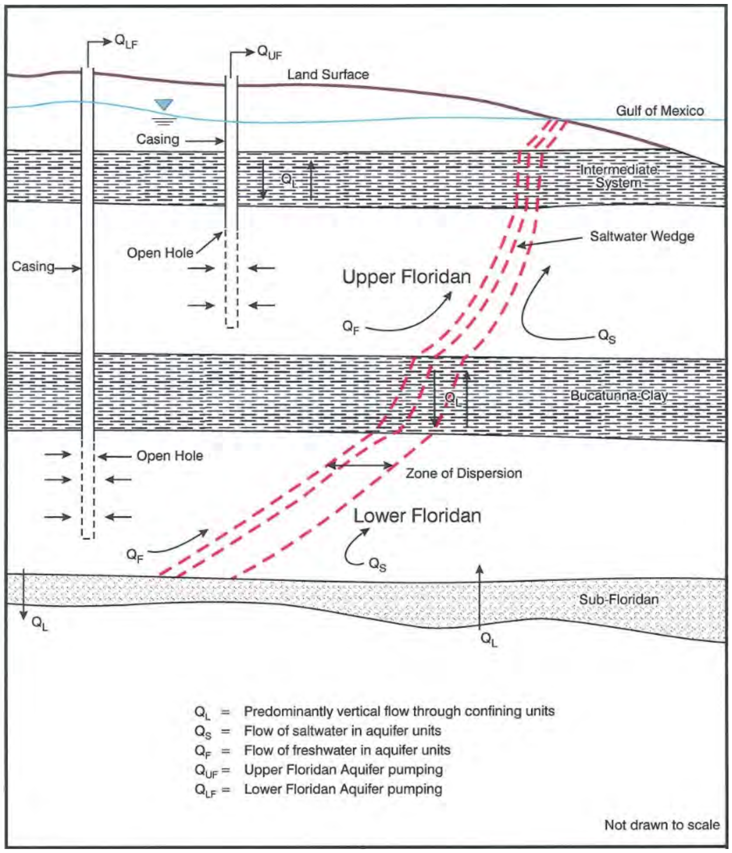
# Results of the Minimum Aquifer Levels Evaluation for the Upper Floridan Aquifer in Water Supply Planning Region II

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## List of Acronyms

| | |
|---|---|
| ADR | average daily rate |
| BEBR | Bureau of Economics and Business Research |
| Cl | chloride |
| EAFB | Eglin Air Force Base |
| FAS | Floridan Aquifer System |
| ft/yr | feet per year |
| gpm | gallons per minute |
| HGL | HydroGeoLogic, Inc |
| HHD | horizontal head difference |
| in/yr | inches per year |
| IS | intermediate system |
| MAE | mean absolute error |
| ME | mean error |
| MFL(s) | minimum flow(s) and level(s) |
| mg/L | milligrams per liter |
| mgd | million gallons per day |
| Na | sodium |
| NWFWMD | Northwest Florida Water Management District |
| Sp Cond | specific conductance |
| s.u. | standard units |
| TDS | total dissolved solids |
| THD | temporal head difference |
| UFA | Upper Floridan aquifer |
| uS/cm | microsiemens per centimeter |
| VHD | vertical head difference |
| WRA | Water Resource Assessment |
| WSA | Water Supply Assessment |

## Acknowledgements

This technical assessment was developed by the Northwest Florida Water Management District to evaluate the need for establishing minimum aquifer levels for the Upper Floridan aquifer along the coast of Water Supply Planning Region II (Santa Rosa, Okaloosa, and Walton counties) in accordance with Section 373.042, Florida Statutes. The report was prepared under the supervision and oversight of Lyle Seigler, Executive Director, and Carlos Herd, Director, Division of Resource Management.

The author would like to thank the City of Freeport, Fred Gannon Rocky Bayou State Park, and Holley-Navarre Water System, Inc. for allowing access to their properties for well construction and aquifer testing activities. The author is also grateful to other property owners who allowed access to existing wells for water quality sampling and/or water level monitoring. The author would like to recognize personnel from Tetra Tech, Cardno, Jim Stidham and Associates, Trinity Analysis and Development Corp, RMBaker LLC, Southeastern Surveying and others who performed field services and/or groundwater modeling in support of this project.

# 1.0 Introduction

The purpose of this technical evaluation report is to document the background and the methodology used to evaluate the need for establishing a minimum aquifer level to prevent significant harm to potable water supplies caused by saltwater intrusion induced by pumping from the Upper Floridan aquifer in water supply planning Region II. Region II includes Santa Rosa, Okaloosa, Walton counties (Figure 1). If necessary, the goal of any proposed minimum aquifer level(s) would be to mitigate the freshwater-saltwater interface movement inland to continue use of the Upper Floridan aquifer as a potable water source for planning Region II.

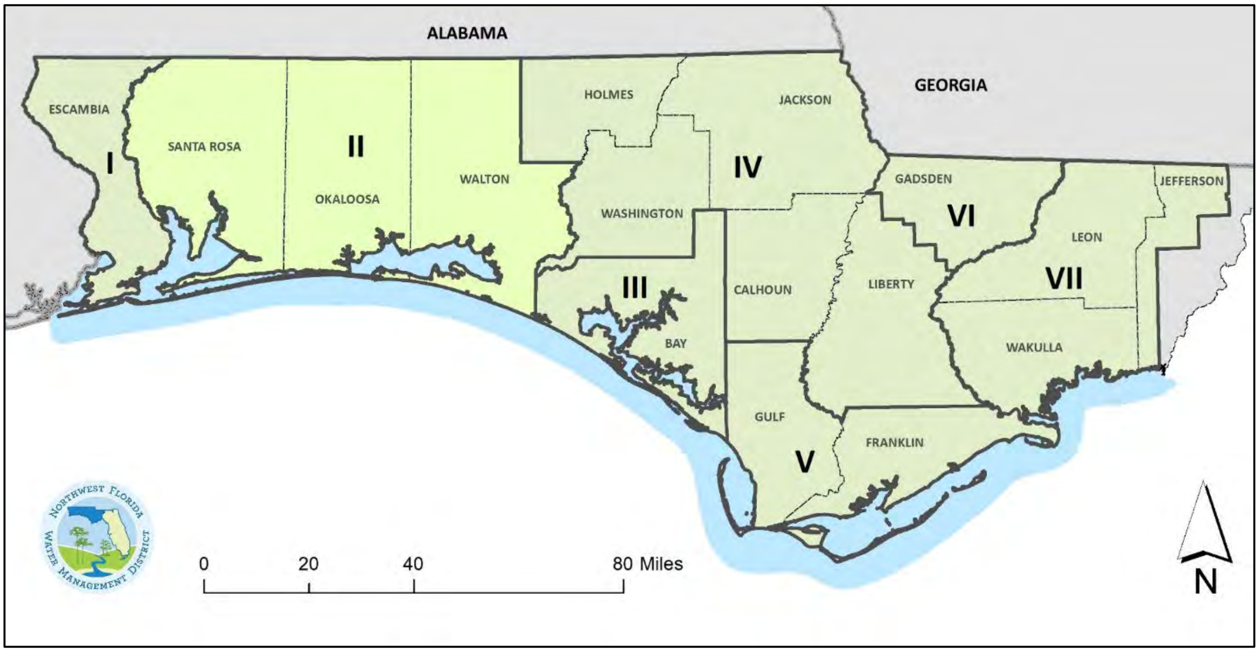


*Figure 1. Water Supply Planning Regions*

## 1.1 Statement of Issue

Current and historical withdrawals of groundwater within Region II have lowered the water levels within the Upper Floridan aquifer and created a persistent cone of depression below sea level in the aquifer's potentiometric surface. This has created the potential for saltwater intrusion into the potable water source from beneath the Gulf of Mexico and deeper parts of the Floridan aquifer threatening regional water supplies.

## 1.2 Overview

The Northwest Florida Water Management District (District) is required to establish minimum flows and minimum water levels (MFLs) for specific water bodies located within its boundaries (Section 373.042, Florida Statutes). Due to the potential for saltwater intrusion, the Upper Floridan aquifer in Region II was included on the District's MFL Priority List for evaluation to determine the need for minimum aquifer level development. Section 373.042(1), Florida Statutes, states that "The minimum water level is the level of groundwater in the aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resource or ecology of the area." The water resources and ecology of the area must be considered in relation to ten environmental values and include natural seasonal fluctuations, non-consumptive uses, and any structural alterations as described in Rule 62-40.473, Florida Administrative Code, and Section 373.0421, Florida Statutes. To determine the need for establishing a minimum aquifer level for the Upper Floridan aquifer in Region II, a resource evaluation has been performed to describe the resource of interest, identify resource concerns, develop cause and effect relationships, and determine consequences of different courses of action. This report describes the results of the resource evaluation.

## 1.3 Background

Groundwater development in Region II began in earnest in the 1930s with the construction of Eglin Air Force Base. Over the next couple of decades, development was concentrated south of Eglin Air Force Base along the coast in the vicinity of Fort Walton Beach and expanded east and west into adjacent counties (Figure 2). Pumping to meet water demands in these areas has created a large cone of depression below sea level in the potentiometric surface of the Upper Floridan aquifer which has spread across portions of Santa Rosa, Okaloosa, and Walton counties. Additional withdrawals from the Florida aquifer in communities north of Eglin Air Force Base, such as Crestview, have also contributed to this drawdown. This drawdown of the potentiometric surface is inducing saltwater intrusion.


*Figure 2. Map showing the locations of cities and Eglin Air Force Base in Region II*

Prior to the Florida Water Resources Act of 1972, most legislation dealing with water addressed surface water management and issues with drainage (NWFWMD, 1976). Issues related to water quality, water supply, and environmental degradation were also reported in the 1970's. The Governor and Legislature at the time passed the Florida Water Resources Act which created the Florida water management districts (NWFWMD, 1976). In 1982 a Regional Water Supply Development Plan was prepared to address the existing and projected water availability problems along the coastal areas of Bay, Walton, Okaloosa, Santa Rosa, and Escambia counties (NWFWMD, 1988).

After the release of the Regional Water Supply Development Plan, a Growth Management Plan was prepared for the coastal areas of Okaloosa and Walton counties. The Plan recommended the formation of a regional authority which would address water supply and waste disposal. In 1986, the Walton/Okaloosa/Santa Rosa Regional Utility Authority (RUA) was created to coordinate water supply and waste disposal among regional utilities. The RUA included Santa Rosa, Okaloosa, and Walton counties, Fort Walton Beach, Freeport, Destin, Mary Ester, and Gulf Breeze (NWFWMD, 1988).

In response to existing and anticipated water supply problems, the NWFWMD Governing Board designated the coastal area of Region II as a Water Resource Caution Area in 1989 (Figure 3). Within the designated area, new and expanded uses of the Floridan aquifer for non-potable uses are generally prohibited and water use permittees are subject to increased reporting requirements, water conservation measures, and improved water use efficiencies. They must also evaluate the feasibility of using reclaimed water.

In 1998, the first comprehensive districtwide assessment of water supply needs and sources was completed (Ryan et al., 1998). The District was divided along county lines into seven water supply planning regions based on similar water supply sources and issues (Figure 1). Region II included Santa Rosa, Okaloosa, and Walton counties. The significant cone of depression within the potentiometric surface of the Upper Floridan aquifer and alteration of potable water quality were the focus in Region II. It was determined that available water supply sources within Region II were not adequate to meet projected water demand over the 2000 – 2020 planning period. A regional water supply plan was recommended to address the water supply deficiency.

A Regional Water Supply Plan (RWSP) for Santa Rosa, Okaloosa, and Walton Counties was developed in 2000 (Bartel et al., 2000) to evaluate multiple water supply source options to address future water needs for the region. The plan proposed the reallocation of coastal Upper Floridan aquifer pumping to inland sources. Three alternative water supply sources were identified and developed, including the inland Floridan aquifer wellfield in central Walton County north of Freeport, inland Floridan aquifer wells in central Okaloosa County around Crestview, and inland sand-and-gravel aquifer wellfield in east-central Santa Rosa County between the Blackwater and Yellow rivers (Figure 3).

Public water supply facilities within and between planning regions have been interconnected to facilitate the transfer of water between utilities during periods of high demand or water supply disruption. The RWSP also encouraged conservation and reuse projects. A reassessment of the need for a RWSP in Region II was made during Water Supply Assessment updates in years 2008, 2013, and 2018. The RWSP continues to be implemented, with updates in years 2006, 2012, and 2019. Due to ongoing resource concerns, the Floridan aquifer in Region II was added to the MFL Priority List and Schedule in 2013. This technical evaluation represents the results of that assessment.

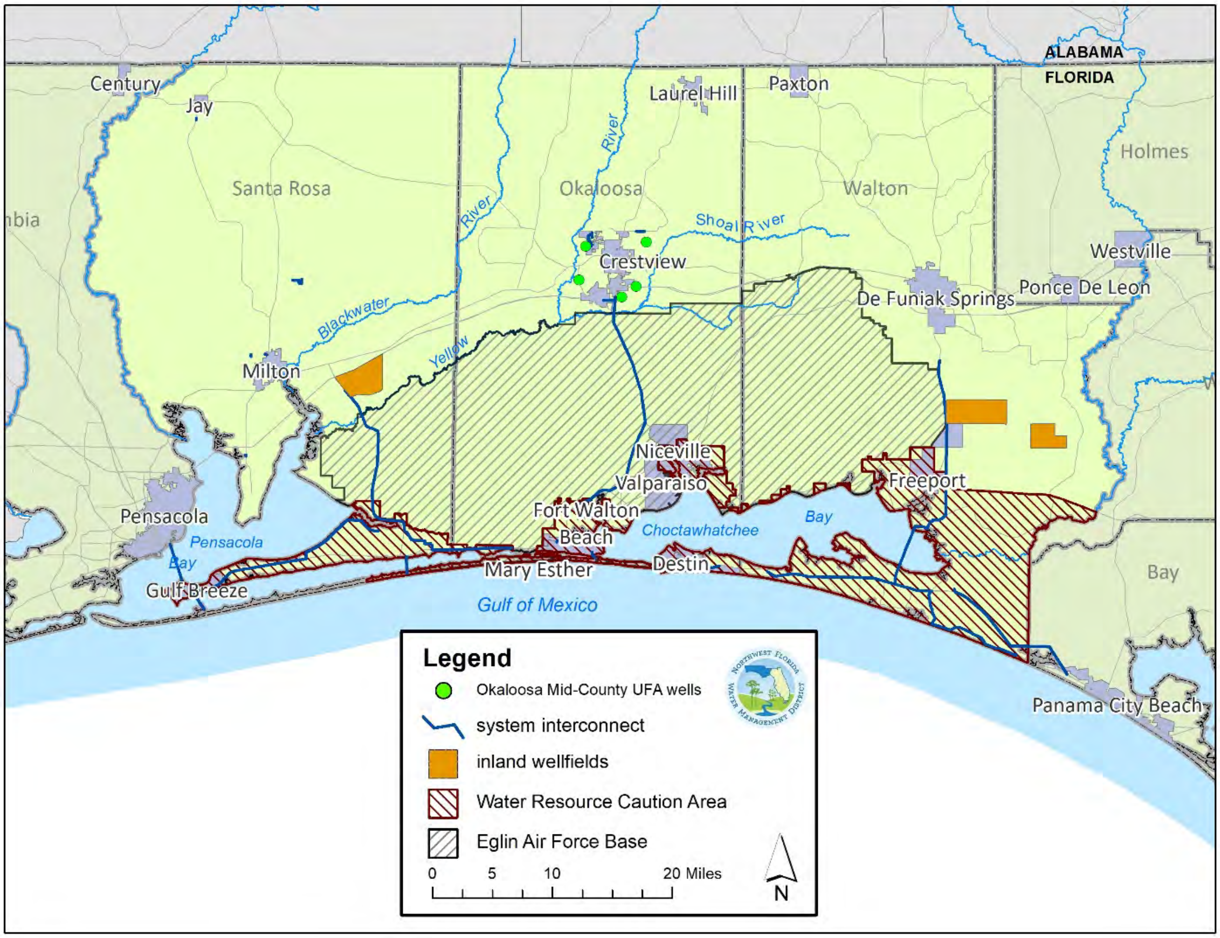


*Figure 3. Map showing Water Resource Caution Area and locations of inland alternative water supply sources*

Rule 62-40.473, Florida Administrative Code, and Section 373.0421, Florida Statutes, requires consideration be given to natural seasonal fluctuations in water flows, non-consumptive uses, structural alterations, and ten environmental values when establishing minimum flows. The ten environmental values listed in Rule 62-40.731, Florida Administrative Code, are referred to herein as Water Resource Values (WRVs). All WRVs were considered for MFL analysis but the two most relevant to the Region II Floridan Aquifer were "maintenance of freshwater storage and supply" and "water quality". These water resource values are adversely affected by saltwater intrusion into freshwater portion of the Upper Floridan aquifer. As the primary source of potable water within the region, the alteration of Upper Floridan aquifer water quality due to groundwater pumping (i.e., saltwater intrusion) represents the biggest threat. This threat has been addressed over the last twenty years through regulatory and planning programs by limiting Upper Floridan aquifer pumping along the coast and redistributing current and future pumping inland (NWFWMD, 2019). Water use and well construction permitting are examples of programs designed to help manage the resource. However, due to the continued resource concern, coastal Region II has been identified as a priority area for evaluating the need for establishing minimum aquifer levels. This technical assessment was initiated in 2015 to evaluate the need to set a minimum aquifer level for the Upper Floridan aquifer along the coast in Region II.

## 1.4 Previous Work

Due to the regional importance of the Upper Floridan aquifer for potable water supply, prior studies have been conducted to describe the resource, provide for a history of its use, and evaluate impacts that have affected its use or may limit its use in the future.

Over the decades, the Florida Geological Survey has prepared many county-wide studies of the hydrogeology and groundwater resources in the western panhandle. These include geologic and water resource investigations of Bay (Schmidt and Clark, 1980), Washington (Rupert and Means, 2009), Holmes (Vernon, 1942), Walton (Pascale, 1974; Schmidt, 1984), Okaloosa (Clark and Schmidt, 1982), Santa Rosa and Escambia (Marsh, 1966; Musgrove et al., 1965) counties. These studies described the local geology and hydrologic conditions within the counties. Summaries of historical and current hydrologic trends and the availability of geologic and water resources are also presented. These studies form the basis of the conceptual understanding needed to evaluate potential impacts to the natural systems by anthropogenic activity.

Barr, Hayes, and Kwader (1985) described the hydrology of southern Okaloosa and Walton counties with emphasis on the Upper Floridan aquifer. Historical and current water use were summarized and indicated groundwater development along the coast was inducing saltwater intrusion. At the time, the regional depression in the potentiometric surface of the Upper Floridan aquifer was as much as 160 feet below estimated predevelopment levels. An additional 20 to 30 feet of additional drawdown within the Upper Floridan aquifer was observed due to seasonal trends in water use. Withdrawals from the aquifer ranged from approximately 10.9 mgd in January 1978 to approximately 19 mgd in June 1978, during the height of the tourist season. The characteristics of the primary hydrogeologic units and their relationships to one another are presented. Water quality within the sand-and-gravel aquifer was evaluated as being satisfactory for most uses but limited in quantity. Quality and quantity of water from the Upper Floridan aquifer was evaluated as satisfactory although concentrations of saline parameters were noted as increasing towards the coast.

Richards (1993) evaluated the feasibility of developing an inland Floridan aquifer wellfield on the western side of Eglin Air Force Base in southeastern Santa Rosa County. The development of an inland wellfield in this area was the preferred alternative, at the time, to the continued use of the Upper Floridan aquifer in southern Santa Rosa County and southwest Okaloosa County. A steady-state numerical groundwater flow model was developed based on available data and calibrated to average 1990 hydrologic and pumping conditions. The model was verified by simulating an estimated pre-development potentiometric surface of the Upper Floridan aquifer. The results of the study indicated moderate permeability of the Upper Floridan aquifer in the vicinity of the proposed inland wellfield and suggested modest simulated pumping (3 to 4 mgd) may produce significant drawdown. As a result, development of the sand-and-gravel aquifer was recommended in lieu of developing the Floridan aquifer on the western side of Eglin Air Force Base.

Pratt, Milla, Clemens, and Roaza (1996) evaluated the availability of additional groundwater supplies from the Floridan aquifer in southern Walton County. The authors determined that the variability in saline water quality parameters with location and depth along the coast make the potential for further development of the Upper Floridan aquifer extremely limited. Well yields are low and exacerbate the impacts of drawdown and vertical movement of poor-quality water towards pumping wells. A hydrologic assessment was performed including numerical groundwater flow modeling. Based on the results, recommended well drilling methods were proposed to maximize the production intervals coincident with good water quality. Areas of relatively better yield and water quality were also identified.

McKinnon and Pratt (1998) compiled water quality and pumping data for select wells in Santa Rosa, Okaloosa, Walton, and Bay counties in support of proposed groundwater flow and transport modeling. Water quality data were presented for 85 wells in the vicinity of the potentiometric surface depressions centered on coastal Okaloosa and Bay counties. Plots were presented for the following six parameters where data were available: chloride, sodium, total dissolved solids, specific conductivity, sodium/chloride ratio, and pumpage. Exceedances in primary and secondary drinking water standards were highlighted. The compiled data confirmed the increase in saline water quality parameters in supply wells along coastal Region II.

In 2000, several deep Upper Floridan aquifer monitor wells were drilled and tested at three sites along the coast in Region II (Pratt, 2001). A total of four wells were geophysically logged and sampled to determine the vertical position of the freshwater-saltwater interface (if present). These were the first of nine new Upper Floridan aquifer wells to be constructed in coastal Region II as part of a saltwater intrusion monitoring network. Several supply wells owned by Eglin Air Force Base (EAFB) were also sampled as part of this study. The hydrogeologic and water quality data collected from these wells in 2000 were subsequently used to develop regional flow and transport groundwater models.

In 2000, HydroGeoLogic, Inc. (HGL) developed a regional groundwater flow model for the Upper Floridan aquifer. The model was calibrated to 1990 pumping conditions (HGL, 2000). After flow model development, HGL developed two subregional, density-dependent flow and transport models using their proprietary DSTRAM modeling code. The models were called the western domain (HGL, 2005) and eastern domain models (HGL, 2007) and collectively covered the coast from Gulf Breeze in the west to Panama City Beach in the east. The calibrated models were used to evaluate the impact of existing and projected withdrawals from the Upper Floridan aquifer on the position of the freshwater-saltwater interface. The regional groundwater flow model and subregional flow and transport models have been updated as part of the current study. Model updates are described in *Section 3.4* of this report.

## 1.4 Methodology

A work plan was initiated in 2014 which outlined the methods to assess the need for and potentially develop minimum aquifer level(s) to manage saltwater intrusion in the Upper Floridan aquifer along the coast of Region II (Cardno, 2015). These methods included data review and collection, estimation of the position of the freshwater-saltwater interface, evaluation of water level and water quality trends, the update of regional groundwater flow and transport models, and the performance of predictive simulations under various pumping scenarios.

### 1.4.1 Data Collection – Existing Wells

Data collection needs were assessed and an expanded network of existing and proposed new monitor wells within Region II was identified (Cardno, 2015). This expanded monitoring network covers areas where the Upper Floridan aquifer potentiometric surface was below sea level in the year 2000, where the estimated position of the 250 mg/L chloride iso-concentration contour is onshore, and where poor water quality on the eastern side of Choctawhatchee Bay and major pumping centers exist (Figure 4). Existing wells to be included in the network were selected from the District's regularly monitored

Groundwater Level (GWL) and Groundwater Quality (GWQ) Trend networks and Coastal Groundwater Quality (CGWQ) monitoring network. The District Trend networks monitor changes in groundwater levels and quality over time and are typically sampled every quarter. One hundred and four (104) Trend wells from Region II were included in the expanded network. The CGWQ monitoring network is a sub-network of wells from the GWQ Trend network located along the District's Gulf Coast and is sampled annually for saline water quality parameters. In Region II, six CGWQ monitoring wells were selected and as part of the expanded monitoring network the CGWQ well sampling frequency was increased to twice a year. Nineteen additional existing wells not routinely sampled were also included to increase data density within Region II where possible.

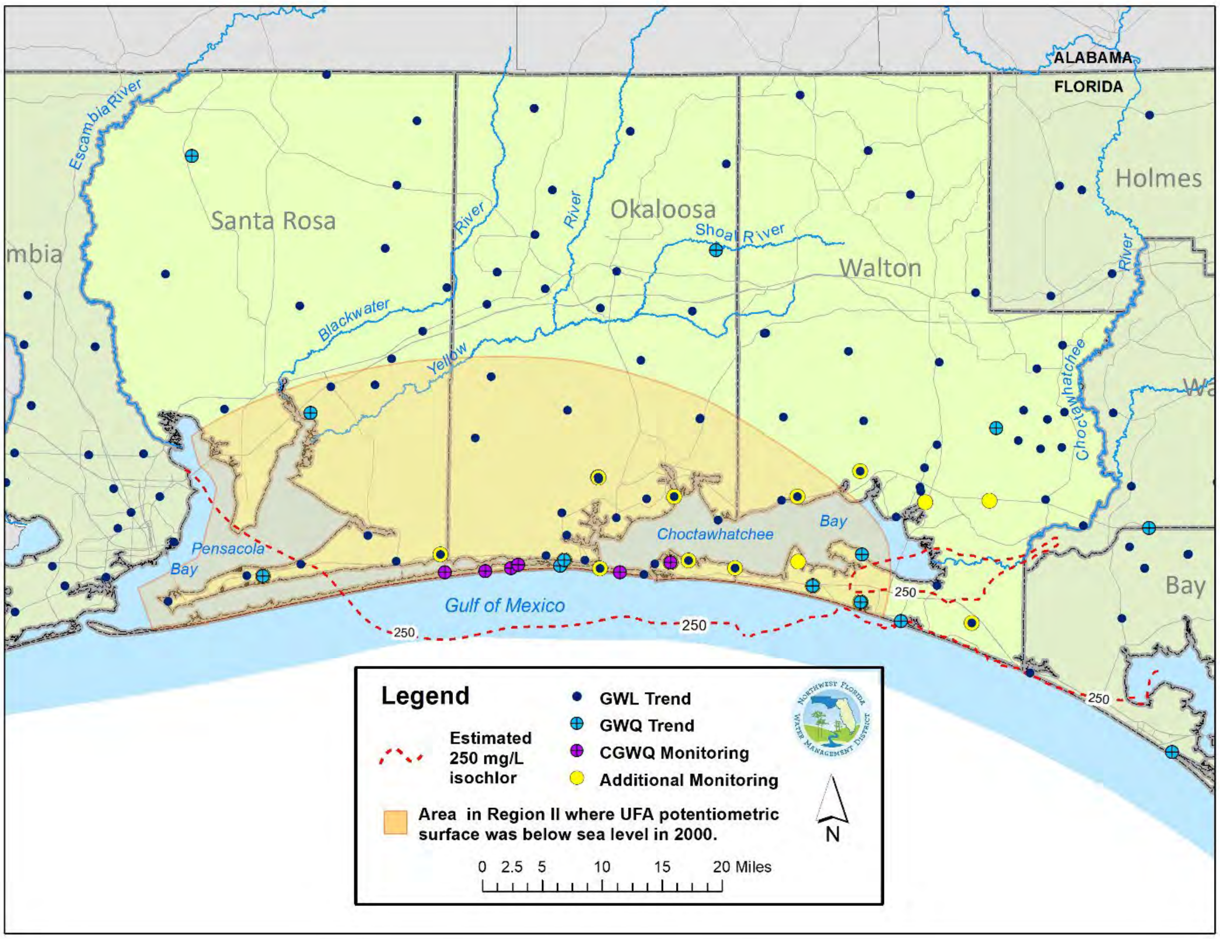


*Figure 4. Map showing expanded network of existing monitoring wells*

Existing wells were included in the expanded network based on location, data type availability and period of record length. Wells with multiple data types and long periods of record were prioritized over those with less information. Data types included groundwater water levels, water quality, pumpage, lithology, and geophysical logs. Several wells had period of records going back to the 1930s and 1940s for water levels; however, most data were collected within the last forty years. Wells with saline water quality data were of most interest and included the parameters sodium, chloride, total dissolved solids, and specific conductance. Existing wells included in the expanded monitoring network are shown in Figure 4.

In October 2015, the well casings and open hole conditions of twelve wells located in strategic monitoring locations were assessed by geophysical logging and downhole video surveys to determine if these wells were suitable for proposed enhanced monitoring. Enhanced monitoring includes pumping tests, packer tests, discrete interval water quality sampling, and continuous water level monitoring with downhole data loggers. The results of the assessment revealed four wells were ready for use, six wells needed minimal to moderate rehabilitation, and two wells needed extensive rehabilitation. Recommendations for minimal to moderate rehabilitation included one or more of the following: mechanically brushing the well casing, cleaning out borehole debris, re-development, and/or modifying the well casing at the surface to secure the wellhead. Extensive rehabilitation included those recommendations plus the installation of a casing liner and riser. Assessment results and recommendations are documented in detail by Cardno (2015b) and provided as Appendix A.

### 1.4.2 Data Collection – New Wells

Where the existing well network presented spatial data gaps, new monitor wells were installed. A total of eight new monitoring wells were installed at four sites to fill these gaps with enhanced data collection (Figure 5). The enhanced data collection at the new monitoring well sites included deep exploratory drilling with lithologic sampling, discrete-interval water quality sampling, geophysical logging, and aquifer testing.

Work at the four new well sites was performed between August 2016 and October 2017. At each new well site, the Upper Floridan aquifer was fully penetrated by an exploratory boring to collect lithologic samples. Discrete water quality sampling and geophysical logging were performed during drilling to determine when the freshwater-saltwater interface and/or base of the Upper Floridan aquifer were reached. Water samples were collected for field analysis of temperature, specific conductance and chlorides and for lab analysis of specific conductance, chlorides, and total dissolved solids (TDS). The results of sampling during drilling did not indicate a freshwater-saltwater interface or transition zone within the open boreholes. The base of the Upper Floridan aquifer was reached at each site. The highest parameter concentrations were detected in a post-development pumped sample collected from the completed deep Upper Floridan aquifer well at Site A-4. Monitor well NWFWMD A-4 is open to the aquifer between 600 to 700 feet below land surface. Specific conductance, chloride, and TDS laboratory results were 6,010 uS/cm, 789 mg/L, and 3,100 mg/L, respectively. These results indicate non-potable water is present within the lower formations of the Upper Floridan aquifer at this location near the eastern end of Choctawhatchee Bay.

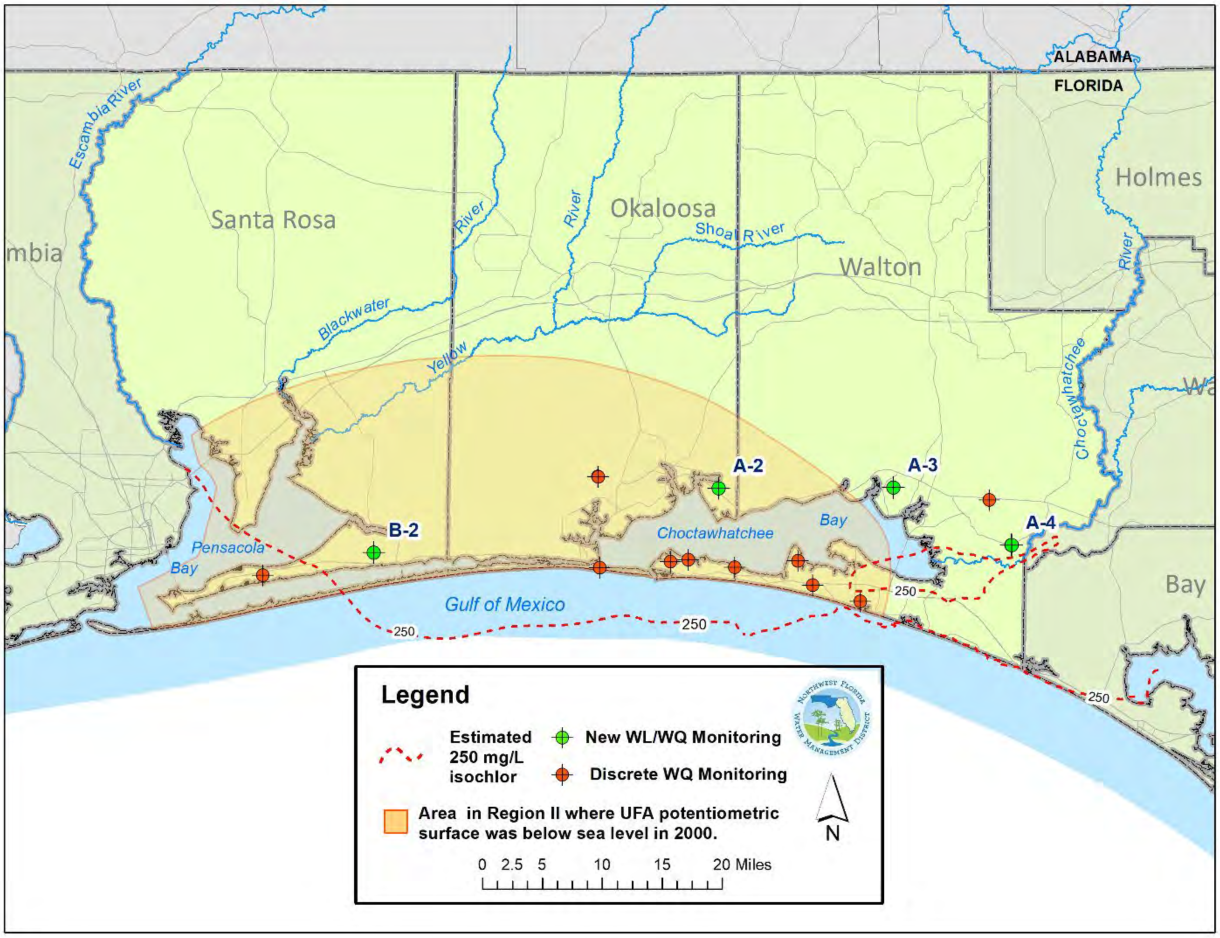


*Figure 5. Map showing locations of new and discrete monitoring sites*

After drilling, deep Floridan aquifer wells were constructed for testing and long-term, saltwater intrusion monitoring. Shallow wells were also installed to monitor water levels in the surficial aquifer for direct comparison with water levels in the Upper Floridan aquifer. The difference in water levels between the surficial and Upper Floridan aquifers indicates the degree of hydraulic connection and vertical direction of groundwater flow. Well construction specifications are summarized in Table 1.

Aquifer testing was performed to estimate hydraulic properties of the Upper Floridan aquifer. A single-well, step-drawdown test was performed on the deep Upper Floridan aquifer well at each new site. Each test was run for four hours at multiple pumping rates ranging from 292 gpm to 1,100 gpm. Specific capacity values were calculated from the test results and indicated an increasing trend in aquifer permeability from Site B-2 in the west to Site A-4 in the east (Figure 5). Calculated values from west to east were 10 gpm/ft (Site B-2), 32 gpm/ft (Site A-2), 56 gpm/ft (Site A-3) and 213 gpm/ft (Site A-4), respectively. This trend is consistent with other test results in the region which indicate Upper Floridan aquifer permeability is low where the aquifer formations are deep, significantly confined and differentiated in the west (Site B-2) and higher to the east in the vicinity of the Choctawhatchee River (Site A-4). A 72-hr multi-well aquifer test performed at Site A-4 with a production rate of 1,200 gpm further supports this trend. The transmissivity and storage coefficient of the Upper Floridan aquifer were calculated to be approximately 91,000 $ft^2$/day and $1x10^{-3}$, respectively (Cardno, 2016).

*Table 1. Summary of new well construction and testing for enhanced monitoring*

| Site# W-E | Exploratory Boring Depth (ft-bls) | NWF_ID | Well Name | Dia (in) | Total Depth (ft-bls) | Casing Depth (ft-bls) | Well Finish | Aquifer | UFA Specific Capacity (gpm/ft) |
|---|---|---|---|---|---|---|---|---|---|
| B-2 | 1,160 | 12848 | NWFWMD B-2 | 6 | 1150 | 1050 | open hole | deep UFA | 10 |
| A-2 | 900 | 12840 | NWFWMD A-2 | 6 | 885 | 740 | open hole | deep UFA | 32 |
| | | 12841 | NWFWMD A-2b | 4 | 64 | 44 | screened | surficial | - |
| A-3 | 700 | 12838 | NWFWMD A-3 | 6 | 670 | 560 | open hole | deep UFA | 56 |
| | | 12839 | NWFWMD A-3b | 4 | 40 | 30 | screened | surficial | - |
| A-4 | 720 | 12811 | NWFWMD A-4 | 6 | 700 | 600 | open hole | deep UFA | 213 |
| | | 12812 | NWFWMD A-4a | 6 | 385 | 200 | open hole | shallow UFA | - |
| | | 12813 | NWFWMD A-4b | 4 | 60 | 40 | screened | surficial | - |

Note: ft-bls = feet below land surface; gpm/ft = gallons per minute per foot of drawdown (rounded)

At the completion of well construction and testing activities, the new wells were instrumented with data loggers to continuously measure changes in water levels. The geologic, hydrologic, and water quality data collected from the new wells were used to improve the conceptual understanding of the groundwater resources in the region and update existing models. These well construction and data collection activities are documented in detail by Cardno (2016, 2017a, 2017b, and 2017c) and provided as Appendix B through E.

### 1.4.3 Data Collection – Discrete Interval Water Quality Sampling

In addition to the water sampling and logging during well construction, three separate discrete water quality sampling events were performed between October 2017 and February 2019 on the new Upper Floridan wells and a subnetwork of existing wells to evaluate the vertical position of the freshwater-saltwater interface, if present, within the borehole (Figure 5). For this evaluation, the potable water interface as defined by Florida drinking water standards was used as an analog for the freshwater-saltwater interface. The discrete interval sampling events were timed to coincide with seasonal pumping in Region II: fall 2017, summer 2018, and winter 2019. Water use varies throughout the year due to the transient nature of the population. Increased tourism in the spring and summer months results in increased demand for public water supply. The sampling was conducted in two phases. The first phase involved running geophysical logs on each well to be sampled to create a water quality profile within the borehole to 1) determine if an interface based on potable water quality standards exists and 2) identify discrete depths at which water quality samples would be collected. The types of geophysical logs collected included fluid conductivity, temperature, specific conductivity, differential temperature and conductivity, natural gamma, deep and shallow electrical resistivity, spontaneous potential, and single-point resistance. The potable water interface was identified in several of the logged wells. These sampling events are documented in detail by Jim Stidham & Assoc. Inc. (2017 and 2018) and Cardno (2019) and provided as Appendix F through H.

## 2.0 Resource Description

According to the 2018 Water Supply Assessment Update, Region II is the District's largest and fastest growing water supply planning region covering a total area of approximately 3,495 square miles. Walton County has the fastest growing population in the District and is projected to be nearly double the 2010 census population by the end of 2040 (NWFWMD, 2019). Most of the Pensacola Bay System watershed is within Region II, in addition to about half of the Choctawhatchee River and Bay watershed. Eglin Air Force Base occupies approximately 464,000 acres (725 square miles) and extends across the three counties of Region II (Figure 6). The 2015 Bureau of Economics and Business Research (BEBR) population for Region II was 415,510. The seasonally adjusted population was 469,615, reflecting a regional average seasonal rate of 13% (NWFWMD, 2019).

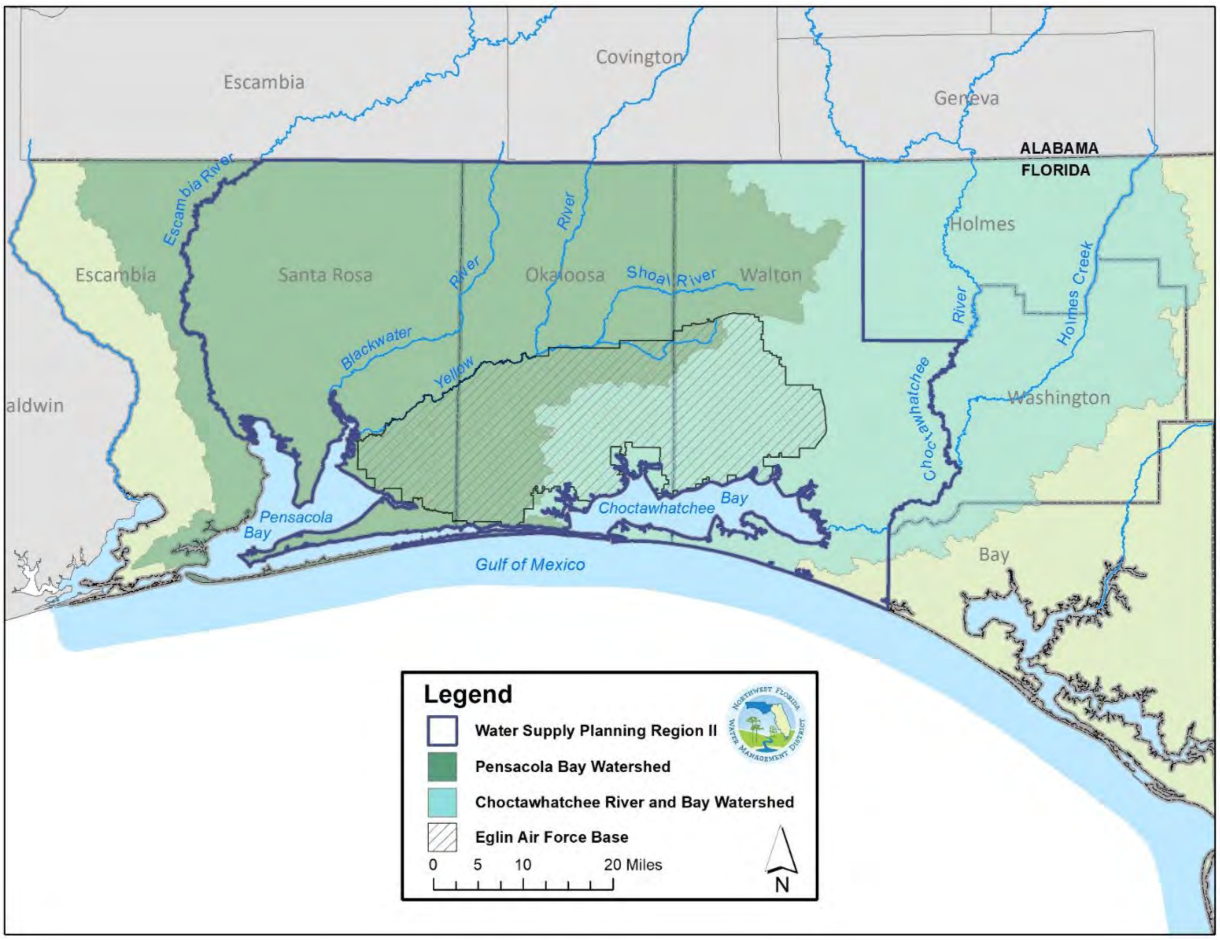


*Figure 6. Map showing regional surface watersheds*

### 2.1 Hydrogeology

The hydrogeology within Region II includes the following units from land surface: the surficial aquifer system, the intermediate system, the Floridan aquifer system and the sub-Floridan system (described below). The hydrogeologic units are differentiated based on differences in hydraulic properties that are characteristic of the unit's ability to store and transmit water. These characteristics are dependent, in part, on the rock or sediment type and areal and vertical extent of the geologic formations that make up the unit. Descriptions of the hydrogeologic systems in the following subsections are based on Pratt et al. (1996), Ryan et al. (1998) and data collected as part of this study.

### 2.1.1 Surficial Aquifer System

The surficial aquifer system includes the water-table and shallow aquifers that are comprised primarily of unconsolidated to poorly consolidated, siliciclastic sediments of late Miocene to Recent age. These sediments consist of quartz sand, gravel, silt and clay with minor amounts of organic matter and/or shell. Permeability of these sediments varies depending on the degree of sorting which ranges from good to poor resulting in high to low permeability, respectively. Sand and gravel form the more permeable zones with silt and clay forming less permeable, discontinuous layers that can create locally confining or perched water-table conditions. The thickness of these sediments varies, especially in the northern half of the region where land surface elevations are higher and high relief exists between the creeks that cut into the aquifer. The surficial aquifer system generally thickens from northeast to southwest across Region II. In northern Walton County and northeastern Okaloosa County, the surficial aquifer is thin with the permeable zones being tens of feet thick and separated by thicker sequences of clay above and below. The permeable zones thicken considerably to the south and west forming the regionally significant sand-and-gravel aquifer.

The sand-and-gravel aquifer is a major aquifer within the surficial aquifer system of the western panhandle. The aquifer is divided into hydrostratigraphic zones based on sediment permeability. The surficial zone is contiguous with land surface and includes the water table. Depth to the water table is highly variable depending on land surface elevation and proximity to surface water features ranging from less than a foot to tens of feet. In areas where the depth to water table is greater than a few feet (on average), surface water and groundwater interactions may be complex with isolated surface water features serving as points of recharge. Discharge from the surficial zone feeds many of the creeks and riparian wetlands in the region. Below the surficial zone is the low permeability zone. The low permeability zone is described as the first relatively thick sequences of laterally continuous sandy clays, clayey sands and silts that impede vertical flow from the upper to lower part of the aquifer. Beneath the low permeability zone is the main producing zone. This thick sequence of well-sorted gravels and sands stores and transmits large quantities of water to supply wells and as discharge to the larger rivers and bays in the region. Where substantially thick, the sand-and-gravel aquifer can consist of multiple low permeability and main producing zones.

Ample local rainfall infiltrates the permeable sediments of the sand-and-gravel aquifer and recharges the aquifer with large quantities of good quality water with low concentrations of dissolved solids. This characteristic makes the water suitable for commercial and industrial uses. It is also used as the primary source of potable water for public supply in Escambia and Santa Rosa counties. However, the aquifer's proximity to land surface makes it vulnerable to impacts by anthropogenic activities. Some major supply wells pumping from the sand-and-gravel aquifer have had to be abandoned due to the high cost of treating groundwater contaminated by storage tank spills and poor waste management activities.

### 2.1.2 Intermediate System

The intermediate system across the region includes several geologic formations that vary in lithology and range in age from early to late Miocene. The intermediate system dips southwest and thickens from 50 feet in the northeast of Region II to over 1,000 feet in southwest Santa Rosa County. The intermediate system primarily consists of fine-grained, clastic sediments along with clayey limestone and shells zones. The unit is thin, discontinuous, and breached by karst features (e.g., sinkholes) within the Dougherty Karst groundwater region where the Upper Floridan aquifer is semi-confined to unconfined (Figure 7). Recharge through the intermediate system to the Upper Floridan aquifer is high in this groundwater region. Large rivers and creeks such as the Choctawhatchee River and Holmes Creek cut through the intermediate system and represent major discharge features for the Upper Floridan aquifer. Where sufficiently thick, the intermediate system is a confining unit between the surficial aquifer and Upper Floridan aquifer impeding the vertical exchange of water. Within Region II, this area coincides with the Western Panhandle groundwater region (Figure 7). However, limestone formations of limited thickness and areal extent within the unit form minor aquifers (mainly along the coast in southeastern Walton County) which provide small quantities of water locally to domestic and irrigation wells. These minor intermediate aquifers extend along the coast east into Bay County and the Apalachicola Embayment groundwater region (Figure 7).

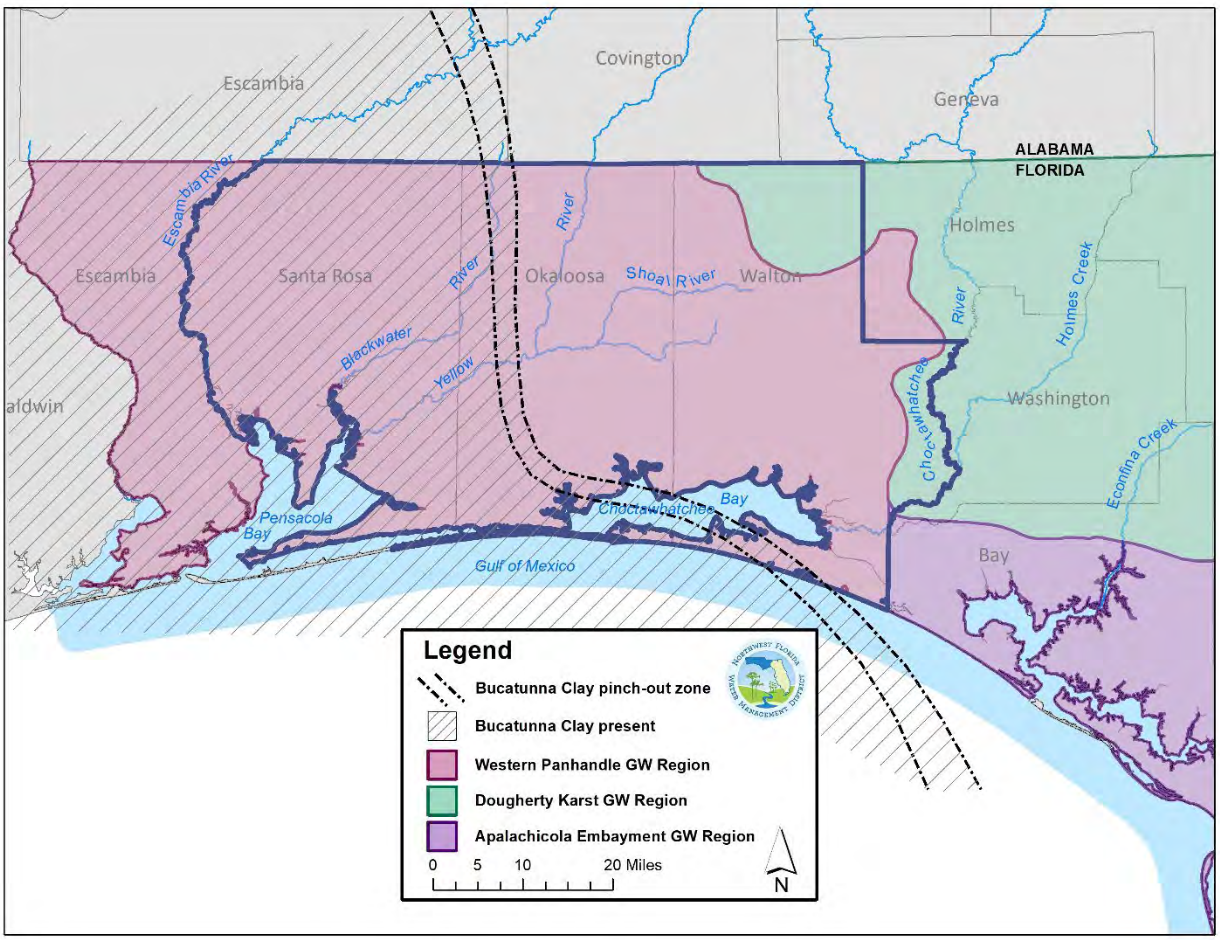


*Figure 7. Map showing the extent of the Bucatunna Clay confining unit and GW Regions*

### 2.1.3 Floridan Aquifer System

Underlying the intermediate system, the Floridan aquifer system consists of a thick sequence of consolidated carbonate formations of varying permeability and a regionally extensive clay confining unit (where present). These formations range in age from late Eocene to middle Miocene. In Region II the aquifer ranges in thickness from 50 feet to over 700 feet. Transmissivities range from 2,000 $ft^2$/day to more than 40,000 $ft^2$/day.

In the eastern half of the study area, the Floridan aquifer system is represented by the Upper Floridan aquifer and is undifferentiated. Although relative permeability varies between the geologic formations that make up the undifferentiated Upper Floridan aquifer, the formations collectively act as one hydrologic unit. The upper semi-confining intermediate system is thin to absent in some areas with sinkhole breaches interconnecting the surficial and Floridan aquifers. Aquifer transmissivities are some of the highest in the District; particularly in the area east of the Choctawhatchee River in Washington County. This area is part of the Dougherty Karst groundwater region with distinctive karst features such as cover-collapse sinkhole lakes and springs (Figure 7). Moving west into Region II, the Upper Floridan aquifer becomes more confined by the intermediate system and transmissivities are lower.

In the western half of the study area, the Floridan aquifer system is differentiated into three hydrogeologic units, the Upper Floridan aquifer, the Bucatunna Clay confining unit, and the Lower Floridan aquifer. In this area the Upper Floridan aquifer is well confined from above by the intermediate system and serves as a major potable water source. The Upper Floridan aquifer consists of limestone formations ranging in age from Oligocene to middle Miocene. The Bucatunna Clay is a regional significant confining unit that separates the Upper and Lower Floridan aquifers. The Bucatunna Clay formation is early Oligocene and extends into the western Florida panhandle from Alabama. The unit thins to a pinch-out across a zone oriented north-south through western Okaloosa County then turning east into Walton County along the coast (Figure 7). The unit consists of a stiff grey clay to greyish-brown, sandy clay. Where present, the low permeability of the Bucatunna Clay restricts the vertical movement of water between the Upper and Lower Floridan aquifers. The Lower Floridan aquifer underlies the Bucatunna Clay and is comprised of limestone formations of late Ecocene age. The depth to the top of the Lower Floridan aquifer below land surface in Region II ranges from approximately 200 to 2,000 feet.

### 2.1.4 Sub-Floridan System

The base of the Floridan aquifer system in coastal Region II is characterized by less permeable, glauconitic sand, limestones and sandy shales of middle Eocene age. The permeability of the formations that make up the Sub-Floridan system are orders of magnitude less than that of the overlying Floridan aquifer system. The origin of the silicious clastic material which make up these sedimentary rocks are primarily terrigenous, or land based. The sediments are less reactive to groundwater and are less prone to develop secondary porosity which can enhance formation permeability. This contrasts with the marine-based carbonate formation of the Floridan aquifer system. The uppermost geologic formation in the Sub-Floridan system is the Lisbon Formation and the formation top serves as the base of the active groundwater flow system for this study. Groundwater within the Lisbon Formation along the coast of Region II is saline.

### 2.1.5 Groundwater Availability

Most of Region II is in the Western Panhandle groundwater region (Figure 7), which is primarily characterized by a thick, productive surficial aquifer (i.e., sand-and-gravel aquifer), an effective upper confining unit (part of the intermediate system) and deeply buried Upper Floridan aquifer (Pratt et al., 1996). Groundwater availability from the Upper Floridan aquifer is generally moderate to low in the Western Panhandle groundwater region within Region II. Several factors that influence groundwater availability include 1) mineralized water within the Upper Floridan aquifer where the aquifer is deep and well confined in Escambia and western Santa Rosa County, 2) the higher cost of drilling deep Upper Floridan aquifer wells to potable water in Santa Rosa County when developing large quantities of good quality water from the sand-and-gravel aquifer is much less expensive, and 3) excessive withdrawals along the coast that have caused mineralized/saline water to invade the freshwater portion of the aquifer. Based on Pratt et al. (1996), a small portion of the eastern-northeastern boundary of Region II is within the Dougherty Karst groundwater region (Figure 7). As the name implies, the region is impacted by widespread karst processes which have developed features such as sinkhole, swallets, and springs. The upper confining unit is thin to absent in the north, overlying a thin Upper Floridan aquifer. Both units thicken to the south. Groundwater availability from the Upper Floridan aquifer is generally moderate to high and of good quality in the Dougherty Karst groundwater region.

## 2.2 Water Quality

Groundwater quality in Region II is variable and reflective of the source water and aquifer. As water moves through the aquifers it reacts with the surrounding rock and sediment picking up organic and inorganic constituents that reflect the subsurface geology (Fetter, 1988). As described above, the surficial aquifer/sand-and-gravel aquifer consists primarily of unconsolidated sand, silt and clay with varying amounts of gravel and shell (Pratt et al., 1996). These sediments are mainly composed of silicate minerals that are resistant to dissolution by slightly acidic rainwater which recharges the aquifer locally. With an average groundwater pH value of approximately 5.5, the surficial sediments lack significant carbonate minerals that tend to dissolve in acidic environments and buffer the groundwater (Ryan et al., 1998). Specific conductance values average 40 uS/cm and total dissolved solids are typically less than 100 mg/L making surficial groundwater desirable for commercial and industrial uses. However, this "softer" water also leaches iron-rich minerals increasing dissolved iron concentrations which may exceed secondary drink water standards. Also, the proximity of the surficial aquifer to land surface makes it vulnerable to potential impacts from anthropogenic activities (Ryan et al., 1998).

Water quality from the Upper Floridan aquifer is much more reflective of the carbonate minerology that dominates the rock formations. Slightly acidic recharge water that reaches this aquifer reacts with and dissolves the limestone resulting in groundwater with more neutral pH (Barr, et al., 1985). However, the increased dissolution of rock material also results in water with much higher specific conductance values and TDS concentrations. The dissolution of the limestone can create secondary porosity significantly increasing the permeability of the rock formations. Water quality within the Upper Floridan aquifer is highly variable depending on several factors including depth within the aquifer, degree of overlying and underlying confinement, and proximity to recharge (inland) and discharge (coastal) areas. Water quality within the aquifer ranges from fresh (< 1000 mg/L TDS) to brackish (1,000 – 10,000 mg/L TDS) to saline (>10,000 TDS) (Fetter, 1988).

Groundwater pumping can alter the natural flow of groundwater and move poor quality water (e.g., saline or highly mineralized) into fresher parts of the aquifer. That movement may be horizontal from offshore areas or vertical from deeper parts of the aquifer. Up-coning is the upward vertical movement of groundwater directly below a pumping well from deeper parts the aquifer. If saltwater is present below a pumping well, up-coning may cause the more saline water to move into the fresher zone and degrade water quality.

## 2.3 Water Use

Groundwater is the principal source of water supply for virtually all uses in Region II. In Okaloosa and Walton counties most groundwater is obtained from the Upper Floridan aquifer. In Santa Rosa County, major Upper Floridan aquifer use has historically been limited to the southeastern coastal and east-central, mid-county areas west of where the Bucatunna Clay confining unit pinches out (Figure 8). In this area the Upper Floridan aquifer is differentiated into thinner upper and lower units and dips deeper below land surface. Further west in Santa Rosa County, water in the Upper Floridan aquifer becomes highly mineralized and is not suitable as a potable source. The Lower Floridan aquifer in Santa Rosa and Escambia counties is used to dispose of treated industrial wastewater due to its depth and confinement by the Bucatunna Clay formation (Andrews, 1994). In these counties, groundwater from the sand-and-gravel aquifer is the primary potable water source as large quantities of high-quality water can be obtained at less expense from shallower wells. A small amount of surface water is withdrawn within the region for non-potable uses. Table 2 provides a summary of estimated water withdrawals by source for the year 2015 (WSA, 2018).

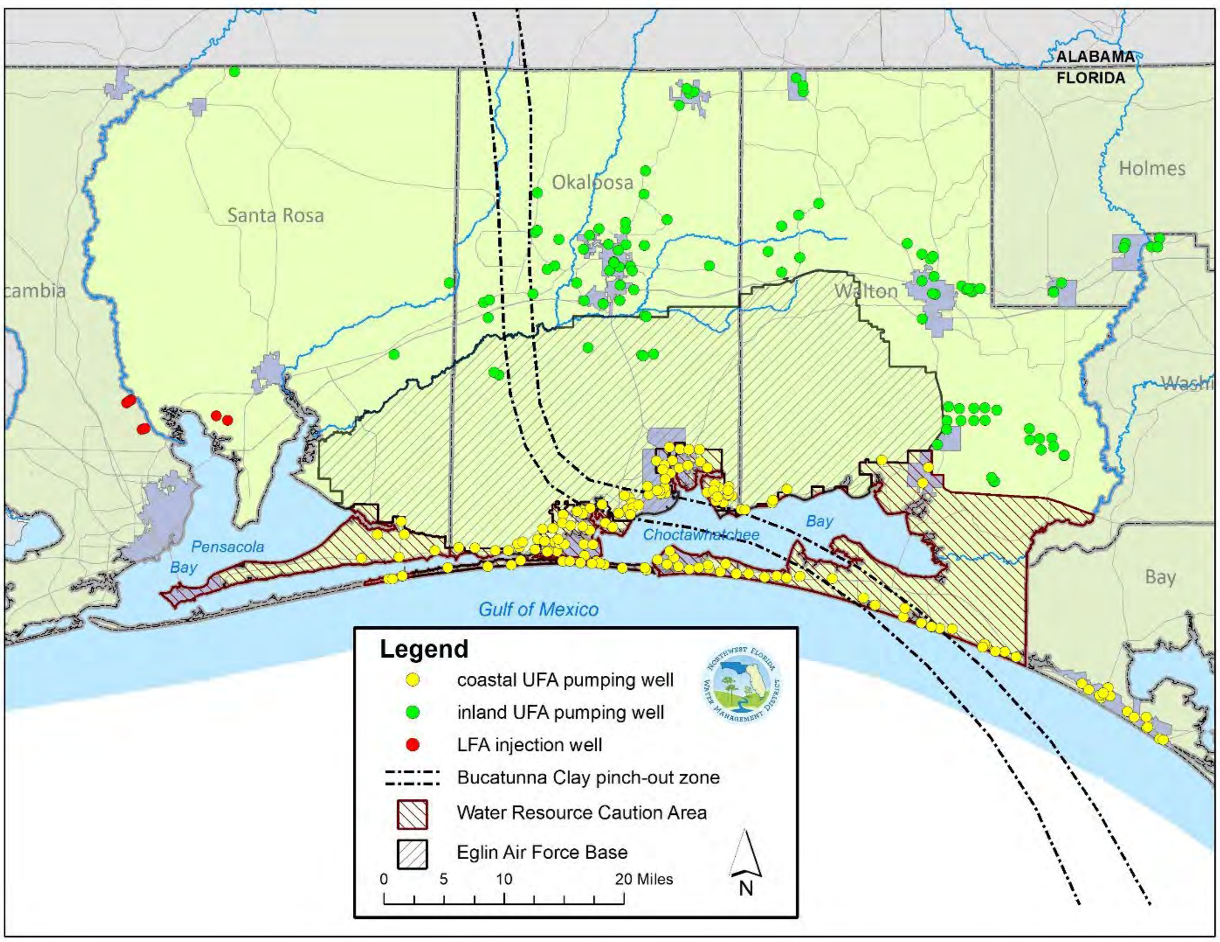


*Figure 8. Major Upper Floridan aquifer pumping and Lower Floridan aquifer injection well locations*

*Table 2. NWFWMD 2015 Water Withdrawals by Source (mgd) (Hollister et al. ,2018)*

| Planning Region | County | Groundwater Aquifer Systems | | | | TOTAL Groundwater | TOTAL Surface Water |
|---|---|---|---|---|---|---|---|
| | | Coastal Floridan | Inland Floridan | sand-and-gravel | minor aquifers | | |
| II | Okaloosa | 13.006 | 11.203 | 2.690 | - | 26.899 | 1.336 |
| | Santa Rosa | 1.398 | 0.461 | 19.706 | - | 21.565 | 0.128 |
| | Walton | 1.572 | 13.758 | 1.502 | 0.635 | 17.467 | 2.339 |
| | **Region Totals** | **15.976** | **25.422** | **23.898** | **0.635** | **65.931** | **3.803** |

For regional water supply assessment and planning purposes, Region II wells permitted to withdraw water from the Upper Floridan aquifer have been divided into two groups: coastal Floridan aquifer wells and inland Floridan aquifer wells (Figure 8). Upper Floridan aquifer supply wells south of and on the south side of Eglin Air Force base and wells south of Hwy 20 in Walton County are included in the coastal wells group. The coastal wells are within the Water Use Caution Area. The Upper Floridan aquifer supply wells north of these areas are included in the inland wells group. In addition, there are seven injection wells associated with long-term, industrial waste disposal into the Lower Floridan aquifer located along the western side of Region II in Santa Rosa and Escambia counties (Figure 8, red dots). The Bucatunna Clay in this area is approximately 200 feet thick and forms a competent and effective confining unit between the Upper and Lower Floridan aquifers (Pratt et al., 1996).

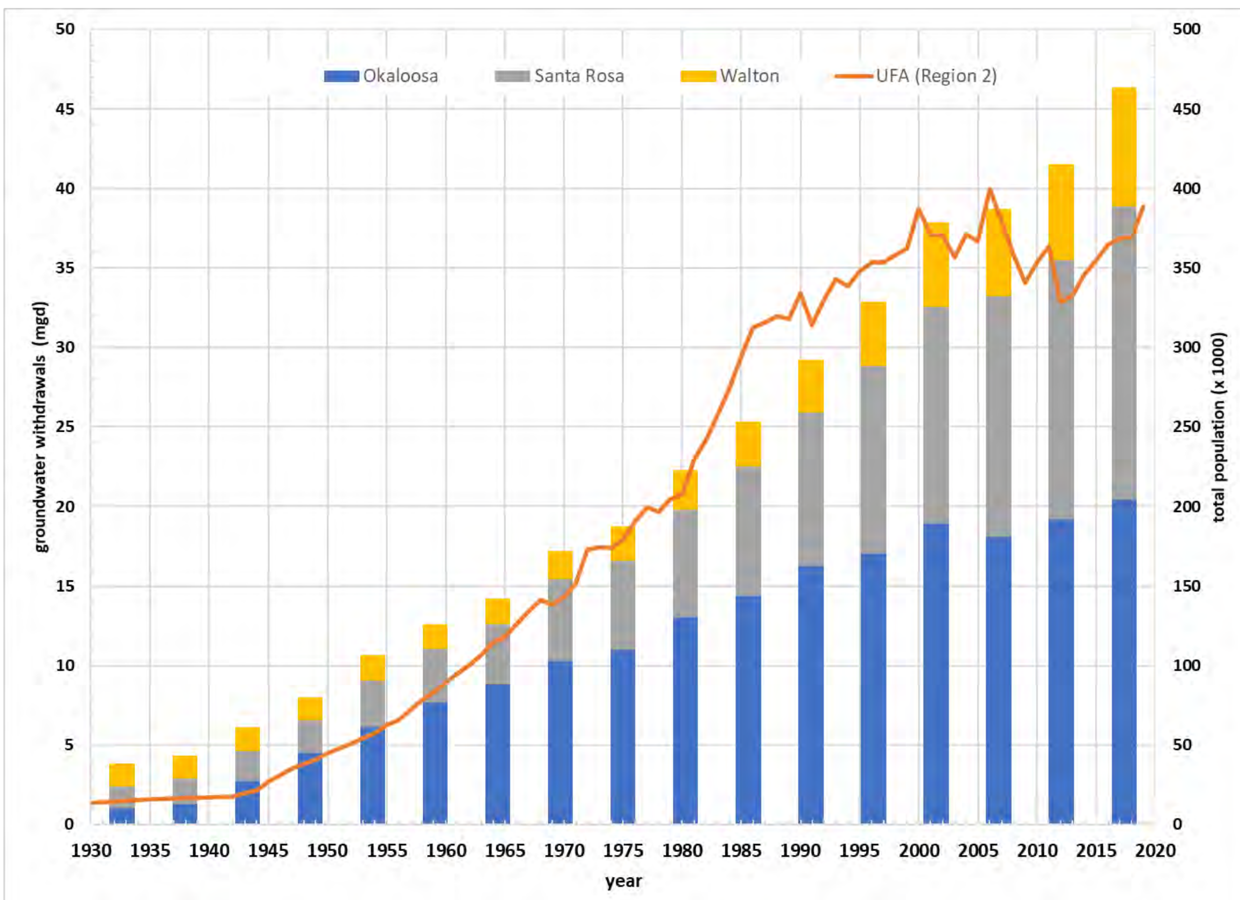


*Figure 9. Estimated Upper Floridan aquifer public supply withdrawals and population in Region II between 1930 and 2020*

Figure 9 shows the changes in estimated public supply pumping from the Upper Floridan aquifer compared to changes in population for Region II between 1930 and 2020. Historically, groundwater development and population increases have coincided spatially along the coast contributing to the current threats to groundwater supplies within the region. Water supply planning in the last 20 years has modified this relationship to protect the Upper Floridan aquifer as a potable water source. Changes in the magnitude and spatial distribution of major Upper Floridan aquifer pumping and population over time are described in the following paragraphs.

Prior to the construction of Eglin Air Force Base groundwater withdrawals from the Upper Floridan aquifer for all uses was less than two (2) mgd (Bartel et al., 2000). Construction of Eglin Air Force Base began in the 1930s. The population of the surrounding communities increased significantly over the next few decades with the influx of military and civilian workers (Figure 9). Groundwater development was concentrated in the area around Fort Walton Beach. Figure 10 shows the estimated spatial distribution and magnitude of major pumping from the Upper Floridan aquifer in 1942. The Lower Floridan industrial waste injection wells in Escambia and Santa Rosa counties did not exist at that time.

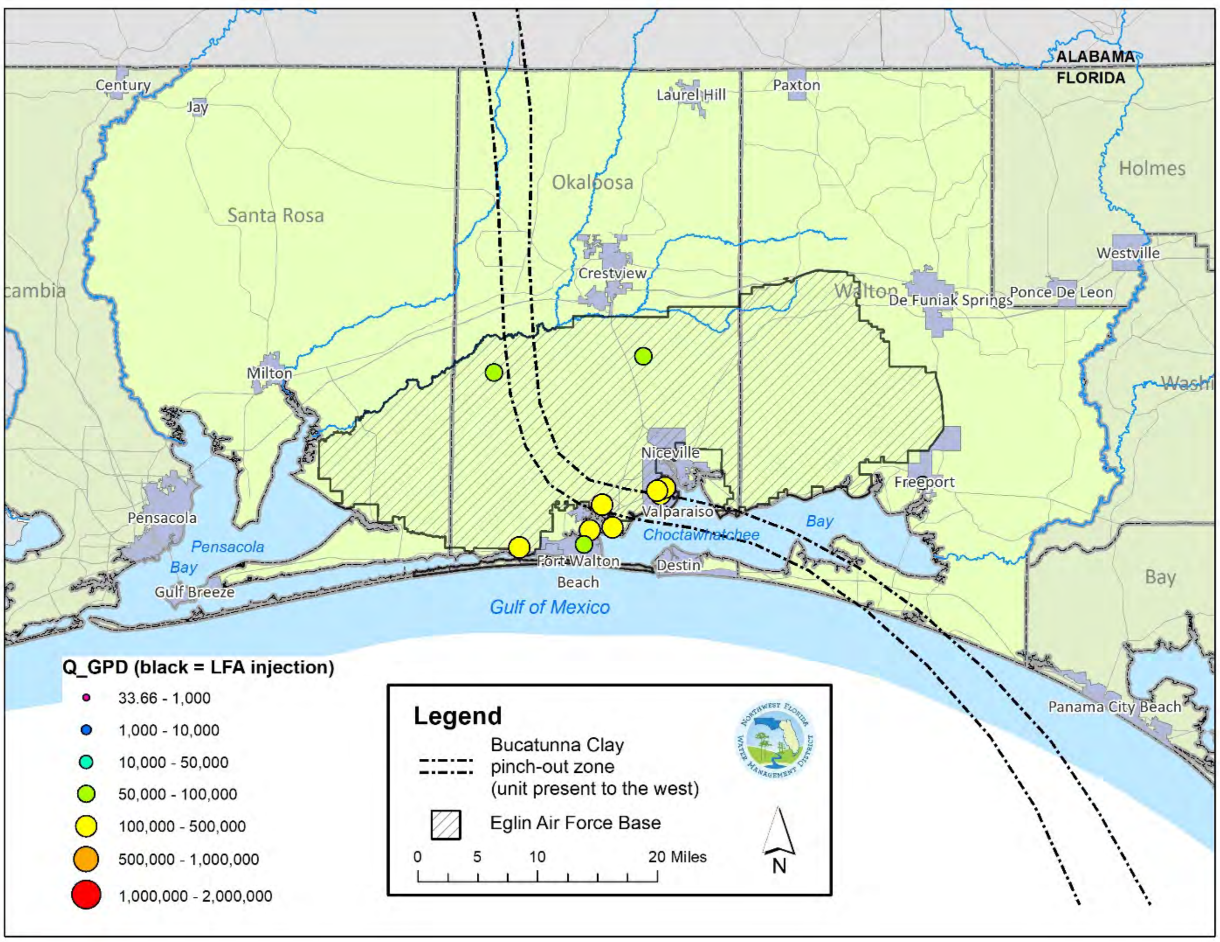


*Figure 10. Estimated spatial distribution and magnitude of major pumping in the Upper and Lower Floridan aquifer in 1942*

Between 1942 and 1980, major regional pumping from the Upper Floridan aquifer increased at a rate of approximately 486,000 gals/day/year reaching approximately 20.8 mgd in 1980 (Tetra Tech, 2020b). By 2000, major pumping from the Upper Floridan aquifer in Region II had increased to approximately 39 mgd (Figure 9).

Figure 11 shows the estimated spatial distribution and magnitude of major pumping from the Upper Floridan aquifer in 2000. Although pumping from the Upper Floridan aquifer had moved inland, north of EAFB over the years, the majority of regional Upper Floridan aquifer pumping was still concentrated along the coast in southern Okaloosa County. In 2000, most supply wells in the coastal group were each pumping 100,000 gals/day or more from the Upper Floridan aquifer. A cluster of public supply wells each pumping more than 500,000 gals/day (orange dots) were present in southeast Santa Rosa County. This area is where the Upper Floridan aquifer is differentiated by the Bucatunna Clay (Figure 11). Here the Upper Floridan aquifer is thinner and at its western limit for use as a potable water source. The significant drawdown in coastal Region II at this time resulted in several wells closing due to a decline in water quality. Similarly, to the east where the Upper Floridan aquifer is undifferentiated along the Walton County coast, public supply wells pumping 50,000 to 100,000 gals/day (green dots) had to close due to up-coning of poor-quality water. Figure 11 also shows the locations of injection wells pumping industrial wastewater into the Lower Floridan aquifer (black dots) in Escambia and Santa Rosa counties.

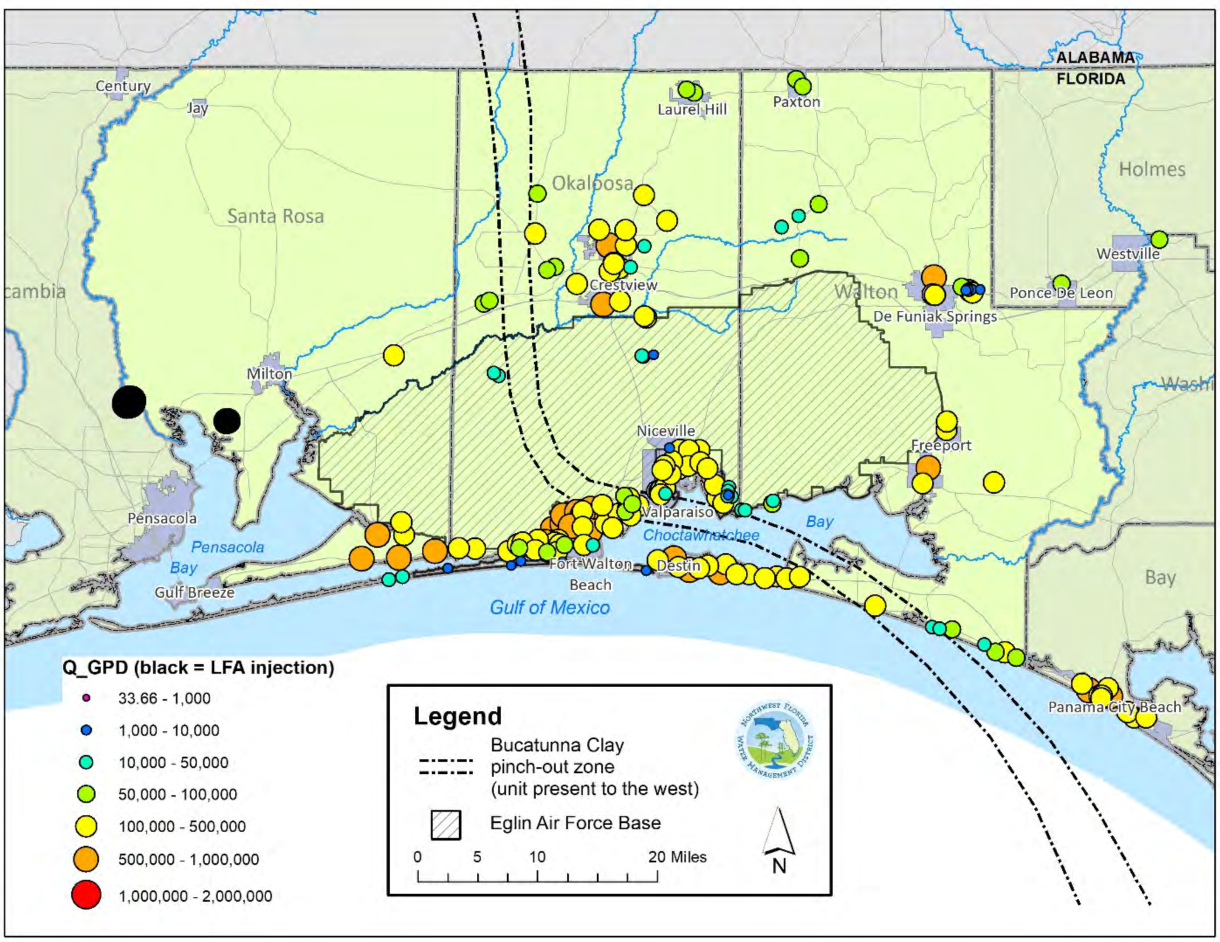


*Figure 11. Estimated spatial distribution and magnitude of major pumping in the Upper and Lower Floridan aquifers in 2000*

It was recognized that pumping of this magnitude along the coast of Region II was inducing saltwater intrusion and alternative water supplies were needed. Alternative water supply projects were developed to move coastal pumping inland as part of the Region II Water Supply Plan (Bartel et al., 2000).

Figure 12 shows the estimated spatial distribution and magnitude of major pumping from the Upper Floridan aquifer in 2015. As can be seen, Upper Floridan aquifer pumping had moved inland to areas identified for alternative water supply development. This redistribution resulted from the District and local utility partnerships and funding established to implement the water supply projects included in the 2000 Regional Water Supply Plan. These include the area north of EAFB around Crestview and the central Walton County area north of Freeport (Figure 3). In southeastern Santa Rosa County, pumping from the Upper Floridan aquifer was reduced altogether and moved inland to the sand-and-gravel aquifer between the Blackwater and Yellow rivers. This reduction in Region II coastal pumping of approximately 13 mgd has allowed water levels in the Upper Floridan aquifer to recover as will be discussed in the section on water level trends (*Section 3.2*). Figure 12 also shows the injection wells put into service between 2000 and 2015 in Escambia County to pump additional industrial wastewater into the Lower Floridan aquifer.

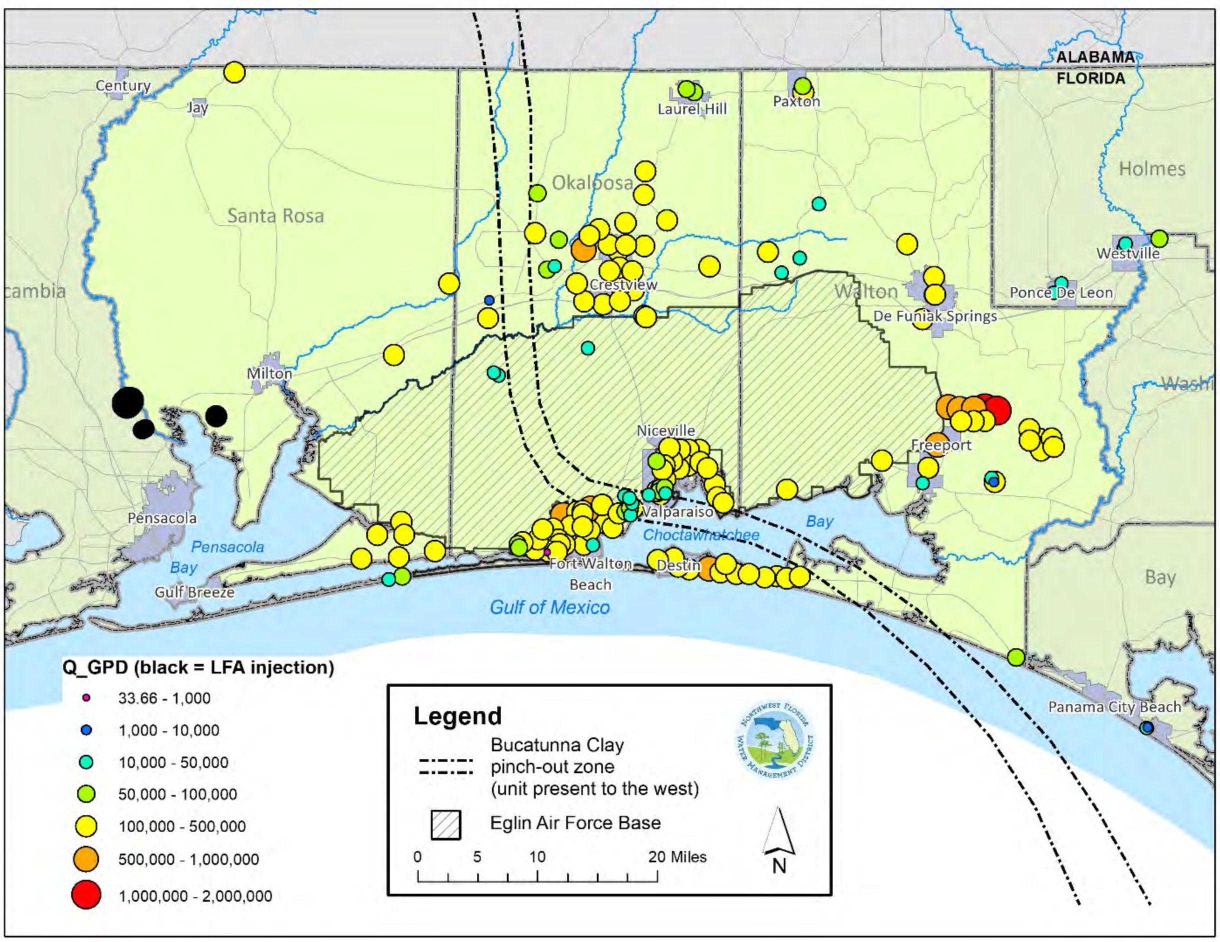


*Figure 12. Estimated spatial distribution and magnitude of major pumping in the Upper and Lower Floridan aquifers in 2015*

Upper Floridan aquifer pumping within Region II has remained relatively stable over the last twenty years since the first water supply assessment was completed in 1998 (Ryan et al., 1998). Figure 13 shows a comparison of Region II coastal, inland and total pumping from the Upper Floridan aquifer from 1998 through 2018. Total Upper Floridan aquifer pumping ranged from approximately 36 mgd in 1998 to approximately 41.5 mgd in 2010. In 1998 coastal and inland Upper Floridan aquifer withdrawals were approximately 28 mgd and 8 mgd, respectively. However, over the next two decades coastal pumping decreased and inland pumping increased as coastal Upper Floridan aquifer pumping is reallocated to alternative water supply sources including the newly developed inland sand-and-gravel wellfield. Inland withdrawals begin to exceed coastal withdrawals in 2009.

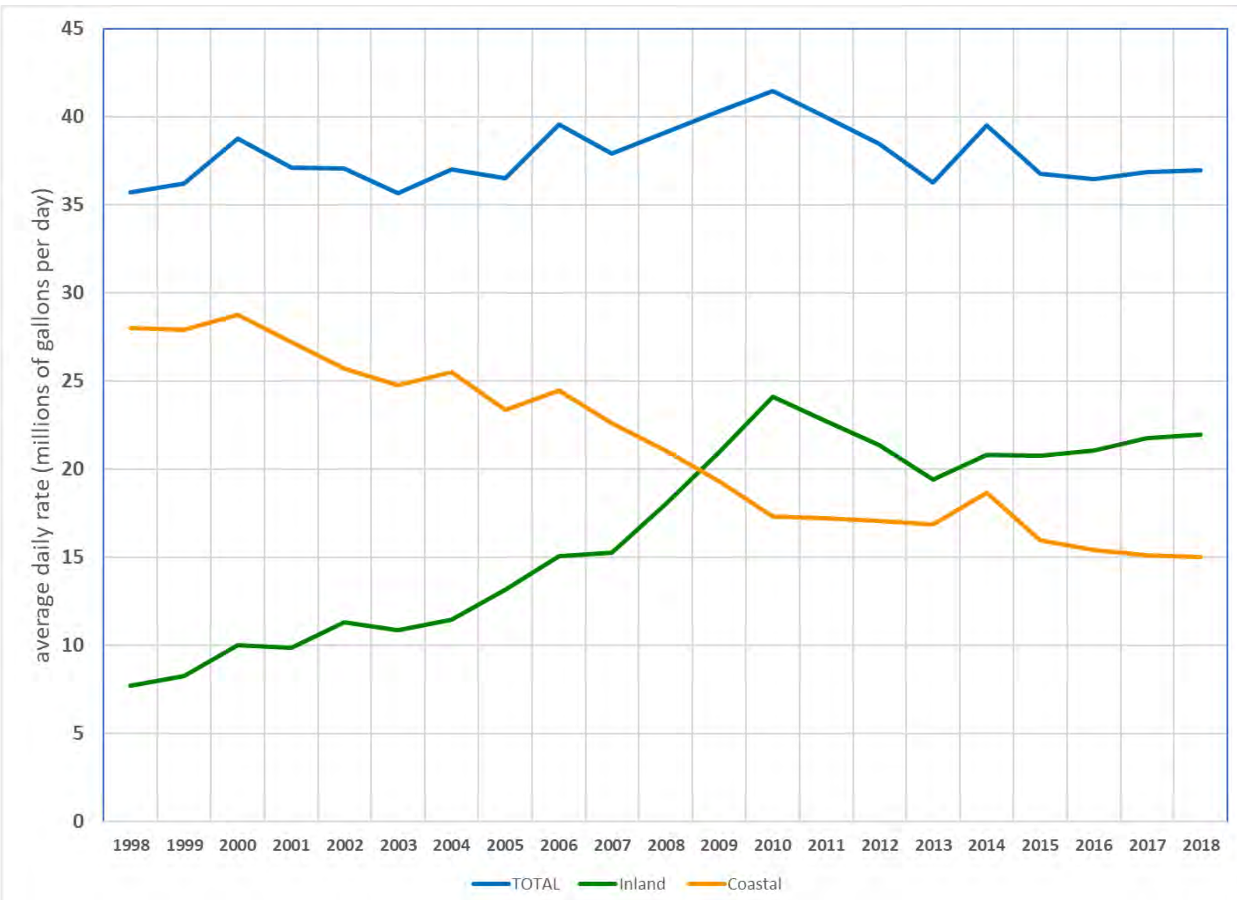


*Figure 13. Region II Upper Floridan aquifer pumping between 1998 and 2018*

As part of the 2018 WSA update (Hollister et al., 2018), water demand projections were developed in five-year increments for the 2020-2040 planning period. These projections are based on BEBR (Bureau of Economics and Business Research) population estimates and projections and public supply utility customer service and pumping reports. Some utilities also provided system demand projections for the duration of their water use permit. Figure 14 shows the estimated spatial distribution and magnitude of projected major pumping from the Upper Floridan aquifer in the year 2040. Wells that were actively pumping as of 2015 were assumed to be pumping in 2040 and assigned the projected rate, unless otherwise indicated by a utility report. For projections provided or estimated at a water supply system level, 2040 pumping was spatially distributed proportional to the historical rates of each well in the system. Information on the future of industrial wastewater injection was not available at the time of this evaluation, therefore 2015 injection rates are shown in Figure 14. For this assessment, the 2040 major pumping in the Upper and Lower Floridan aquifers as shown in Figure 14 was simulated to evaluate the effect of projected water use on the position and movement of the freshwater-saltwater interface (*Section 3.4.4*).

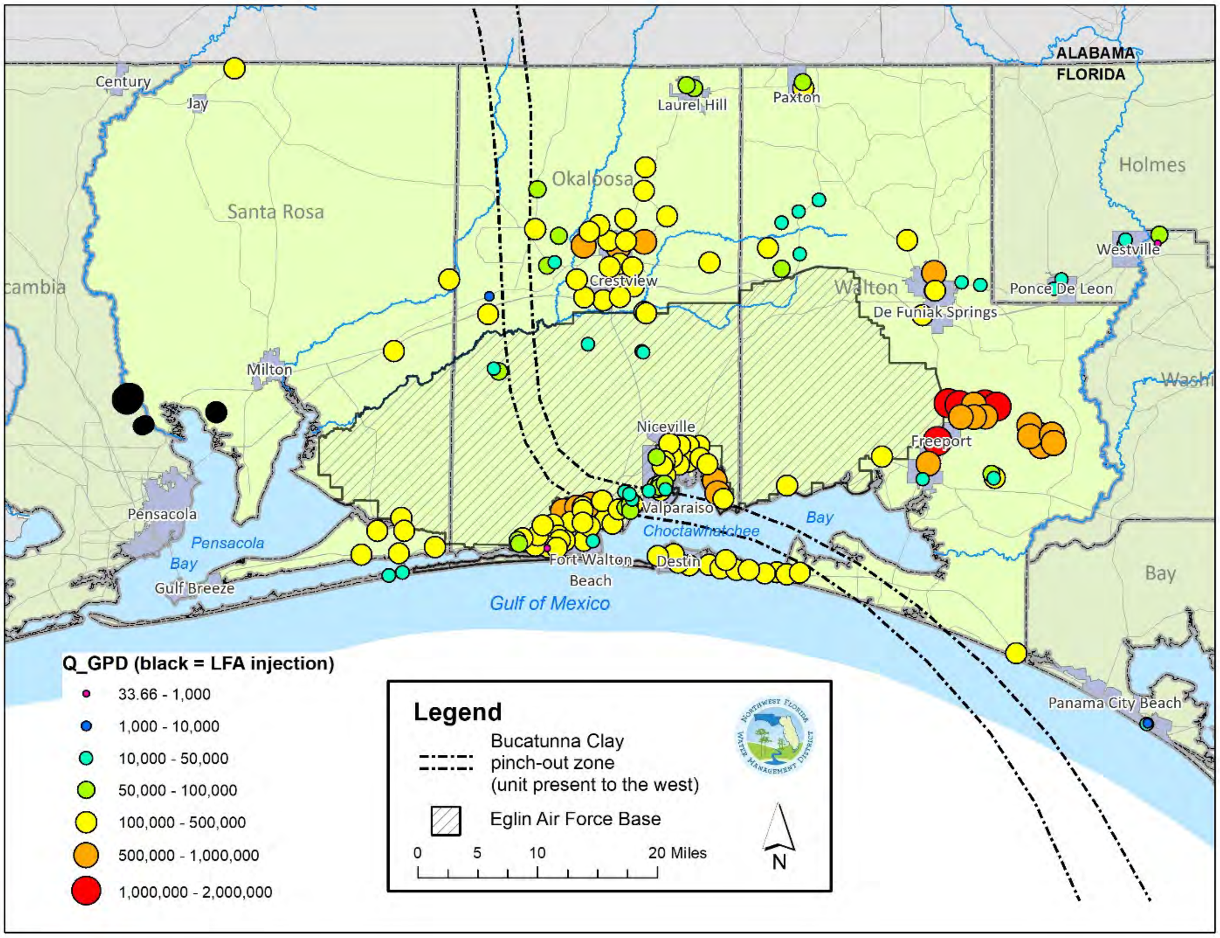


*Figure 14. Estimated spatial distribution and magnitude of major pumping in the Upper and Lower Floridan aquifers in 2040*

# 3.0 Assessment of Saltwater Intrusion

## 3.1 Freshwater-Saltwater Interface

In coastal aquifers, fresh groundwater from inland areas flows toward the coast and merges with saline groundwater within the aquifer. A graphical depiction of groundwater flow along the freshwater-saltwater interface transition zone is shown in Figure 15. Saline groundwater has a higher dissolved solids content and is therefore more dense than fresh groundwater. This density difference is important and affects the physics of groundwater flow. The saltwater moves beneath the freshwater at the interface creating a stratified wedge of more dense water at the base of the aquifer. Out-flowing fresh groundwater mixes with more dense saline water within a transitional mixing zone. The nature of the transition zone is controlled by the hydraulic conductivity of the aquifer which considers the properties of both the aquifer and the groundwater. The transition zone describes the interface between the fresh and saline groundwaters. The interface can be thin, or sharp, with a narrow zone of mixing or can be wide and diffuse with a shallow gradient in changing water quality. Width of the transition zone is variable ranging from tens of feet in the vertical direction to several miles in the horizontal direction (Barlow, 2003).

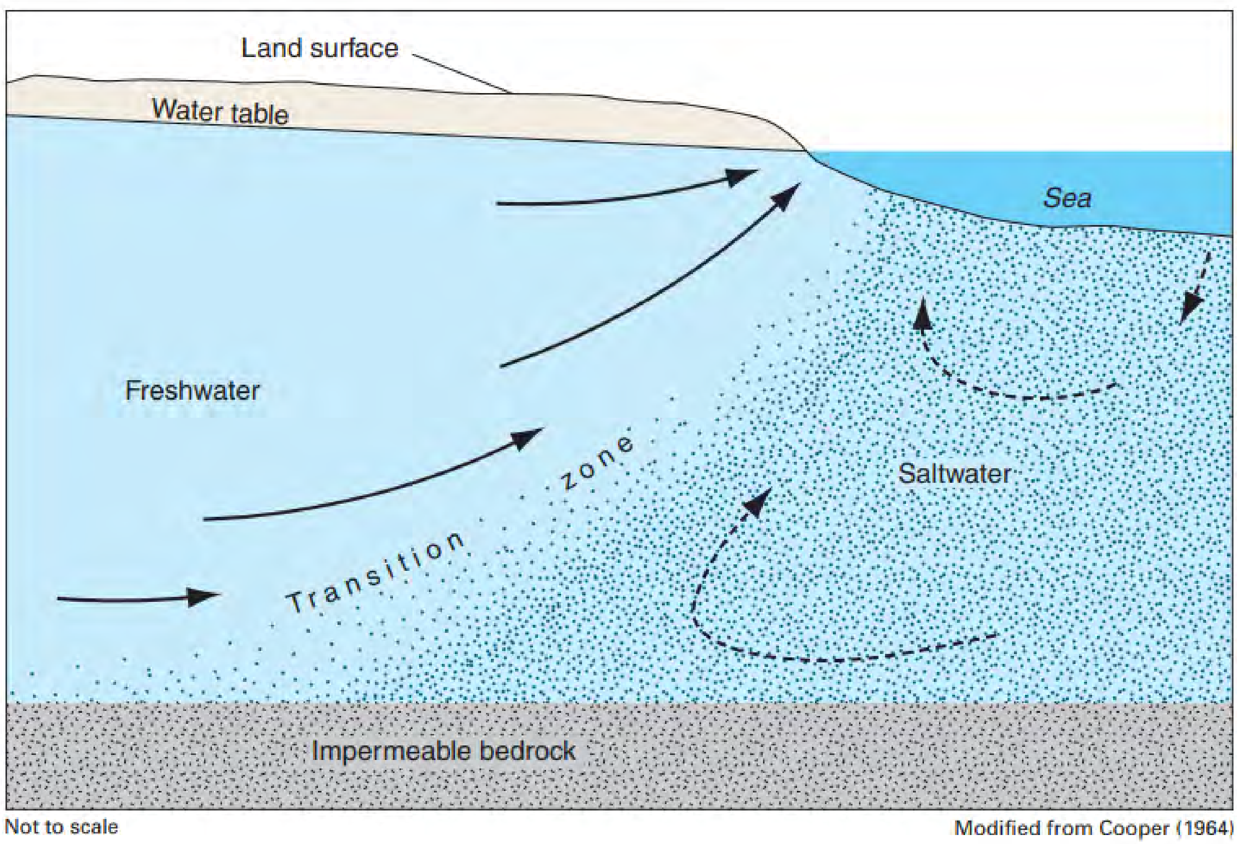


*Figure 15. Idealized graphical depiction of the transition zone along the freshwater-saltwater interface*

Saltwater is present in all aquifers and is typically in equilibrium with freshwater moving from inland recharge areas to discharge areas offshore. This equilibrium maintains the position of the freshwater-saltwater interface in the long term. Under predevelopment conditions, the position of the freshwater-saltwater interface within the Upper Floridan aquifer was located offshore under the Gulf of Mexico

(Ryan et al., 1998). Increased onshore withdrawal of groundwater lowers the upgradient head pressure and over time reduces the rate of freshwater flow offshore. If groundwater pumping along the coast is of high magnitude and concentrated geographically, as it is in the Fort Walton beach area of Region II, water levels can drop below sea level resulting in a reversal of hydraulic gradient from offshore to onshore. A state of disequilibrium is created causing the denser saltwater to move toward the area of reduced head pressure. This movement of the saltwater inland due to groundwater pumping is referred to as saltwater intrusion.

For this assessment, saltwater was defined as having the following saline analyte concentrations:

- 35,000 mg/L Total Dissolved Solids (TDS)
- 19,400 mg/L Chloride (Cl)
- 10,800 mg/L Sodium (Na)
- 66,400 uS/cm Specific Conductance (field measured)

However, to evaluate potential impacts to potable supply wells the following primary and secondary drink water standards (FAC 62-550) for these analytes were used:

- 500 mg/L TDS (secondary standard)
- 250 mg/L Cl (secondary standard)
- 160 mg/L Na (primary standard)

The position of the potable water interface was assessed as part of three geophysical logging and discrete interval sampling events described in *Section 1.4.3* above (JSA, 2018, JSA, 2019, and Cardno, 2019). These events were timed to coincide with periods of low and high seasonal pumping from the Upper Floridan aquifer.

## 3.2 Water Level Trend Analysis

As previously described, persistent pumping of water from the aquifer can reduce groundwater flow rates and change the direction of groundwater movement. If withdrawals increase over time decreasing trends in groundwater levels may be observed (Fetter, 1988). Also, as the area of pumping expands, spatial trends in groundwater withdrawals may become evident. These water level trends are discussed in more detail in the 2018 Water Supply Assessment Update (Hollister et al., 2018) but are summarized here.

"The potentiometric surface for a confined aquifer is the surface representative of the level to which water will rise in a well cased to the aquifer" (Fetter, 1988). Figure 16 shows the estimated potentiometric surface of the Upper Floridan aquifer under predevelopment conditions as reinterpreted by Bush and Johnston (1988). The original predevelopment interpretation was based on limited data and informed adjustments to the May 1980 potentiometric surface map for the Upper Floridan aquifer by the USGS. The Bush and Johnston (1988) interpretation suggests 1) head pressure within the Upper Floridan aquifer was higher, 2) water levels were above land surface along much of coastal Region II and 3) artesian conditions existed. Estimated predevelopment, Upper Floridan aquifer water levels in the Fort Walton Beach area were approximately 50 feet above sea level (Ryan et al., 1998).

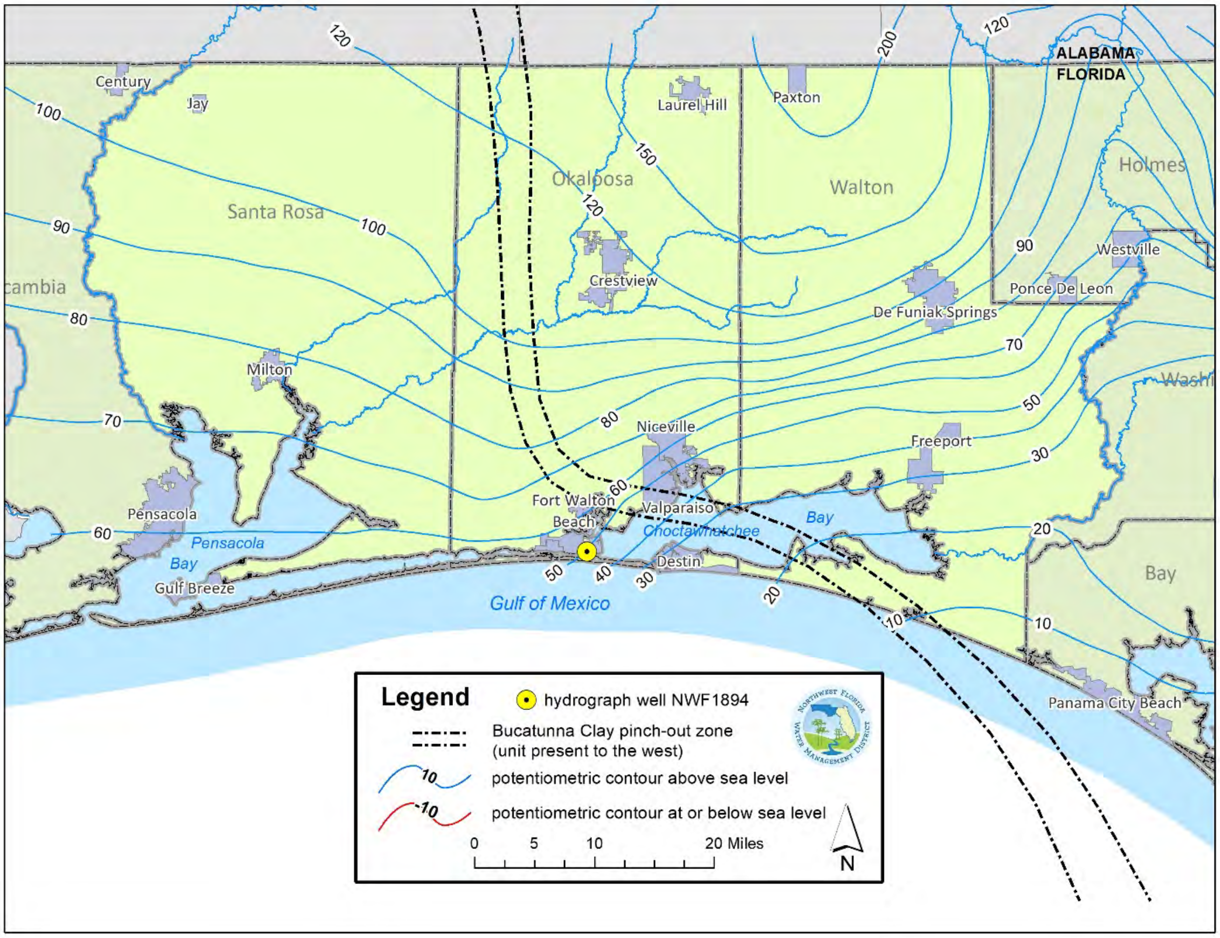


*Figure 16. Estimated predevelopment potentiometric surface of the Upper Floridan aquifer*

The Okaloosa County School Board well (NWF1894) is in Fort Walton Beach, Florida approximately 0.75 miles from the Gulf of Mexico (Figure 16). Fort Walton Beach has been the geographic center of historical groundwater development within Region II. The hydrograph for this well (Figure 17) is provided to illustrate how increased groundwater pumping over the last 80 years has lowered water levels below land surface and created the potential for saltwater intrusion within the Upper Floridan aquifer. The earliest water level value was measured at approximately 62 feet above sea level. With a land-surface elevation of approximately 16 feet above sea level at the well site, this well was under 46 feet of head pressure at the wellhead and actively flowing before significant pumping from the Upper Floridan reduced the head pressure in the aquifer.

The hydrograph shows a steady decline in water levels between the 1930s and 1980s as regional water use and pumping from the Florida aquifer increased. Seasonal fluctuations in water levels on the order of 20 to 40 feet are apparent. These seasonal fluctuations are due to the transient nature of the population and its associated water use. Tourism increases the population during the spring and summer months.

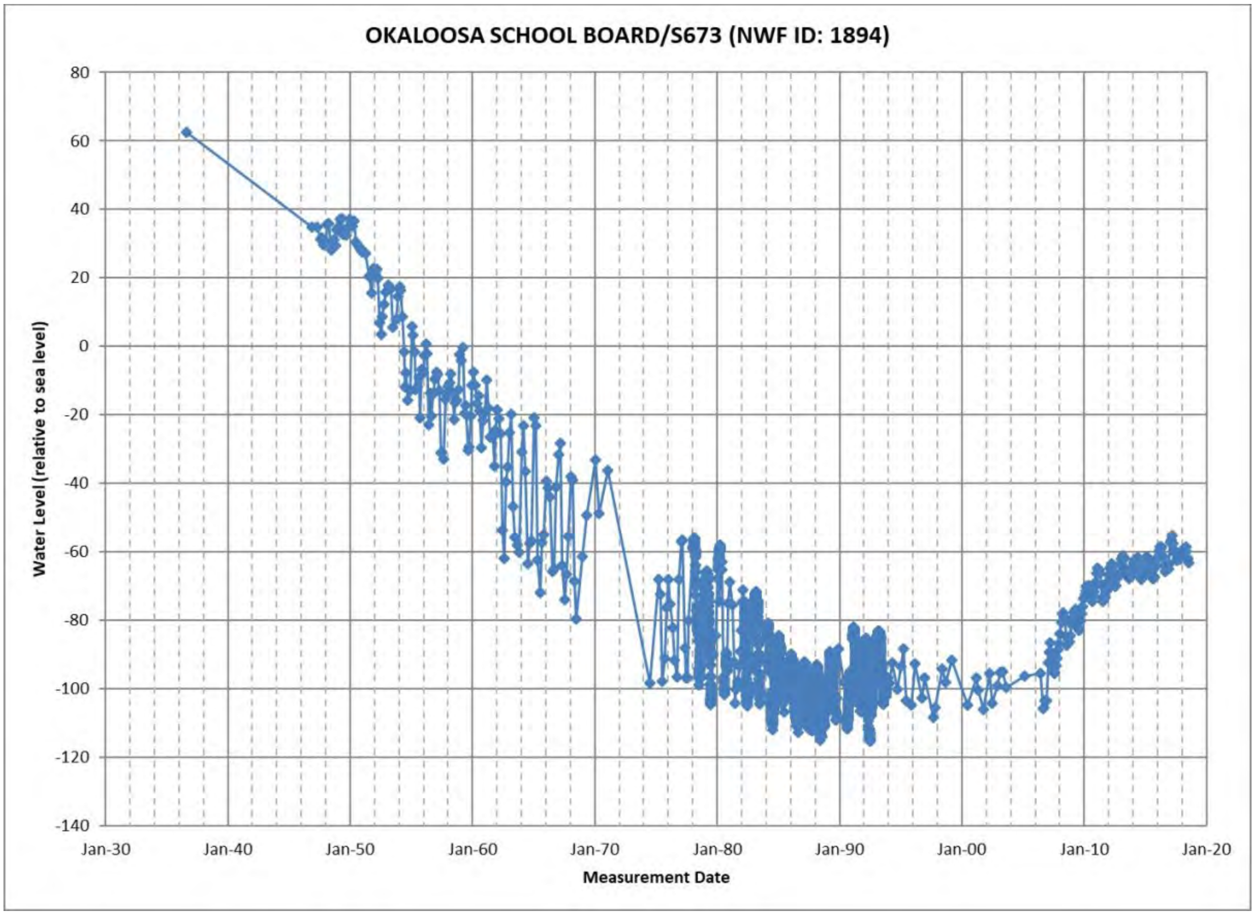


*Figure 17. Hydrograph for Okaloosa School Board Well (NWF1984) in Fort Walton Beach, Florida*

The Okaloosa School Board well stopped artesian flow at some point within the mid-1950s as water levels dropped below land surface. From 1980 to 1986, Floridan public supply pumping increases from about 21 to 31 mgd. The water resource assessments in the 1980s and Water Supply Assessment in 1998, provided the support for limiting Upper Floridan aquifer groundwater withdrawals along the coast and prohibiting the expanded use of the aquifer for non-potable purposes. As can be seen in the hydrograph, the water level decline from previous decades begins to flatten out in the 1990s. The most extreme drawdown was observed in October 1997 in a public supply well approximately 3.26 miles west of the Okaloosa School Board well. At that time the water level was measured at 156 feet below sea level.

A regional cone of depression within the potentiometric surface of the Upper Floridan aquifer began to develop at the end of the 1940s as concentrated pumping in the Fort Walton Beach area drew local water levels below those of surrounding areas. The cone of depression expanded and deepened over time with increased pumping. During 2000, major pumping from the Upper Floridan aquifer in Region II averaged approximately 39 mgd. Figure 18 shows the Upper Floridan potentiometric surface in the year 2000.

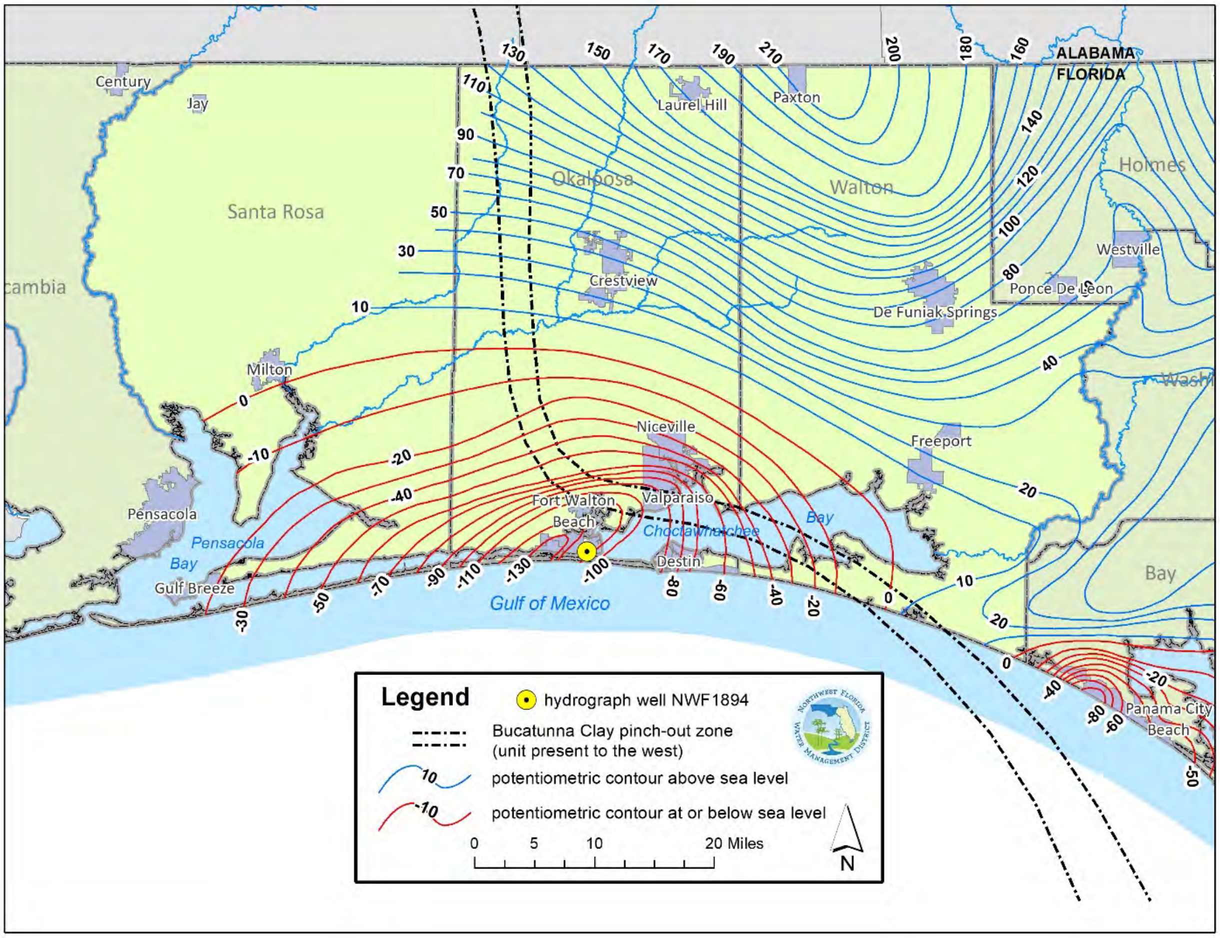


*Figure 18. Potentiometric surface of the Upper Floridan Aquifer, May-June 2000*

At that time, the regional cone of depression was estimated to be approximately 135 feet below sea level in the vicinity of Fort Walton Beach and had expanded further inland with the zero foot-mean sea level contour line closer to Crestview in central Okaloosa County (Figure 18). An undetermined amount of drawdown within the Upper Floridan aquifer was also extending offshore beneath the Gulf of Mexico. This interpretation represents a head loss of approximately 200 feet from predevelopment. A cone of depression was also present along the coast of Bay County to the east (Figure 18). That depression was approximately 78 feet below sea level and is the result of significant pumping along Panama City Beach. It was recognized that under this pumping stress the Upper Floridan aquifer would not be sustainable as a potable water source.

As part of the 2000 Region II Water Supply Plan, alternative water supply projects were proposed by local governments and implemented in cooperation with the District to reduce pumping at the coast and move future production to inland groundwater sources. Since the completion of alternative water supply projects in the early 2000s and the implementation of new water use permitting rules limiting new and expanded uses of the coastal Upper Floridan aquifer to potable supply, water levels at the center of the cone have recovered approximately 70 feet (Figure 17). Figure 19 shows the Upper Floridan aquifer potentiometric surface in the year 2015.

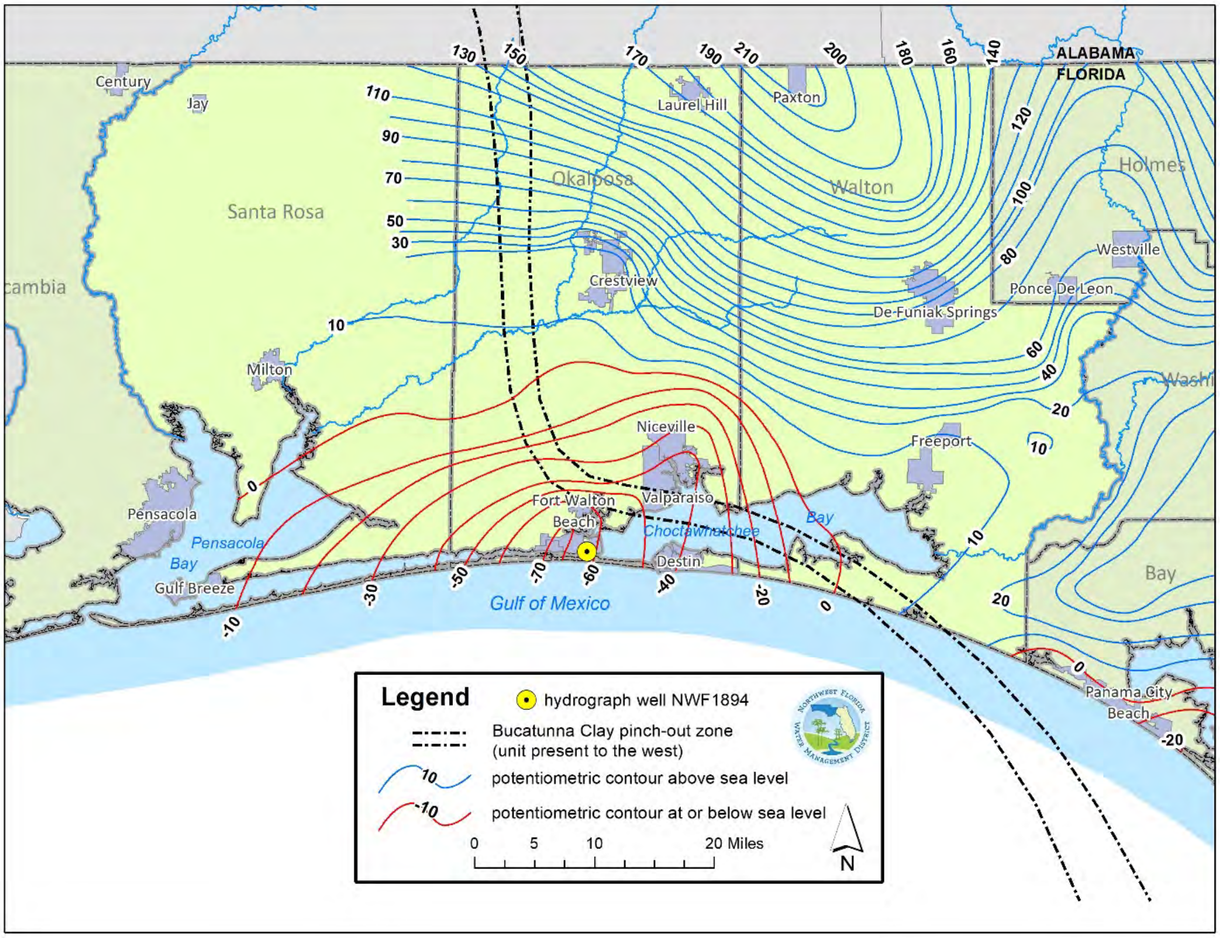


*Figure 19. Potentiometric surface of the Upper Floridan aquifer, May 2015*

During 2015, major pumping from the Upper Floridan aquifer in Region II averaged approximately 35.5 mgd. At that time, the center of the cone of depression was estimated to be approximately 70 feet below sea level in the Fort Walton Beach area (Figure 19). The depression along coastal Bay County has recovered approximately 53 feet due to the closure of 13 public supply wells on Panama City Beach in 2002. It should also be noted that water levels are being drawdown in the central Walton County wellfield area. The 10-foot mean sea-level contour line along the northeast side of Choctawhatchee Bay is bending northeast and a small depression in the potentiometric surface is evident just northeast of Freeport (Figure 19). Water levels below sea level have been observed within this depression and are associated with increased seasonal pumping within the Central Walton County wellfield area.

## 3.3 Water Quality Trend Analysis

### 3.3.1 District Water Quality Data

To determine long term trends in Region II groundwater quality, the District's water quality database was queried for groundwater sites with results for the saline parameters of interest. Water quality data were reviewed for 123 wells that were mostly near the coast in Region II and had measurements for at least one of the following parameters: specific conductance (Sp Cond), sodium (Na), chloride (Cl), or total dissolved solids (TDS). District staff performed QA/QC on the data by checking for outliers and correcting incorrect or missing entries. The dataset was further refined for trend analysis by requiring that each well meet the following additional criteria:

- Have a minimum of 20 data points for at least one of the parameters of interest (Sp Cond, Na, Cl, and TDS),
- Have a minimum of 10 years between the first and last data point, and
- Have at least a portion of the record occurring within the 2010-2019 timeframe.

After these criteria were applied, 75 wells were deemed suitable for trend analysis with 181 total tests that could be run for the parameters of interest.

### 3.3.2 Statistical Methods

Two types of statistical tests were chosen to check for long term trends in the data: monotonic trend test and step trend test. The type of test performed was based on the nature of the available data record for each well and parameter.

**Monotonic Trend Tests -** A monotonic trend test evaluates continuous rates of change over time in a series of data. Criteria used to select appropriate datasets for monotonic trend testing included:

- No data gaps longer than 5 years, and
- For datasets that have a gap larger than 5 years and with few data values (less than 10) on one side of the gap but with many data values (20 or more) on the other side, the data on the side of the gap with few data values were removed from the analysis.

Wells with data which met these criteria were subsequently evaluated with a monotonic trend test (see Figure 20 for example dataset). The data presented in Figure 20 come from a public supply well (NWF2404, Figure 22) located in Fort Walton Beach near the center of the cone of depression in the potentiometric surface of the Upper Floridan aquifer. Samples were collected at variable frequencies throughout the period of record, ranging from daily to annual quarters. All raw data not flagged as an outlier were used in the analysis.

For monotonic trend testing, the Mann-Kendall test was used. The Mann-Kendall test is a non-parametric test that is widely used for evaluating monotonic trends. The test considers rank order of observed values and their order in time when computing the test statistic. If later observations in the time series tend to be higher than earlier observations, the test statistic will be positive and may indicate an upward trend or increase in parameter concentration over time. The opposite is true if later observations in the time series tend to be less than earlier observations (decreasing trend). Trends are considered significant if the test P-value is less than or equal to 0.05. The Mann-Kendal test includes multiple assumptions including:

- The dataset is not affected by seasonality,
- Data are independent and identically distributed (minimal autocorrelation effects), and
- Data were collected with consistent frequency with minimal data gaps.

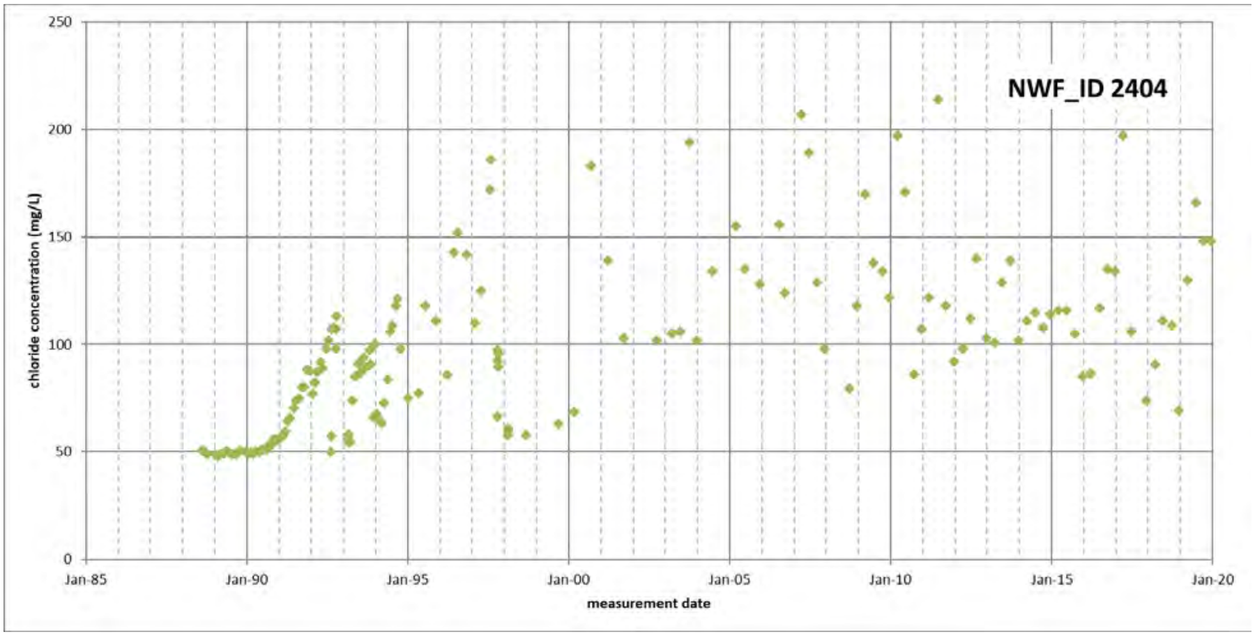


*Figure 20. Example of dataset analyzed by statistical monotonic trend test*

**Step Trend Tests** - A step trend test evaluates discrete or abrupt changes in a time series and is generally used to compare differences before and after an event. For purposes of this analysis, data subgroups before and after a data gap of at least 5 years were compared. Generally, datasets had one single data gap occurring in the 1990's when data collection efforts were discontinued for several stations. Criteria used to select appropriate datasets for step trend testing included:

- A data gap of at least 5 years between the subgroups, and
- At least 10 data values within each subgroup.

Wells with data which met these criteria were subsequently evaluated with a step trend test (see Figure 21 for example dataset). The data presented in Figure 21 also come from a public supply well (NWF2807, Figure 22) located in Fort Walton Beach near the center of the cone of depression. Samples were collected at variable frequencies throughout the period of record, ranging from every two months to biannually. A nine-year gap (1989 – 1998) exists between the two subgroups being compared. Samples from the first subgroup were collected by the USGS. Samples from the second subgroup were collected by the utility in compliance with their water use permit.

Three step trend tests were considered to evaluate data from these wells. They include the two-sample t-test, the Wilcoxon rank sum test, and Kruskal-Wallis rank sum test.

The two-sample t-test is a parametric test that compares the means of two groups. Assumptions of the two-sample t-test include:

- Data should be independent,
- Data should have constant variance, and
- Data should be normally distributed.

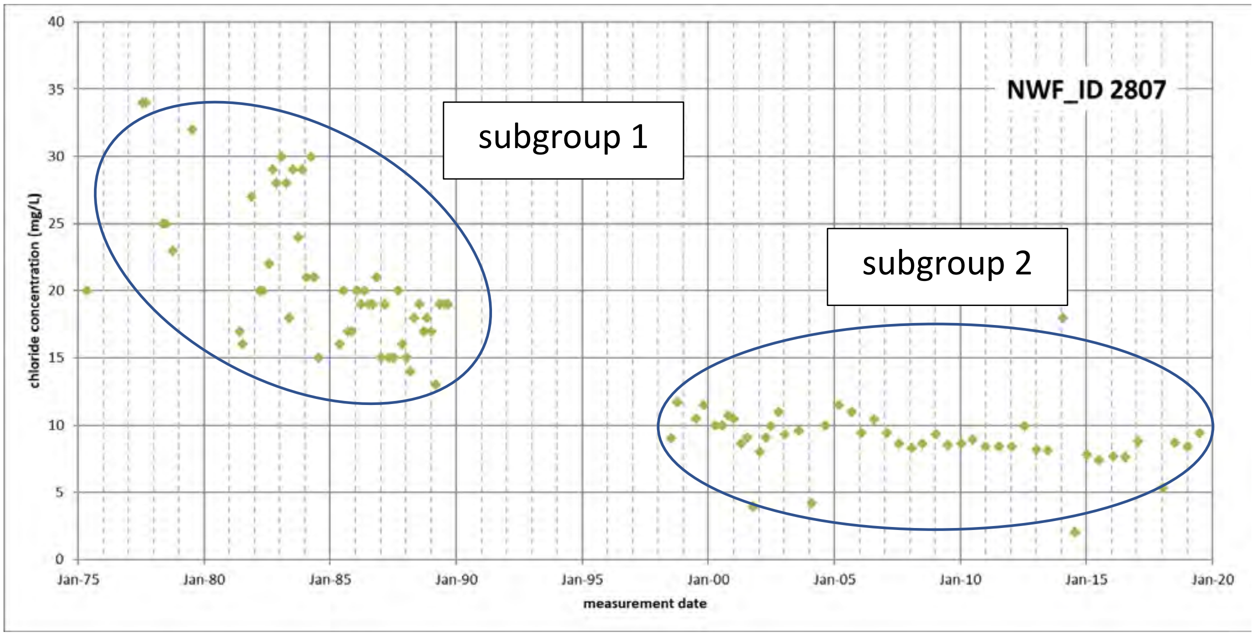


*Figure 21. Example of dataset analyzed by the step-trend test*

The Wilcoxon and Kruskal-Wallis rank sum tests are nonparametric tests. Unlike parametric tests, nonparametric tests do not assume the data are normally distributed. Values are ranked by order and by size, and the sums of the ranks of the two groups are compared. The Wilcoxon and Kruskal-Wallis rank sum tests are similar except that the Kruskal-Wallis test can be used to compare more than two groups. Trends are considered significant if the test P-value is less than or equal to 0.05. Assumptions of the Wilcoxon and Kruskal-Wallis rank sum tests include:

- Data does not have to be normally distributed, and
- Dataset subgroups have similar distributions.

Data meeting step-trend criteria were initially evaluated using all three tests (two-sample t-test, the Wilcoxon rank sum test, and Kruskal-Wallis rank sum test). After a review of the results, the two-sample t-test was selected as the most robust step trend test. Several of the Wilcoxon and Kruskal-Wallis test results were influenced by data points that had not qualified for removal as an outlier but created differences in the distribution shape between the two subgroups. This caused the tests to return a significant difference result for wells that did not have a significant difference between the two subgroups. The two-sample t-test was not affected by these outlier data points. It should be noted, for most tests, the Wilcoxon rank sum test and Kruskal-Wallis rank sum test returned the same or similar results as the two-sample t test.

All statistical tests, monotonic and step trend tests, were run in R statistical software. Data for each well to be evaluated were put into individual spreadsheets and plotted for graphical inspection. Plots were reviewed and data outlier values were removed. The resulting datasets were exported into individual tab-delimited files for each well. An R script was created to read a list file with unique well identifiers (NWF_ID) and file names for each well. The script then ran each dataset through the selected statistical test(s) and wrote the results to comma-delimited text files. A second R script was also created to plot the data. This script looped through each dataset file, plotted the data and saved the plot in Adobe PDF format. To run the Mann-Kendall test, an R package created by an independent party was downloaded (McLeod. 2011). Standard R packages were used to run the two-sample t-test. Results for a few tests were checked using the statistical software SYSTAT to make sure the R script ran correctly. The resulting text files were imported into Microsoft Excel for tabulation and review. Trends were considered significant if the test P-value was less than or equal to 0.05. A total of 162 Mann-Kendall tests and 19 two-sample t-tests were run for this evaluation.

### 3.3.3 Trend Analysis Results

Of the 75 Upper Floridan aquifer wells with water quality data meeting the criteria for trend analysis, 53 of the wells showed statistically significant trends (P-value <= 0.05) in at least one parameter tested. Of the 181 parameter-trend tests run, 80 tests showed significant trends. Table 3 summarizes the test results. There are a total of 46 tests with significant increasing trends (9-Na, 28-Cl, and 10-TDS) and 34 tests with significant decreasing trends (1-Sp Cond, 16-Na, 12-Cl, and 6-TDS). Relative to the number of tests performed, the numbers of increasing and decreasing trends are similar.

*Table 3. Results of the water quality trend analysis*

| Parameter | Statistical Test | Increasing Trend | Decreasing Trend | No Trend |
|---|---|---|---|---|
| Specific Conductance | Mann-Kendall | 0 | 1 | 3 |
| Sodium | Mann-Kendall | 6 | 16 | 26 |
| | two-sample t-test | 3 | 0 | 1 |
| Chloride | Mann-Kendall | 23 | 11 | 27 |
| | two-sample t-test | 4 | 1 | 7 |
| Total Dissolved Solids | Mann-Kendall | 10 | 4 | 35 |
| | two-sample t-test | 0 | 1 | 2 |
| **Trend Totals** | | **46** | **34** | **101** |

Figure 22 shows the spatial distribution of statistically significant water quality trends along coastal Region II. Both increasing and decreasing trends are observed with a couple of spatial patterns. Where the Bucatunna Clay confining unit is present (west of the pinch-out zone) the wells with increasing and decreasing trends seem to be randomly interspersed landward from the coast. Where the Bucatunna Clay confining unit is absent in the vicinity of Niceville, all identified water quality trends are increasing (Figure 22). This may be due to the lack of underlying confinement which separates the Upper Floridan aquifer from the Lower Floridan aquifer and the potential for up-coning of poorer quality water from below the water supply production zone. Plots for wells showing significant increasing and significant decreasing trends are provided in Appendix I and J, respectively. Wells with increasing trends and those that currently exceed drinking water standards are discussed in more detail in *Section 4.0*, relative to the wells evaluated to be "at risk" of up-coning.

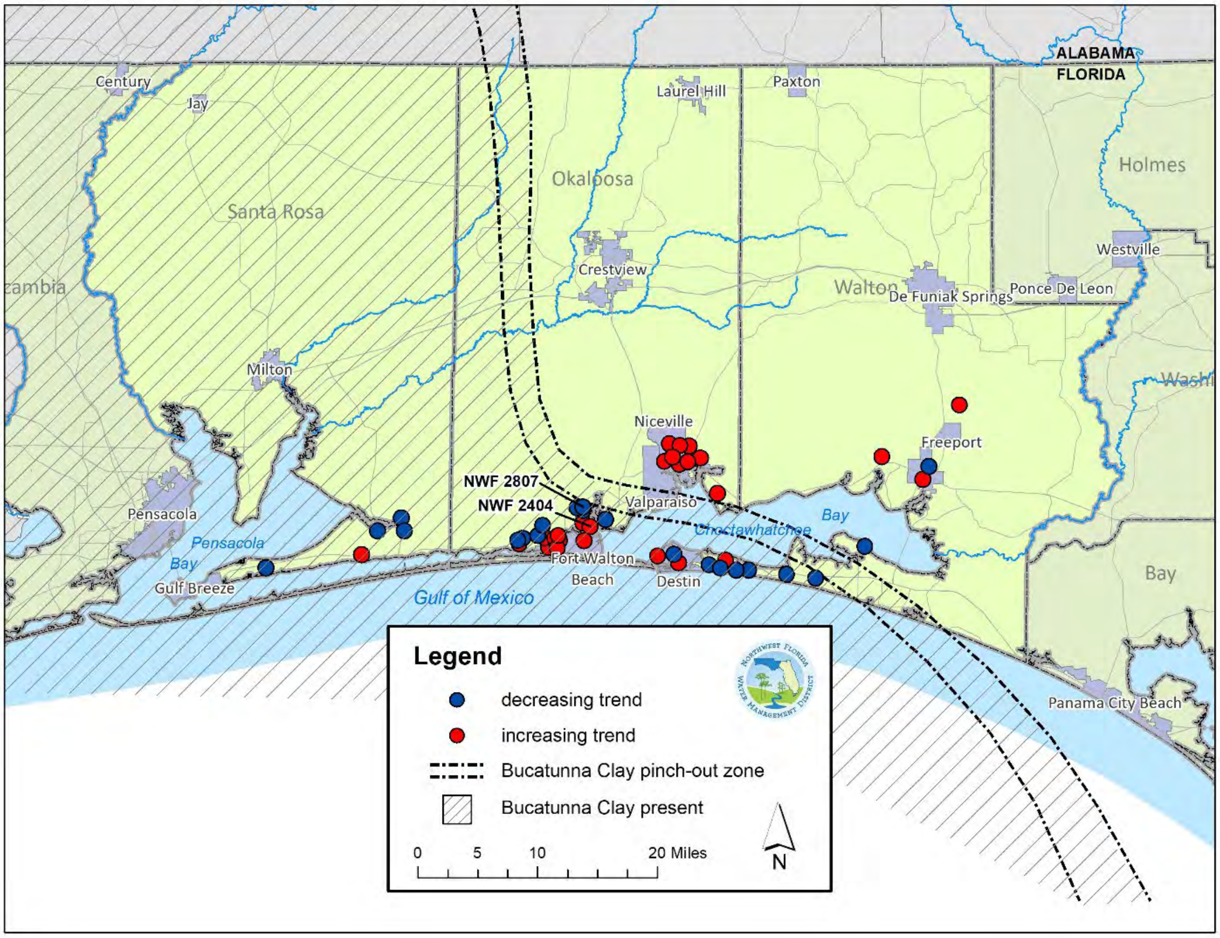


*Figure 22. Map showing spatial distribution of the water quality trend results*

The District will continue to monitor water quality trends through 1) the periodic sampling of its groundwater quality trend monitoring network, 2) geophysical logging and discrete interval water quality sampling of select coastal wells, and 3) review of compliance data submitted by permittees as required by individual water use permits. Existing monitoring wells and wells recently constructed for this technical evaluation will eventually meet the data requirements established for the trend analysis providing additional insight into the regional water quality trends.

## 3.4 Groundwater Modeling

In 2000, HGL developed a groundwater flow model for the District using the USGS MODFLOW code (HGL, 2000). The steady-state, finite-difference regional model was calibrated to 1990 pumping conditions. After flow model calibration, two density-dependent, subregional, finite-element groundwater flow and transport models were developed using HGL's proprietary modeling code DSTRAM (HGL, 2004; HGL, 2007). A steady-state predevelopment simulation and a transient, post-development calibration to heads were performed. The regional model was used to generate constant head boundaries along the outside of the DSTRAM models at the beginning of each stress period. The domain extents of the HGL Region II MODFLOW model and DSTRAM models are shown in Figure 23. These models were used to support Region II water supply planning and applied historical, current, and future projected estimates of major Upper Floridan aquifer pumping to evaluate the position of the freshwater-saltwater interface. Rates of interface horizontal movement ranged from 8 to 30 ft/yr (HGL 2005, HGL 2007). As part of this MFL technical evaluation, the existing MODFLOW and DSTRAM models were used as the basis to construct updated groundwater models. These updated models incorporate hydrogeological, water level and water quality data collected since the calibration of the original models.

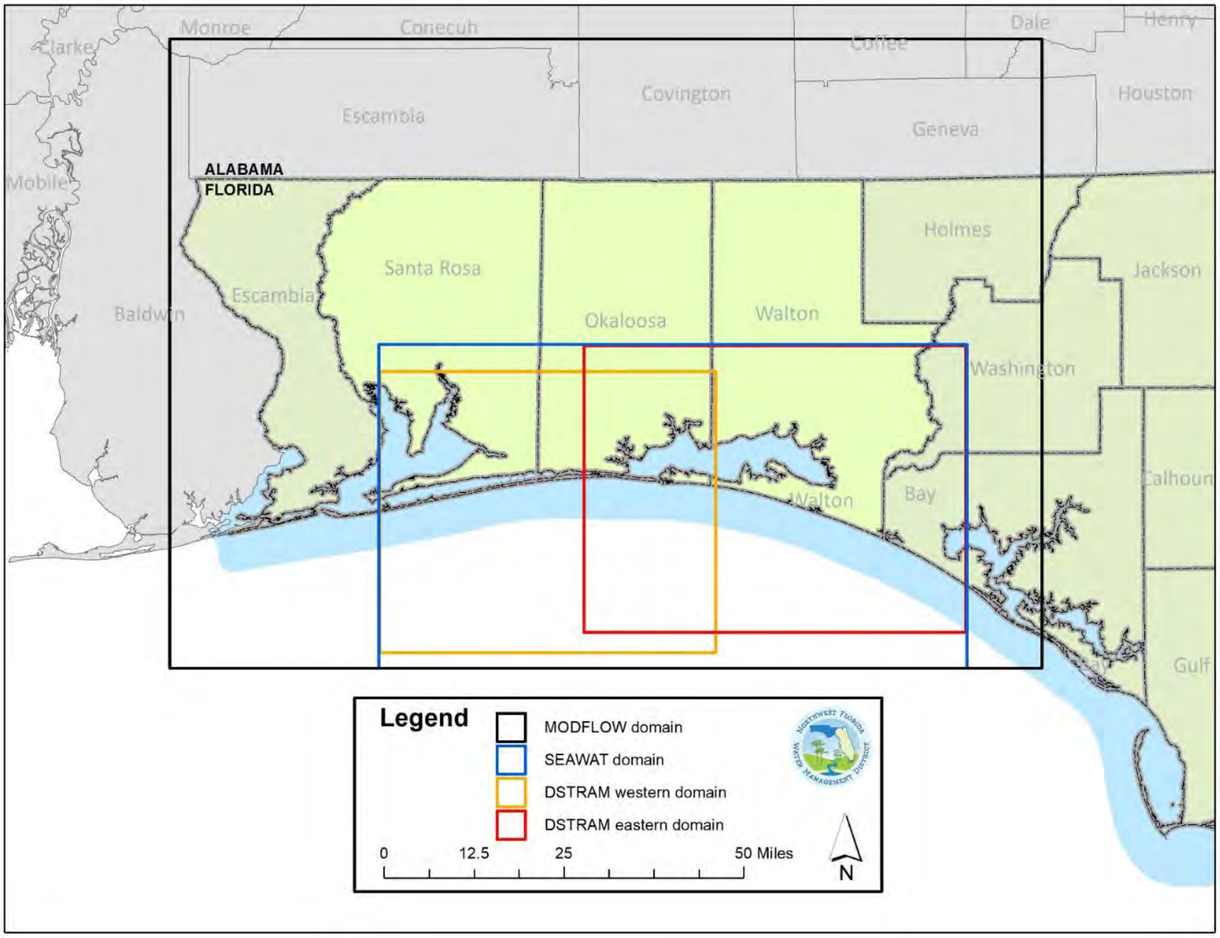


*Figure 23. Map showing the extent of the Region II groundwater flow and transport model domains*

### 3.4.1 SEAWAT Model Construction

Information from the two HGL DSTRAM models were used to construct a single SEAWAT (referred to as "CR2SWT") model covering the same subregional geographic areas (Figure 23). Model parameters and boundary conditions were transferred from the DSTRAM model datasets to the initial CR2SWT model. The initial CR2SWT model was spatially discretized in a similar manner with some interpolation necessary to accurately transfer the layer tops and bottom elevations from the DSTRAM finite-element nodes to the CR2SWT finite-difference cell centers. The initial CR2SWT model consisted of 20 layers, 184 rows, and 334 columns with a constant grid-cell size of approximately 1,293 feet along both rows and columns.

Simulated output from the initial CR2SWT model was qualitatively compared to that of the two DSTRAM models. The initial CR2SWT head output was converted to freshwater equivalent heads for comparison.

Although there were differences in several model specifications (e.g., layering and properties in the DSTRAM model overlap areas, discretization of the grid, numerical solution method) the compared results showed similar magnitudes, spatial patterns and temporal trends in head and concentrations. The conversion of the DSTRAM models to SEAWAT is documented in detail by Tetra Tech (2020a) and provided in Appendix K.

### 3.4.2 Regional Groundwater Flow Model Calibration

The original MODFLOW96, Region II steady-state groundwater flow model developed by HGL was converted to MODFLOW 2005 and recalibrated to a transient pumping dataset (referred to as "R2MF" model). The original 114 rows, 175 columns, and five layers representing the surficial aquifer system, intermediate system, Upper Floridan aquifer, Bucatunna Clay confining unit, and Lower Floridan aquifer were retained, as well as the variable, horizontal grid spacing and model domain extent (Figure 23). Table 4 shows the relationship of the simulated model layers to the hydrogeologic units within the R2MF model domain. Based on the conceptual model, Layers 3, 4, and 5 represent the differentiated Floridan aquifer (three hydrologic units) in the western portion of the R2MF model domain and the undifferentiated, Floridan aquifer (one hydrologic unit) in the eastern portion of the R2MF model domain.

*Table 4. Groundwater model layer and hydrogeologic unit relationship*

| West | R2MF | CR2SWT | East |
|---|---|---|---|
| **hydrogeologic unit** | **MODEL LAYER** | | **hydrogeologic unit** |
| sand-and-gravel aquifer | 1 | 1 | surficial aquifer |
| intermediate confining unit | 2 | 2-4 | intermediate aquifer/confining unit |
| Upper Floridan aquifer | 3 | 5-9 | Upper Floridan aquifer (undifferentiated) |
| Bucatunna Clay confining unit | 4 | 10-12 | |
| Lower Floridan aquifer | 5 | 13-18 | |
| Sub-Floridan System | - | 19-21 | Sub-Floridan System |

Major annual-average pumping within the Upper Floridan aquifer was simulated from 1942 to 2015. Figure 24 compares the total simulated pumping domain-wide to simulated pumping within Region II only. The plot shows simulated pumping within the Region II portion of the R2MF model domain to be 80% - 99% of the total pumping over the simulation period.

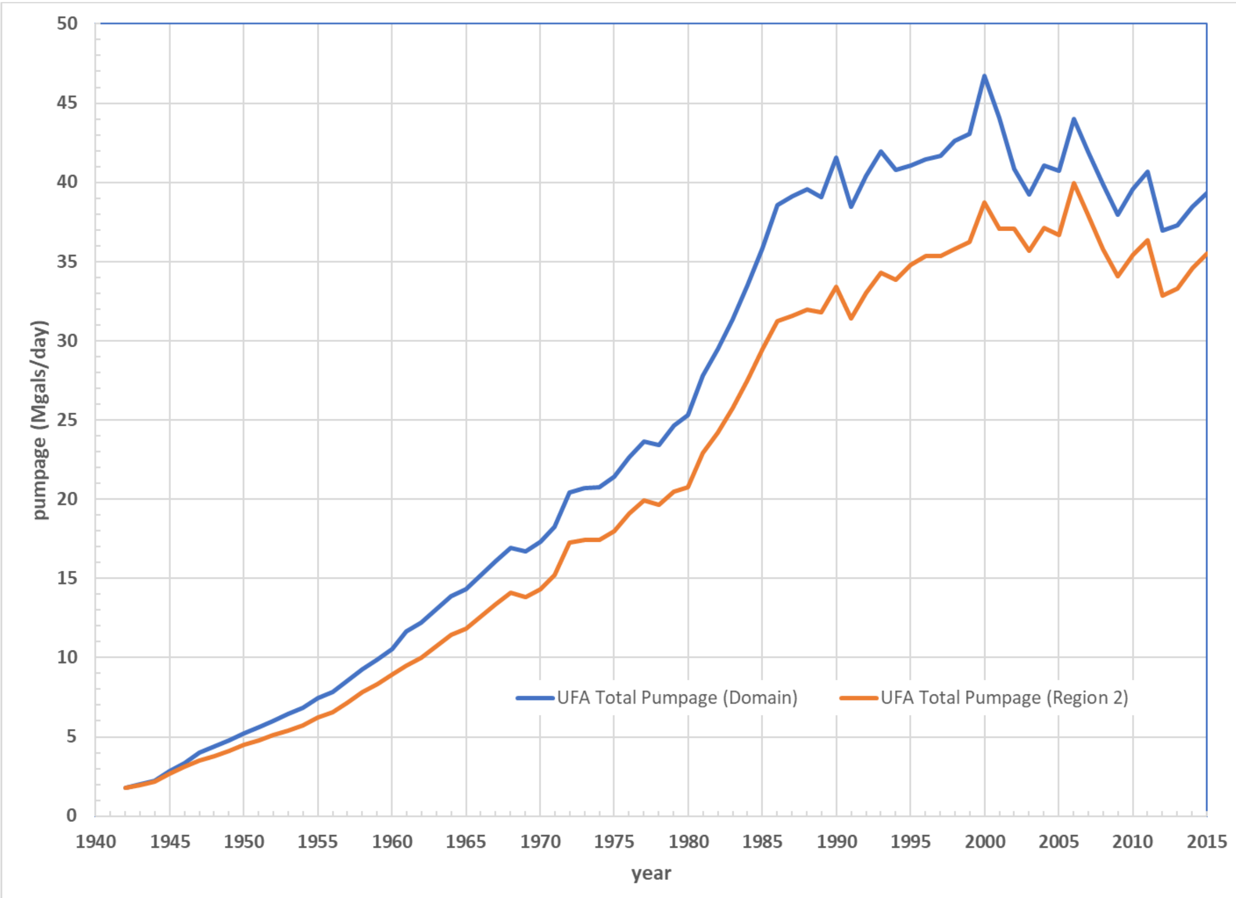


*Figure 24. Simulated major Upper Floridan aquifer pumping for Region II MODFLOW groundwater flow model calibration*

Calibration was performed using PEST parameter estimating software within an automated pre- and post-processing framework. Pilot points were used to define the spatial distribution of horizontal hydraulic conductivity in aquifers (Layers 3 and 5) and vertical hydraulic conductivity in confining units (Layers 2 and western portion of 4). Multipliers were used to adjust initial values for other properties including Layer 1 hydraulic properties, Layers 2 through 5 hydraulic conductivity anisotropy, and riverbed conductance. Multiple target types were used to inform PEST including post-development heads, horizontal-head difference (HHD), vertical-head difference (VHD), and temporal-head difference (THD). Targets were assigned to temporal or locational groups and weights were adjusted during calibration. Head and HHD targets were divided into the following temporal groups: 1942 – 1965, 1966 – 1990, and 1991 – 2015. VHD targets were divided into the following temporal groups: 1977 – 1990, 1991 – 2003, and 2004 – 2015. THD targets were divided into three groups based on their location relative to the subregional SEAWAT domain (i.e., outside of domain, eastern half of domain, or western half of domain).

Smaller calibration metric values for mean error (ME) and mean absolute error (MAE) were applied to targets within the footprint of the subregional SEAWAT model domain (Figure 23). The improved match of targets to observations in the subregional area facilitated the subsequent calibration of the SEAWAT model. All domain-wide and subregion calibration metrics were met except for the subregion MAE metric (Table 5).

*Table 5. Region II MODFLOW (R2MF) model calibration metrics*

| NWF R2MF Final Calibration Metrics | | | | Calibration Goals | |
|---|---|---|---|---|---|
| Calibration Target Type | Calibration Metric | Domain-Wide Metric Value | Subregion Metric Value | Domain-Wide Metric Target | Subregion Metric Target |
| Post-dev Groundwater Heads | Mean Error | 0.40 ft | -0.08 ft | +/- 5 ft | +/- 2 ft |
| | Mean ABS Error | 5.39 ft | 5.28 ft | 10 ft | 5 ft |
| Pre-dev Groundwater Heads | Mean Error | 1.99 ft | 2.24 ft | NA | NA |
| | Mean ABS Error | 3.59 ft | 5.89 ft | NA | NA |
| VHDs | Mean ABS Error / Range | 6.78% | 6.20% | 10% | 10% |
| HHDs | Mean ABS Error / Range | 3.35% | 5.28% | 10% | 10% |
| THDs | Mean ABS Error / Range | 1.88% | 2.07% | 20% | 20% |
| Incremental Baseflows | Mean ABS Error / Range | 15.29% | NA | 40% | NA |

The R2MF model is capable of simulating heads and head differences through space and time reasonably well. This demonstrates that the R2MF model is a suitable tool for defining boundary conditions and providing initial estimates of aquifer parameters for the subregional CR2SWT model. Parameterization and calibration of the R2MF model is documented in detail by Tetra Tech (2020b) and provided in Appendix L.

### 3.4.3 SEAWAT Model Calibration

The new CR2SWT model was revised to better represent the Upper Floridan aquifer by including hydrogeologic and water quality information collected since the original DSTRAM models were constructed. The pre-and post-processing procedure developed for the regional MODFLOW model calibration was used to calibrate the SEAWAT model. The transient calibration period was identical to that of the R2MF model as annual average simulated heads from the regional flow model were used as boundary conditions for the CR2SWT model. Both models include a long predevelopment stress period followed by a post-development period with 74 annual stress periods representing 1942 – 2015. The R2MF and CR2SWT models were successively run during the calibration to transfer the updated hydraulic properties from the SEAWAT model to the MODFLOW model so regional heads could be generated to provide new SEAWAT boundary conditions. The CR2SWT model grid spacing was retained but an additional upper layer representing the surficial aquifer was added to be consistent with the R2MF model. Table 4 shows the relationship of the simulated model layers to the hydrogeologic units within the CR2SWT model domain. Groundwater concentrations were simulated in terms of relative salinity units (RSUs) based on the saline parameter relationships listed in *Section 3.1* above (i.e., one RSU is equivalent to 10,800 mg/L Na, 19,400 mg/L Cl, and 35,000 mg/L TDS). For evaluation purposes, simulated RSUs were converted to Na, Cl, or TDS values to compare results to drinking water standards based on available well data. For example, a simulated concentration value of 0.014 RSU would equal 151 mg/L Na, 272 mg/L Cl and 490 mg/L TDS suggesting near exceedances of the Na (160 mg/L) and TDS (500 mg/L) drinking water standards and a slight exceedance in the Cl (250 mg/L) standard.

In addition to the target types used to calibrate the regional flow model, the following target types were added to the PEST calibration: groundwater concentrations in RSU, vertical concentration difference (VCD), and temporal concentration difference (TCD). As with the regional flow model calibration, all CR2SWT calibration metrics were met except for the head MAE (Table 6). However, the "MAE ÷ simulated head range (209.5 ft)" is less than 5% qualifying the calibration as good. Calibration of the CR2SWT model is documented in detail by Tetra Tech (2020c) and provided in Appendix M.

*Table 6. Coastal Region II SEAWAT (CR2SWT) model calibration metrics*

| **NWF CR2SWT Final Calibration Metrics** | | | **Calibration Goals** |
|---|---|---|---|
| **Calibration Target Type** | **Calibration Metric** | **Metric Value** | **Metric Target** |
| Groundwater Heads | Mean Error | 0.78 ft | +/- 2 ft |
| | Mean ABS Error | **6.25 ft** | **5 ft** |
| VHDs | Mean ABS Error / Range | 3.62% | 10% |
| HHDs | Mean ABS Error / Range | 6.81% | 10% |
| THDs | Mean ABS Error / Range | 3.99% | 20% |
| Goundwater Concentrations | Mean Error | 0.0010 RSU | +/- 0.0025 RSU* |
| | Mean ABS Error | 0.0031 RSU | 0.0050 RSU |
| VCDs | Mean ABS Error / Range | 6.15% | 10% |
| TCDs | Mean ABS Error / Range | 1.51% | 20% |

* The concentration Mean Error target value of 0.0025 RSU is equal to 54 mg/L Na, 97 mg/L Cl and 175 mg/L TDS based on the established saline parameter relationships listed in *Section 3.1*.

### 3.4.4 SEAWAT Predictive Sims

The calibrated coastal Region II SEAWAT (CR2SWT) model was used to simulate the effects of major permitted and projected pumping through year 2040 within the model domain on the rates and direction of saltwater movement. The predictive simulations start at the end of the SEAWAT calibration period with simulated 2015 groundwater heads and concentrations used as initial conditions. Three pumping scenarios were simulated for the 2020 – 2040 planning period: 2020 permitted average daily rates, 2018 WSA projected average daily rates, and 2018 WSA projected rates with sea level rise. Simulated pumping was applied to wells within a permitted water supply system proportional to their average historical rates. Summaries of simulated regional and domain-wide initial and 2040 pumping rates, by pumping scenario and water use type, are provided in Tables 7 and 8, respectively.

*Table 7. Summary of simulated Region II initial and 2040 pumping rates by pumping scenario and water use type*

| **Region II** | **2015 ADR (initial conditions)** | | **2040 Permitted ADR (Scenario 1)** | | **2040 WSA Projected ADR (Scenarios 2 and 3)** | |
|---|---|---|---|---|---|---|
| **Water Use** | **pump(gpd)** | **inject (gpd)** | **pump(gpd)** | **inject (gpd)** | **pump(gpd)** | **inject (gpd)** |
| Ag Irrigation | | | 299,900 | | 50,408 | |
| Aquaculture | 241,077 | | 564,000 | | 307,623 | |
| Golf Course Irrigation | 255,249 | | 677,000 | | 310,611 | |
| Industrial | | | | | | |
| Institutional | 109,975 | | 174,969 | | 143,336 | |
| Injection | | 245,598 | | 323,136 | | 323,136 |
| Limited Public Supply | | | | | | |
| Public Supply | 34,884,720 | | 68,768,502 | | 46,704,737 | |
| | | | | | | |
| **Region II Total** | **35,491,021** | **245,598** | **70,484,371** | **323,136** | **47,516,716** | **323,136** |

*Table 8. Summary of simulated domain-wide initial and 2040 pumping rates by pumping scenario and water use type*

| **Domain Wide** | **2015 ADR (initial conditions)** | | **2040 Permitted ADR (Scenario 1)** | | **2040 WSA Projected ADR (Scenarios 2 and 3)** | |
|---|---|---|---|---|---|---|
| **Water Use** | **pump(gpd)** | **inject (gpd)** | **pump(gpd)** | **inject (gpd)** | **pump(gpd)** | **inject (gpd)** |
| Ag Irrigation | | | 299,900 | | 50,408 | |
| Aquaculture | 241,077 | | 564,000 | | 307,623 | |
| Golf Course Irrigation | 255,249 | | 677,000 | | 310,611 | |
| Industrial | 275,956 | | 368,281 | | 436,728 | |
| Institutional | 109,975 | | 174,969 | | 143,336 | |
| Injection | | 3,391,813 | | 3,460,154 | | 3,460,154 |
| Limited Public Supply | 23,317 | | | | 21,466 | |
| Public Supply | 38,424,692 | | 76,379,721 | | 51,005,593 | |
| | | | | | | |
| **Domain Total** | **39,330,266** | **3,391,813** | **78,463,871** | **3,460,154** | **52,275,766** | **3,460,154** |

Scenario 1 simulated the effects of rapidly increasing Upper Floridan aquifer withdrawals from the estimated 2015 amounts to permitted annual average daily rates in 2020. It was assumed that permitted water systems in 2020 would still be permitted and pumping at permitted amounts in 2040. Simulated pumping was linearly increased from initial conditions to permitted amounts between 2015 and 2020, then held constant through year 2040. This abrupt increase was intended to simulate the maximum effect of pumping 2020 permitted rates on water levels and rates of saltwater intrusion. Under the Scenario 1, two significant areas of drawdown in the Upper Floridan aquifer are centered on Fort Walton Beach and Niceville with 2040 simulated heads more than 200 and 120 feet below sea level, respectively. Simulated withdrawals to the north, outside the CR2SWT model domain are creating a high in the potentiometric surface between Crestview and Niceville with divergent flow moving north toward the model boundary and south toward the Fort Walton Beach pumping center. Drawdown in the Central Walton wellfield area is below sea level. It should be noted from Table 7, simulated Region II permitted Upper Floridan aquifer allocations (70,484,371 gpd) are approximately double the estimated 2015 simulated withdrawals (35,491,021 gpd). Public water supply (68,768,502 gpd) represents 97.6 percent of the 2040 Region II permitted quantities. This extreme pumping scenario represents a worst-case simulation as WSA 2018 projected pumping in 2040 (scenario 2) is approximately 33 percent less than currently permitted allocations.

Scenario 2 simulated the effects of 2020 - 2040 projected Upper Floridan aquifer pumping in the model domain as estimated in the 2018 WSA (Hollister et al., 2018). Major water demand projections were reported in the WSA at five-year intervals from 2020 to 2040. For this evaluation, average pumping was interpolated annually between the five-year projections from the 2015 initial conditions to 2040 projected amounts. The simulation provides a good estimate of pumping to evaluate potential impacts from saltwater intrusion over the 2020 - 2040 planning period.

As previously described (Table 4), the Upper Floridan aquifer in the CR2SWT model is divided into five layers (Layers 5 – 9). To evaluate the effect of projected pumping on Upper Floridan aquifer water levels, simulated heads from the middle of the aquifer (Layer 7) for years 2015 and 2040 were compared. Simulated Layer 7 heads for 2015 and 2040 are shown in Figures 25 and 26, respectively.

The simulated 2015 pumping results in the 0-ft mean sea level contour being located between Crestview and the Fort Walton Beach/Niceville area in Okaloosa County and along the eastern end of the Choctawhatchee Bay in Walton County. The simulated 2015 pumping was estimated based on reported water use from the Upper Floridan aquifer in Region II. Under this simulated pumping scenario, the main cone of depression in the Fort Walton Beach area is coalescing with a minor depression in the Niceville/Valparaiso area (Figure 25). The simulated centers of the main and minor depressions are approximately 102 feet and 69 feet below sea level, respectively, and still located along the coast. The simulated potentiometric surface for the middle of the Upper Floridan aquifer is similar to the estimated potentiometric surface for May 2015 (Figure 19) interpolated from observed Upper Floridan aquifer water level data. The estimated centers for the main and minor depressions from the May 2015 map are approximately 75 feet and 45 feet below sea level, respectively. The simulated and estimated differences between the main and minor depressions are 33 feet and 30 feet, respectively.

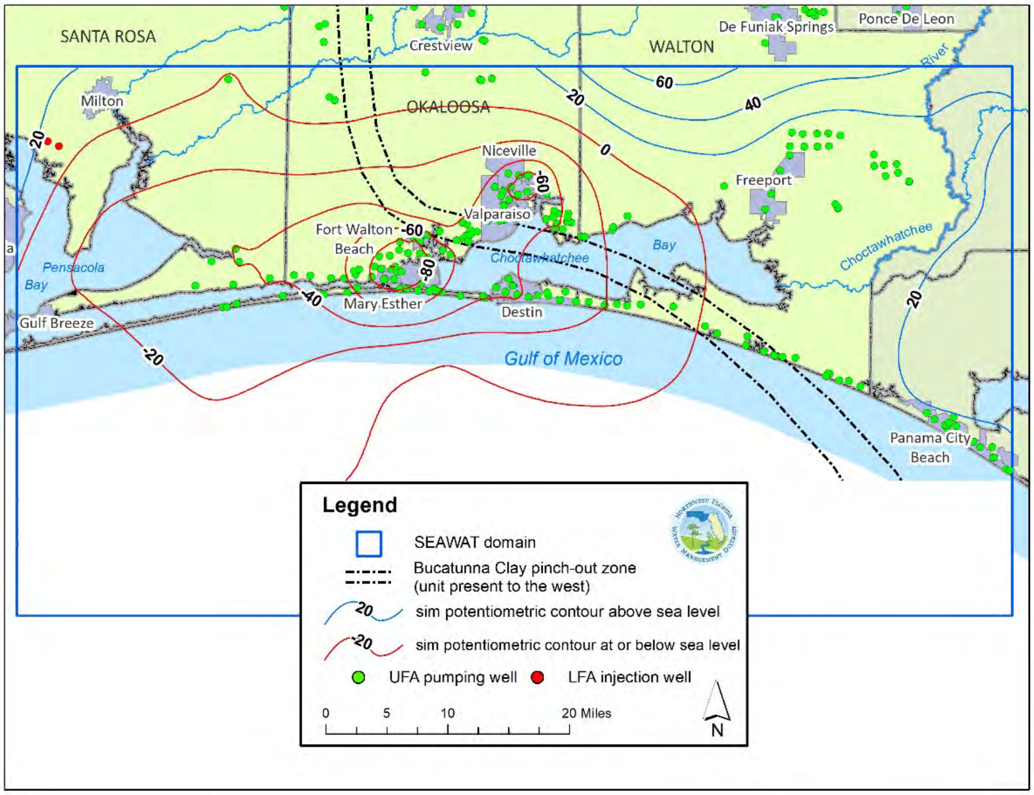


*Figure 25. Simulated 2015 potentiometric surface of the Upper Floridan (Layer 7, mid-aquifer) for Scenario 2*

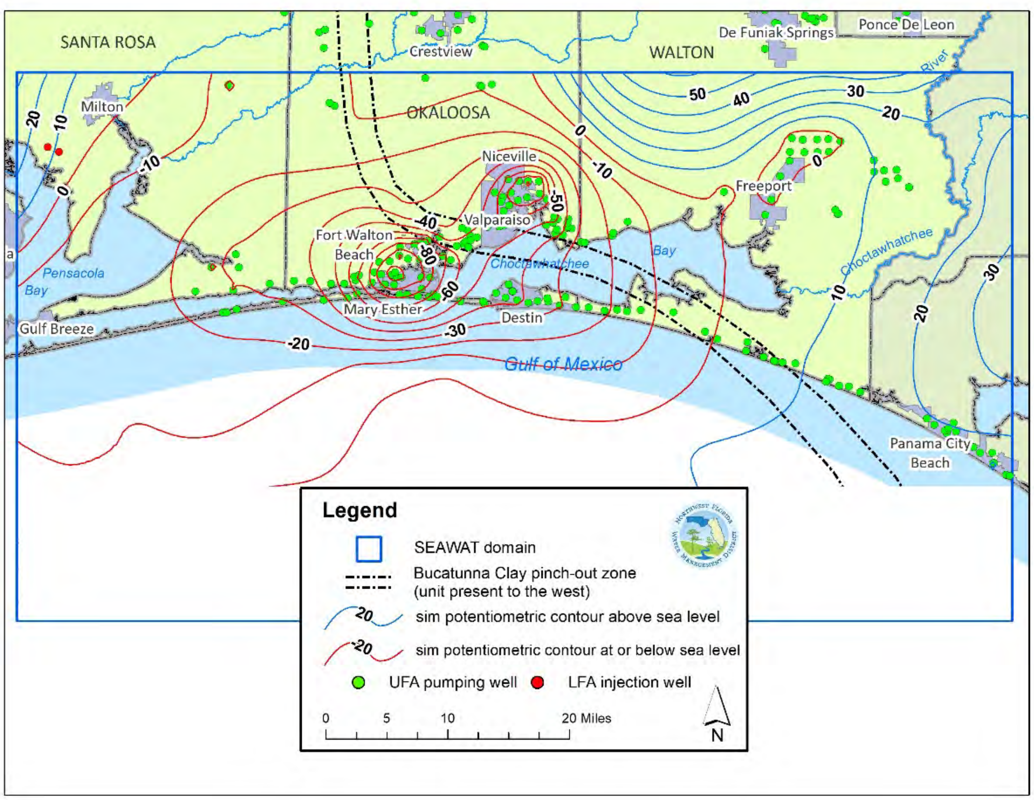


*Figure 26. Simulated 2040 potentiometric surface of the Upper Floridan (Layer 7, mid-aquifer) for Scenario 2*

By 2040, simulated pumping reduces the heads in these areas by an additional 4 feet in the main depression and 14 feet in the minor depression (Figure 26). The 2040 simulated results also show the commensurate increases in drawdown associated with projected pumping allocated to the inland areas developed as alternative water supplies in central Okaloosa and Walton counties. The area south of Crestview, in central Okaloosa County, shows over 20 feet of additional drawdown along the northern edge of the model domain (Figure 27).

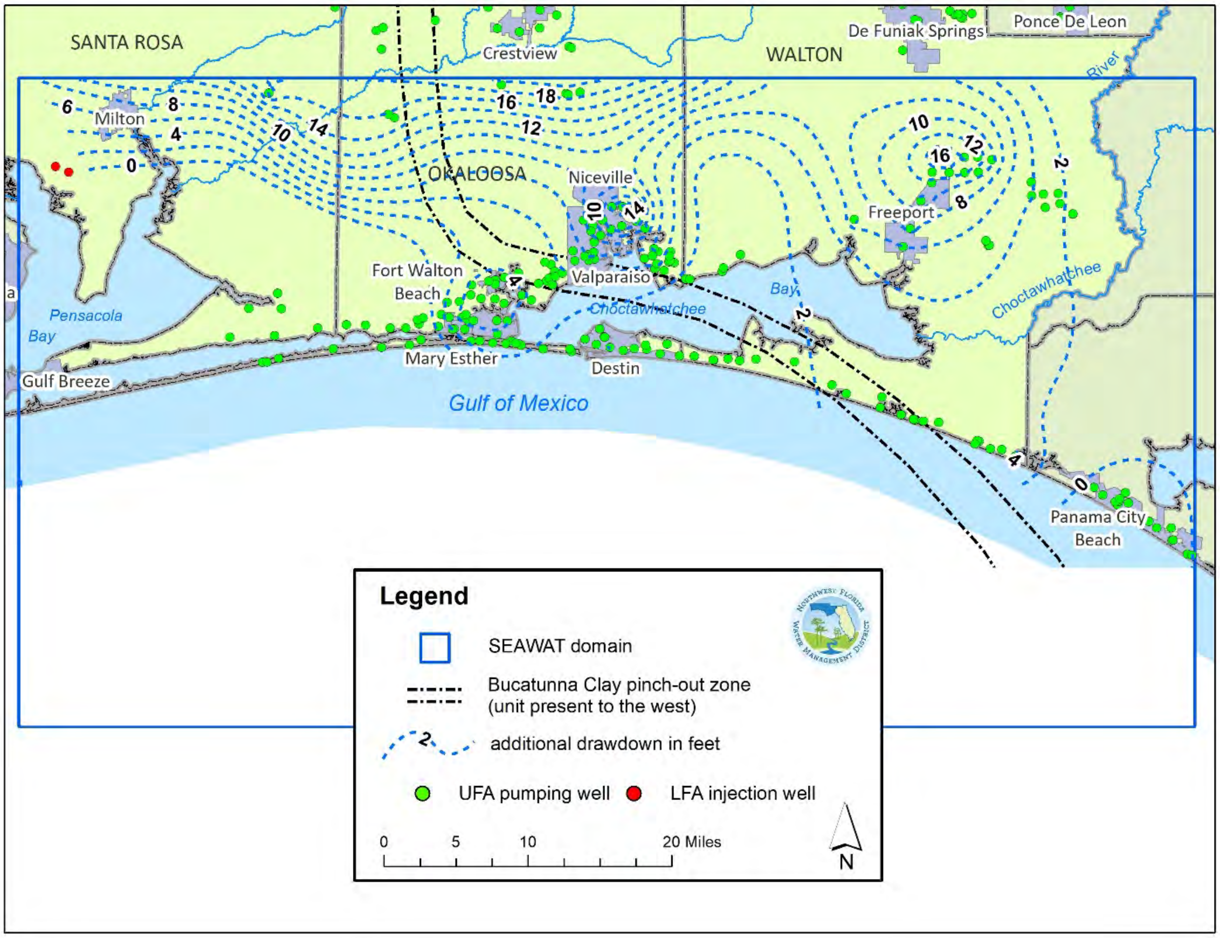


*Figure 27. Simulated additional drawdown within the Upper Floridan (Layer 7, mid-aquifer) between 2015 and 2040, Scenario 2*

Similarly, the effect of projected pumping on Lower Floridan aquifer water levels was evaluated by comparing the simulated 2015 and 2040 heads from Layer 15. Layer 15 represents the middle of the Lower Floridan aquifer (Table 4). Simulated Layer 15 heads for years 2015 and 2040 are shown in Figures 28 and 29, respectively. Simulated increase in drawdown in Layer 15 between 2015 and 2040 is shown in Figure 30.

Under 2015 pumping conditions a cone of depression is simulated in the Lower Floridan aquifer centered along the Bucutunna Clay confining unit pinch-out zone in the vicinity of Niceville and Valparaiso (Figure 28). Simulated water levels at the center of the cone are on the order of 40 feet below sea level. This demonstrates how pumping from the Upper Floridan aquifer can reduce the pressure below the production zone where the Bucatunna Clay formation is thin to absent. Drawdown can propagate to lower parts of the aquifer, and even below the Bucatunna Clay, increasing the hydraulic gradient of groundwater flow and the potential for movement of poorer quality water towards production wells. The 2040 projected pumping results show simulated heads even lower near the center of the central depression with an expansion of the cone to the north toward Crestview and east toward the Central Walton wellfield area (Figure 29). A closed depression below sea level is simulated in the Central Walton wellfield area due to increased 2040 projected pumping.

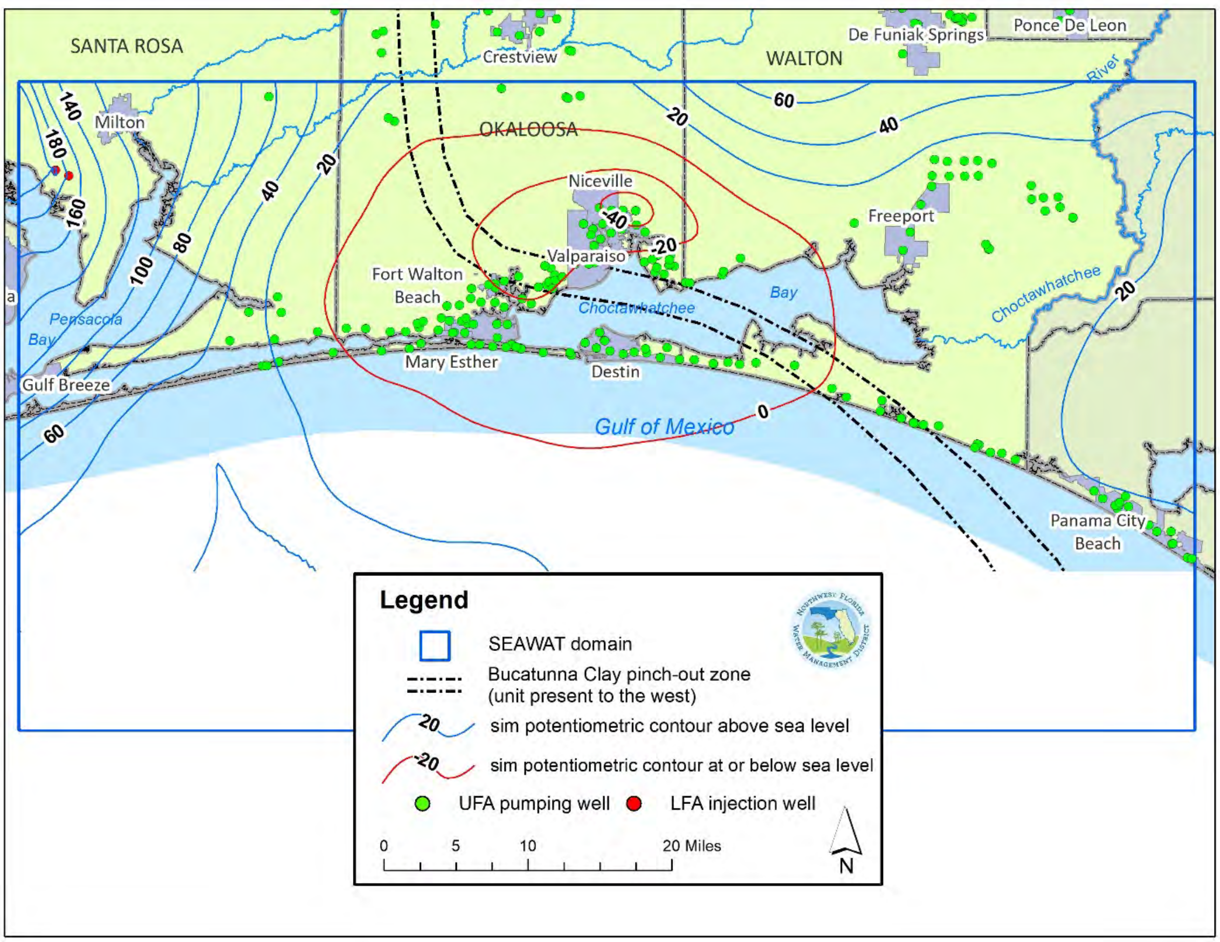


*Figure 28. Simulated 2015 potentiometric surface of the Lower Floridan aquifer (Layer 15, mid-aquifer) for Scenario 2*

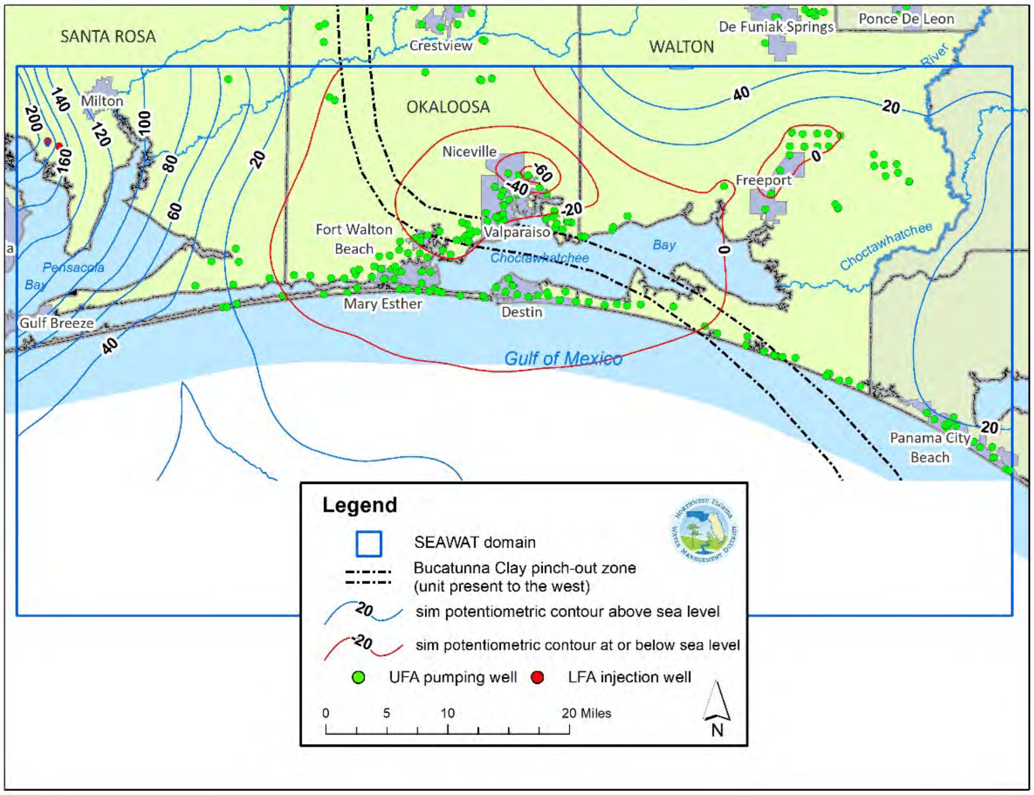


*Figure 29. Simulated 2040 potentiometric surface of the Lower Floridan (Layer 15, mid-aquifer) for Scenario 2*

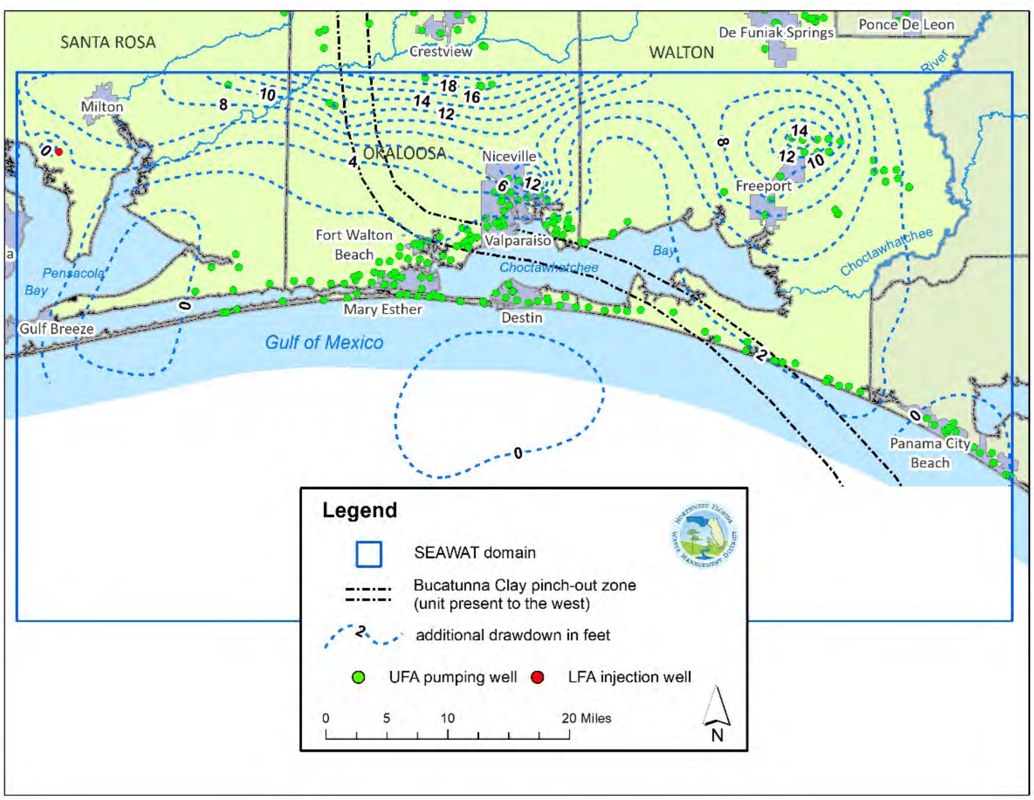


*Figure 30. Simulated additional drawdown within the Lower Floridan (Layer 15, mid-aquifer) between 2015 and 2040, Scenario 2*

In addition to simulated water levels, changes in simulated TDS concentrations are also described as an indication of saltwater movement. The 2015 and 2040 simulated TDS concentrations for the middle of the Upper Floridan aquifer are compared in Figure 31 and increases between those years due to projected pumping are shown in Figure 32. The color flood scale is the same for both years with differences reflected in the dashed contour lines. As with the simulated head results, simulated concentrations from Layer 7 (mid-aquifer) are compared. The highest simulated concentrations of TDS in the Upper Floridan aquifer occur where they are conceptually anticipated. Concentrations greater than 1,000 mg/L are simulated beneath the mouth of the Choctawhatchee River and eastern end of Choctawhatchee Bay (Figure 31) in both 2015 and 2040. This is where the heads in the Upper Floridan aquifer are close to sea level and the intermediate system is thin and permeable. An increasing west-southwest trend in TDS concentrations is also simulated in the western half of the model domain where the Upper Floridan aquifer's depth and degree of confinement increase. Non-potable water is present in the Upper Floridan aquifer to the west. The greatest increases in Upper Floridan aquifer TDS concentrations between 2015 and 2040 are simulated in two areas of interest (Figure 32). Area 1 is located between Fort Walton Beach and Niceville/Valparaiso and Area 2 is located near Freeport south of the Central Walton wellfield area.

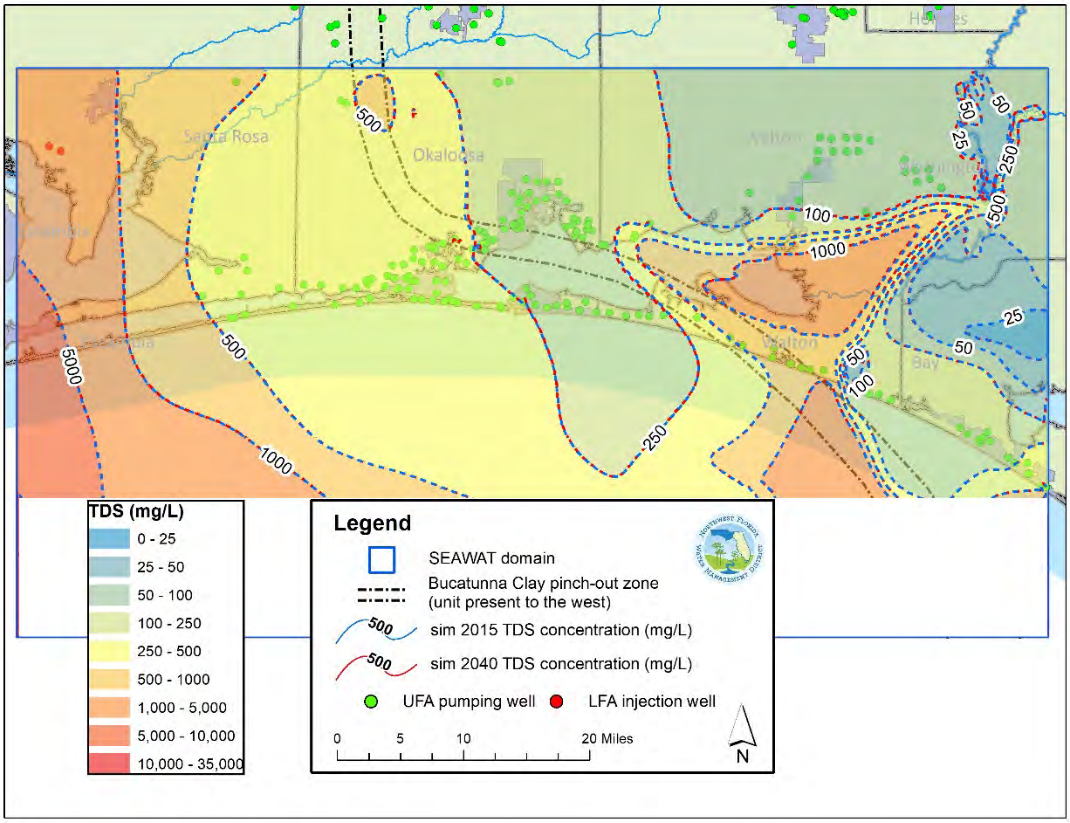


*Figure 31. Upper Floridan (Layer 7, mid-aquifer) simulated TDS concentrations for 2015 and 2040, Scenario 2*

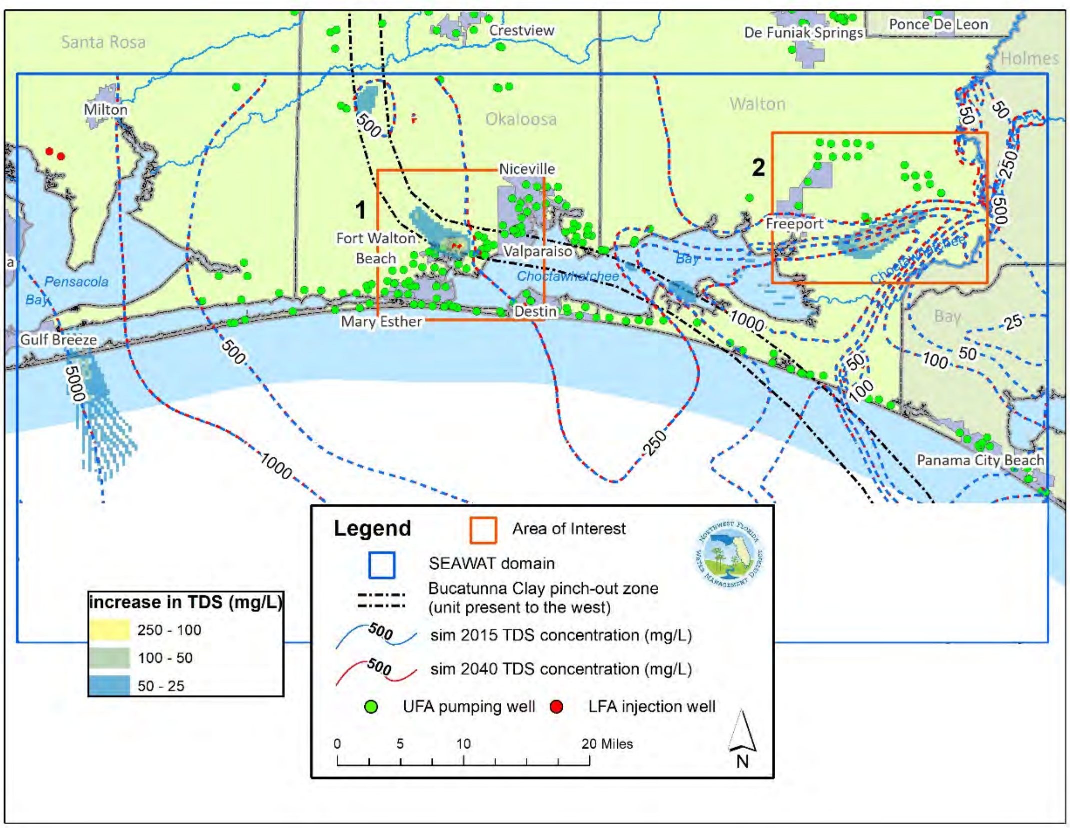


*Figure 32. Simulated increases in Upper Floridan TDS concentration (Layer 7, mid-aquifer) between 2015 and 2040*

Simulated 2015 and 2040 TDS results for the Upper Floridan aquifer in Area 1 are shown in Figure 33. Under 2040 projected pumping conditions, TDS concentrations along the Bucutunna Clay confining unit pinch-out zone, just north of Fort Walton Beach, increase between 100 and 250 mg/L, eventually exceeding the 500 mg/L TDS secondary drinking water standard (Rule 62-550, Florida Administrative Code) by 2040 (Figure 33). The closed shape of the concentration increase suggests that the increase is due to up-coning of poorer quality water from deeper in the Upper Floridan aquifer.

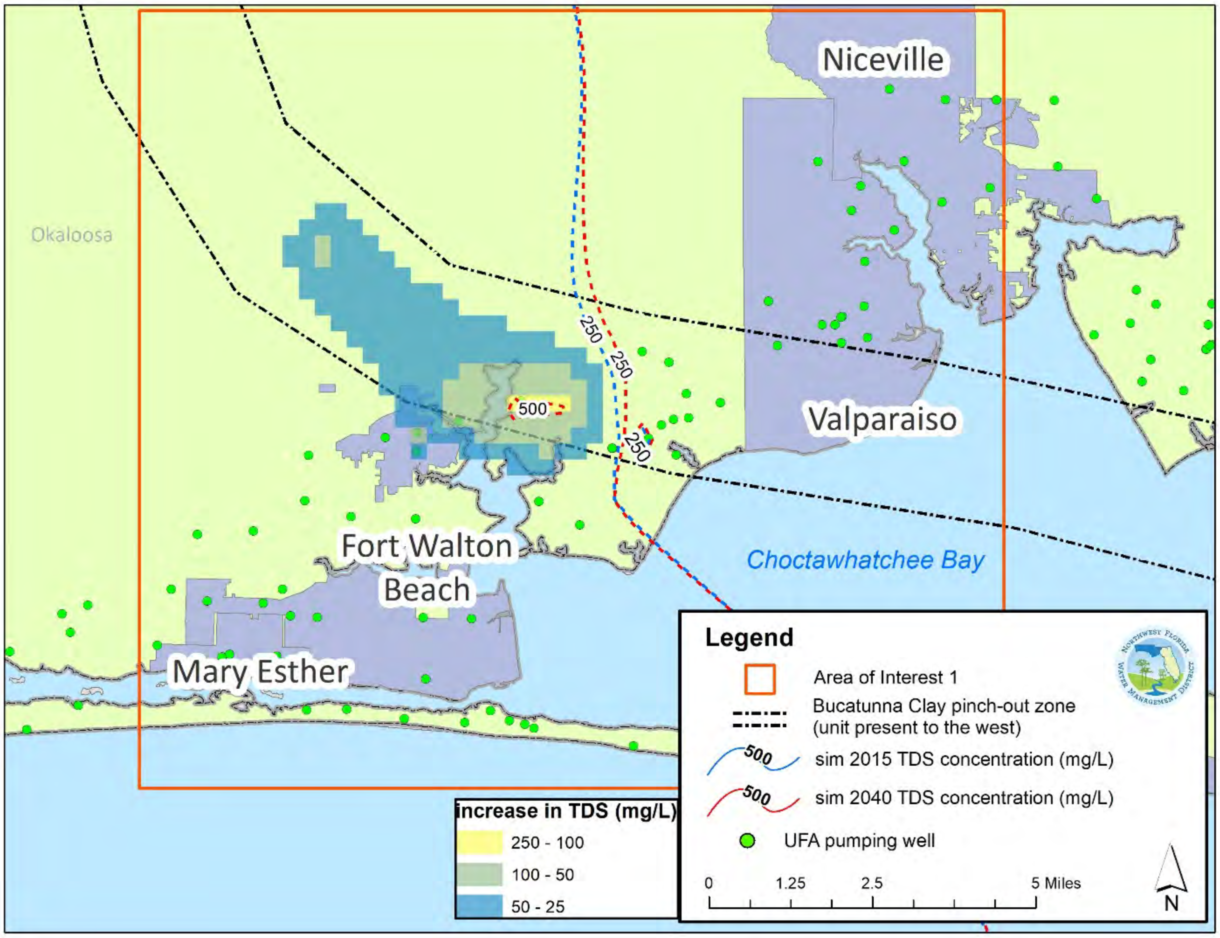


*Figure 33. Simulated increases in Upper Floridan TDS concentration between 2015 and 2040 (Area of Interest 1)*

Simulated 2015 and 2040 TDS results for the Upper Floridan aquifer in Area 2 are shown in Figure 34. Groundwater that exceeds the secondary drinking water standard for TDS is simulated to be present in the middle of the undifferentiated Upper Floridan aquifer approximately 2.5 miles to the south of the Central Walton wellfield area in both 2015 and 2040. The close spacing of the TDS iso-concentration lines (Figure 34) indicates that the potable water interface is onshore and steeply inclined. Between 2015 and 2040, the predicted horizontal interface movement north towards the wellfield is approximately 1,350 feet (approximately 54 ft/yr). The CR2SWT model also predicts movement of induced recharge from the Choctawhatchee River east toward the wellfield. However, this may instead represent reduced groundwater baseflow to the Choctawhatchee River from the Upper Floridan aquifer.

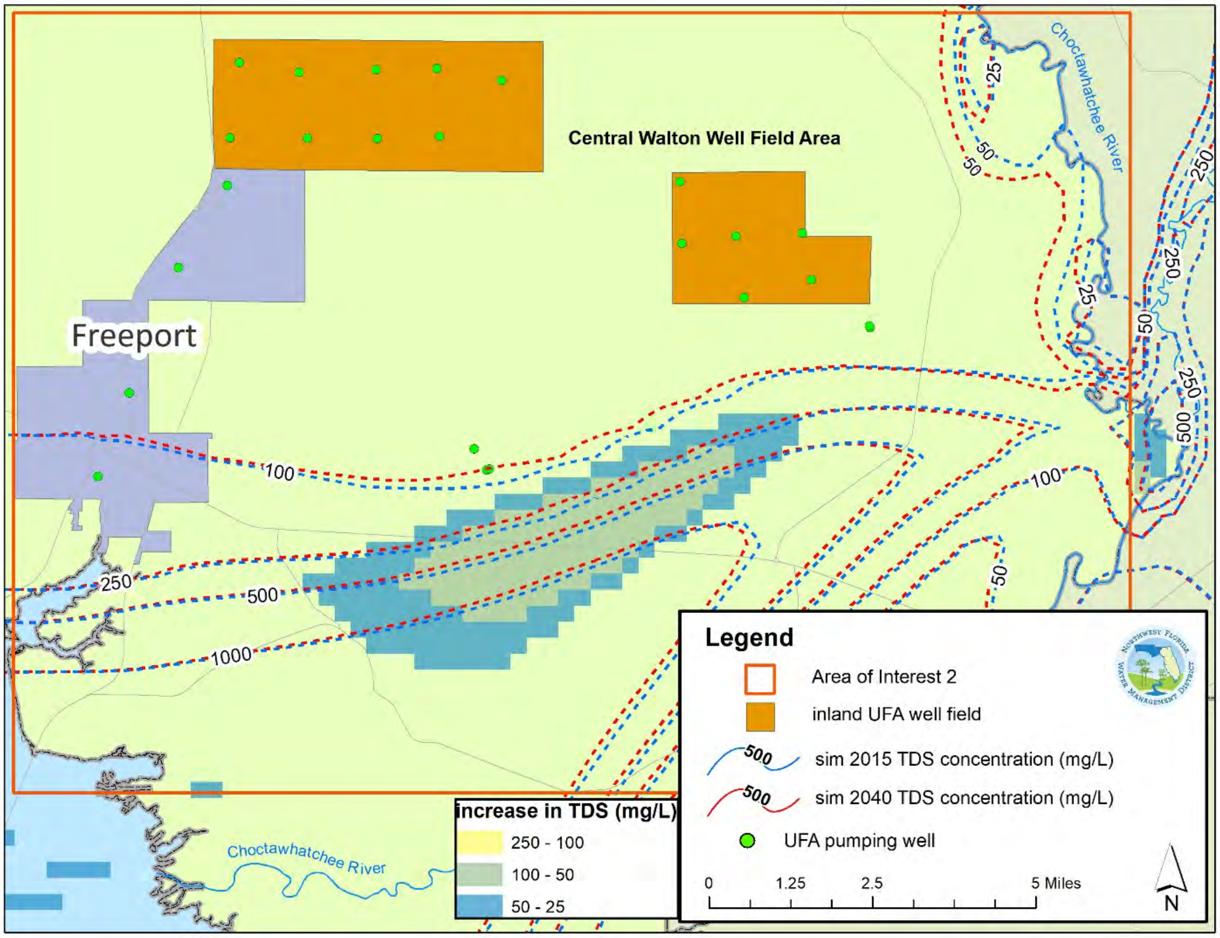


*Figure 34. Simulated increase in Upper Floridan TDS concentration between 2015 and 2040 (Area of Interest 2)*

The 2015 and 2040 simulated TDS concentrations for the middle of the Lower Floridan aquifer are compared in Figure 35 and increases between those years due to projected pumping are shown in Figure 36. Again, simulated results from Layer 15 (mid-aquifer) are compared. The ambient TDS concentrations in the Lower Floridan aquifer and lower part of the undifferentiated Upper Floridan aquifer are much higher than in the production zone of the Upper Floridan aquifer (Figure 35). Simulated TDS concentrations exceed 500 mg/L throughout most of the CR2SWT model domain. Water quality data are limited for the Lower Floridan and lower part of the undifferentiated Upper Floridan aquifer. However, the sampling of a Lower Floridan aquifer monitor well drilled in 1997 at Destin indicates that pumped concentrations of sodium, chloride and TDS have, over time, varied little from samples collected during initial construction (Hollister et al., 2018). Sodium, chloride and TDS concentrations in 1997 were 1,010 mg/L, 1,700 mg/L, and 3,220 mg/L, respectively. The same parameter concentrations of samples collected in June 2021 were 1,240 mg/L, 1,800 mg/L, and 3,220 mg/L, respectively.

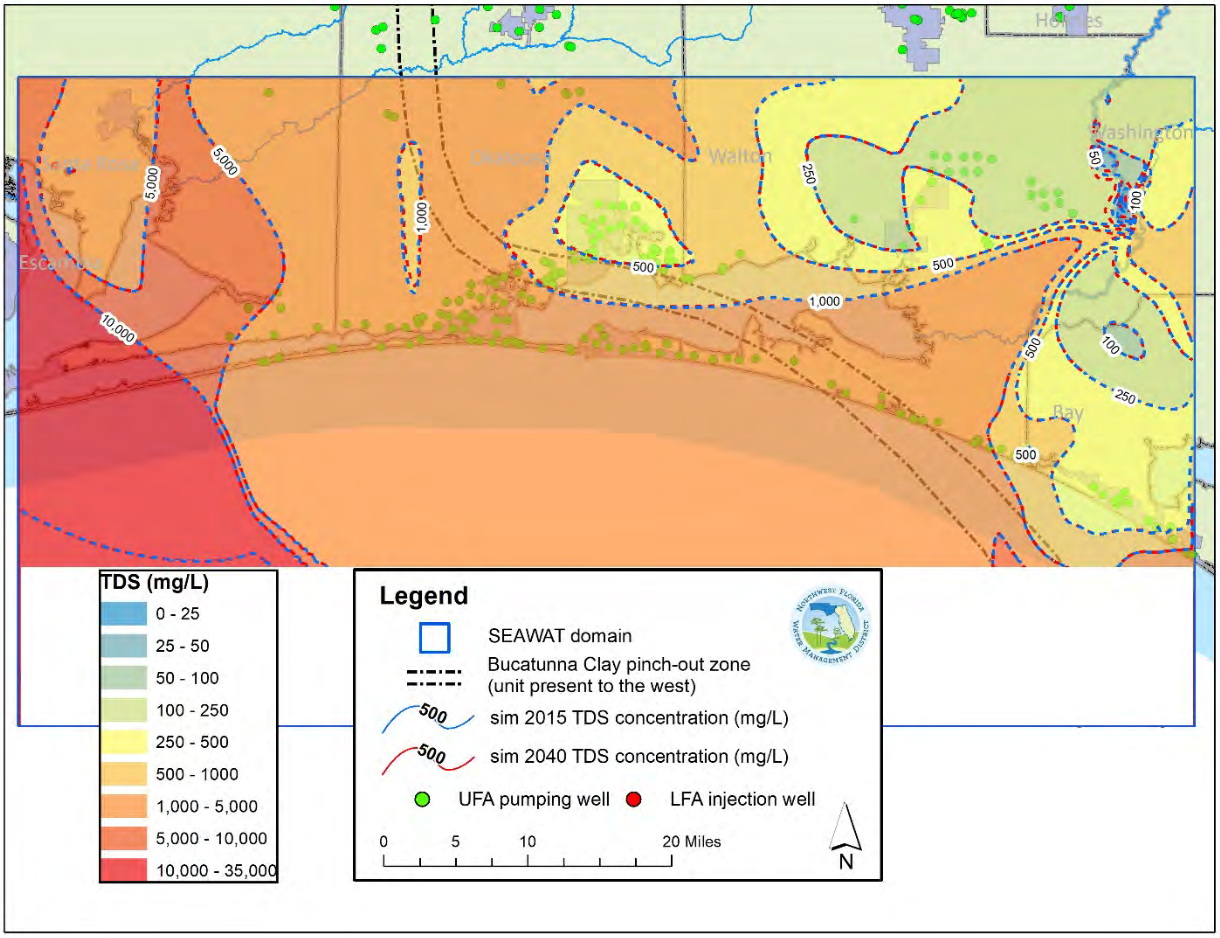


*Figure 35. Lower Floridan (Layer 15, mid-aquifer) simulated TDS concentrations for 2015 and 2040, Scenario 2*

Simulated lateral movement of the freshwater-saltwater interface, as expressed by the difference in 2015 and 2040 TDS iso-concentration lines (Figure 36), is less in the lower part of the aquifer as compared to the upper part because most of the pumping occurs higher up in the more productive aquifer formations. However, the induced baseflow from the Choctawhatchee River east of the Central Walton wellfield area is still apparent where the Upper Floridan aquifer is undifferentiated, thinner, and unconfined. The concentration increase noted in Area 1 between Fort Walton Beach and Niceville/Valparaiso is more pronounced in the lower part of the aquifer. This is associated with the lower heads observed in Figures 28 and 29.

One other notable area of increasing simulated TDS concentrations is onshore in Santa Rosa County (Figure 36) in the northwest corner of the model domain where the Lower Floridan aquifer is overlain by the Bucatunna Clay formation. The enclosed 5,000 mg/L TDS iso-concentration line around and south of Milton is associated with the simulated injection of treated industrial wastewater into the Lower Floridan aquifer. Water quality sampling results indicate the injected wastewater has lower median values of specific conductance, sodium, and chloride than the ambient groundwater (Andrews, 1994) giving an appearance of “fresher” water in the aquifer. The area of increasing TDS concentration to the west is most likely the simulation of the higher specified concentration boundary water mixing with the specified “fresher” injection water.

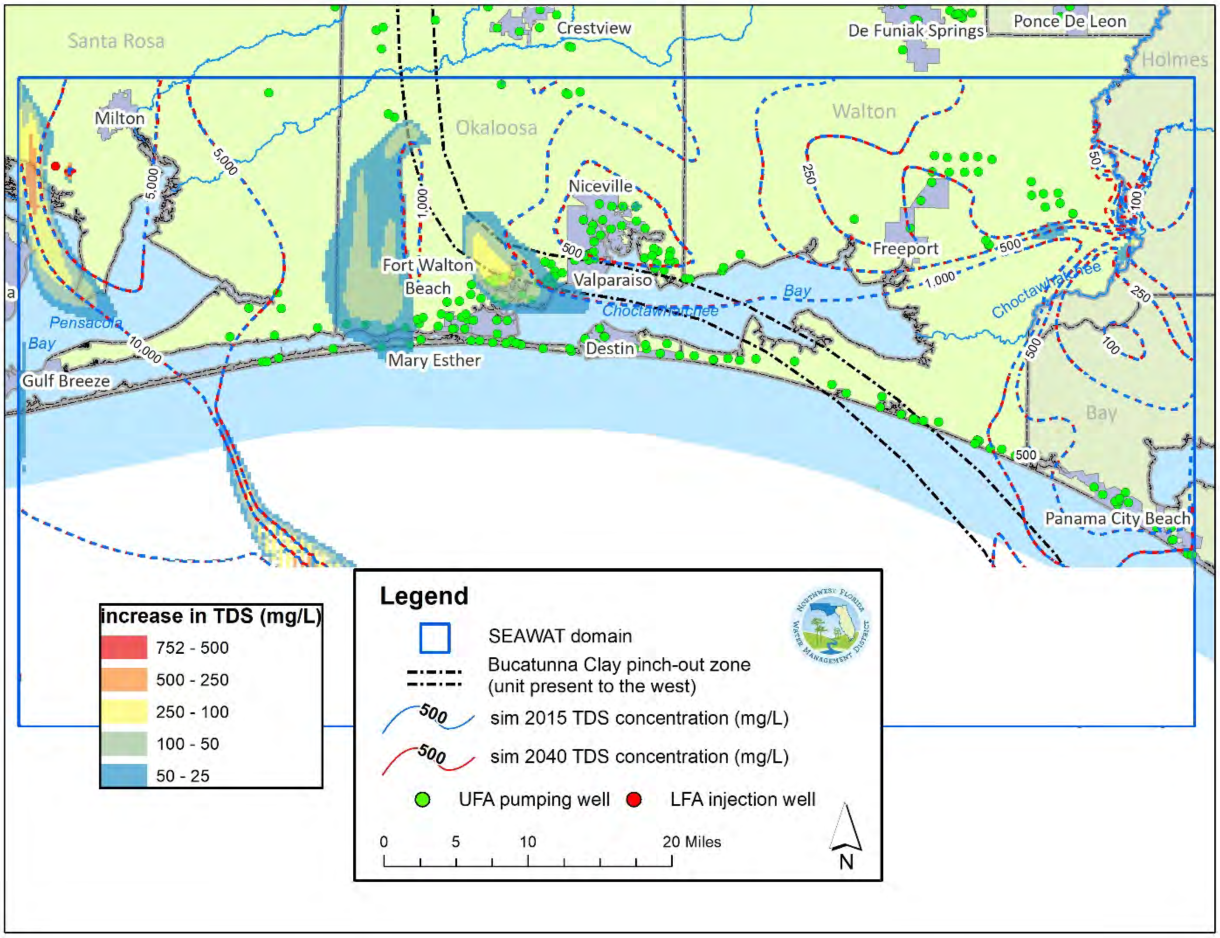


*Figure 36. Simulated increase in Lower Floridan TDS concentration (Layer 15, mid-aquifer) between 2015 and 2040*

Scenario 3 simulated the projected pumping as in Scenario 2 but with a steady rate of sea level rise applied to the Layer 1 bay and offshore specified heads in both the R2MF and CR2SWT models. Lateral offshore boundaries were also modified to account for the overlying change in specified head due to the applied sea level rise. A constant rate of 8.22 mm/yr was applied based on the average rate of increase observed from 2000 – 2020 at the NOAA Panama City and Pensacola gaging stations (NOAA, 2020). The effects of adding sea level rise to the projected pumping simulation did not produce any notable differences in results between Scenarios 2 and 3 (Tetra Tech, 2021).

However, minor reductions in vertical seepage velocities beneath Choctawhatchee Bay were simulated in Scenario 3 as specified bay stage values were increased at the applied sea level rise rate. Simulated heads below the bay, in the upper model layer of the intermediate system (Layer 2), are higher than the specified heads in the bay. Under these conditions, simulated groundwater flow under the bay is from the intermediate system to the bay. As the specified head assigned to the model cells representing the bay are increased at the rate of sea level rise, the hydraulic gradient between the simulated intermediate system heads and bay stage is decreased, decreasing flow.

Along the western end of Choctawhatchee Bay near the cone of depression centered on Fort Walton Beach (Figure 26), outflow from the intermediate system to Choctawhatchee Bay was reduced by approximately 0.008 in/yr. Near the eastern end of Choctawhatchee Bay the greatest absolute reduction in outflow from the intermediate system is on the order of 0.03 in/yr. These results indicate that the effect of sea level rise on simulated flow between the intermediate system and Choctawhatchee Bay is more pronounced where the intermediate system is thinner and more permeable and drawdown within the Upper Floridan aquifer can propagate upward lowering intermediate system heads.

The transient predictive simulations were performed and documented by Tetra Tech (2021) and are provided in Appendix N.

# 4.0 Wells and Water Supply at Risk

Public water supply wells along the coast are potentially susceptible to impacts from saltwater intrusion. There are several routes by which saltwater can move toward wells pumping groundwater from the Upper Floridan aquifer within Region II (HGL, 2004, 2007):

1. Lateral, inland movement within the Upper Floridan aquifer beneath the Gulf of Mexico,
2. Upward, vertical flow through or around the Bucatunna Clay confining unit from the Lower Floridan aquifer,
3. Up-coning from deeper formations within the undifferentiated Upper Floridan aquifer,
4. Leakage through the intermediate system from the overlying surficial aquifer adjacent to Choctawhatchee Bay and the Gulf of Mexico, or
5. Any combination of the above.

Several Upper Floridan aquifer public supply wells along the coast have been closed and abandoned due to increasing saline analytes over time. For example, wells associated with the former Florida Community Service Corp. system, located in southern Walton County, began to experience periodic exceedances in sodium (160 mg/L) and chloride (250 mg/L) drinking water standards in the late 1990s (Pratt, et al., 1998). These increases appear to be the result of up-coning of poor-quality water from below the impacted wells. The affected wells were taken out of service until water quality standards could be met. According to Pratt, et al. 1998, the increasing occurrence of down time for these wells reduced the utilities' ability to meet demand. As a result of collaborative efforts between the District and water utilities to reduce Floridan aquifer pumpage in coastal areas, an inland wellfield was constructed in 2001 and all wells in the system along the coast were subsequently abandoned.

The CR2SWT model results for projected-pumping Scenario 2 indicate that increased TDS concentrations within the Upper Floridan aquifer occur primarily along the Bucatunna Clay confining unit pinch-out zone just north of the center of the cone of depression in coastal Okaloosa and southern Walton County (Figure 32). In addition, the area south of the Central Walton wellfield area just east of Choctawhatchee Bay shows signs of increased up-coning of poor-quality water. Water quality at the base of the Upper Floridan aquifer where the Bucatunna Clay formation is present or the base of the main production zone where the Upper Floridan aquifer is undifferentiated is likely most susceptible. For this evaluation, a supply well is considered "at risk" if groundwater exceeding water quality standards is present below the production interval. The criterion assumes that if the pumping rate from a well "at risk" is high enough to induce up-coning, water quality in the well may decline and eventually exceed water quality standards. This assumption is conservative, as there may be vertical separation between the bottom of the production interval and the uppermost interval of poorer quality water.

Considering the impacts of up-coning of poor-quality water from deeper parts of the aquifer to potable water supplies along the coast in Region II, an evaluation of the number of wells "at risk" to up-coning was performed. The secondary water quality standard of 500 mg/L TDS (Rule 62-550, Florida Administrative Code) was used as the criteria for determining which Upper Floridan aquifer supply wells from the CR2SWT Scenario 2 simulation are "at risk" from potential up-coning.

As shown in Table 4, CR2SWT model Layer 9 represents the base of the Upper Floridan aquifer above the Bucatunna Clay confining unit, where present, and the base of the main production zone of the undifferentiated UFA to the east. In this evaluation, the position of the 500 mg/L TDS iso-contour line at the base of the production zone represents the toe of the potable water interface. If a well is spatially located where the simulated TDS concentration in Layer 9 is greater than or equal to 500 mg/L, the potable water interface is present below the well's production interval and the well is assumed to be "at risk" by up-coning of poor-quality water. This evaluation does not consider that some areas may meet the TDS water quality standard but exceed other water quality standards, such as sodium and chloride.

The results of the projected pumping simulation (Scenario 2) were used to evaluate the number of Upper Floridan aquifer public supply wells "at risk" of potentially exceeding the 500 mg/L TDS water quality standard. Evaluated wells were active as 2015. Under 2015 simulated pumping conditions, 13 active public supply wells were identified as being "at risk" (Figure 37).

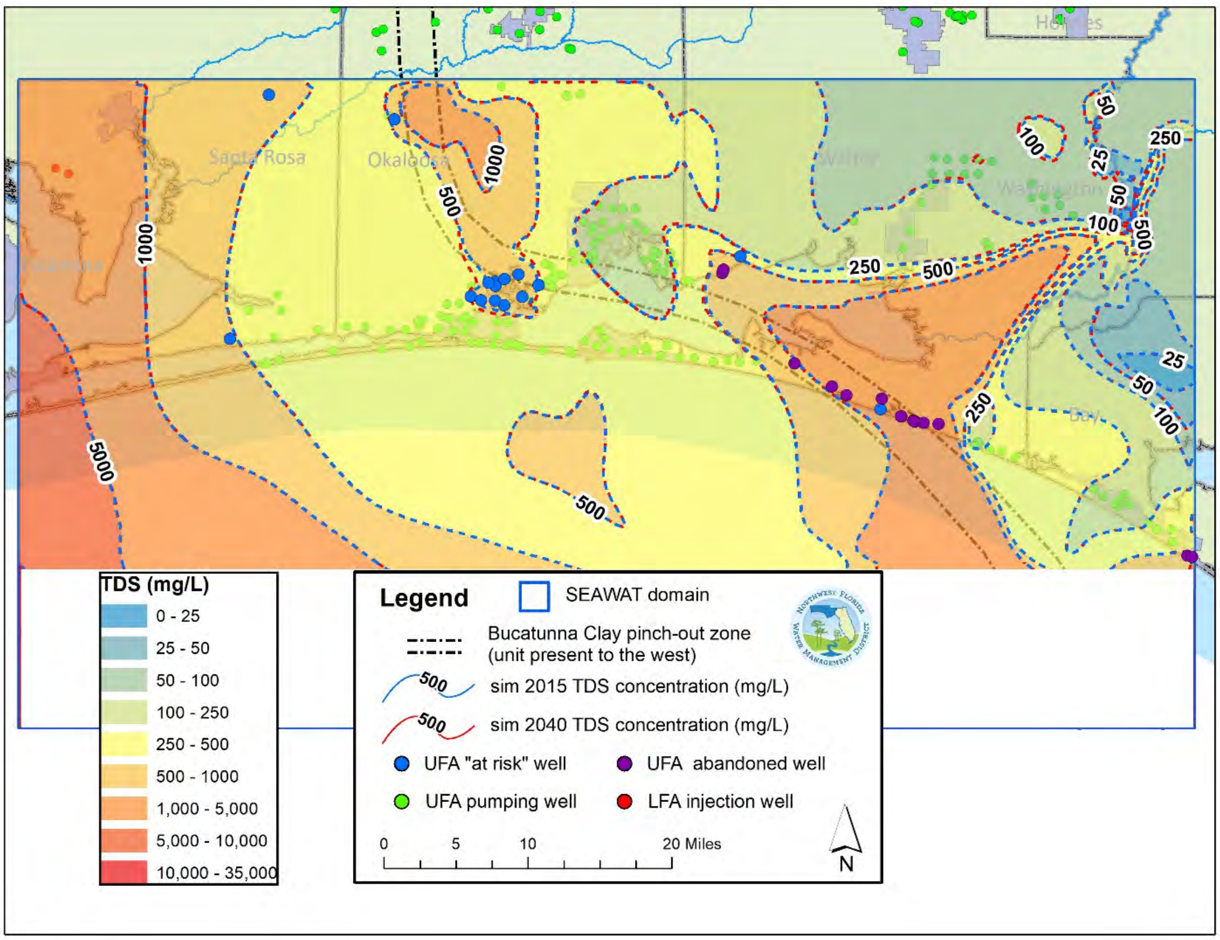


*Figure 37. Upper Floridan (Layer 9, base of production zone) simulated TDS concentrations for 2015 and 2040, Scenario 2*

Of the 13 wells "at risk", ten (10) wells are designated as coastal and are in areas previously described as being vulnerable to up-coning (i.e., vicinity of Fort Walton Beach and east end of Choctawhatchee Bay). One of these wells (NWF1841, Figure 38) currently has an average TDS concentration just above the standard (i.e., 512 mg/L TDS) and indicates an increasing trend in TDS concentration. The remaining nine are currently meeting drinking water standards for TDS and their data do not indicate increasing trends in TDS concentrations. The TDS concentrations in these nine wells range from 147 to 401 mg/L. Three other wells are designated as inland and located where TDS concentrations at the base of the Upper

Floridan aquifer production zone is greater than 500 mg/L. TDS concentration data are only available for one of these inland wells (NWF4262, Figure 38). The TDS concentration in year 2007 was 230 mg/L and no increasing trend is indicated. These 13 wells represent approximately 4.56 mgd, or approximately 13%, of the estimated 2015 major withdrawals from the Upper Floridan aquifer in Region II (Table 7).

It should be noted that an additional 17 former public supply wells were also identified as being "at risk" under 2015 simulated conditions. However, 16 of these wells had already been abandoned; most likely due to pumping related water quality degradation. One was taken out of service years ago and is periodically monitored for water quality. This well has an average TDS concentration of 570 mg/L. The location of wells estimated to be "at risk" and wells previously abandoned are shown in Figure 37.

As simulated Upper Floridan aquifer pumping increases and varies spatially throughout the projected period, the position of the 500 mg/L TDS iso-concentration line changes as well. Like the simulated mid-aquifer concentrations within the Upper Floridan aquifer (Layer 7) and Lower Floridan aquifer (Layer 15), Figure 38 does not show much horizontal movement of the TDS iso-concentration lines between 2015 and 2040 at the base of the Upper Floridan aquifer production zone (Layer 9).

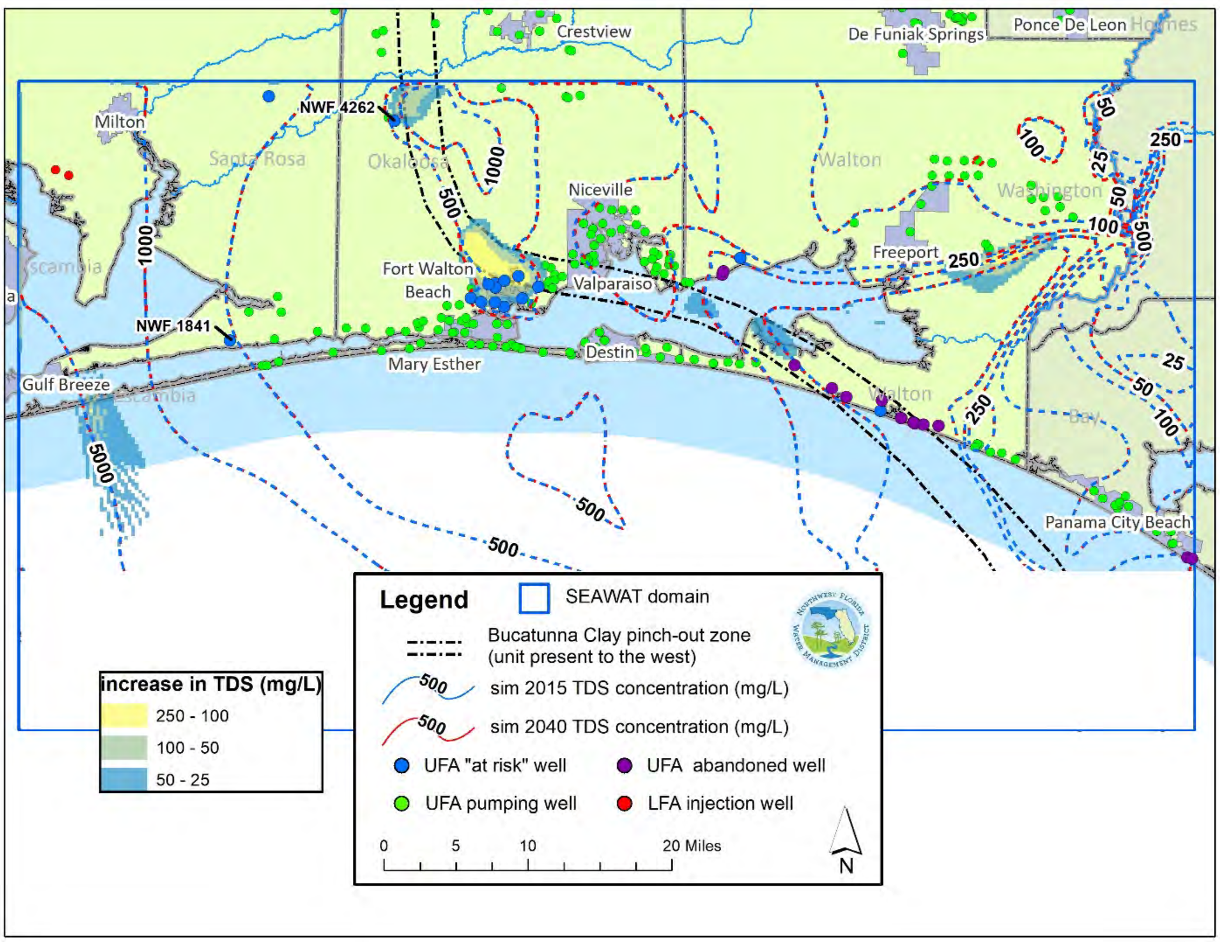


*Figure 38. Simulated increase in Upper Floridan TDS concentration (Layer 9, base of production zone) between 2015 and 2040*

Maximum horizontal movement of the 500 mg/L TDS iso-concentration line at the base of the Upper Floridan aquifer production zone (Layer 9) is approximately 0.7 miles near the center of the Fort Walton Beach cone of depression along the Bucatunna Clay confining unit pinch-out zone. This equates to an average horizontal movement of approximately 92 feet/year. Horizontal movement of the 500 mg/L TDS iso-concentration line east of Choctawhatchee Bay between 2015 and 2040 is simulated to be approximately 670 feet (17 feet/year) north toward the central Walton County wellfield area at the base of the Upper Floridan aquifer production zone (Layer 9). Maximum TDS concentration increases within Layer 9 are less than 250 mg/L onshore over the projected period (Figure 38). These areas of increase coincide with Areas of Interest 1 and 2 (Figure 32) but with larger increases over time than in the middle of the Upper Floridan aquifer (Figures 33 and 34).

The new position of the 500 mg/L TDS iso-concentration line at the end of the projected pumping simulation indicates three (3) public supply wells, in addition to the 13 identified in 2015, would be "at risk" of poor-quality water up-coning by 2040. Specifically, modeling results indicate these three wells will be "at risk" to up-coning between the years 2028 and 2036. These additional wells are in Fort Walton Beach on the seaward side of the area of increasing TDS concentrations identified in Area of Interest 1 (Figures 39 and 40).

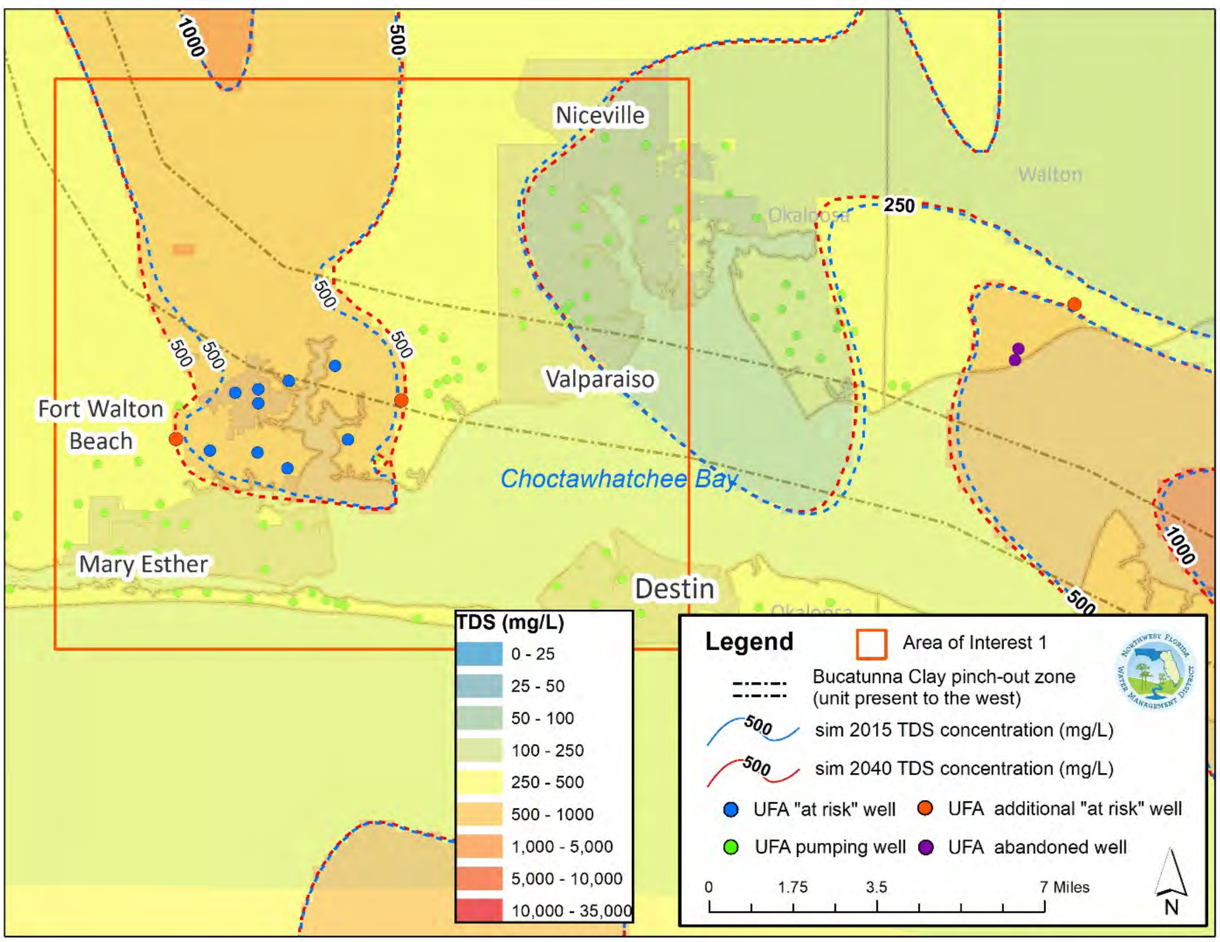


*Figure 39. Base of Production Zone (Layer 9) simulated TDS concentrations for 2015 and 2040 (Area of Interest 1)*

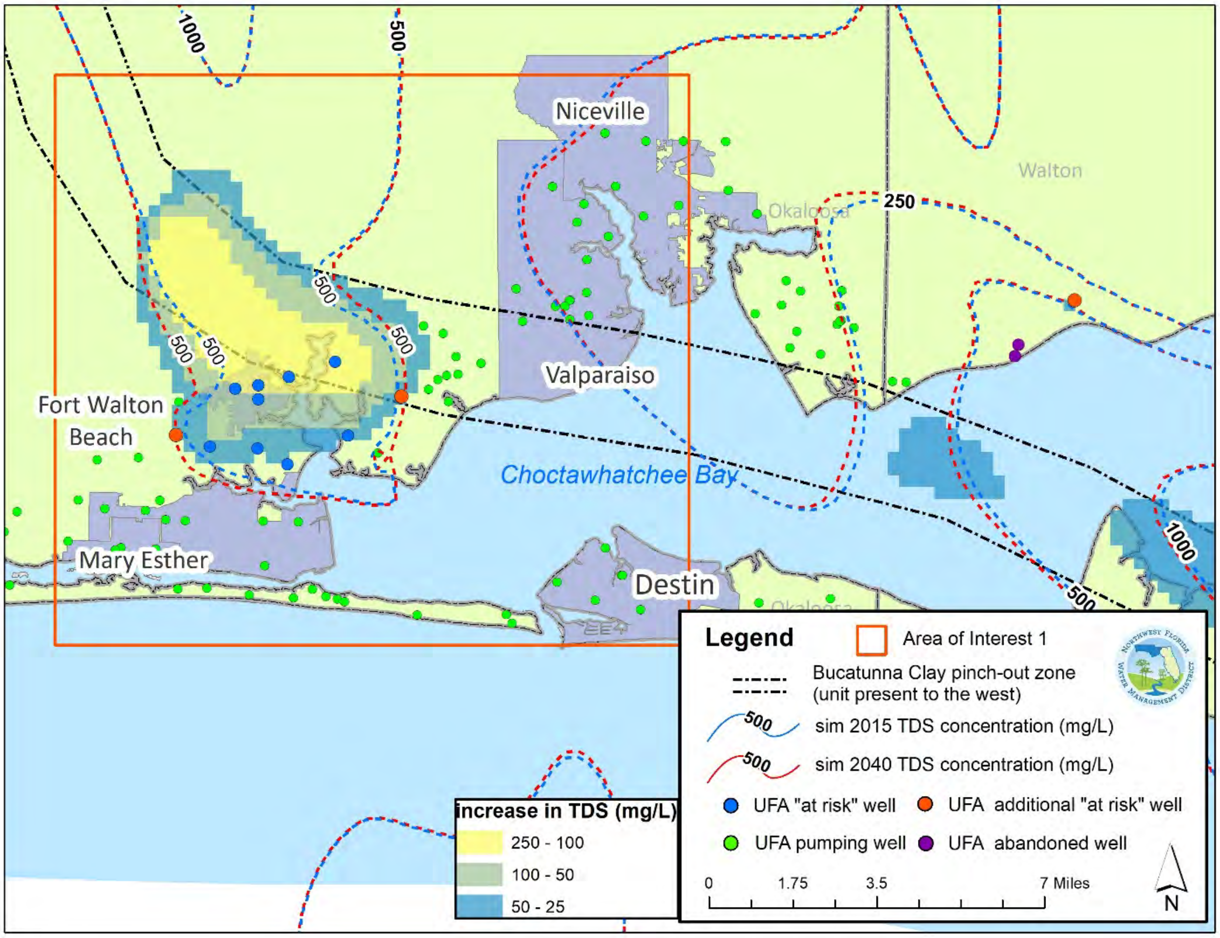


*Figure 40. Simulated increase in Base of Production Zone (Layer 9) TDS concentration between 2015 and 2040 (Area of Interest 1)*

These wells are currently meeting drinking water standards for TDS and do not exhibit increasing trends in TDS concentrations. Under 2040 simulated pumping conditions, the 16 wells “at risk” represent approximately 5.15 mgd, or approximately 11%, of the projected 2040 withdrawals from the Upper Floridan aquifer in Region II (Table 7). Although an increased number of Upper Floridan aquifer production wells are simulated to be “at risk” in 2040, the estimated volume of water to be pumped from these coastal supply wells represents a smaller fraction of the total regional 2040 projected withdrawals. This indicates that a larger percentage of future withdrawals from the Upper Floridan aquifer will be from inland sources as shown in Figure 14.

Similar evaluations were also performed to determine the number of Upper Floridan aquifer supply wells and water production volume “at risk” of exceeding sodium (Na) and chloride (Cl) water quality standards. Simulation results indicate 12 supply wells representing approximately 9.5% (3.36 mgd) of estimated 2015 pumping and 13 supply wells representing approximately 9% (4.34 mgd) of projected 2040 pumping would be “at risk” of potentially exceeding the 160 mg/L, Na primary water quality standard. One of the wells (NWF1841, Figure 38) currently has a recent Na concentration of 217 mg/L, exceeding the drinking water standard. Well NWF2404 is currently meeting the drinking water standard with a recent concentration of 140 mg/L Na, and exhibits an increasing trend in Na concentration.

However, the rate of increase indicates the drinking water standard will not be exceeded before the year 2040. The eight remaining supply wells with available Na water quality data are currently meeting the drinking water standard and range in concentration from 15 to 107 mg/L. These eight wells do not exhibit increasing trends in Na concentrations.

Simulation results also indicate 25 supply wells representing approximately 15% (5.26 mgd) of estimated 2015 major pumping and 26 supply wells representing approximately 13% (6.18 mgd) of projected 2040 major pumping would be “at risk” of up-coning and potentially exceeding the 250 mg/L, Cl secondary water quality standard. Ten wells in addition to the 16 previously discussed as being “at risk” of up-coning and exceeding the TDS drinking water standard are identified in this group. One well (NWF6016) currently exceeds the Cl drinking water standard with a concentration of 640 mg/L. Twenty-three remaining wells with available Cl water quality data currently meet the drink water standard and range in concentration from 2 to 160 mg/L Cl. Twenty of these wells do not indicate an increasing trend in concentration. Three wells (NWF1796, NWF2093, and NWF2506) exhibit increasing trends in Cl concentrations, but are not expected to exceed the Cl drinking water standard before 2040 based on the estimated rate of increase for each well. These results also show that a larger percent of future Upper Floridan aquifer pumping is anticipated to occur inland away from the coast. The 26 wells simulated to be “at risk” of exceeding the Cl water quality standard by 2040 include all of the same wells simulated to be “at risk” of exceeding the TDS and sodium water quality standards.

Predictive simulation Scenario 3 was run to evaluate the potential effect of sea level rise on the position and movement of the potable water interface. The results of predictive Scenario 3 indicate that sea level rise would have no noticeable effect on the movement of the potable water interface over the 25-year simulation period and suggests that no additional wells would be “at risk” of exceeding evaluated water quality standards due to simulated sea level rise.

# 5.0 Recommendation

The results of the water quality trend analysis and groundwater modeling indicate the rate of saltwater intrusion in coastal Region II is low and the increased risk to existing water supply wells due to projected Upper Floridan aquifer pumping through year 2040 is minimal. However, 25 Upper Floridan aquifer public supply wells are currently estimated to be “at risk” of potential up-coning and exceeding one or more of the water quality standards for Na, Cl, and TDS. These 25 supply wells represent approximately 15% (5.26 mgd) of estimated 2015 major pumping from the Upper Floridan aquifer in Region II. One additional well is predicted to be “at risk” of up-coning by 2040. The 26 supply wells represent approximately 13% (6.18 mgd) of the 2040 projected water demand from the Upper Floridan aquifer in Region II.

The goal of the District’s existing regulatory and planning programs is to provide for a sustainable water resource. The District’s water use permitting and water supply planning programs over the last 20 years have been successful in recovering approximately 70 feet of head in the potentiometric surface of the Upper Floridan aquifer within the cone of depression centered on Fort Walton Beach. This recovery has slowed the movement of saltwater toward regional pumping wells. Further reductions in coastal pumping enabled through the implementation of water conservation, reuse, and the continued development of alternative and inland water sources may prolong the usefulness of the Upper Floridan aquifer as a potable water supply. Careful management of the spatial distribution and magnitude of pumping from the Upper Floridan aquifer can minimize the number of wells affected by up-coning and lateral saltwater intrusion, particularly near the areas of interest identified in Figure 32.

Monitoring of water quality in coastal areas is anticipated to be continued, particularly in those areas where pumping is concentrated. Newly collected water quality data is anticipated to be used to periodically update trend analyses and verify current modeling results. Due to the anticipated continued effectiveness of the District’s water use permitting and water supply planning programs, the establishment of minimum aquifer levels for the Upper Floridan aquifer along the coast of Region II are not recommended.

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# 7.0 Appendices

7.1 Appendix A: Geophysical Investigation Report, NWFWMD, Planning Region II

7.2 Appendix B: Region II Well Construction and Testing Report for Site A-4, NWFWMD

7.3 Appendix C: Region II Well Construction and Testing Report for Site A-3, NWFWMD

7.4 Appendix D: Region II Well Construction and Testing Report for Site A-2, NWFWMD

7.5 Appendix E: Region II Well Construction and Testing Report for Site B-2, NWFWMD

7.6 Appendix F: Discrete Interval Water Quality Sampling (Fall 2017)

7.7 Appendix G: Discrete Interval Water Quality Sampling (Summer 2018)

7.8 Appendix H: Discrete Interval Water Quality Sampling (Winter 2019)

7.9 Appendix I: Plots of Significant Increasing Water Quality Trends

7.10 Appendix J: Plots of Significant Decreasing Water Quality Trends

7.11 Appendix K: Construction of a Coastal Region II SEAWAT Model

7.12 Appendix L: Transient Calibration of the Region II Groundwater Flow Model

7.13 Appendix M: Calibration of the Transient Coastal Region II SEAWAT Model

7.14 Appendix N: Transient Region II SEAWAT Model Predictive Simulations