SCOPE OF WORK

Task 1 Project Management, Meetings, and Communication
The project will require coordination between the Project Team, TWDB staff, and interested stakeholders. To monitor work efficiently amongst the Project Team, the project manager will use GanttProject, an open source project planning and tracking software, as the tool for tracking and managing tasks and deadlines. Use of the project management software will allow us to update TWDB staff and stakeholders quickly with a quantifiable assessment of the project completion status. As part of our coordination with the Project Team, TWDB staff, and stakeholders, we will provide updates on the project status in the form of a Gantt chart with each monthly status report.

The project will be complete prior to CONTRACT EXPIRATION DATE and the draft final report will be completed by THE STUDY COMPLETION DATE.

Meetings with TWDB Staff
We anticipate four meetings with TWDB staff during the course of the project. However, we understand that we or the TWDB may need to schedule additional technical meetings either in person, through a webinar, or teleconference to discuss Project progress and issues. We also are aware that TWDB staff may periodically visit the Project Team's offices to assess progress on the Project. All meetings and/or conference calls will be held on regular business days (Monday through Friday) during regular business hours (8:00 a.m. to 5:00 p.m. CT) upon agreed dates and times. The following tasks describe the anticipated meetings.

TWDB Meeting 1: Project Kickoff Meeting
We will meet with the TWDB within two weeks following signing of the contract for a project kickoff meeting. We anticipate that this meeting will focus on schedule refinements TWDB interaction, and data acquisition and evaluation.

TWDB Meeting 2: Discussion and Approval of Project Methodology Meeting
After reaching 75 percent completion of Task 2, we will meet with TWDB staff to discuss the status of the compiled data. Prior to this meeting, the Team will submit to the TWDB staff a draft report documenting the techniques and approaches selected for geophysical well log interpretation of aquifer total dissolved solids concentration (see Task 2.5). This meeting will allow the Project Team and the TWDB to collaborate on the identification of potential data gaps that we can address prior to completion of the project. In addition, we will discuss revised or additional evaluation that the compiled data may dictate.

TWDB Meeting 3: Discussion of Potential Production Areas Meeting
The Project Team will meet with the TWDB staff in the afternoon on the same day of the second stakeholder meeting to discuss the potential production areas and prioritization for production calculations. During this meeting, we anticipate focusing on the apparent water quality at specific

locations within the study area, the spatial and temporal trends in water quality with regard to salinity, the areas that meet criteria for potential production areas, and the application of methods for evaluating the potential production areas.

TWDB Meeting 4: Final Draft Report Completion
This meeting will involve presentation of the final report and project results. During this meeting the Project Team will demonstrate the three-dimensional GIS datasets developed during the project that illustrates the salinity zones. The Team will also discuss the results of the evaluations conducted for the defined potential production areas.

Stakeholder Meetings
Stakeholders will be able to provide data and important insights that the data may not readily reflect. We anticipate two stakeholder meetings as described below. For the stakeholder meetings, we understand that the TWDB staff will organize the meetings and invite stakeholders. The Project Team will attend and present information and results at the second stakeholder meeting.

Stakeholder Meeting 1: Discussion of House Bill 30 (Meeting Conducted on October 26, 2015)
The first stakeholder meeting discussed in the RFQ occurred on October 26, 2015. During this first meeting, the TWDB staff discussed House Bill 30 and sought input on key phrases in the bill. Specifically, the TWDB staff sought stakeholder input regarding the meaning of "significant impact" and "significant source." In addition, TWDB staffed posed the question of how they should define "hydrogeologic barriers sufficient to prevent significant impacts?" Comments on these phrases were accepted through October 30, 2015 and will help guide the evaluations to be conducted during the latter part of the study.

Stakeholder Meeting 2: Solicitation of Input on Potential Production Areas
LBG-Guyton will determine the date and will need to provide a one-month notice to TWDB to set up the second stakeholder meeting. Following completion of Task 4, the TWDB will coordinate the stakeholder meeting to present the results of the salinity delineations and solicit input on the potential production areas. During this meeting the Project Team will present a summary of the data collected, the methodology for evaluating the salinity of the groundwater in the aquifer, the three-dimensional datasets develop that quantify the estimated groundwater salinity throughout the aquifer, and discuss potential production areas to determine the 30 and 50-year volumes of brackish groundwater production and the effect that production may have on other areas or aquifers.

Monthly Progress Reports to TWDB
The Team's project manager will summarize progress by providing the TWDB with monthly progress reports for the duration of the project. The project manager will document any problems or unexpected data shortfalls in each report, and if necessary, will call to discuss problems with the TWDB project manager. The progress reports will include a Gantt chart showing the original or adjusted schedule with and detail how the Project is progressing.

The Team's project manager will provide detailed descriptions of the progress made by task and correlate the progress descriptions with the submitted invoice.

Task 1 Deliverables
Detailed monthly progress reports will be submitted to the TWDB outlining:
- Original or adjusted schedule and relative progress
- Project invoices
- Consistent with the budget description
- Issues that may arise

Meetings:
- Stakeholder Meeting 1: Already held on October 26, 2015 in Austin, TX to explain TWDB's approach in implementing House Bill 30, solicit feedback on what constitutes "significant impact", and receive general comments concerning implementation of the legislation.
- TWDB Meeting 1: Project Initiation Meeting
- TWDB Meeting 2: Discussion and approval of Project methodology; date to be determined by the Contractor
- Presentation for the second stakeholder meeting one week before the scheduled meeting.
- Stakeholder Meeting 2: Presentation and discussion of Potential Production Areas with stakeholders in the morning; date to be determined by the Contractor. The Contractor will set the date and TWDB will organize the meeting and invite stakeholders.
- TWDB Meeting 3: Discuss prioritization areas for production calculations with TWDB staff in the afternoon on the same day of the stakeholder meeting.
- TWDB Meeting 4: Project completion; formal presentation at the end of the Project.

Additional technical meetings may be scheduled either in person, through a webinar, or teleconference venue to discuss project progress and issues. TWDB staff may periodically visit the Contractor's work premises to assess progress on the project.

Task 2 Hydrogeologic Data Acquisition and Compilation
In addition to data available from the TWDB (BRACS Database, Groundwater Database, and Submitted Driller's Report Database), we will also scour data sources such as the Texas Railroad Commission, the Texas Commission on Environmental Quality, Bureau of Economic Geology, General Land Office of Texas, U.S. Geological Survey, Environmental Protection Agency, Log Libraries, and local stakeholders (such as, conservation districts, municipalities, public water suppliers, etc.). During this task we will compile all data obtained into the Brackish Resources Aquifer Characterization System (BRACS) Microsoft Access database format (Meyer, 2014) and Groundwater Database format, as applicable.

The Project Team has extensive experience in the Nacatoch Aquifer, providing a distinct advantage for data assimilation. LBG-Guyton Associates developed a regional groundwater availability model (GAM) for the Nacatoch Aquifer (LBG-Guyton Associates, 2009). This two year effort involved the collection of data, integration files, and the construction and calibration of

a MODFLOW model of the aquifer system. All collected and developed spatial data for this project adhered to strict GIS source data geodatabase protocol and FGDC metadata standards required by the TWDB for GAM development. Staff of LBG-Guyton also authored "Ground-Water Resources of the Nacatoch Aquifer," TWDB Report 305 (Ashworth, 1988). The report includes the determination of the occurrence, availability, quality, and quantity of groundwater from the Nacatoch Aquifer. The Bureau of Economic Geology, a member of the Project Team, also authored "Depositional Systems in the Nacatoch Formation (Upper Cretaceous) Northeast Texas and Southwest Arkansas" (McGowen, 1983). This study was designed to determine the depositional framework of the basin during deposition of the Nacatoch Formation. The Project Team has developed a clear and robust understanding of locally available data, developed strong relationships with local stakeholders, and has developed tools and methods for efficient evaluation of the aquifer conditions within the Nacatoch Aquifer.

The Project Team will prepare and implement a quality control plan that will include specific checklists for use during work progression and will address the following:
- **Verification** – Part of our standard quality control procedure is to verify data entered into a database against the original source data, if available. Data imported from an internal agency database or an outside database will be compared against the post-imported database to check records for accuracy and ensure that duplication of data has not occurred.
- **Level of confidence** – Mapping and visualization requires significant data, but in some parts of the study area the available data are limited measure of confidence for all new data to inform subsequent evaluations with regard to quality and uncertainty of the data point. We will develop procedures to screen the validity of data and rank them according to specified levels of confidence in data accuracy. We can then use these confidence rankings during interpolation and mapping to help estimate potential errors associated with low-confidence data. We will coordinate with the TWDB in this effort.
- **Self-validation** – We will build a series of automated checks into the system for self-validation. Examples may include instrument reporting ranges, historic data for a sampling location (where available), expected ranges of values, correlations between measurements (for example, chlorides and total dissolved solids), missing data fields, consistency of units, or the identification of duplicate records. This is an efficient method proven for validating data and identifying outliers.

Brackish Resources Aquifer Characterization System Database
The BRACS Database will be our starting point for data acquisition and compilation. Our work will focus on enhancing and building upon the work conducted by others to develop and maintain the current database (Ortuño, et al., 2012; Meyer, 2014). We will not modify the current BRACS Database, but will work with the TWDB BRACS group to ensure seamless synchronization with the most recent BRACS Database format.

Groundwater Availability Model and Model Datasets
The groundwater availability model (GAM) developed for the Nacatoch Aquifer (LBG-Guyton Associates, 2009) provides a robust repository of data relative to the hydrogeologic framework for

the aquifer. In addition to the model itself, work associated with the development of the GAM included compilation of data used to define the geologic structure, lithology, and movement of groundwater. We will compile the GAM data with the existing BRACS data and crosscheck the data to ensure we do not include duplicates in the final datasets. LBG-Guyton, Bureau of Economic Geology, and Collier have performed significant hydrogeologic evaluations, brackish studies, well completion, and aquifer testing in aquifers throughout Texas and realize some of the limitations of the existing structure interpretations, hydraulic properties, and water quality information. The Project Team will use the publically available data to enhance this study.

Two key components to the volumetric calculation of groundwater are the static water level and specific yield of the aquifer. We will incorporate the specific yield data compiled for and included in the GAM into the project database for reinterpolation, if needed, during our evaluations. The Project Team will also use GAM simulated water levels from the end of the model calibration period for each model to perform calculations.

Water Quality Sample Data
The TWDB Groundwater Database is a regularly updated database containing groundwater quality data. For public water systems, we will review the TCEQ Safe Drinking Water Information System to obtain source water quality data. We will supplement these datasets with water quality data available from the U.S. Geological Survey National Water Information System. The team will work with local Districts, water authorities, and well owners to collect any additional data for inclusion in the dataset.

We will also collect data from the U.S. Geological Survey Produced Water Database, which will provide information on the composition of water in deeper portions of the geologic units. We will also be able to use the total dissolved solids (TDS) data to aid in calibrating salinity calculations from geophysical logs.

For these datasets, we will use well identification numbers, well location, well completion, and sample results to identify duplicate samples. We will remove duplicates from the dataset, but the well identifier from the non-BRACS database will be added to the BRACS foreign key table to relate it back to the BRACS well ID. During the acquisition process we will work diligently to ensure the reliability of the sample data. Format of the data will be compatible with the Groundwater Database table design. Water quality reports not currently in the BRACS Database will be cataloged and related to the BRACS well ID.

Geophysical Logs and Well Reports
There are several opportunities for obtaining nonproprietary geophysical logs and well reports. For many public supply wells, we will work to obtain geophysical logs from TCEQ. In addition, we will work with local Districts and well owners to obtain additional well logs or reports. We will also gather logs for oil and gas wells from the Railroad Commission and Bureau of Economic Geology (Groundwater Advisory Unit and Integrated Core and Log Database) that are additional to those previously delivered to the TWDB as part the work by Ortuño, et al. (2012).

For reports and logs obtained that is in addition to those already in the BRACS Database, we will catalog the well logs and relate the log to the BRACS well ID in the database. As with the samples, we will use information from the log header to compare each log and ensure we do not create duplicates in the database. For logs not currently in digital format, we will scan the log to a Tagged Image File Format (TIFF) to allow rapid access via hyperlink in the BRACS Database. If available, we will also include the geophysical log data in Log ASCII Standard (LAS) format. We will assure all geophysical well logs and interpretation data values are documented in BRACS Database table format with links to well numbers, log numbers, depths, and names of geological formations.

Draft Evaluation Technique and Approach Report
While acquiring and compiling data for evaluating the brackish groundwater resource, the Project Team will prepare a draft report documenting the techniques and approaches proposed for geophysical well log interpretation of aquifer total dissolved solids concentration. The report will include information on the types of geophysical well logs available in the project area, how the interpreted total dissolved solids concentration from geophysical well log analysis relates to existing aquifer water chemistry as determined by direct measurements, how the log correction factors are determined, and how the interpretation techniques will be applied across the entire salinity range within the aquifer. We will submit this draft report to the TWDB staff for review at least four weeks prior to the Discussion and Approval of Project Methodology Meeting

Task 2 Deliverables
A draft report documenting the technique(s) and approaches for geophysical well log interpretation of aquifer total dissolved solids concentration. The report shall:
- Identify types of geophysical well logs available in the area,
- Describe how the interpreted total dissolved solids concentration from geophysical well log analysis relates to existing aquifer water chemistry as determined by direct measurements
- Describe how the log correction factors are determined, and
- Describe how the interpretation techniques will be applied across the entire salinity range within the aquifer
- TWDB will have up to 10 business days to review the draft report, and the Contractor will schedule a meeting to discuss the techniques.

Task 3. Hydrogeologic Evaluation
During and subsequent to compilation of available data, the Project Team will apply their intimate knowledge of the Nacatoch Aquifer. Project Team members will focus on their area of expertise while the project manager will facilitate coordination amongst the experts.

In many areas, we expect a high degree of uncertainty associated with the data. To incorporate the data uncertainty into our evaluations we anticipate applying Bayesian kriging (Pilz, et al., 2005) or fuzzy kriging (Masoomia, et al., 2011), as the data dictate, to interpolate the water quality data at well sites to the defined grid in the study area. Our evaluations will begin with determining the vertical distribution of water quality at well sites throughout the study area. The following during

Task 3 to develop the water quality information for the geologic units penetrated by well.

Geologic Framework
The current Nacatoch Aquifer GAM (Beach, 2009) provides an excellent basis for the geologic and hydrologic framework of the aquifer and confining units. Nonetheless, as regional models, the GAMs necessarily provide only a rough approximation of the geologic structure and lithology. While it is beyond the scope of this project to develop additional conceptual models for the area, we will identify and record structural and lithologic characteristics, as evidenced by geophysical log data that are not currently recorded in existing datasets. As applicable, we will extend the aquifer surface in the downdip direction beyond the extent of the existing GAM to allow calculating volumes of higher salinity groundwater than the current surface would permit.

To evaluate the lithologic characteristics, we will apply the four-class system discussed by Young, et al. (2010, p. 81) to representative geophysical logs. In addition, we will use select geophysical logs containing a gamma ray curve to calculate the shale percentage based on the log signature. Using these two methods will allow the Project Team to evaluate the lithology at select locations and form a preliminary assessment of potential conceptual models especially with regard to how the lithology affects apparent groundwater quality.

With the derived information, we will also be able to calculate net sand thicknesses within defined intervals for use in subsequent volumetric calculations of stored groundwater.

Water Quality Sample Data
To conduct our evaluation of the collected water in LBG-Guyton Associates Evaluation of Hydrochemical and Isotopic Data in Groundwater Management Areas 11, 12 and 13 (Kreitler, et al., 2013). As discussed in that report, with regard to water quality data the Team used the following criteria as the standard for eliminating potentially erroneous information:
• A well must have total depth estimate or documented completion intervals;
• A site must have a location accuracy of one minute or better; and,
• A water quality analysis must have a charge balance within five percent.

LBG-Guyton Associates applied the same criteria in evaluating data quality in work performed in Groundwater Management Areas 3 and 7 (Kreitler, et al., 2013). For this project, we will follow these established protocols to assess the reliability of all data acquired to supplement our existing dataset. Importantly, we will not remove any of the compiled data from the database; rather, we will assign a reliability flag to the sample in order to eliminate potential duplication of data compilation and assessment work in the future.

Once we have evaluated the reliability of the data, we will have a final XYZCt water quality sample dataset. That is, we will have a value (C) for various constituents and TDS at a spatial location (XYZ – latitude, longitude, elevation) at a specified time (t) for each reliable water quality sample. While the focus of this project is the TDS of the groundwater resources, we will use this final dataset to prepare Piper diagrams and Stiff diagram maps that will illustrate spatial changes in overall water quality and TDS. Brackish treatment approaches and the type of anions

and cations in the water. Providing these summaries will help stakeholders develop preliminary treatment methods and cost estimates. If data are sufficient, we will prepare these illustrations for time intervals that will provide insight into the temporal changes in water quality throughout the study area. In addition, we will use the most recent and reliable data available to identify the representative TDS values for use in future modeling and analyses, including volumetric calculations.

Geophysical Logs

Geophysical logs will provide the majority of the data for the aquifers. Unlike a water quality sample, which is only representative of the interval from which the sample was collected, a geophysical log provides essentially continuous measurements of the solid, liquid, and gas properties in and near a borehole across all of the formations penetrated. In a study such as this one, we will use these signatures to develop estimates of the salinity concentration of water in sand and clayey sand layers.

The Project Team will apply our unique expertise to the evaluation of geophysical logs for estimating formation water salinity. Mr. Wise will apply his direct experience as coauthor of BRACS reports (Wise, 2014; Meyer, et al., 2014) to serve as technical lead for the evaluations. In addition, Dr. Hughbert Collier (1993), author of TWDB Report 343, will lend his extensive experience regarding the quantification of groundwater salinity from geophysical logs to the project.

There are several methods for developing estimates of salinity from geophysical logs (Turcan, Jr., 1966; Guyod, 1972; Ken E. Davis Associates, 1988; Collier, 1993; Estepp, 2010). As listed in the BRACS database, these methods include (Estepp, 2010):

- The SP (Spontaneous Potential) Method
- The Alger Harrison Method
- The Estepp Method
- The Mean Ro Method
- The Rwa Method

The BRACS Database notes that these methods, as applied within the BRACS Database, are most applicable to waters with TDS concentrations less than 10,000 milligrams per liter (mg/L). In waters with TDS concentrations greater than 10,000 mg/L TDS, sodium (Na) and chloride (Cl) ions typically dominate the solution and will control its resistivity. In fact, while other ions (for example calcium, magnesium, bicarbonate, and sulfate) affect the resistivity of the formation water, their influence is most significant in fresh water, but their concentrations can be converted to represent a NaCl solution.

During our analysis of geophysical logs, we will conduct all calculations to determine the concentration in parts per million (ppm) of an equivalent NaCl solution. By focusing on the determination of an equivalent NaCl solution salinity, we will be able to make a direct calculation of the salinity from the formation water resistivity as calculated from log signatures. That is, we

can use derived formulas, such as those used to create reference charts (Schlumberger, 2009, p. 8), for calculating formation water salinity in ppm using methods discussed below. For each geophysical log, we will use as many methods as are applicable. The logging curves available for each geophysical log image will dictate the methods used. As discussed by Ortuño, et al. (2012), the majority of the geophysical signatures provided as a deliverable for their project contained an SP curve followed in quantity by conductivity then resistivity curves. When porosity curves are available, we will incorporate those measurements into the formation factor calculations (see below). We anticipate being able to develop resistivity of water estimates throughout the sand zones identified during Task 3.1 using these three curves. We will then convert the water resistivity to salinity of a NaCl solution.

All calculations will begin with the information provided on the log header. If it is available, from the header for each well we will obtain its identification, location, elevation, measuring point, total depth, mud resistivity and temperature, mud filtrate resistivity and temperature, mud density, and bottom-hole temperature. For the resistivity of the mud filtrate, we will crosscheck the value entered on the log header by recalculating the filtrate resistivity based on the mud density and resistivity (Schlumberger, 2009, p. 4). These data will be critical for subsequent calculations.

One drawback of the SP method is its sensitivity to clay or shale in and near the sand zone. To overcome some of the sensitivity we will apply a bed thickness correction factor to the SP reading. While charts are available for determining the correction factor (Schlumberger, 2009, pp. 52-55), for expediency and the mud resistivity, flushed zone resistivity, and bed thickness to determine the correction factor. We will multiply the correction factor and the SP deflection to determine the static SP, which we will then use to calculate the resistivity of the water at the formation temperature (Asquith & Gibson, 1982, p. 29).

We will use the deep conductivity and resistivity curves in 100 percent water saturated sand zones to calculate the resistivity of the formation water directly. In the zones that are 100 percent saturated with water, the true formation resistivity is equal to the deep resistivity and the resistivity of the formation water is equal to the deep resistivity divided by a formation factor (Asquith & Gibson, 1982, p. 99). However, the formation factor can vary greatly and is dependent on the porosity, tortuosity, and cementation of the formation. While standard values for tortuosity and cementation are presented in the literature (Asquith & Gibson, 1982, p. 44), we anticipate calibrating these components versus measured TDS values to obtain specific coefficients for the studied aquifers.

Where data permit, we will prepare plots of the salinity calculations versus the TDS values from water quality samples. These plots will allow for developing equations relating salinity of the equivalent NaCl solution to TDS that are applicable to specific aquifers, sand zones, or geographic areas, as appropriate. In addition, the plots will allow us to crosscheck and calibrate the constants in the salinity calculations. These equations will allow us (LBG-Guyton Associates, 2006).

An advantage of calculating the salinity from geophysical logs is the opportunity to calculate salinity at multiple points within the sand zones. The many calculations will allow the Project Team to apply a statistical analysis (for example mean, median, or mode) to the multiple values for later use in volumetric calculations. Following verification of the results, we will compile the calculated values in the BRACS Database format. In addition, we will prepare box-and-whisker plots to illustrate the statistical salinity characteristics at various locations in the aquifers.

Task 3 Deliverables
1. Copies of water well reports, water quality reports, and geophysical well logs used in the study that were not already in the BRACS Database
2. Tools, files and/or scripts used to delineate salinity zones and volumes.
3. Figure showing the study area for the report
4. Figure showing the stratigraphy for the final report
5. Figure showing the salinity zones for the final report
6. Table showing the volumes of different groundwater salinity classes
7. Salinity Zone GIS datasets
8. Volume calculations
9. Description of the study area for the final report
10. Description of the salinity zones for the final report
11. Description of the volumes for the final report

Task 4 Geographic Information System (GIS) Dataset Development
The dataset developed during Task 2 and evaluations conducted during Task 3 will provide information located primarily at point locations in the study area. That is, the information developed will represent the aquifer at specific well locations rather than conditions across wide areas of the aquifer. Calculation of the three-dimensional delineation of groundwater salinity will require some form of interpolation. Interpolation is required because TDS values will be available at specific points, but we will need to develop estimates of the water quality at all locations in the aquifer. Performing an interpolation will enable the assignment of probable TDS concentrations over large geographic regions from the comparatively small number of data points.

Convert BRACS Database to ESRI Geodatabase Format
The Project Team will compile and integrate pertinent geologic and hydrogeologic data from the datasets into a GIS geodatabase to facilitate technical analysis and organize, store, and document the information used to delineate fresh, brackish (slightly saline and moderately saline), and very saline groundwater in the Nacatoch Aquifer.

We will use the standard data model framework developed by the TWDB for geologic structure and groundwater modeling projects to accomplish this task. The ArcGIS geodatabase supports a model of spatially-related feature classes, as well as more complex related GIS datasets that can be added in the future, if desired (for example, surface soils and precipitation distribution),

relationships (for example, estimated recoverable groundwater, water level declines versus local water well production), and relevant geoprocessing tools.

Within the geodatabase, a geology feature dataset will contain all of the point, line, and polygon feature classes and a water quality dataset will contain sample results, calculated salinity of an equivalent NaCl solution, and calculated TDS values as point data. The Project Team will manage raster data within the geodatabase as a raster catalog. Any scanned hardcopy water quality maps will be georeferenced and managed within the geodatabase raster catalog. The stratigraphic GIS data sets will include well location, well depth, log type, and aquifer top and bottom elevations and depth from land surface. The Team will develop metadata for each data layer that documents data descriptions, spatial characteristics, attribute information, data structure, data reliability, relevant dates, sources, field descriptions, units (as applicable), and contact information. We will develop the metadata within the editor in ESRI ArcCatalog and will comply with Federal Geographic Data Committee standards, in particular ISO 19139:2007. In addition, we will use BRACS program-naming conventions and map projection parameters for all datasets.

Interpolate Data to Enable Water Volume Calculations
The Project Team has extensive experience in the application of a variety of approaches to interpolating concentrations of various chemicals and solutes in groundwater. For this application, we anticipate focusing on the inverse distance weighted (IDW) and Kriging interpolation methods. The Team will assume that vertical are either 1) minor and can be neglected or 2) are substantial and can be handled by splitting the aquifer into discrete units and performing the computations on each unit.

The IDW method operates with the assumption that conditions at points close to one another are more alike than conditions at points that are farther apart. The IDW method predicts values at unmeasured locations based on the measured values in proximity to those unmeasured locations. The measured values closest to the predicted location have greater influence on the predicted value than do the measured values that are further away. The key parameters for the IDW method are the search radius, the number of samples to use within this search radius, and the power value. We can determine an optimal value for the power parameter, which determines the strength of the influence that measured points have on a predicted value, by minimizing the root mean square prediction error. Using Python scripting, we can automate the parameter optimization and eliminate the need for manual user input.

The Kriging methods, like the IDW method, assigns weights to the measured point values surrounding an unmeasured location to calculate a predicted value. However, Kriging also factors in the spatial arrangement of the measured points in its weighting scheme under the assumption that this arrangement reflects a spatial correlation that in some way explains the distributions of values. Because of its statistical underpinnings, Kriging can provide an increased measure of the accuracy for the predictions.

Of these two methods, Kriging is more complicated to implement than IDW because it requires scrutiny of the spatial behavior of the phenomenon being represented through calculation of a semivariogram before selecting the optimal parameter values to generate the predictions. This scrutiny and parameter selection process is typically performed manually as it requires a high degree of professional judgment. One way of overcoming this complication is the application of Bayesian Kriging (called Empirical Bayesian Kriging in ArcGIS) methods.

Through an iterative process, the Bayesian Kriging method automatically calculates the parameters that other Kriging methods require the user to declare explicitly. During the interpolation process, the method is able to account for the error introduced by estimating the underlying semivariogram, which provides the user with some quantification of the uncertainty associated with the result. A primary disadvantage of the Bayesian Kriging method is that processing is slower than other Kriging methods; however, as listed in the ArcGIS Geostatistical Analyst extension documentation, advantages of the method include:

- Minimal manual interaction (automated by applying reasonable assumptions);
- Standard errors of prediction are more accurate than other Kriging methods; and,
- More accurate than other kriging methods for small datasets.

For the Nacatoch Aquifer, we will apply multiple interpolation approaches to the measured or calculated TDS concentrations. We will compare the interpolations to the measured and calculated values at the input points to determine the method most appropriate for the data. We will save the final interpolations as raster datasets in the geodatabase. Similarly, we will interpolate and store the top and bottom of the geologic units, thicknesses, specific yield values, and static water level of the aquifer within the geodatabase at the same extent and resolution as a predefined project raster snap grid.

Quantification of the Fresh, Brackish, and Saline Groundwater Volumes
Following interpolation of the point data to raster datasets in Task 4.2, we will use these datasets to calculate the volume of fresh, brackish, and saline groundwater. To ensure the process is repeatable and consistent, we will develop tools in ArcGIS Model Builder for performing the calculations. Calculations will result in a raster dataset with each cell representing the volume of water within each area defined by the raster resolution.

The process will include calculating the volumes according to salinity classification zones developed by the U.S. Geological Survey (Winslow & Kister, 1956). Winslow and Kister based the classification on total dissolved solids where a concentration of 0 to 1,000 milligrams per liter is fresh, 1,000 to 3,000 milligrams per liter is slightly saline, 3,000 to 10,000 milligrams per liter is moderately saline, 10,000 to 35,000 milligrams per liter is very saline, and greater than 35,000 milligrams per liter is brine. The volumes within each salinity category will be summarized by county, groundwater conservation district, groundwater management area, regional water planning area, and river basin.

Delineate Potential Production Areas
Using information gathered from comments received during the first stakeholder meeting (see Task 1.2.1), we anticipate the TWDB will have guidance for definition and quantification of "hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in any part of the same or other fresh water aquifers" (from RFQ paraphrasing House Bill 30). Using this guidance and additional criteria from the statute, we will use the developed datasets to delineate potential production areas. The following summarizes the requirements an area must meet to be designated:

- Average TDS concentration is more than 1,000 milligrams per liter;
- Sufficient hydrogeologic separation from areas in the same or another aquifer with an average TDS concentration of 1,000 milligrams per liter or less;
- Not currently used as a significant source of water supply for municipal, domestic, or agricultural purposes;
- Not part of a geologic stratum that is designated or used for wastewater injection through the use of injection or disposal wells permitted under Texas Water Code Chapter 27; and,
- Not within the Harris-Galveston Subsidence District and the Fort Bend Subsidence District.

We will use the criteria to define the three-dimensional spatial extent of potential production areas within the Nacatoch Aquifer. Each potential production area will be assigned a unique ID for relation to production area attributes (such as, hydraulic properties, volume of brackish groundwater subdivided by salinity classification zones, 30-year and 50-year production calculation estimates). These production area attributes will be populated with values in a Microsoft Access database table, in supporting GIS files (top, bottom, and lateral extent), and in groundwater modeling files during later evaluation work.

The potential production areas will be presented to the TWDB staff for discussion during Task 1.1.3. During this meeting, the areas will be prioritized for performing 30-year and 50-year production calculations.

Task 4 Deliverables
1. All GIS and GAM files used in a project shall be provided to TWDB.
2. All GIS and GAM files will be summarized in an appendix in the technical report listing file names, type, and folder structure. See TWDB Report 383 for examples.
3. All GIS files will have descriptive metadata documenting the content, data structure, source(s), date(s), quality, and other pertinent characteristics of the data using the Federal Geographic Data Committee (FGDC) metadata editor within ESRI's ArcCatalog.
4. All GIS file creation techniques will be described either in the technical report appendix for GIS files or in the section on a particular topic, such as net sand.
5. All interpolation techniques will be described either in an appendix of the technical report for or in a section on a particular topic.

Task 5 Evaluation of Potential Production Areas
The Project Team will present the data acquisition, evaluation, and interpolation results at a stakeholder meeting coordinated by the TWDB (see Task 1.2.2). The presentation will provide information to stakeholders in the form of Microsoft PowerPoint slides and discussion by the Project Team leader. During the stakeholder meeting, the TWDB will solicit input on the potential production areas that will define areas for conducting evaluations during this task.

Using the defined and prioritized potential production areas, the Project Team will perform model simulations to determine the potential effects of the pumping from the area on other groundwater resources. We anticipate applying the GAMs to evaluate the pumping effects for many, if not all, of the defined production areas. In areas that may not be reasonable represent a production area or where the production area is outside of the model boundary, we will develop a simple numerical model that reasonable represents the conceptual understanding the local aquifer conditions.

Evaluation of the areas will focus on developing the estimated volumes of brackish groundwater production in 30- and 50-year timeframes. During the evaluations we will populate the production area attribute tables developed during Task 4.4. The Project Team will develop complete metadata for all new GIS dataset developed during the evaluation of the production areas.

Task 5 Deliverables
1. Tools, files and/or scripts used to estimate the capacity of Potential Production Areas over 30-year and 50-year periods, without causing a significant impact, as defined in Task 4
2. Description of capacity of Potential Production Areas over 30 and 50 year periods, without causing a significant impact, as defined in Task 4, for the final report
3. Table and graph of capacity of Potential Production Areas over 30 and 50 year periods, without causing a significant impact, as defined in Task 4, for the final report

Task 6 Draft Project Report
The project report will detail the work conducted during the acquisition and evaluation of the geologic and water quality data. The report will also include thorough documentation of the tools and techniques used for determining the extent and volumes of the required ranges of total dissolved solids in the groundwater and techniques used to determine if a potential production area is hydrogeologically separated from fresh water aquifers. In the report we will organize the calculated volumes of groundwater within the aquifer and each TWDB prioritized potential production area by salinity classification zone, county, groundwater conservation district, and groundwater management area. We will use the Formatting Guidelines for Texas Water Development Board Reports as our style guide for the report. In addition, we will work to ensure that the report follows the guidelines of the Texas Board of Professional Geoscientists.

We will provide seven hard copies of the draft report to the TWDB. In addition to the hard copies of the draft project report, we will provide a digital copy of the draft report in Microsoft Word format and PDF format, potential production area modeling files, the draft Microsoft Access database, and the draft project geodatabase (which will include: geologic formation top and bottom raster surfaces, net sand raster surfaces, salinity classification zone top and bottom raster

surfaces, proposed production area top and bottom raster surfaces, well control point files, and project raster snap grid). Following delivery of the project report there will be a comment period (to be determined) during which the TWDB staff and stakeholders will be able to provide feedback on the project results.

Task 6 Deliverables
1. The CONTRACTOR will submit the draft report by THE STUDY COMPLETION DATE. All draft reports shall be delivered in Microsoft Word and PDF formats.
2. TWDB will have 30 days to review and provide comments.
3. The CONTRACTOR will have 30 days to address TWDB's comments. These comments must be addressed in the Final Report and a copy of the comments and the CONTRACTORS responses must be incorporated into the final deliverables.

Task 7 Final Project Report
At the end of the draft project report comment period, we will address each comment and incorporate a copy of the submitted comments into the final project report and other deliverables.. We will identify individual authors responsible for the report and those individuals will sign and seal the report per Professional Engineer or Professional Geoscientist requirements, as applicable.

Task 7 Deliverables
1. Updated data for the BRACS Database containing all new well records used in the Project.
2. Copies of water well reports, water quality reports, and geophysical well logs used in the study (unless those reports and logs already exist in the TWDB Groundwater or BRACS databases).
3. Three-dimensional GIS datasets that delineate groundwater salinity zones using ranges of concentrations of total dissolved solids of 0 to 1,000 milligrams per liter (fresh), 1,000 to 3,000 milligrams per liter (slightly saline), 3,000 to 10,000 milligrams per liter (moderately saline), and 10,000 to 35,000 milligrams per liter (very saline).
4. Three-dimensional GIS datasets that delineate potential production areas and the estimated volumes of brackish groundwater production in 30- and 50-year timeframes.
5. A technical report summarizing the study. See Exhibit D for formatting guidelines and Exhibit H for the report outline.
6. All geophysical well logs interpreted for total dissolved solids will be submitted to TWDB and all interpretation data values (input and output) will be documented in table(s) with links to well numbers, log numbers, depths, and names of geological formations in a Microsoft Access database format that can be linked to existing BRACS Database tables. Geophysical well log data obtained for the Project must be non-confidential and submitted in a Tagged Image File Format (TIFF) and, if available, Log ASCII Standard (LAS) format. New well control will be added to the BRACS Database with complete attributes. Water quality data

will be compatible with the Groundwater Database table design and should include the source of the data.

7. To develop new and updated maps of the water resources, the Project should use current information from a variety of non-proprietary databases and geophysical log repositories that are publicly available.

8. The tools and techniques used for determining the extent and volumes of the required ranges of total dissolved solids in the groundwater shall be thorough, use defensible scientific means and approaches, and shall be documented in the technical report. The technique(s) used to determine if a Potential Production Areas is hydrogeologically separated from fresh water aquifers shall be thoroughly documented in the technical report. Each Potential Brackish Production Areas will be assigned a unique ID, and all production area attributes (ID, volume of brackish groundwater subdivided by salinity classification zones, 30-year and 50-year production calculation estimates) will be recorded in a Microsoft Access database table, in supporting GIS files (top, bottom, and lateral extent), and in groundwater modeling files.

9. The calculated volumes of groundwater within each aquifer and each TWDB-prioritized Potential Production Areas will be organized by salinity classification zone, county, groundwater conservation district, and groundwater management area. All GIS data shall be thoroughly documented with metadata including source, field descriptions, and units (as applicable) and use BRACS program-naming conventions and map Projection parameters. Geologic formation top and bottom raster surfaces, net sand raster maps, salinity classification zone top and bottom raster surfaces, proposed production area top and bottom raster surfaces, well control point files, and Project raster snap grid will be submitted to TWDB. All raster surfaces will share the same map Projection and snap grid attributes. TWDB must be able to replicate the volumes estimated and techniques used to determine the extents of each of the salinity classification zones. All Potential Production Areas modeling files will be submitted to TWDB.

10. Training for TWDB staff shall be provided, as needed or requested. Training may include, but not limited to how the volumes were estimated and the techniques used to determine the extents of salinity zones.

11. Final reports shall be delivered in Microsoft Word and PDF formats. TWDB comments must be addressed in the Final Report and a copy of the comments must be incorporated into the final deliverables. Acceptance of the Final Report indicates the successful completion of the Project.

Task 8. TWDB Training
The Project Team will provide instruction to TWDB staff to demonstrate specific methodologies and/or techniques utilized to determine volume calculations, salinity zones extents, or anything that may deemed necessary and appropriate for presentation within a training venue. This training will be provided at the request of TWDB, on an as needed basis.