



SCIENCE AND RESEARCH PLAN

Fort Bend Subsidence District

The Fort Bend Subsidence District is the leader in groundwater regulation and subsidence monitoring in the State of Texas. Since 1989, the District has taken a reasonable and inclusive approach to groundwater regulation to slow the progression of subsidence within the District. The Science and Research objectives in this plan will provide some clarity on the questions that face the District in the near future while providing a firm foundation for future regulatory plan updates.

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VISION STATEMENT

The Fort Bend Subsidence District's vision is a comprehensive description of how the organization will look in the future:

The Fort Bend Subsidence District is the premier water management and subsidence authority in the Upper Gulf Coast Aquifer in Texas. The District plays an integral role in regional water management strategies to insure the long-term viability of all water resources while protecting lives and property within the District from the impacts of subsidence and flooding.

MISSION STATEMENT

The Fort Bend Subsidence District protects lives and property within the District from the impacts of future subsidence by providing reasonable groundwater regulation based on the best available science

GOALS

Utilizing the District's mission and strategic vision, the following goals will be the focus of the District through 2025:

- *Conduct research that enhances the understanding and effective management of the Upper Gulf Coast Aquifer System to minimize subsidence in the District*
- *Educate the community on the importance of water resources, the occurrence of subsidence in the region, and promote water conservation*
- *Communicate effectively with regional water providers and stakeholders*
- *Provide reasonable groundwater regulation in support of the District mission*
- *Develop a diverse, highly-motivated, customer service focused organization while maintaining fiscal stability*

Introduction

This plan represents the "strategic direction" for science and research conducted or supported by the Fort Bend Subsidence District (FBSD) and, as such, is an essential component of the District's regulatory planning process. The Science Plan is being created in an effort to provide clarity to the strategic direction of the District and guidance to future science and research priorities in support of the District Regulatory Plan.

History of the Subsidence District

The Fort Bend Subsidence District was created by the Texas Legislature in 1989 as a conservation and reclamation district (Act of May 26, 1989, 71st Leg., R.S., ch. 1045, 1989 Tex. Gen. Laws 4251). The District's purpose is to provide for the regulation of the withdrawal of groundwater within the District to prevent subsidence that contributes to flooding, inundation or overflow of areas within the District, including rising waters resulting from storms or hurricanes. The District's boundaries are defined as all the territory within Fort Bend County.

Although Fort Bend county had experienced only small amounts of subsidence prior to the 1980's several characteristics of the area raise concern about the potential for increasing subsidence in the future including a water supply dependent on groundwater as its primary source of water, proximity to significant aquifer water-level declines in adjacent Harris County, expected continued rapid population growth.

The District was formed to address measured impacts from the predominant use of groundwater. In addition to the moderate, but noticeable, amounts of subsidence, the heavy dependence of groundwater has resulted in declining water levels in wells in the aquifers. Groundwater levels in wells drawing from the Chicot and Evangeline Aquifers in the eastern part of the District have declined in excess of 150 feet from 1943 to 1977. These declines have resulted in increased operational costs to well users.

The District regularly analyzes the adequacy of previous District policies to meet its enabling legislation. The District's Groundwater Regulatory Plan provides background planning information, descriptions of current groundwater regulatory practices and programs, and an overview of District administrative operations. The regulatory plan assists the District's regulated community and stakeholders as well as other local, regional, and state agencies in understanding the historical direction and proposed future objectives of the District.

The essence of the mission and vision of the District is to control land subsidence and manage groundwater resources through regulation, conservation, and coordination with suppliers of alternative water sources to assure an adequate quantity and quality of water for the future.

As a result of the increasing threat subsidence posed to Fort Bend County, the FBSD adopted a series of regulatory plans to reduce groundwater pumpage, and ultimately mandated, a reduction to only 40% reliance on groundwater by 2014, with those entities having an approved groundwater reduction plan having until 2025 to complete the reduction.

Throughout the years, the District has relied on high-quality relevant science to address the needs of the District. Science and research conducted by the District to date include:

- Evaluate the change in effective stress in the aquifer matrix as result of water use changes;
- Development of numerous PRESS sites throughout the District that utilize detailed site specific information to predict future subsidence;
- Development of numerous numerical models that allow the simulation of estimated subsidence as a result of future water demands;
- Annual water-level measurement that has shown the impact of conversion requirements on the water-level in the aquifer;
- Periodic population and water demand studies;
- And numerous other special studies to address specific understanding needs.

Physical Setting and Eco-regions

The State of Texas encompasses an area of nearly 270,000 square miles and extends almost 850 miles in both length and breadth. Its coastline measures more than 367 miles of Gulf shoreline and 3,300 miles of bay and estuary shoreline. The international border with Mexico is about 1,200 miles in length. Mountains, plateaus, hills, plains, beaches, river valleys, and canyon lands make the State of Texas one of the most physically diverse in the nation.

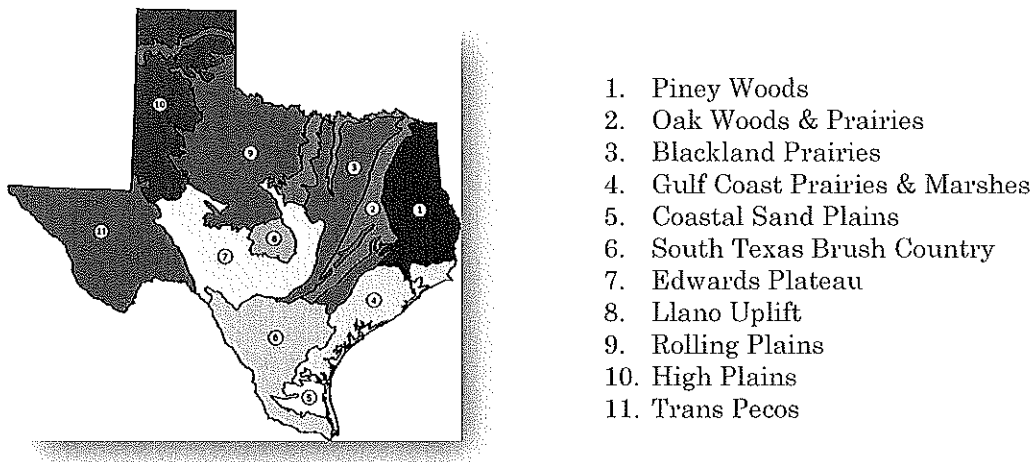


Figure 1. Ecoregions in the State of Texas

The FBSD exists within the ecoregion 4, dominated by Gulf Coast Prairies and Marshes (Figure 1). This nearly level plain area of 13 million acres borders the Gulf of Mexico from the Sabine River to Corpus Christi Bay. Prior to European settlement and twentieth-century development, this landscape included woodlands of sugarberry, pecan, elms, and live oaks, and open prairies with native grasses. The soils of the area range from acidic sands to sandy loams, with clays occurring in the river bottoms.

The Gulf Coast aquifer exists as an accretionary wedge of unconsolidated sediments composed primarily of sand, silt, and clay. Indicative of a transgressive-regressive shoreline,

the interbedded sands and clays are not horizontally or vertically continuous at larger than a local scale. The three primary water bearing units include the Chicot, Evangeline, and Jasper aquifers. The Chicot and the Evangeline aquifers are hydrologically connected and are typically differentiated by well yield analysis. The Jasper is the deepest of the three, and isolated by the regionally persistent Burkeville confining unit. Historically, the Evangeline aquifer has been the most widely used aquifer with the District. Most of the subsidence that has occurred in the region can be sourced to clay-compaction in the shallow water bearing units.

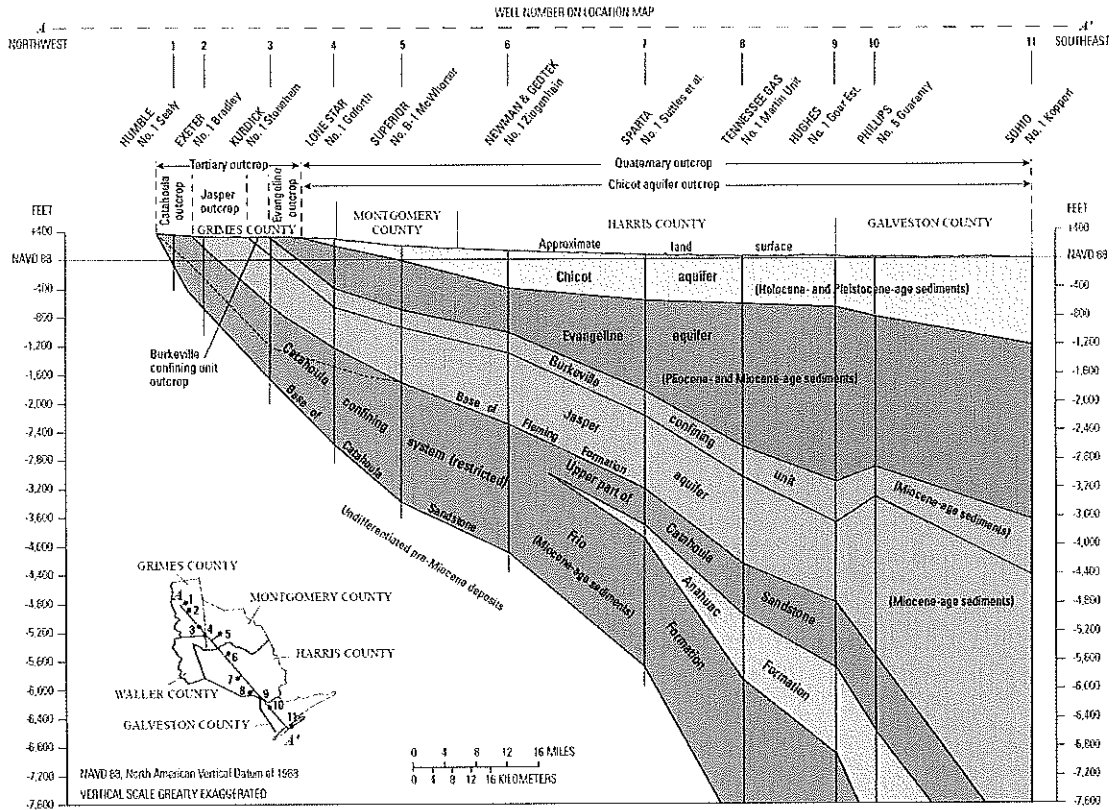


Figure 2. Hydrogeologic section A-A' of the Gulf Coast aquifer system in Grimes, Montgomery, Harris, and Galveston Counties, Texas (modified from Baker, 1979, fig. 4 in Kasmarek and others, 2014).

THE FBSD SCIENCE AND RESEARCH FUND

In 2015, the Board of Directors of the Fort Bend Subsidence District created the Science and Research Fund for the purpose of conducting science and research in support of the District’s Regulatory Plan. The overall scope of the fund is to support all action related to the effective development and maintenance of the regulatory policy of the District including data management, special topic research, and policy analysis

FISCAL CONSIDERATIONS

The Science and Research fund (SRF) was created by the District Board of Directors during fiscal year 2015. The SRF receives revenue annually from the collection of disincentive fees as determined by the District Regulatory plan. Disincentive fee revenue is not consistent from year to year and could be zero in any given year. The Science plan summarizes potential project scopes that may have a wide range of cost and be funded through the Science and Research Fund, the General fund, or other funding sources determined by the Board of Directors.

Projects addressing the priority themes contained within the Science and Research Plan may be funded through multiple mechanisms. Projects may be completed by District staff, other state agencies, Federal agencies, Universities, or private consulting firms. Projects may be funded directly in total or in cooperation with other agencies. The typical project will be funded directly and will last 6-18 months. Board approval of projects will be required based on the District’s fiscal and investment policy.

Table 1. Types of entity the District may work with to accomplish Science and Research objectives.

Entity	Typical Type of Funding	Typical Scope	Funding Mechanism
Federal Agencies	Cooperative Water Program, Direct, Collaboration	Regional	Joint Funding Agreement
Fort Bend Subsidence District	Direct	Regional - Local	Transfer to General Fund
Local Agencies	Collaboration	Regional-Local	Interlocal Agreement
Private Consulting Firm	Direct	Regional-Local	Direct contract
Texas Water Development Board	Direct, In-Kind Cooperation, Collaboration	Regional	Inter-local Agreement
University	Direct, Match	Regional-Local	Direct contract

PRIORITY SCIENCE AND RESEARCH THEMES

The District’s Regulatory Plan (last updated in 2013) provides some direction for the priority science and research themes focused on three primary components: hydrogeology and subsidence and regulatory policy analysis. The primary components focus on understanding needs ahead of the next regulatory plan update. Each of these components will be considered as part of the next regulatory plan update. The purpose of the science and research themes are to generally define the technical objectives for future data management, research, and policy analysis needs.

Hydrogeology and Subsidence

The District has spent millions of dollars and man-hours understanding the effects of stress on the primary water bearing units of the Gulf Coast aquifer within the District. However, in recent years, what was historically undevelopable waters in the aquifer have become economically viable. This is evident in the recent interest in the utilization of the Jasper aquifer. These “new” resources and water management strategies will require thorough study to insure that the development of these resources or the implementation of these new techniques do not have the unintended consequence of subsidence.

Gulf Coast Aquifer Hydrostratigraphy

Through the process of regional water planning, local and state water managers and planners utilize historical surface water and ground water data to determine the current available water and sustainable use of the various source waters. Groundwater under the influence of surface water and other transitional waters are of particular importance to this planning process as they are difficult to quantify and may cause an over or under estimation of the available water in an area.

Recently, the lower portion of the Brazos River Basin was studied to evaluate the interaction of the river and the underlying alluvial and bedrock aquifers. Results from this study showed that it is possible that specific zones of interaction occur over specific aquifer units, and likely occur in other river basins that cross these units in other parts of the state.

There has been some recent work on the hydrostratigraphy of the Gulf Coast completed by the Texas Water Development Board. The conceptual model of groundwater movement in the aquifer has been well studied. Future questions will be more local in focus, and will require a compilation scalable view of the available hydrogeologic information in the region.

Objective: Develop a more vertically and horizontally resolute depiction of the hydrostratigraphy of the District and surrounding areas.

Simulation of Groundwater Flow and Subsidence

Numerical and analytical models are used to adequately predict the impact of the regulatory plan on the groundwater system and subsidence. All models are developed based on historical information. Over time, as more data is made available for analysis, models are validated, updated, and recalibrated to minimize uncertainty within the model, improving the models predictive capability. The District has recently updated the regional groundwater flow model, which is referred to as the Houston Area Groundwater Model (HAGM).

The District has historically utilized two types of models for the prediction of Subsidence: a numerical model developed by the USGS utilizing the MODFLOW model and the analytical PRESS model recently updated by FUGRO. The MODFLOW model provides a regional depiction of the aquifer whereas the PRESS provide predictions at the local scale at several locations throughout the District. Reducing the uncertainty of model predictions while providing a wide depiction of subsidence is an important objective for the District’ regulatory plan.

Objective: Evaluate numerical depiction of the aquifer system and improve resolution where appropriate.

Objective: Evaluate alternative numerical methods by which to simulate the interaction of the primary water bearing units with surficial processes (precipitation, streamflow, evapotranspiration).

Objective: Evaluate the method by which the HAGM simulates subsidence and determine approaches for further improvement.

Objective: Update PRESS model sites and determine potential locations for future press site development.

Objective: Evaluate the impact of the early-conversion of large groundwater users in Fort Bend County on future regulatory conversion timing and requirements.

Brackish Groundwater Resources

The state is continuing to be innovative in the search for new water supplies. The TWDB reports that and estimated 2.7 billion acre-feet of brackish groundwater is available in Texas. Once again the Regional Water Planning Groups (RWPGs) were on the forefront of this effort with the publication of the Brackish Groundwater Manual for Texas Regional Water Planning Groups in 2003. This publication raised the level of interest across the state in the development of brackish groundwater as a source of supply for desalination.

Little is known about the hydrogeology of the parts of most aquifers that contain brackish water compared to the parts that contain freshwater, because the need to utilize brackish ground water has been limited. A need exists to better understand the occurrence of brackish waters in the deeper sediments of the Gulf Coast Aquifer and their viability as municipal or industrial resources verses the potential for compaction and subsidence.

Objective: Determine the occurrence and hydrogeologic characteristics of the brackish resources within the District and surrounding areas.

Aquifer Storage and Recovery

The drought experienced by those that depend on the Brazos River for their alternative water supply was significant and raised concerns on the long-term viability of that resource.

Aquifer storage and recovery (ASR) is the process by which a water source is injected into the aquifer and stored for a period of time, after which it is withdrawn at a theoretical “no-net” loss to the aquifer. ASR projects have been successful throughout the country with some good examples in Florida and Nevada. In Las Vegas, ASR is used as a water management strategy to provide water for the desert city as well as cease subsidence, and it has been successful.

ASR studies in the Texas Gulf Coast are limited. The City of Texas City attempted an ASR project several years ago without success. Of primary concern from the subsidence perspective is the length of time between injection and withdrawal and how that relates to a water-level/subsidence neutral yield.

Objective: Conduct a risk assessment on the subsidence neutral yield of an ASR project in the Gulf Coast aquifer.

Subsidence Monitoring

The District currently (2015) maintains a 19 node network of GPS land deformation monitoring sites (PAM) as part of approximately 90 sites throughout the District and surrounding counties. This network is constantly evolving and requires consistent investment to insure it adequately captures the intended dataset.

Considering the surface area of the District, remote sensing of subsidence throughout the region will provide a more resolute picture of current land surface change. Remote sensing can be accomplished through the use of LIDAR or INSAR methods. When combined with the periodically and continuous stations, this type of information would periodically provide coverage between the GPS network nodes.

Objective: Develop a better understanding of the land surface deformation throughout the District and surrounding areas utilizing INSAR.

Objective: Expand the PAM network to improve the land deformation resolution.

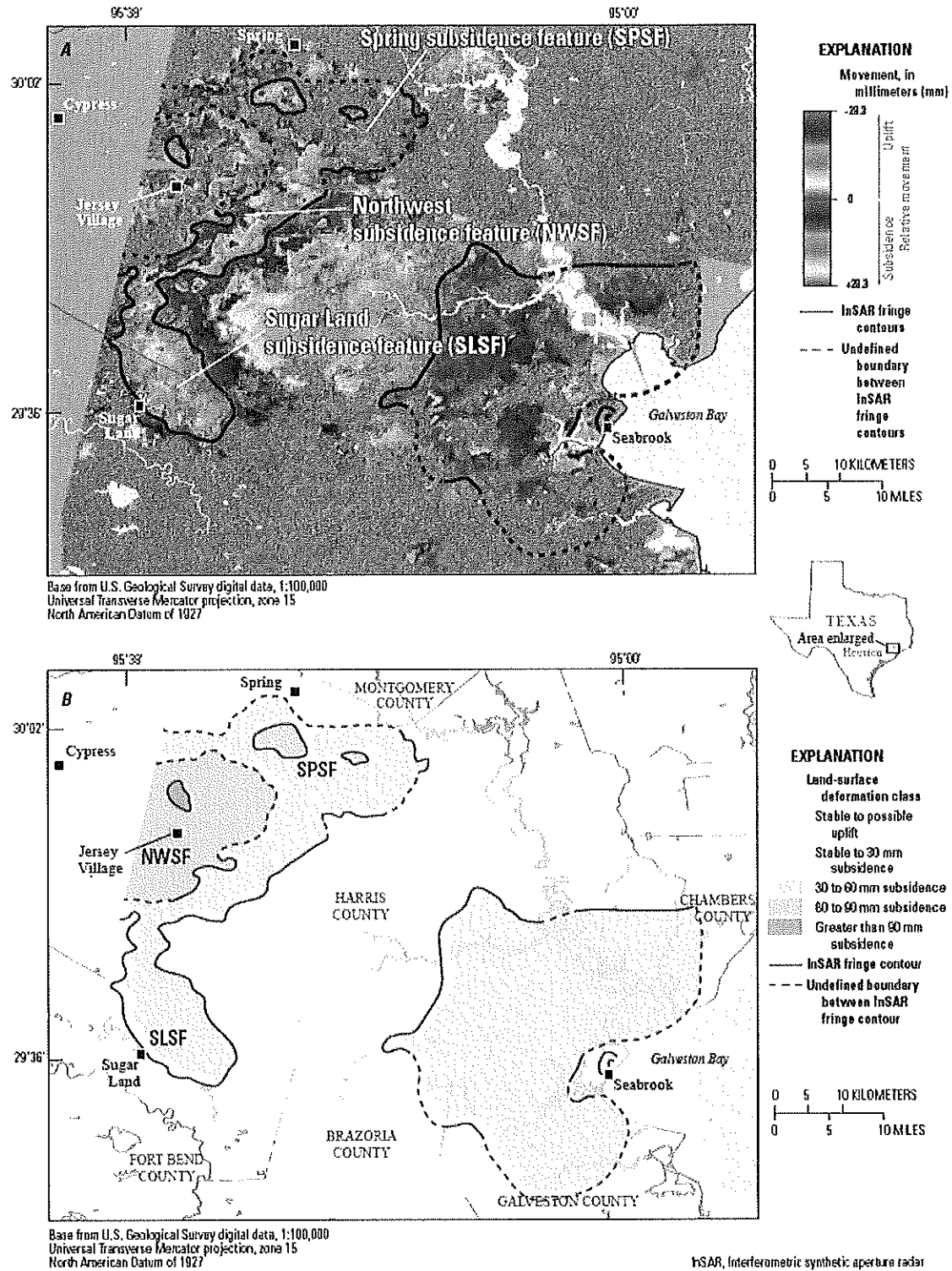


Figure 3. Interferogram for January 30, 1996, to December 30, 1997 showing primary areas of subsidence. A, The named subsidence features to the northwest. B, Interpolated land-surface deformation contours. The blue- and red-shaded areas represent regions with subsidence or uplift. (Bawden and others, 2012).

Groundwater Use and Permit Tracking

The District has participated in the development of several Groundwater Flow models over the last forty years. In each instance the most important model parameter has been water use. The historical water use data has been a vital metric for the District since 1989. The District works closely with permittees to gather accurate water use information annually. Over the years the District has amassed a wealth of information. With this comes the requirement of proper archival and the need for ancillary data sets to better understand the context of the groundwater use.

The evolution of technology and the needs of a data driven regulatory plan will require the update and re-tooling of our District database and permit tracking system.

Objective: Migrate the District's database to a more widely used platform and develop web application tools to improve data analysis and dissemination.

Regulatory Policy Analysis

The District Regulatory Plan requires Regional Water Authorities to provide for the availability of alternative sources of water to replace the mandated reduction in groundwater use. Future alternative source waters will include: reclaimed water, desalinated seawater, surface water, and water savings realized through water conservation. Alternative sources of water are finite, and may become short supplied during even short periods of drought.

Reclaimed water is a significant component to the water management strategies for Region H, and is growing in popularity among Fort Bend County water providers. Alternative water supplies are lynchpins to the District's regulatory plan, without available alternative water supplies, groundwater will be utilized and subsidence will occur. However, reclaimed water does not come without its drawbacks. For example, historically, waste water discharge is the primary component of base flow in many of the rivers, streams, and bayous within the District. A reduction in discharge quantity can have a direct impact on the amount of surface water available to downstream users.

Seawater from the Gulf of Mexico is the most abundant non-groundwater source water in the region. The development of surface desalination plants is a widely used world-wide (i.e. Australia, Israel) but also within the U.S in California and Florida. The largest seawater desalination plant in the country, which is slightly larger than the groundwater desalination plant in El Paso, TX, operates in Florida.

During future droughts, groundwater credits will be utilized to offset shortfalls in alternative supply. Groundwater credits may be earned through over-conversion, the utilization of reclaimed waters, or participation in the District's Water Conservation Program. Although, the District has incorporated "normal" non-drought related groundwater credit use into the 2013 regulatory plan, the impact of wide-spread utilization of credits during a time of prolonged drought has not been specifically investigated.

Groundwater Credit Program

The District's regulatory plan provides for the utilization of groundwater in lieu of a portion of the conversion requirement through the use of groundwater credits with the intent of providing some relief from the regulatory plan during periods of limited alternative source water availability. Groundwater credits may be earned through the District's Water Conservation Program or bought from other groundwater credit holders.

Climatic variability impacts both the supply and the demand for water and therefore plays a crucial role in water management. As water resources are exploited to or beyond their natural limits, climatic variations are of greater concern in all kinds of hydrologic systems.

Increased air temperature in the future will increase rates of evaporation resulting in decreased stream flows by lowering contributions from runoff and groundwater sources. A decrease surface water base flow may have an impact on reservoir volumes and availability of run-of-the-river resources -- causing a renewed dependence on groundwater particularly in Galveston County where recent droughts continue to effect the availability of the Brazos River.

Objective: Develop a risk analysis on the impacts of sustained drought on the District regulatory plan.

Objective: Estimate the impact of over-conversion and groundwater credits on the aquifer during a period of sustained drought.

The District is nearly completely surrounded by Groundwater Conservation Districts governed by chapter 36 of the Texas Water Code. Policies in those Districts that allow for groundwater withdrawal without the consideration for subsidence could have detrimental effects on the long-term success of the regulatory plan. Additionally, changes in regulatory structure, which was counted on in the 2013 regulatory plan, may also have a negative impact on subsidence within the District.

Objective: Develop risk analysis of potential regulatory changes in bordering Districts on subsidence within the District.

COMMUNICATIONS PLAN

The priority themes outlined in the Science and Research Plan will require an effective review and communication of project objectives, plan, progress, and results. Most projects will be initiated through the utilization the Professional Services Act to engage the best qualified entity. Quarterly, the General Manager will provide an update of each ongoing project funded by the District. All projects will be required to document all aspects of the project and summarize the project results in a final report. Each project will require a final report that is adequately quality assured and approved.

All data, interpretations, and final reports will be the property of the District and properly archived in the District's database. Final reports will be available to the public on the District's web site.