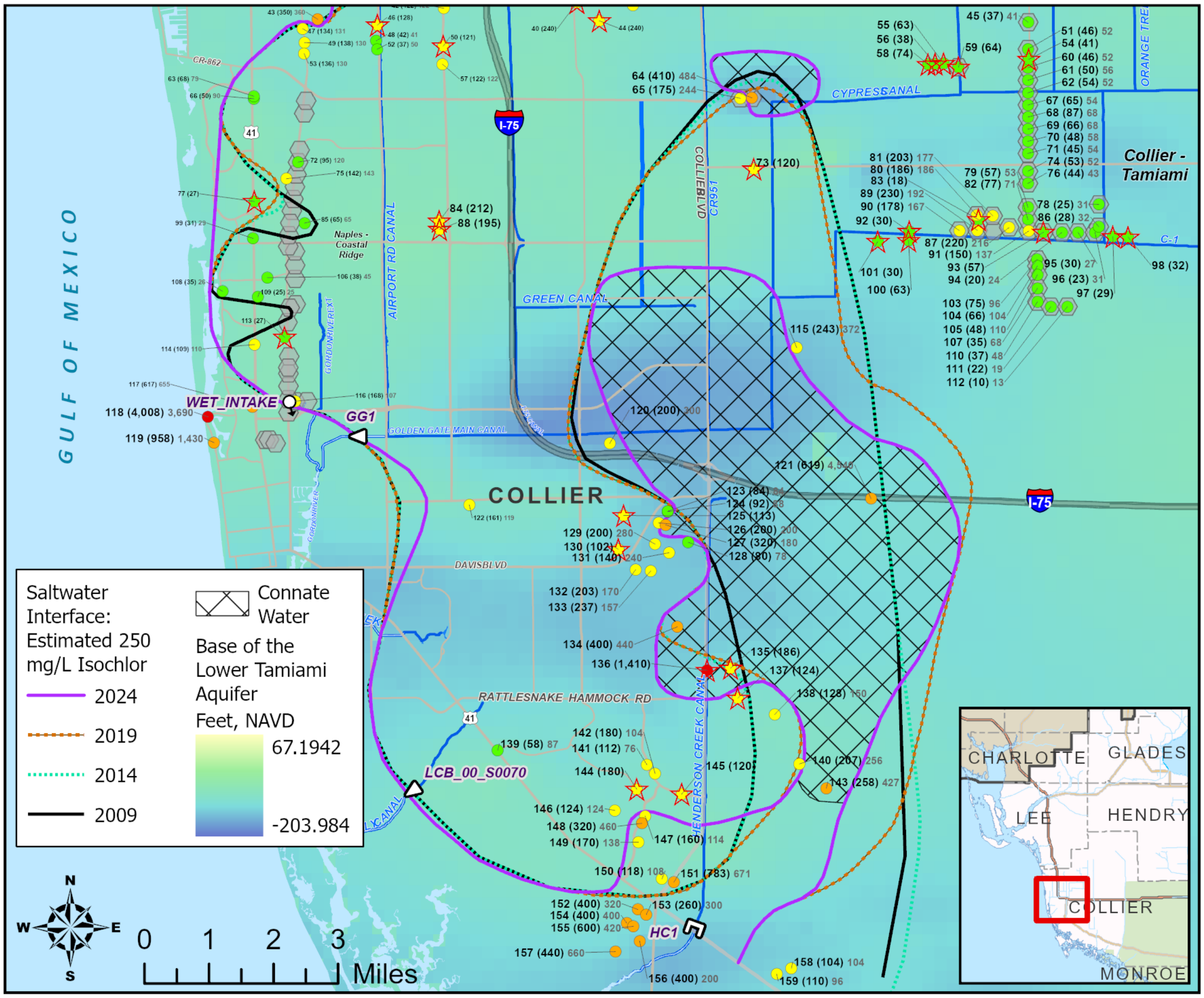

Figure 53. Connate water areas in the LTA, wells with 2024 chloride concentrations, and approximate elevation of the base of the LTA in Collier County (Zumbro et al. 2023).

Within the Lely Resort Community, to the southwest of the connate water areas, the LTA interface moved northwest relative to its 2019 position (**Figure 54**). Most of the wells at the Lely Resort Community are relatively shallow (30 to 50 ft bls) compared to the bottom depth of the LTA in this area (approximately 100 ft NAVD88 or approximately 110 ft bls). However, LRCMW-3 (Map ID 148, **Figure 54**) is 135 ft bls and should provide more representative groundwater chemistry data for the deeper LTA. The March 6, 2024 groundwater sample collected from LRCMW-3 ID 259157 had a chloride concentration of 320 mg/L, so the 2024 saltwater interface was positioned to the north-northwest to encompass this well (**Figure 54**). The time-series plot for LCRMW-3 ID 259157 shows that chloride concentrations at this location have been mostly greater than 250 mg/L since October 2014 (**Figure 55**).

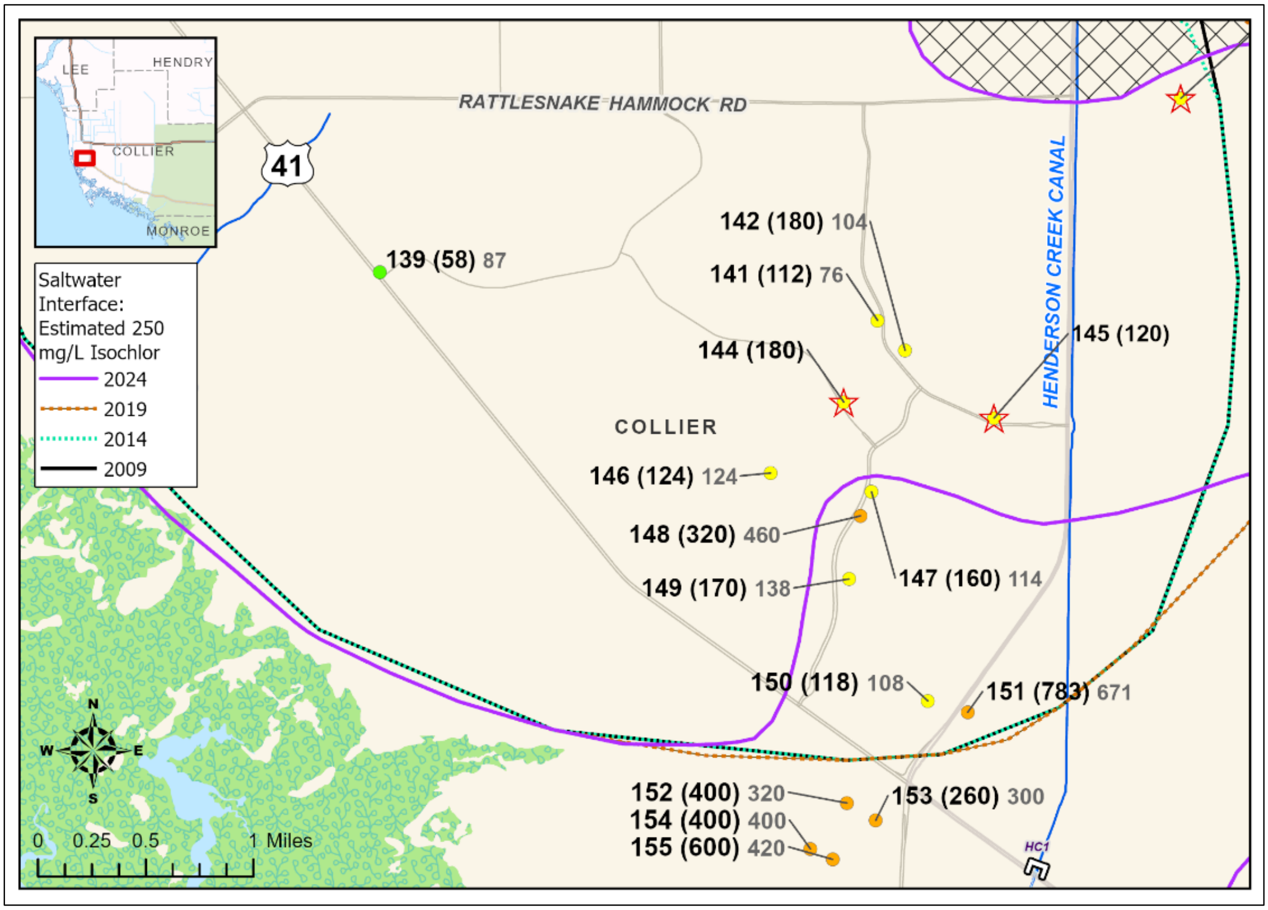

Figure 54. Position of the 2024 saltwater interface in the LTA near the Lely Resort Community in Collier County.

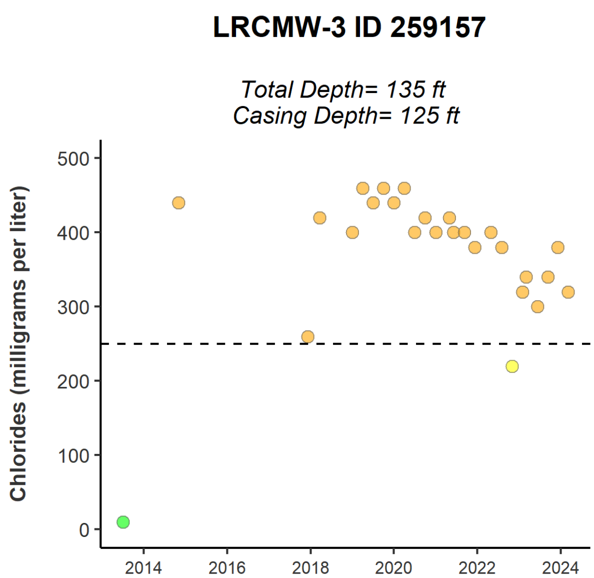

Figure 55. Chloride time-series plot for LCRMW-3 ID 259157 in the Lely Resort Community in Collier County.

5.7 Lee and Collier Counties – Sandstone Aquifer

Chloride concentration data from 72 SSA groundwater samples were used to draw the 2024 saltwater interface in Lee and Collier counties. The SSA saltwater interface has remained relatively static since 2019. The static SSA saltwater interface may be due to agriculture being the primary user of the SSA. Agriculture used 89% of the total reported SSA withdrawals in 2023. The agricultural areas in Collier County are farther inland; therefore, those withdrawals are not influencing the saltwater interface as greatly as if the withdrawals were occurring closer to the coast. Minor adjustments were made to the interface to reflect increases and decreases in chloride concentrations reported at wells between 2019 and 2024. Minor seaward adjustments to the 2024 SSA interface were made in the City of Fort Myers due to decreasing chloride concentrations in a few wells in this area.

Figure 56 shows two areas of minor landward encroachment of the 2024 interface. One area of encroachment is north of Florida Gulf Coast University and northwest of the Lee County Corkscrew PS wellfield, and the second area is located to the south near the Lee County Pinewoods PS wellfield. The chloride time-series plot (**Figure 57**) for LM-7726 ID 142771 (Map ID 38 in **Figure 56**) north of Florida Gulf Coast University shows chloride concentrations ranging from 260 to 400 mg/L between 2003 and 2010 before an apparent decrease in chloride concentrations to less than 250 mg/L between 2010 and 2023. Beginning in 2023, and into 2024, chloride concentrations once again exceeded the 250 mg/L SMCL.

The 2024 interface moved slightly inland due to increased chloride concentrations in monitor well WMH-6 (SS) ID 252909 (Map ID 62 in **Figure 56**) located in the Stoneybrook Golf Club. **Figure 58** shows that the chloride concentrations in LM-7726 ID 142771 have been greater than 250 mg/L since monitoring started at this well in 2010, and that the current chloride concentrations are within the historical range of concentrations at this well.

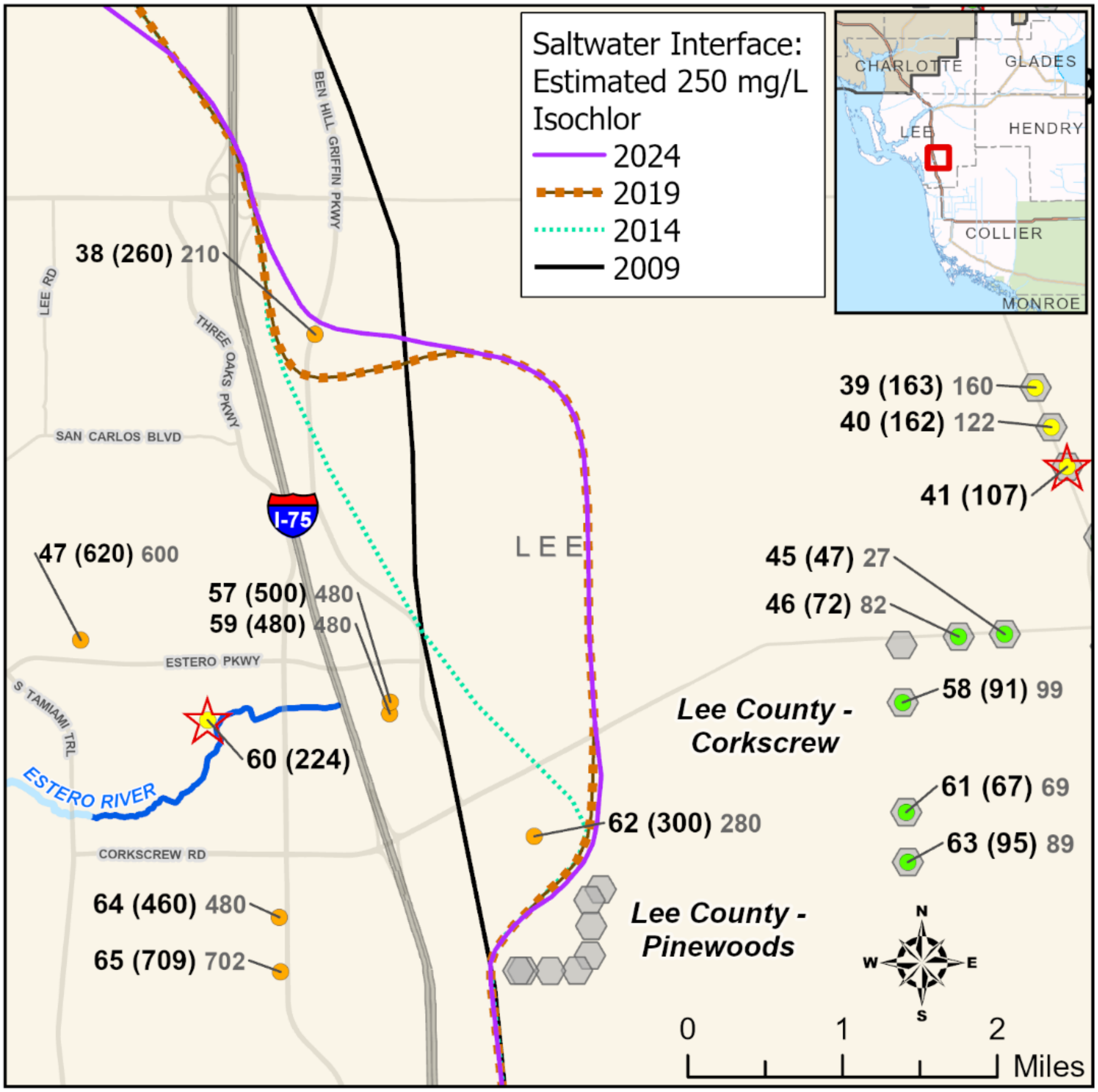

Figure 56. Position of the 2024 saltwater interface in the SSA near Florida Gulf Coast University to the north (near Map ID 38 [LM-7726 ID 142771]) and the Lee County Pinewoods PS wellfield to the south in Lee County.

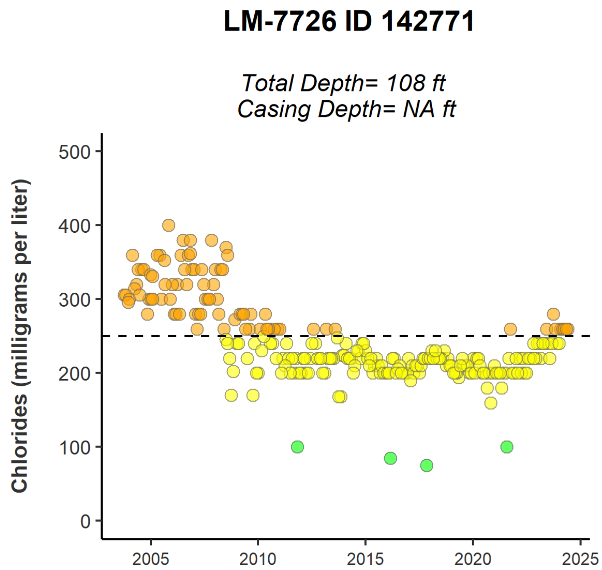

Figure 57. Chloride time-series plot for LM-7726 ID 142771 near Florida Gulf Coast University in Lee County.

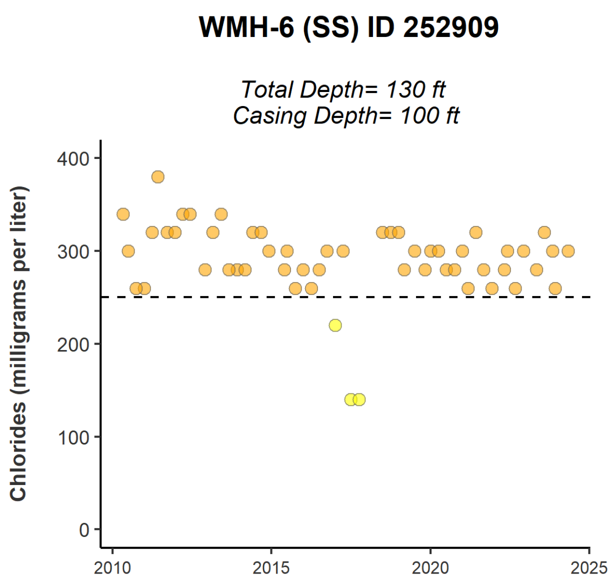

Figure 58. Chloride time-series plot for WMH-6 (SS) ID 252909 west of the Lee County Pinewoods PS wellfield in Lee County.

5.8 Lee and Collier Counties – Mid-Hawthorn Aquifer

Chloride concentration data from 87 MHA groundwater samples were used to draw the 2024 saltwater interface in Lee and Collier counties. The saltwater interface was adjusted in the City of Cape Coral due to a new data point, monitor well L-2644 (Map ID 10 in **Figure 59**).

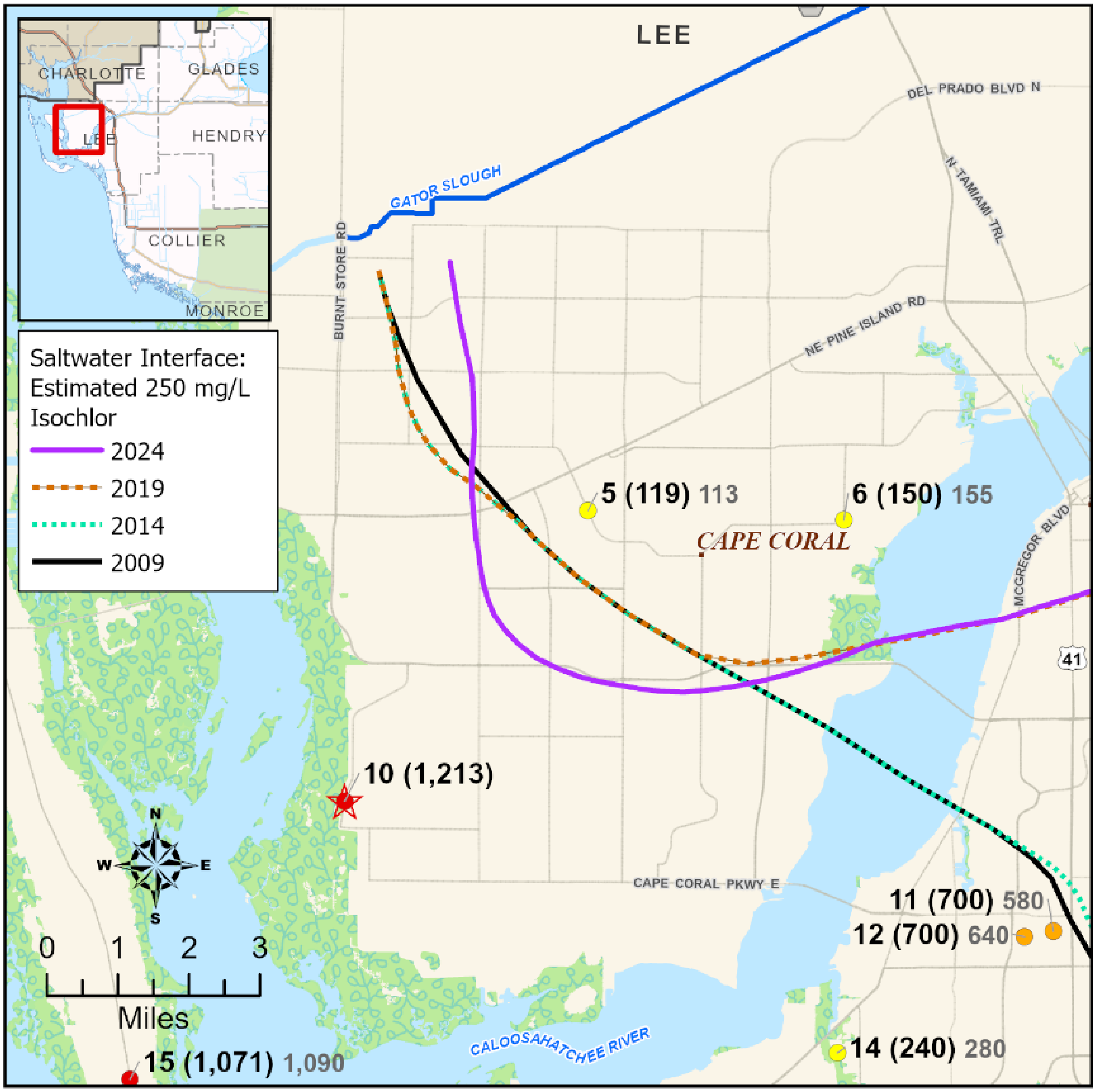

Figure 59. Position of the 2024 saltwater interface in the MHA in the City of Cape Coral in Lee County, reflecting the new groundwater chloride data point in the southwestern corner of the map, which had a 2024 groundwater chloride concentration of 1,213 mg/L.

The 2024 MHA interface moved farther inland in the City of Fort Myers compared to the 2019 interface position (**Figure 60**). The chloride time series (**Figure 61**) for 2 ID 137297 (Map ID 4 in **Figure 60**) shows that chloride concentrations increased in 2021 and have remained relatively elevated since that time although there is some variation in the data.

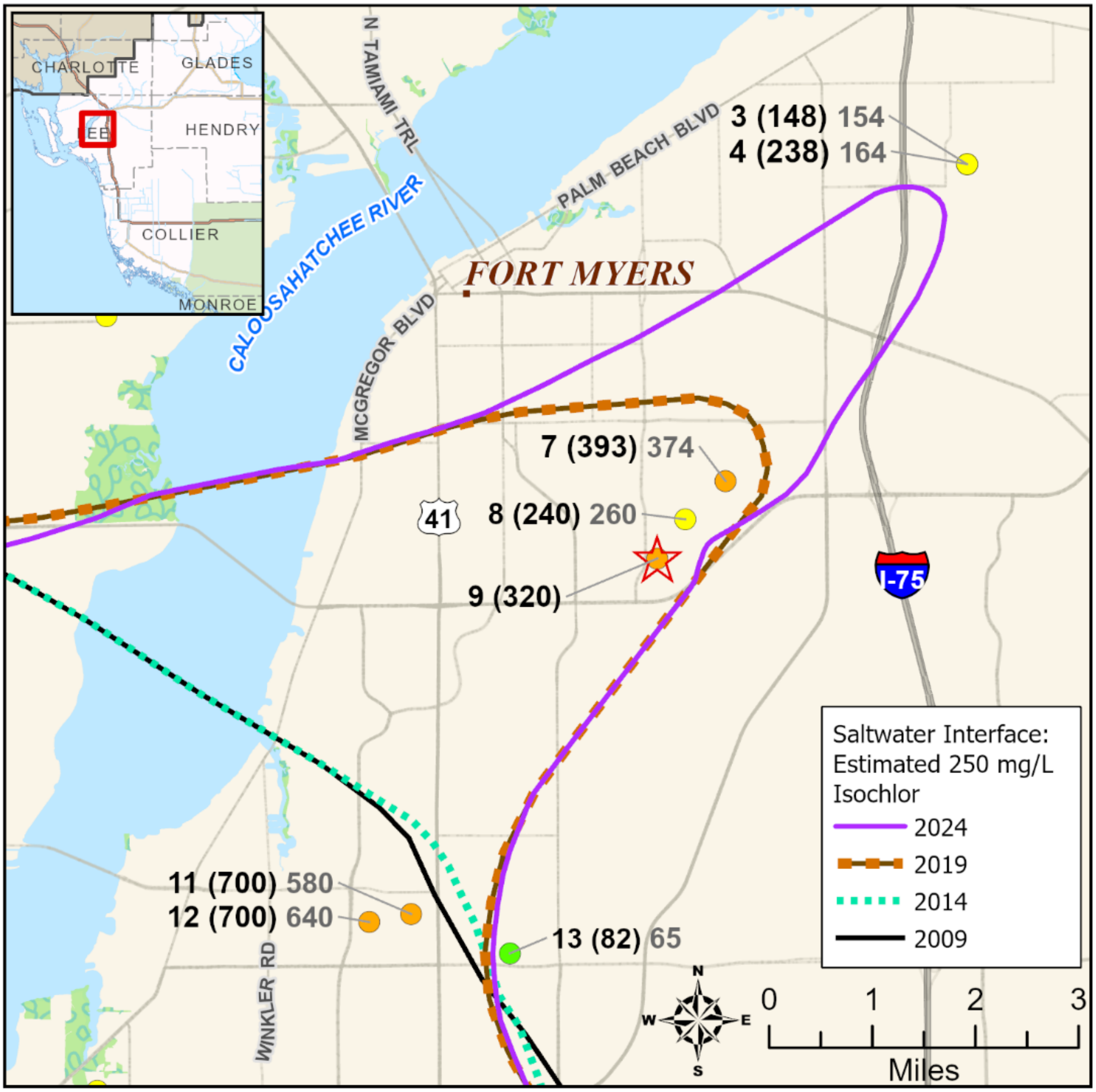

Figure 60. Position of the 2024 saltwater interface in the MHA near the City of Fort Myers in Lee County.

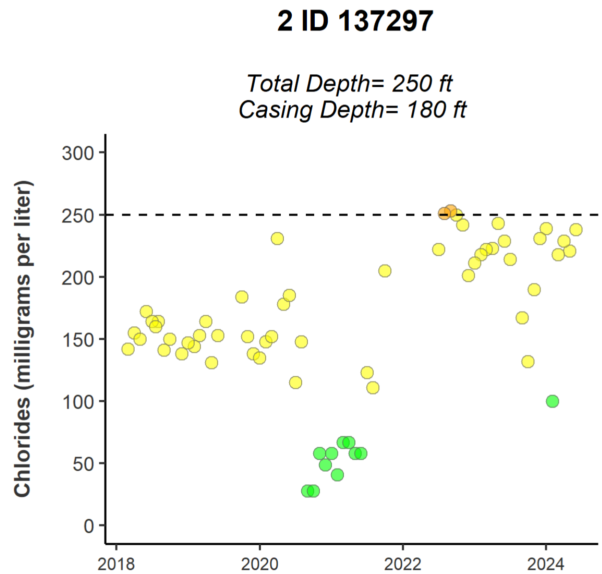

Figure 61. Chloride time-series plot for 2 ID 137297 (Map ID 4 in **Figure 60**) in the City of Fort Myers in Lee County.

In southern Collier County, near Interstate 75 (Alligator Alley), the 2024 MHA interface was positioned farther inland due to two new data points, one located inland of the interface (C-684, Map ID 28) and one located seaward of the interface (C-974, Map ID 49). These two wells and the 2024 interface are shown in **Figure 62**. Monitor well C-974 is a new data point for 2024, and its elevated 2024 chloride concentration (2,030 mg/L) indicates that the saltwater interface is farther inland in 2024 than it was in 2019. The two wells that reported 2019 chloride concentration data (IW-1 ID 254150, Map ID 29 and C-987, Map ID 72) did not show large changes in water quality since 2019, so this adjustment was made because the new data point (C-974, Map ID 49) better defines the location of the interface.

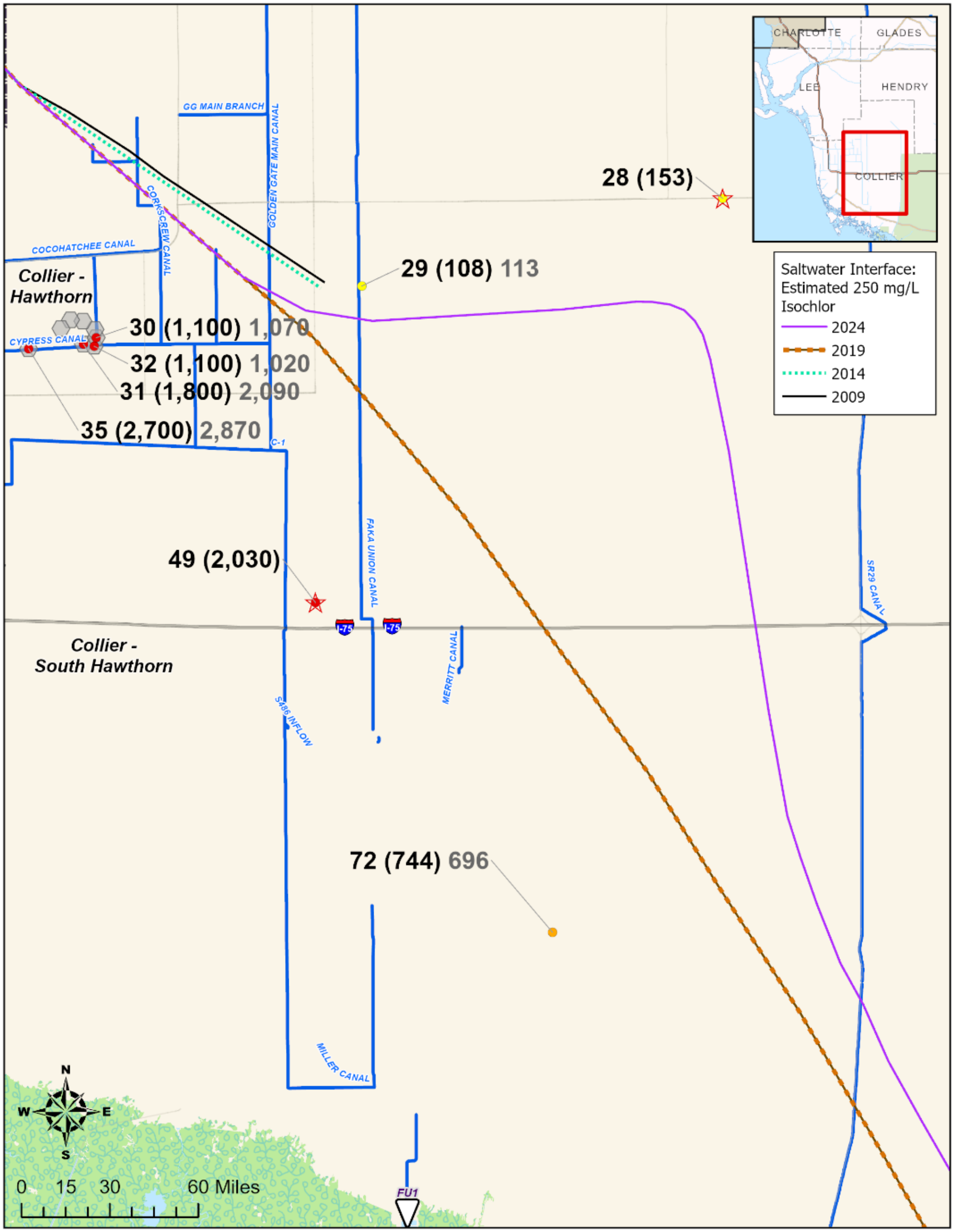

Figure 62. Position of the 2024 saltwater interface in the MHA near Interstate 75 in southern Collier County.

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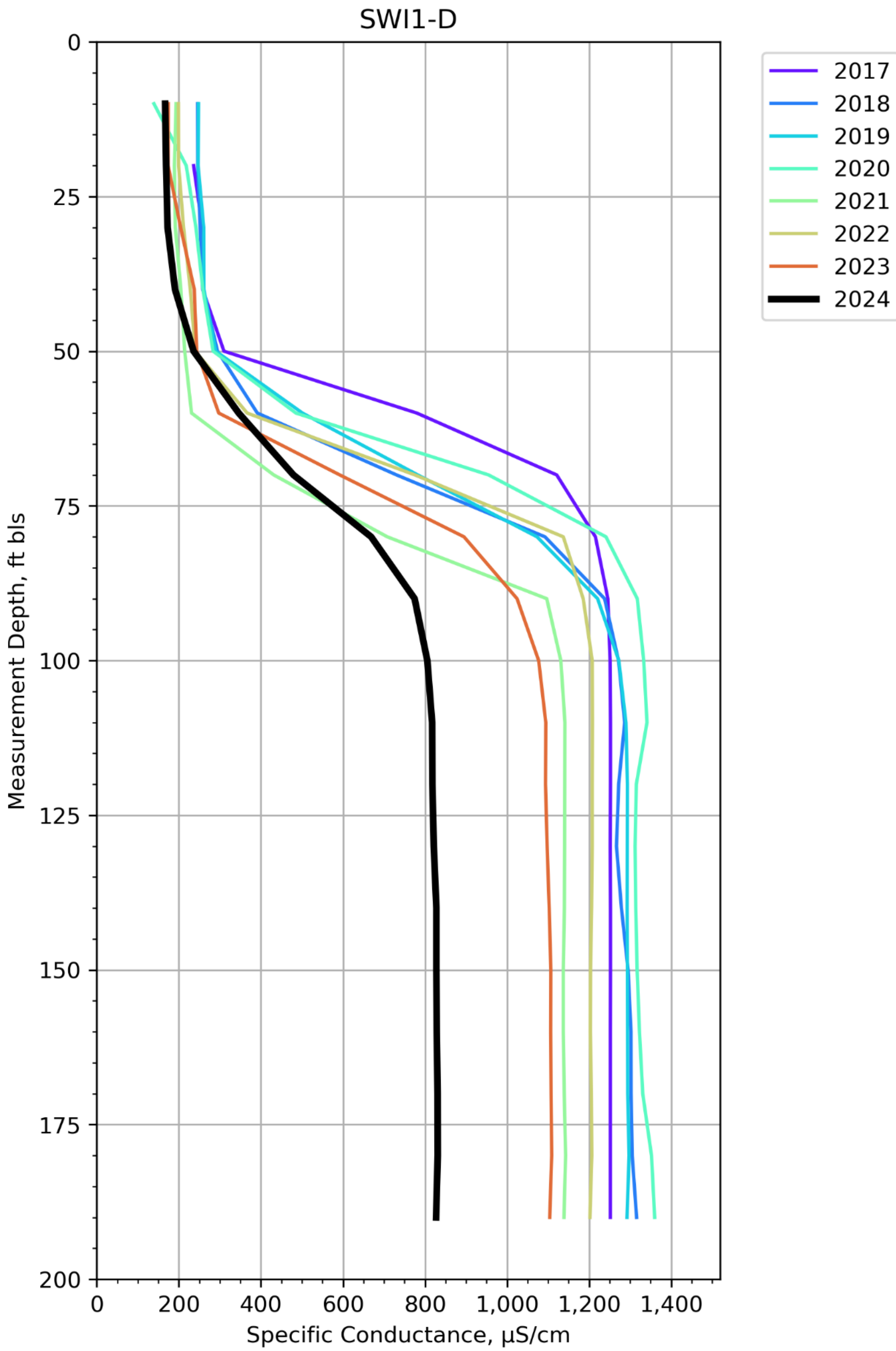
APPENDICES

APPENDIX A:
CITY OF POMPANO BEACH FLUID SPECIFIC CONDUCTANCE PLOTS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2018
2019
2020
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2022
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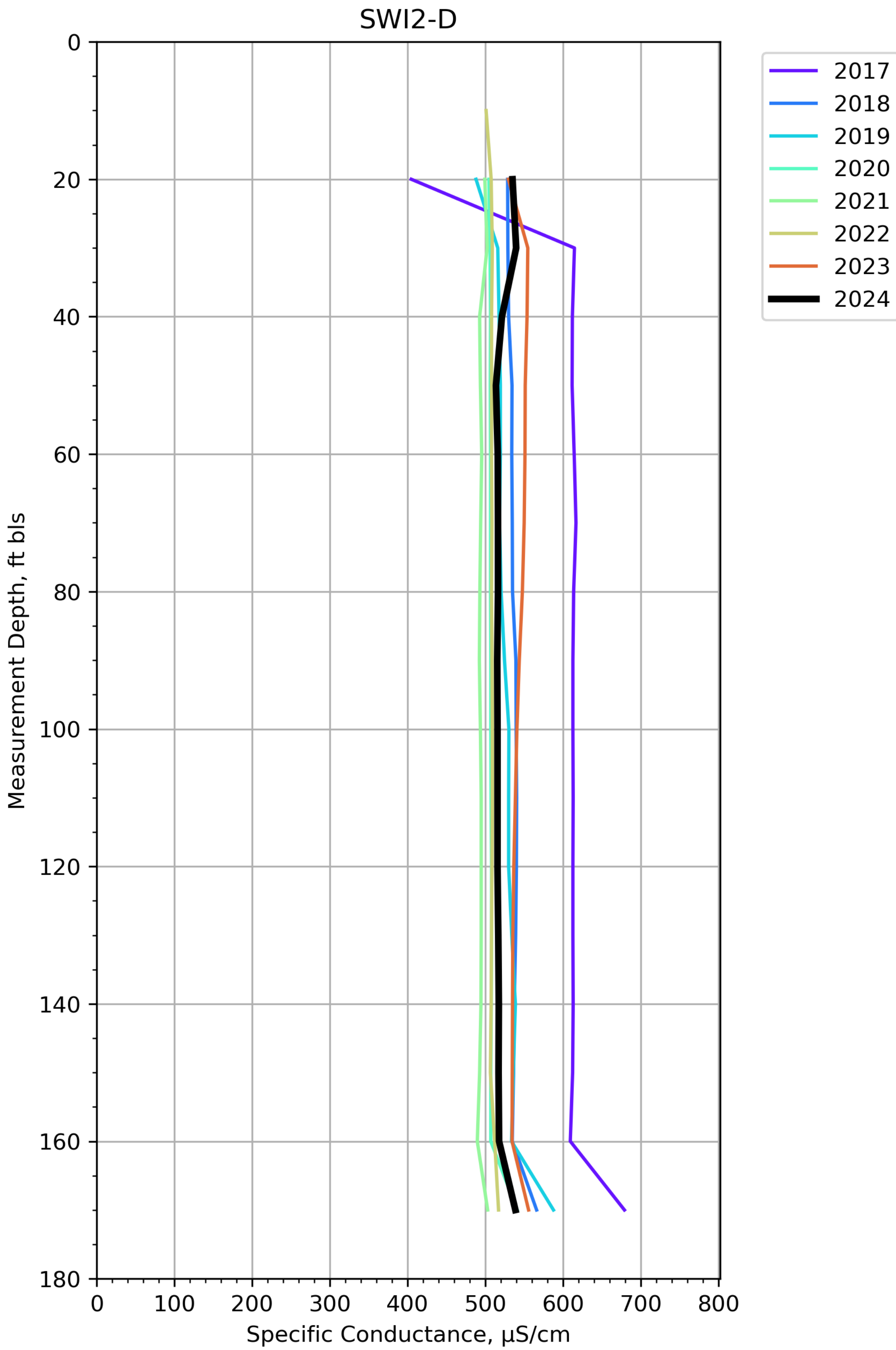
2024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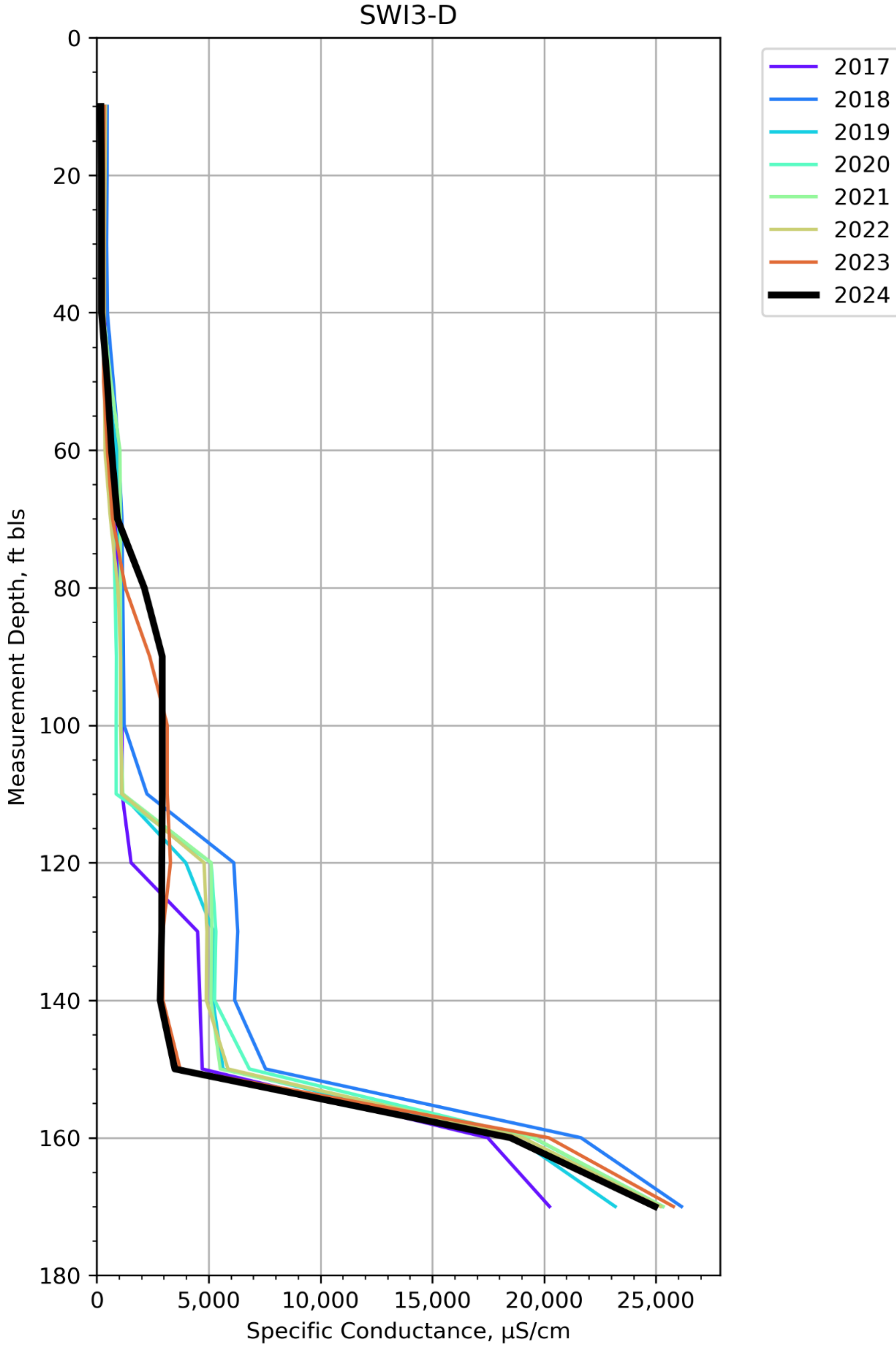

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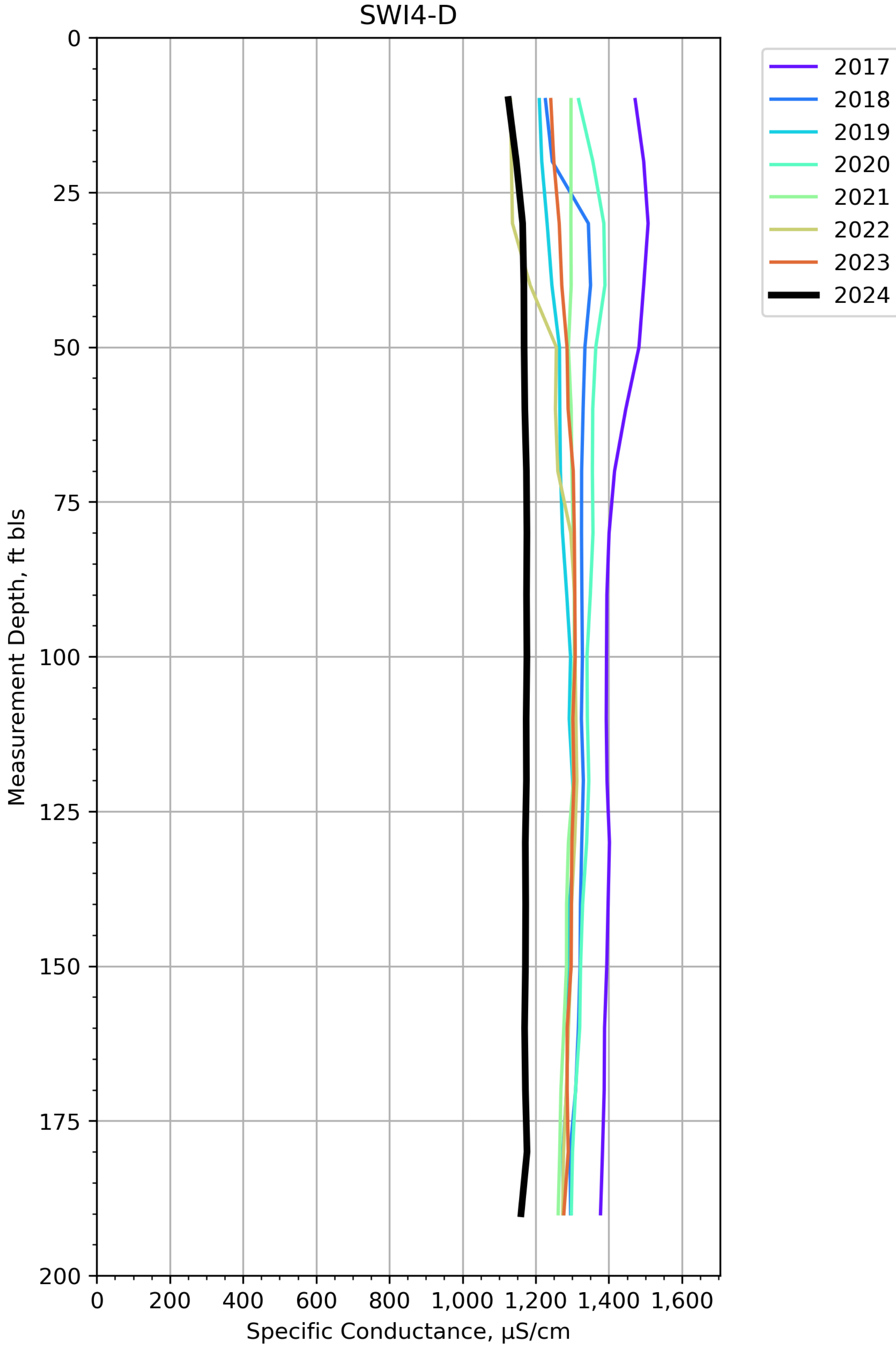
2022
2023
2024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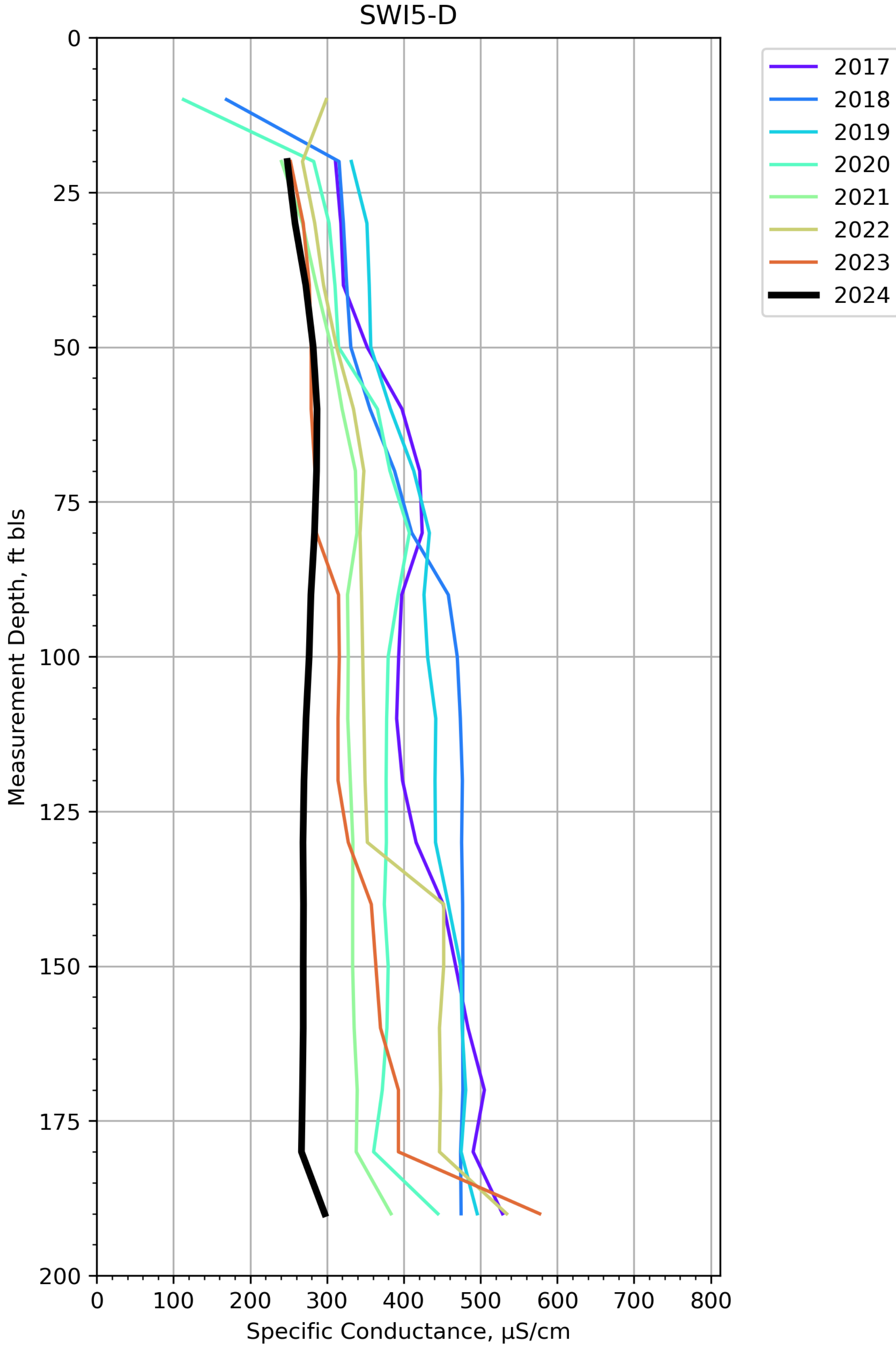
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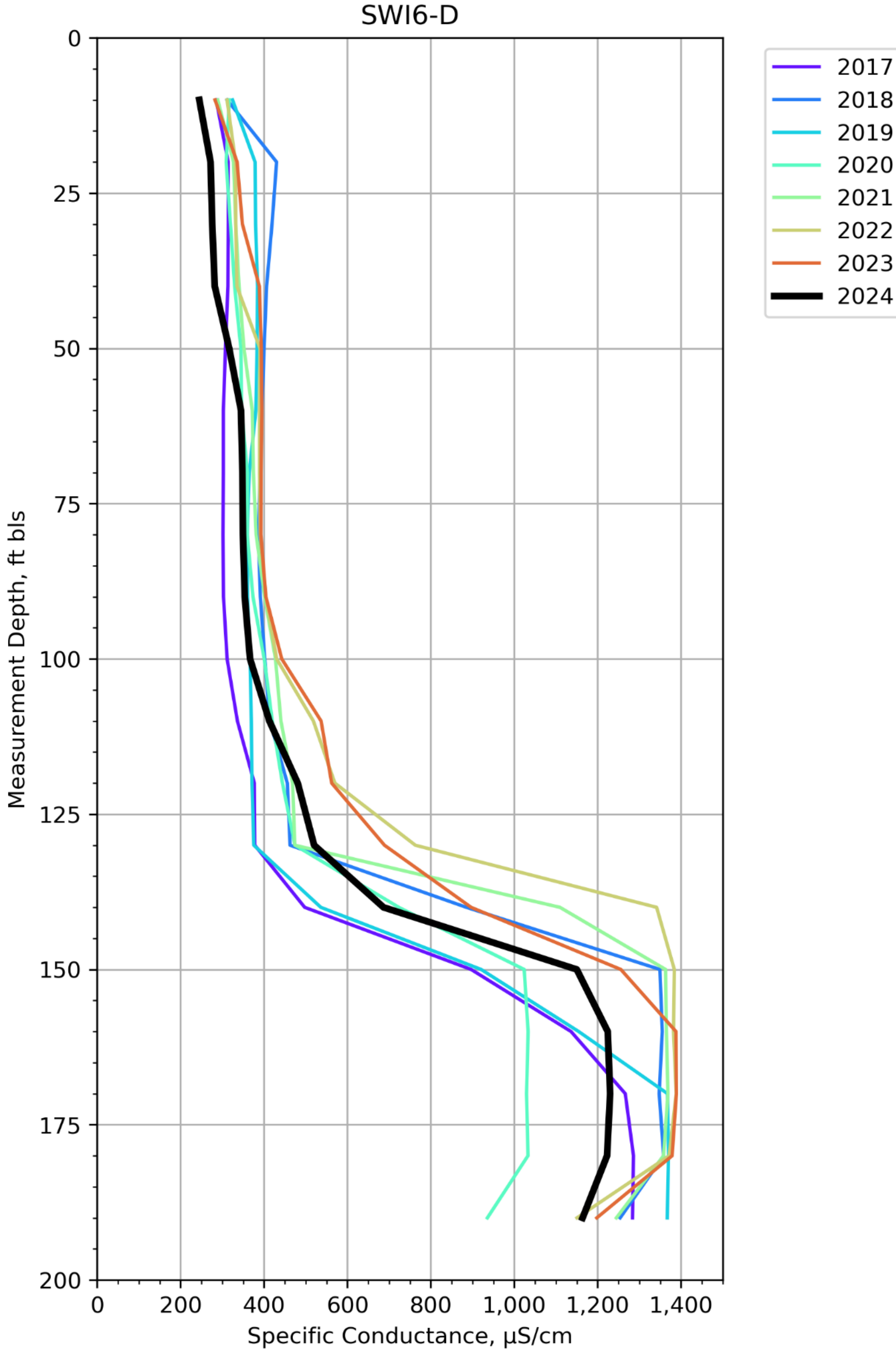

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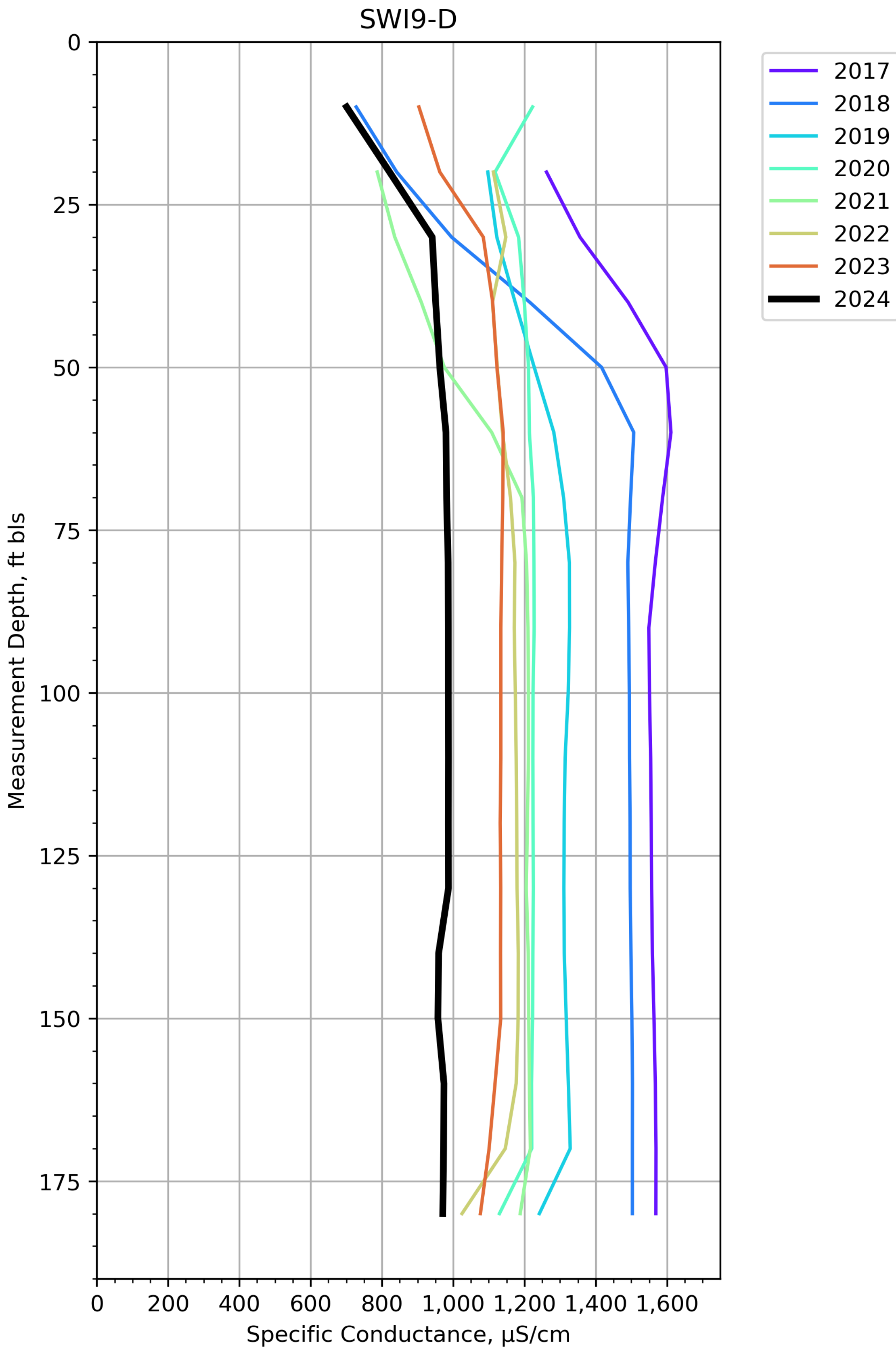
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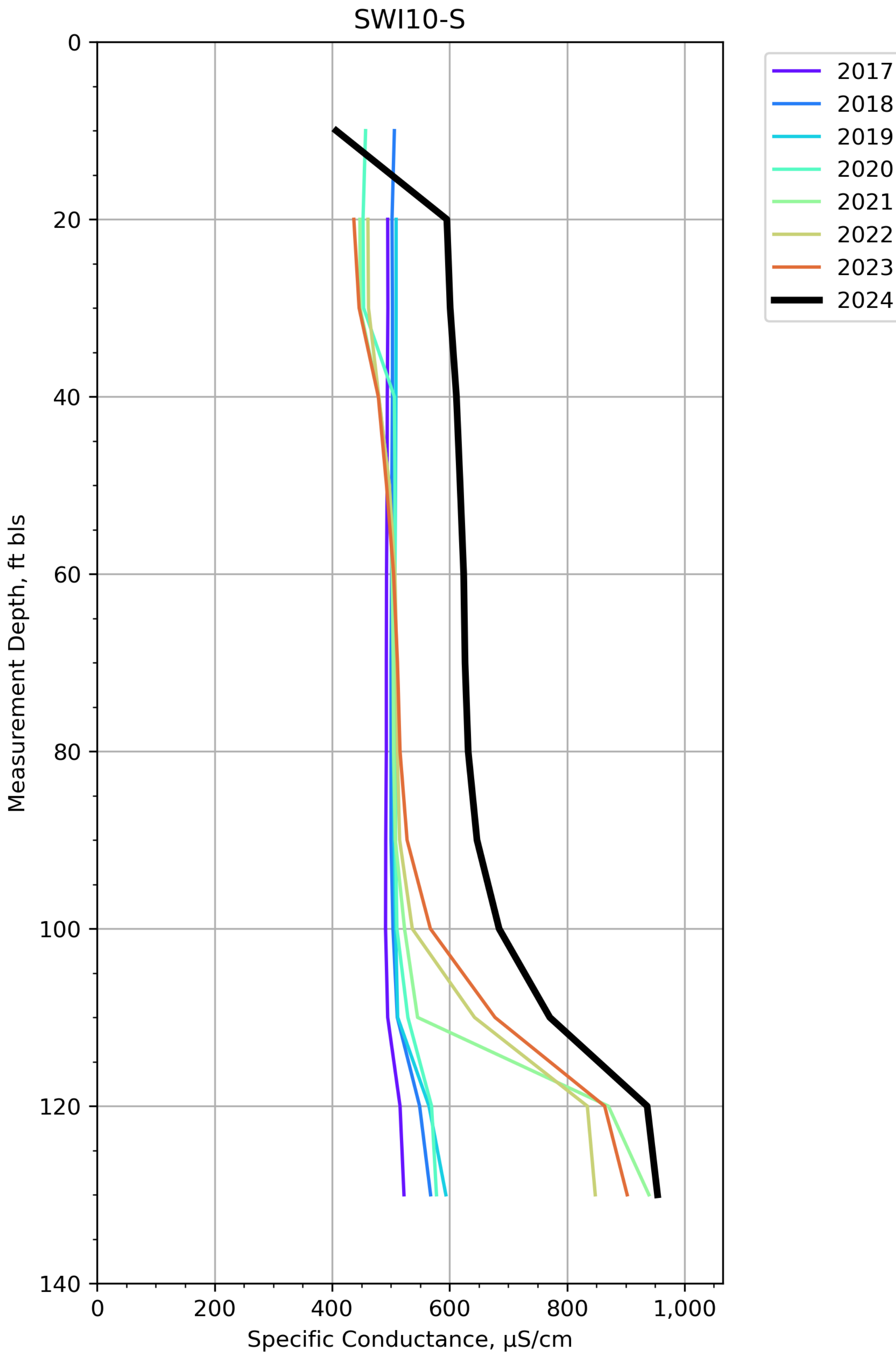
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1,000
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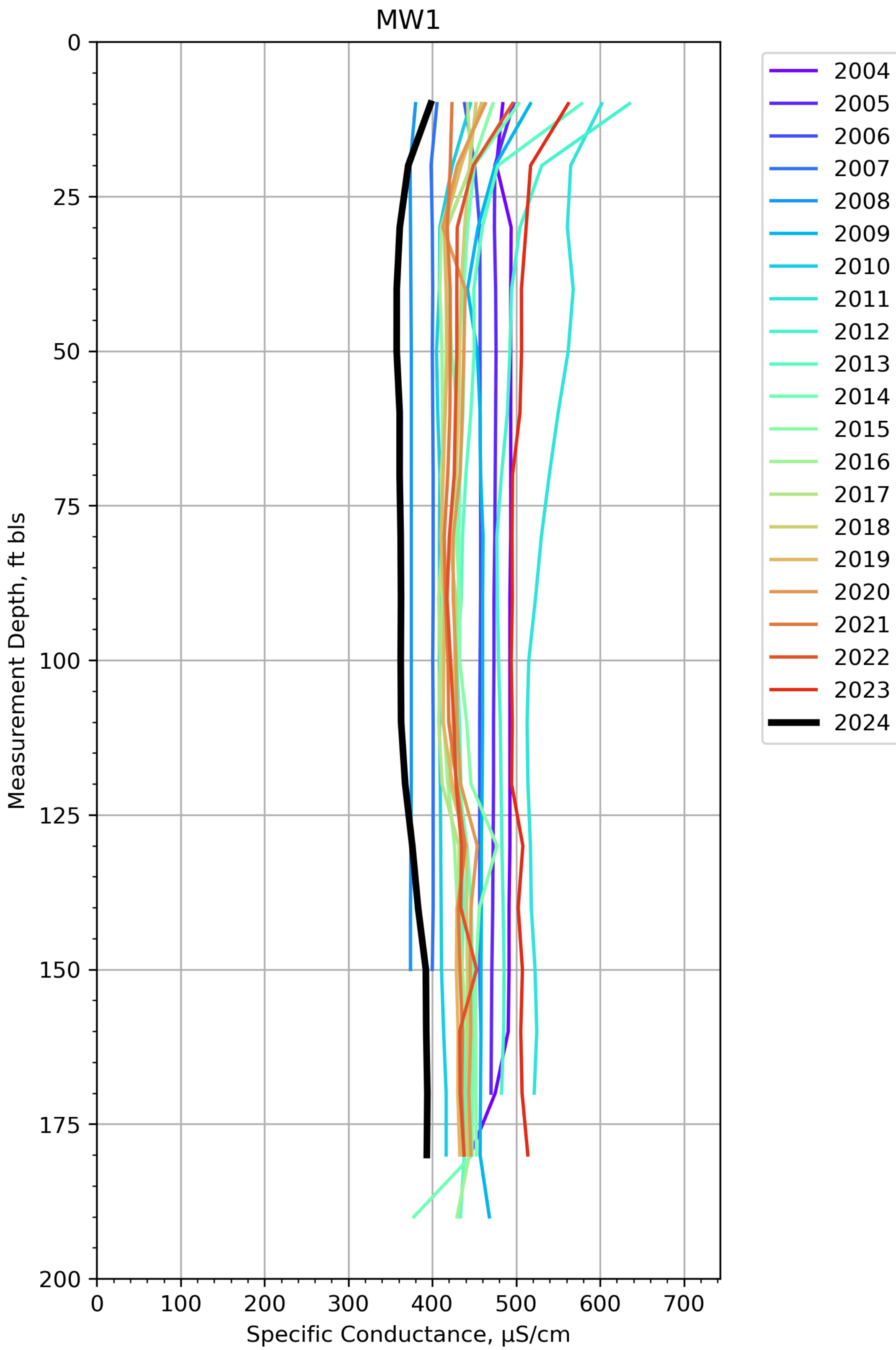
2024

APPENDIX B:
CITY OF FORT LAUDERDALE FLUID SPECIFIC CONDUCTANCE PLOTS



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2004
2005
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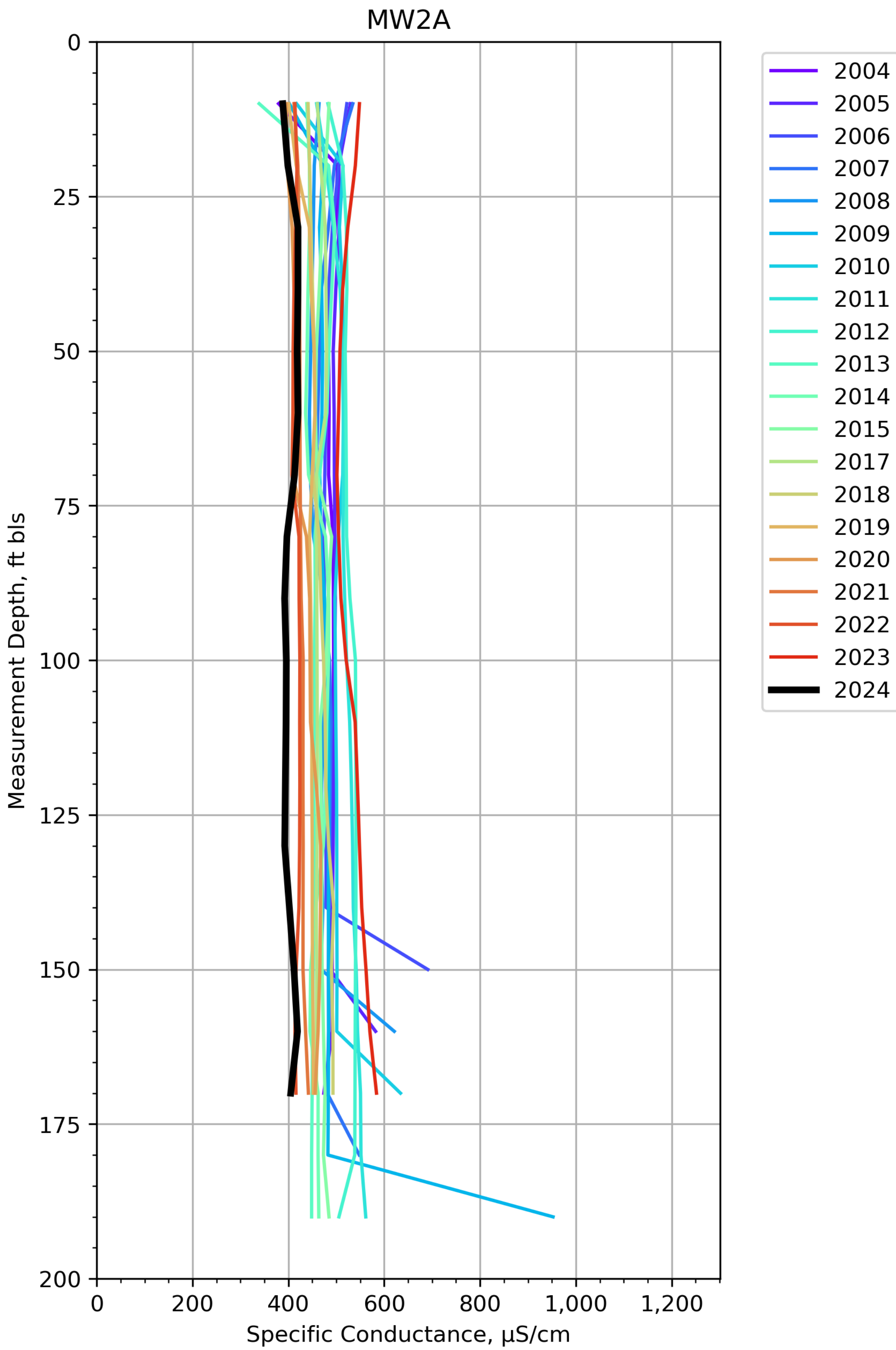
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2004
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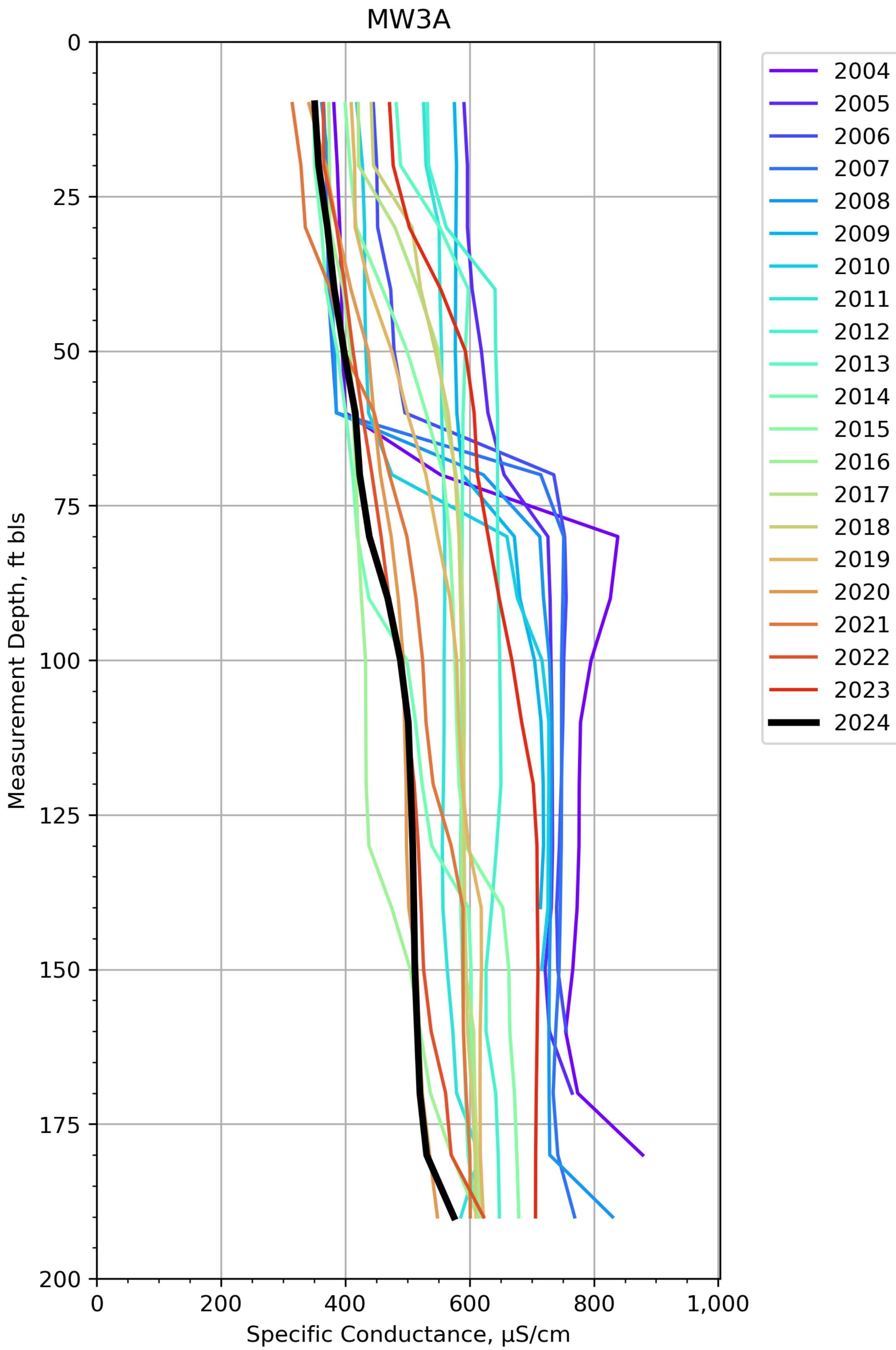

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800
1,000
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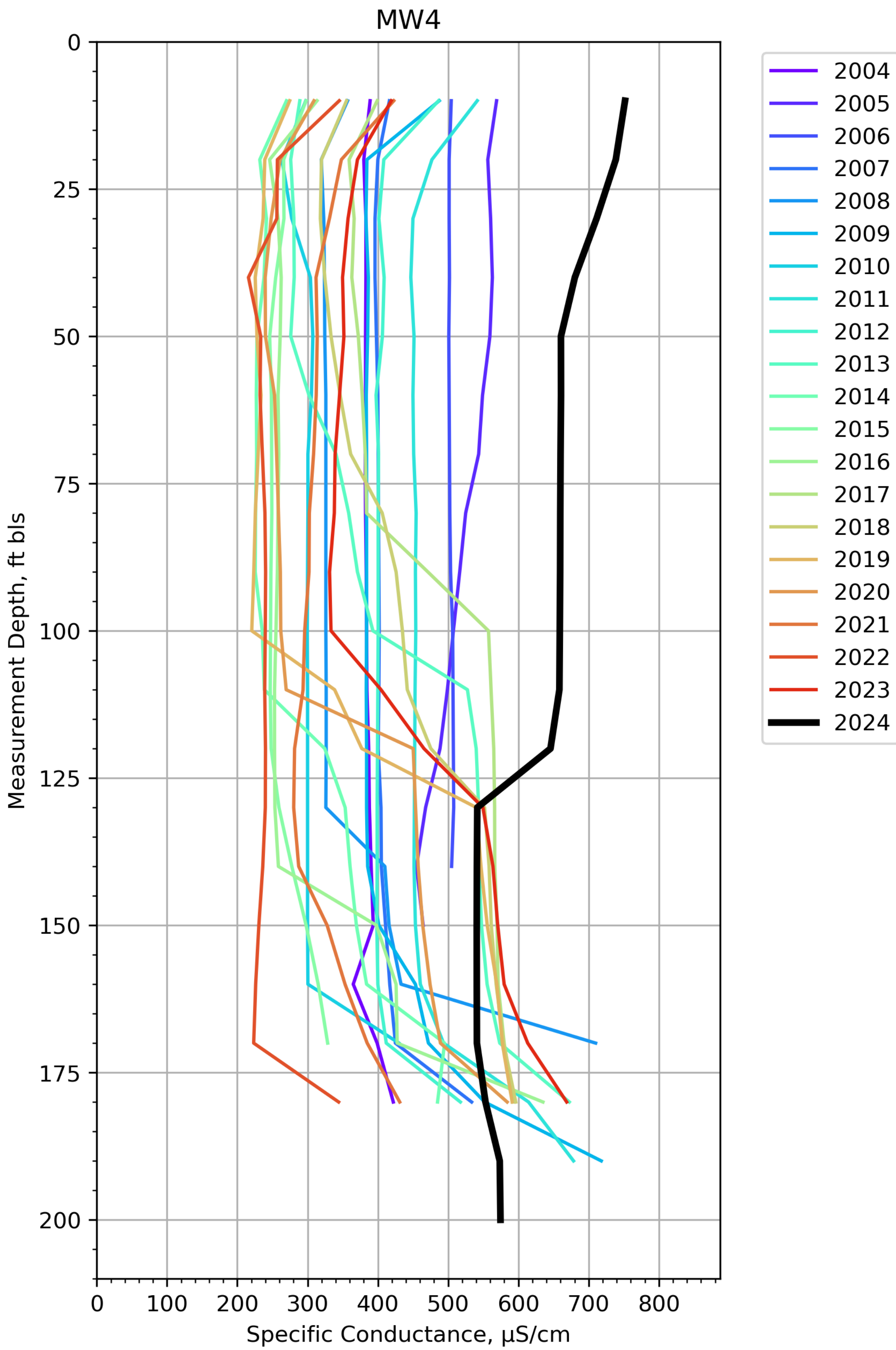
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400
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600
700
800
2004
2005
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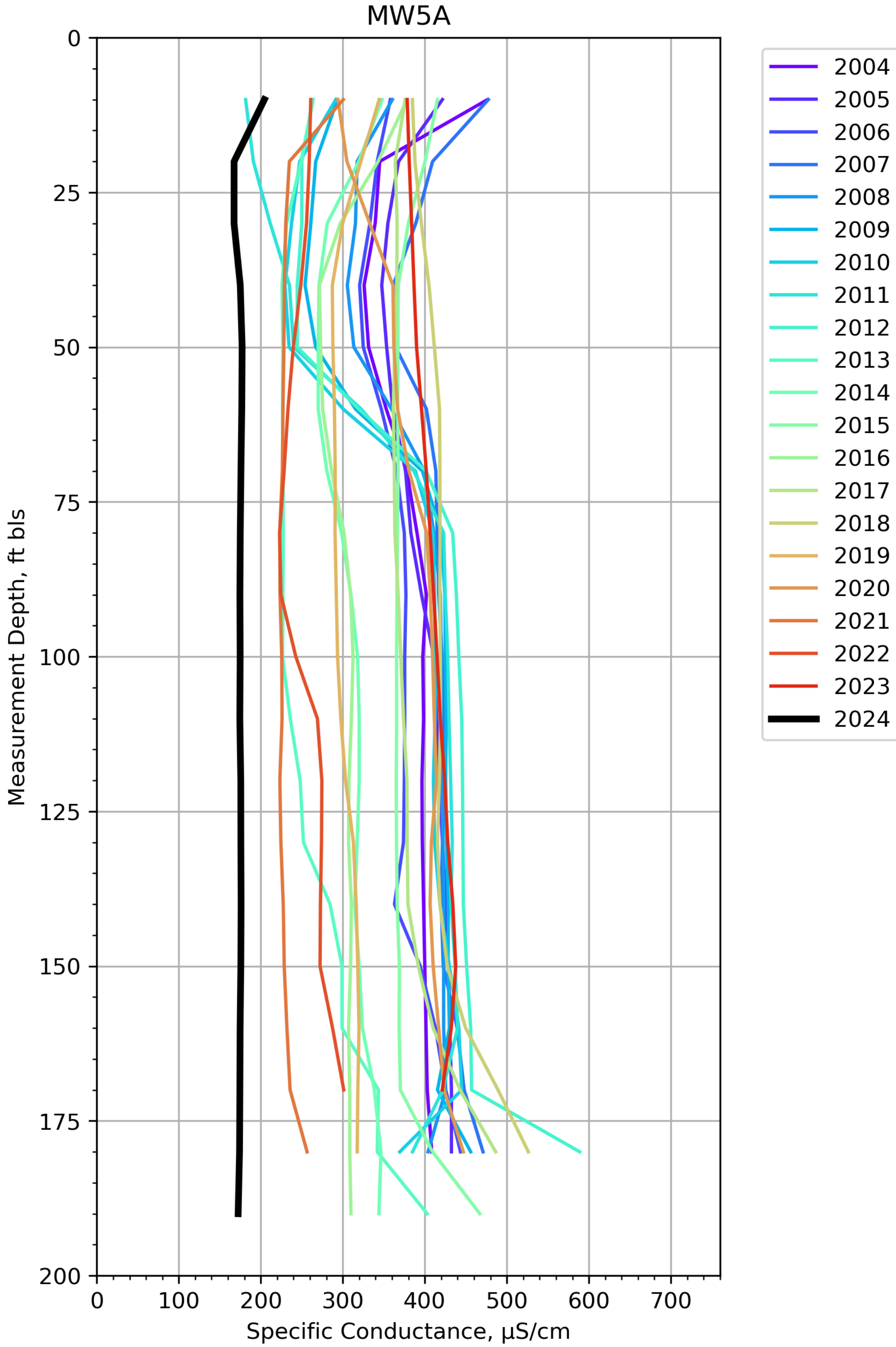
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400
500
600
700
2004
2005
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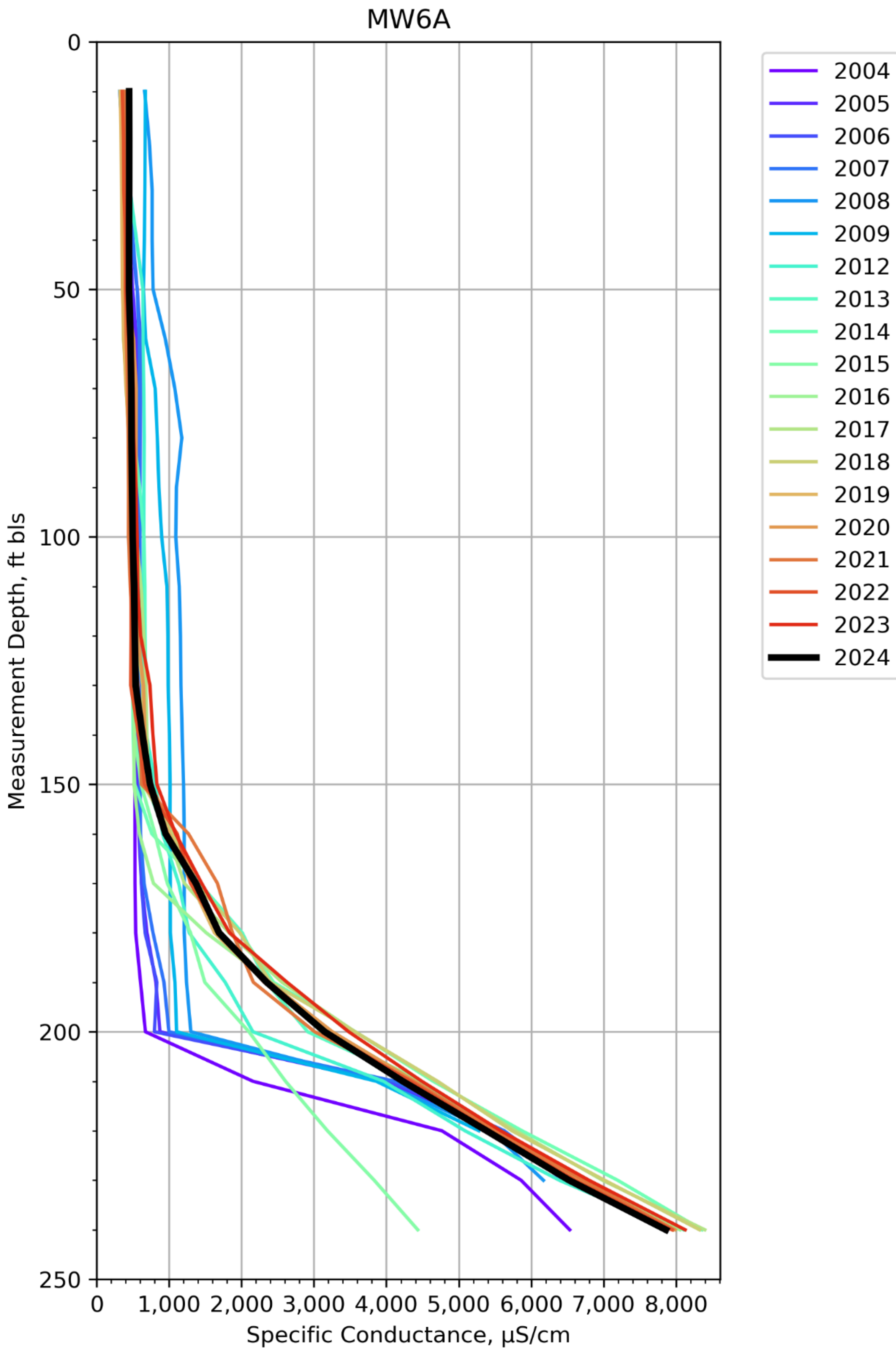
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8,000
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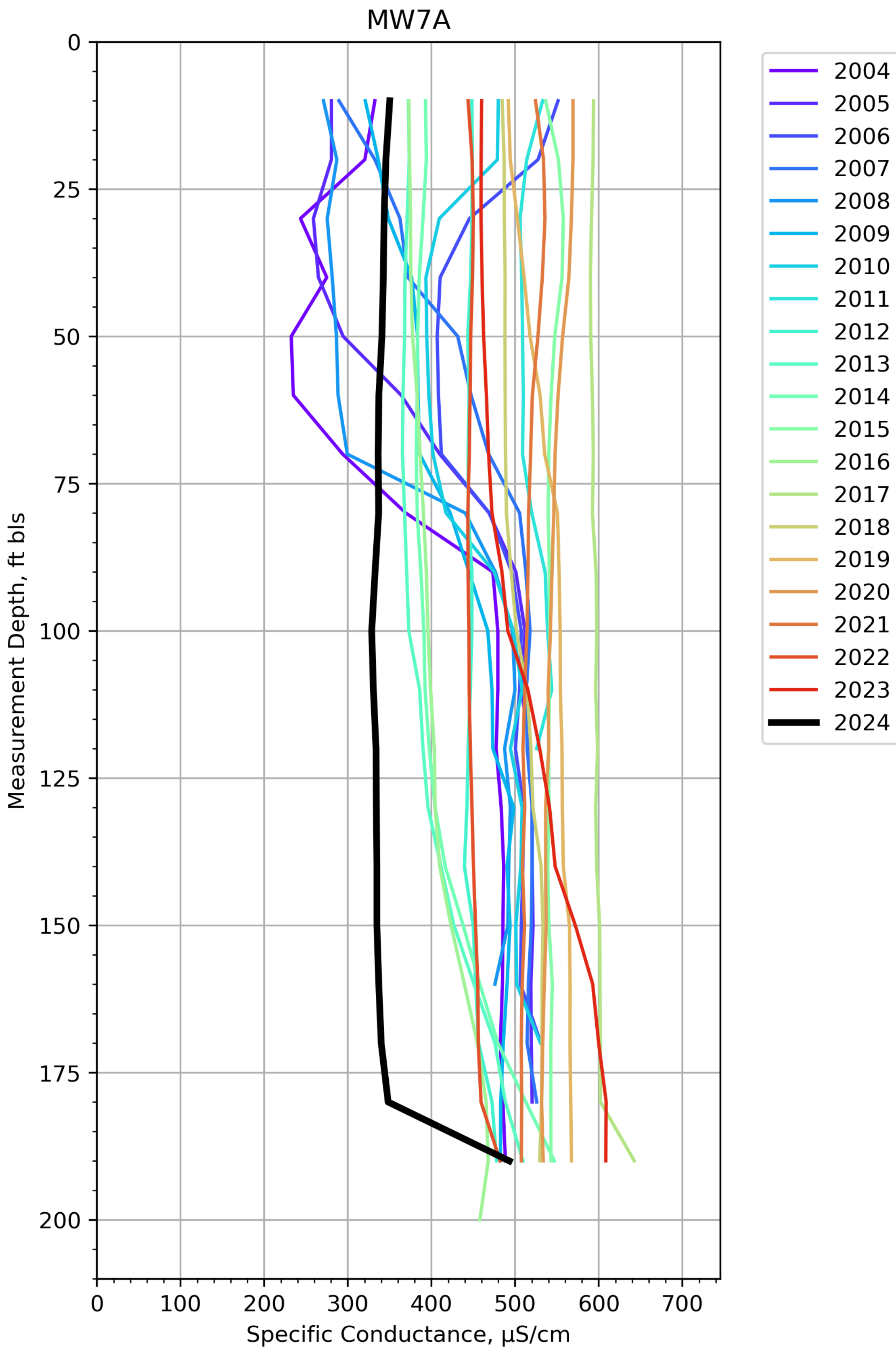

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700
Specific Conductance, µS/cm
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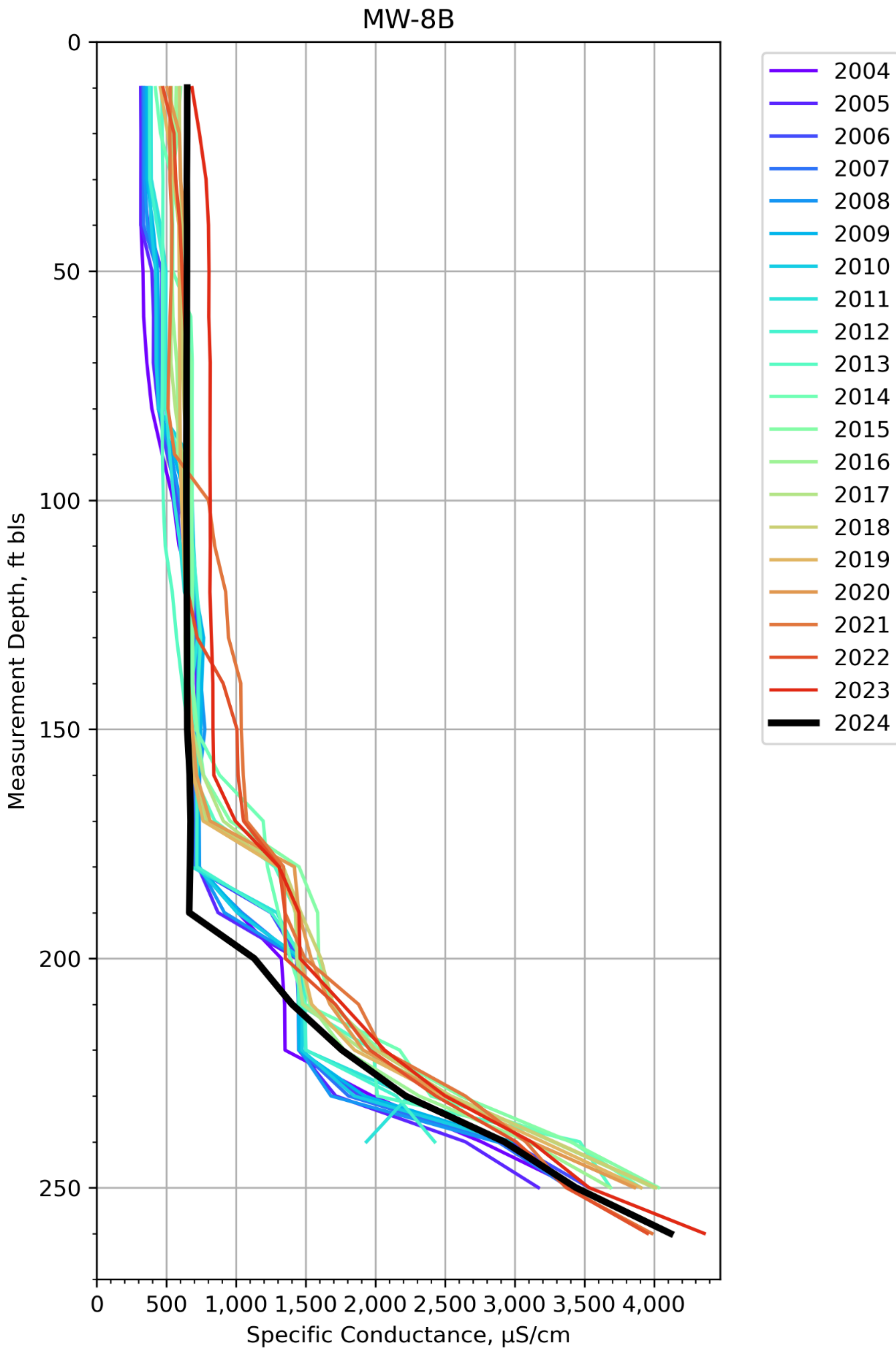

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Specific Conductance, µS/cm
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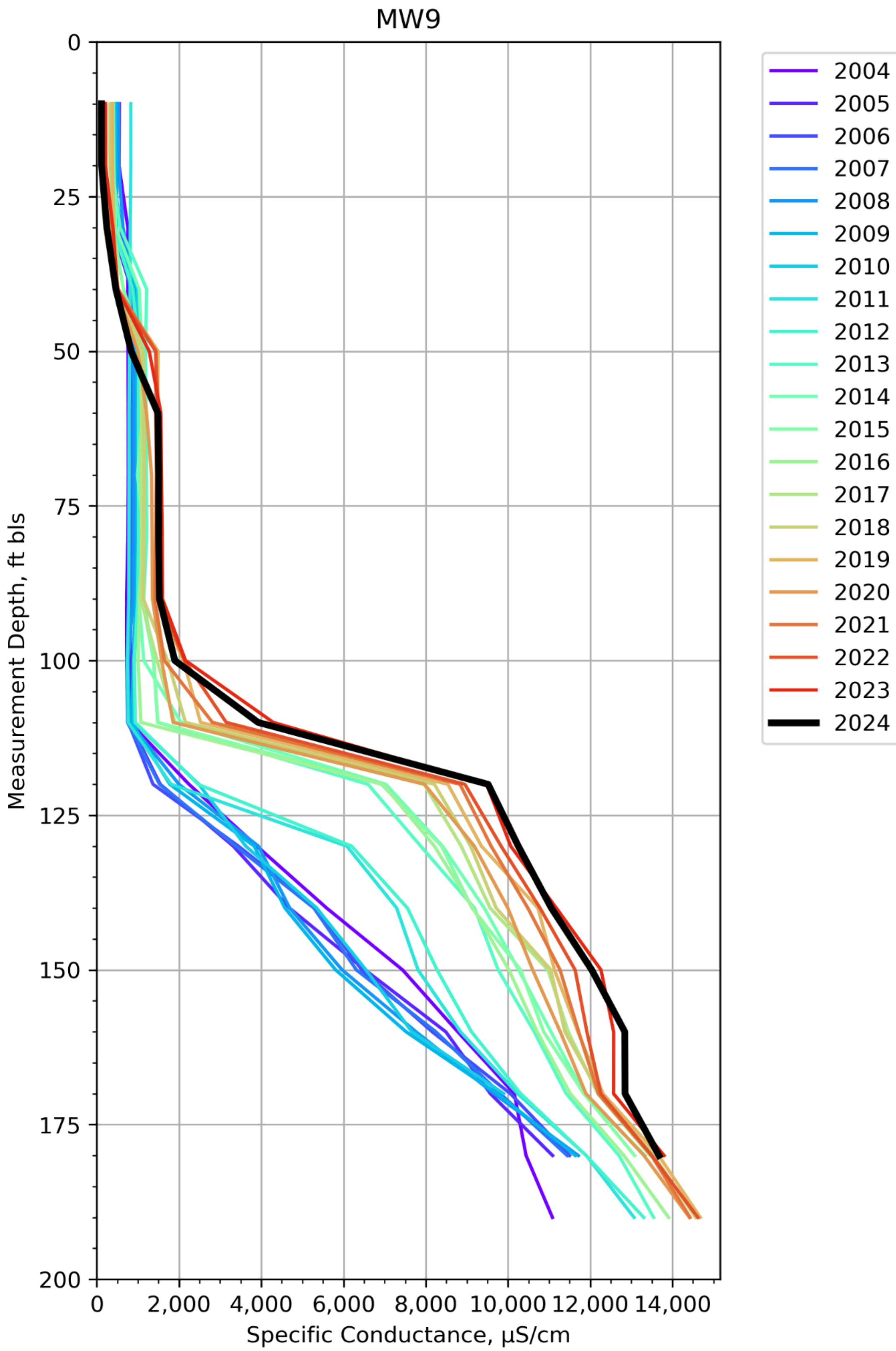
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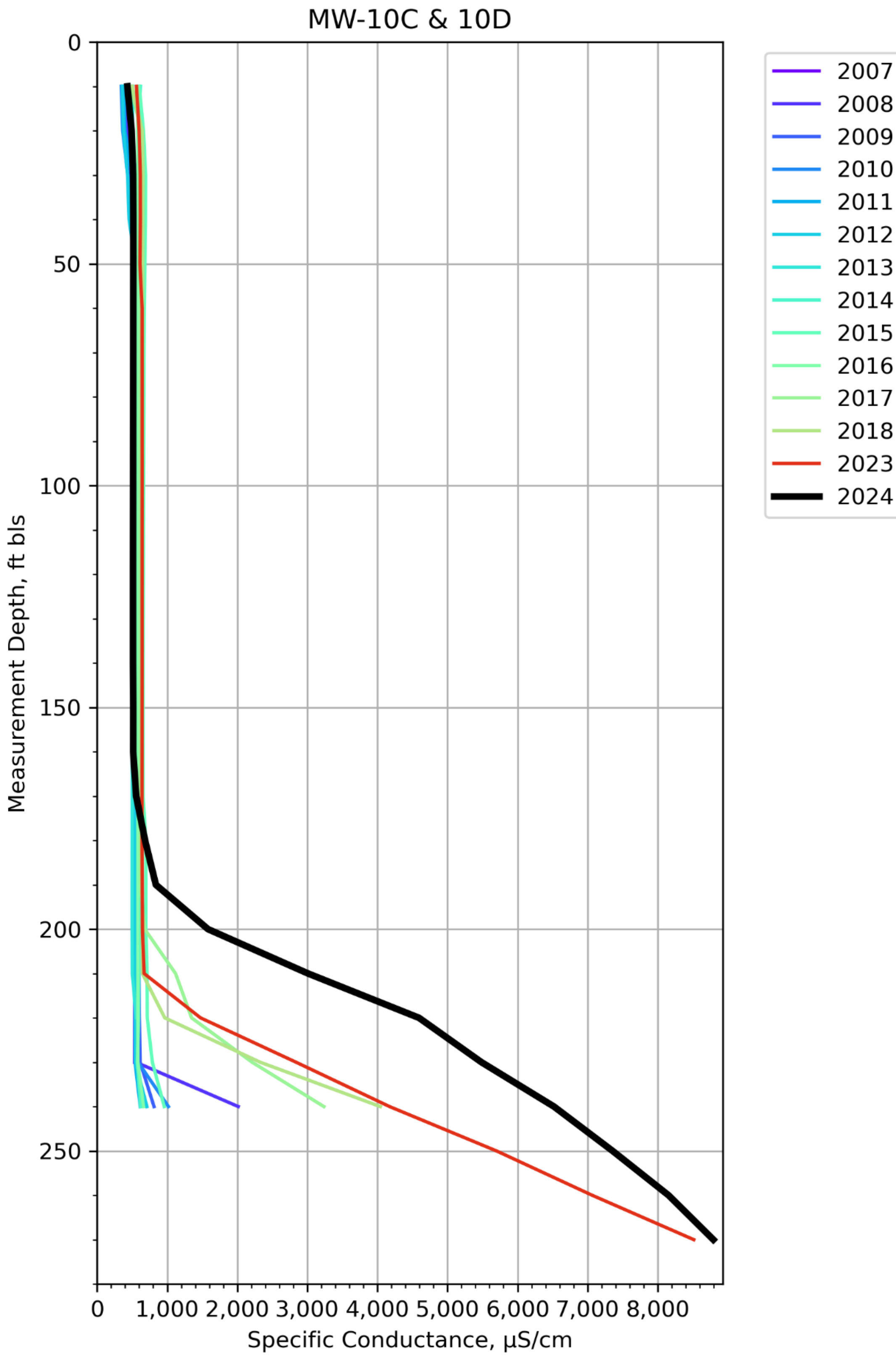
2023
2024


MW-10C & 10D
Measurement Depth, ft bls
Specific Conductance, µS/cm
0
50
100
150
200
250
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2023
2024