Exhibit C
Scope of Work

PANHANDLE REGION A

Study 1 – Quantification of Recharge to the Ogallala Aquifer in the Eastern Panhandle, Texas

Quantify Recharge Rates Using the Chloride Mass Balance Approach

The spatial variability in natural groundwater recharge will be estimated using the chloride mass balance approach.

A. Data Collection: Existing data will be examined to determine optimal sites for field evaluation of recharge rates. Soil texture data will be obtained from STATSGO and SSURGO (USDA, 1994, 1995). Land use information will be obtained from National Land Cover Data (NLCD; 1992) (Vogelmann, 2001). Groundwater level data will be obtained from the Texas Water Development Board to determine thickness of the unsaturated zone. County soil survey reports will be reviewed for Roberts and neighboring counties. Soil and geologic records will be reviewed to determine the distribution of shallow caliche zones. Generally areas with strongly developed, shallow caliche have little or no recharge. Evapotranspiration data from the Bushland Agricultural Research Service from lysimeter records will be examined to determine variations in ET in rangeland and crops.

B. Field Investigation: Boreholes will be drilled in the field and soil samples collected for laboratory analysis of chloride concentrations in pore water to estimate recharge rates.

B1. Borehole Siting: Representative borehole locations will be chosen on the basis of GIS information on various parameters, including topography (DEM), soil texture from SSURGO and STATSGO (USDA 1984, 1985), land cover (Vogelmann, 2001), and water table depth and aquifer saturated thickness (Texas Water Development Board). Preliminary reconnaissance will be conducted using surface geophysics to evaluate variability in apparent conductivity of potential drilling sites.

B2. Geoprobe Sampling: Drilling in year one of the project will be conducted with a Geoprobe drilling rig. Approximately eight boreholes will be drilled. Maximum depths that can be attained with the Geoprobe drill rig are generally 30 to 50 ft. Boreholes will be spatially distributed throughout the study area to represent different topographic settings, geomorphic settings (distance from the river), and land use regions (rangeland, dryland).

B3. Deep Borehole Drilling: On the basis of the results of this drilling, two additional boreholes will be drilled to a maximum depth of 300 to 400 ft in representative areas in year two using a more powerful drill rig (e.g., Central Mine Equipment rig or similar caliber rig).

B4. Soil Sampling: Soil samples will be collected at varying depth intervals in each borehole (6 inches – 20 feet), and these samples will be analyzed for soil

texture, water content, and anions including chloride, cations, and pressure head. Soil texture analyses will include evaluation of carbonate content to determine whether caliche zones are present.

C. Calculation of Recharge Rates: Recharge rates will be estimated using the chloride mass balance equation (Scanlon et al., 2002).

C1. Determine Chloride Concentrations: Chloride concentrations in soil pore water will be analyzed using ion chromatography. Pressure head data will provide information on the direction of water movement (upward or downward) at the time of sampling. The magnitude of the pressure heads will indicate soil wetness.

C2. Calculate Recharge Rates and Evaluate Soil Data Relative to Recharge Process: In addition to the chloride profiles and associated recharge rates, distribution of calcic soils, water content, pressure head, and other anion and cation data will be integrated to provide a comprehensive understanding of recharge processes in this setting.

C3. Extrapolate Results to Study Area: Regionalization of the point borehole recharge estimates will be conducted by comparing recharge estimates from different settings with topography, soil texture data from SSURGO (USDA, 2005), and land cover information (Vogelmann, 2001). These comparisons will help determine the dominant controls on spatial variability in groundwater recharge in this region.

C4. Technical Memorandum: A technical memorandum will be prepared documenting the field studies, calculation of recharge rates, and the spatial variability or recharge across the study area.

D. Evaluate Existing Ponds as Analogs for Enhanced Recharge Structures: Representative man-made ponds that have been operational for different time periods will be examined to determine the depth of penetration of water and the potential for enhanced recharge using similar structures.

D1. Field Study: Depending on availability of such structures, ponds will be chosen in different soils to assess the effect of soil texture on downward water movement. Surface geophysics will be used to estimate depth variations in conductivity as an indicator of subsurface water movement. Shallow boreholes will be drilled where feasible and soil samples analyzed for water content and anions and cations to determine the penetration depth of water movement beneath these features.

D2. Technical Memorandum: A technical memorandum will be prepared documenting the field studies, results, and the potential to utilize similar structures to enhance recharge within the study area.

Work Products

Quarterly technical memorandum will be submitted to the political subdivision and TWDB to report on task progress.

Prepare a draft and final report to include the following sections: executive summary, purpose of study including how the study supports regional water planning, methodology, results, and recommendations, if applicable. The draft report will be submitted to the planning group and the TWDB for review and comment. All comments will be addressed in the final report.

A draft report will be submitted to Regions A and Region O for review and comment.

All GIS layers used in study will be submitted to political subdivisions and TWDB.

Electronic versions of the text (in Microsoft Word format) and graphics (in encapsulated PostScript format) used in the final report, and the consultant shall provide fifty (50) hard copies of the draft Task 1 report and fifty (50) hard copies of the final report to the PRPC. In addition, the consultant shall provide three electronic copies of all data collected and used in this study to the PRPC and TWDB. This report will include tables, graphs, summarized model results, and other result summaries from work in a final report.

Presentation of project methods and results to the political subdivisions of the Regional Water Planning Groups, Groundwater Conservation Districts, and TWDB staff.

The report will be submitted per TWDB requirements and results from this study will be included in the 2011 Panhandle Region A regional water plan. The development, analysis, and reporting of results will follow methodologies and guidance according to Exhibit B, and agency rules.

Study 2- Numerical Modeling of Groundwater Recharge

Unsaturated zone modeling will be conducted to estimate recharge in this region and to evaluate controls on groundwater recharge that would allow regionalization of point recharge estimates from borehole data. In previous studies we have applied this approach to estimate an average recharge rate for Carson County (0.02 inch/yr) and for other counties in Texas (Keese et al., 2005). Modeling analyses will use either the UNSATH or HYDRUS codes.

A. Data Collection: Input data requirements for the model include meteorological forcing, vegetation parameters, hydraulic parameters for different soil types, and initial conditions. Precipitation data will be obtained from the National Climatic Data Center. Potential evapotranspiration will be calculated using the Penman Monteith equation. Vegetation parameters will be obtained from the literature and from discussions with local ecologists and agronomists. Time series of leaf area indices and rooting depths will be input to the model. Initial conditions will be estimated from previous field studies conducted for the Panhandle Groundwater Conservation District (Tachovsky et al., 2006). Soil textural information for the upper 2 m will be obtained from SSURGO version 2 data [U.S. Department of Agriculture (USDA), 1994]. Pedotransfer functions will be used to determine soil hydraulic properties. Rosetta software uses neural network programming

and a database of measured texture, water retention, and saturated hydraulic conductivity to provide estimates of van Genuchten water retention parameters and saturated hydraulic conductivity for input to unsaturated flow models [Schaap et al., 2001].

B. Unsaturated Flow Modeling: Unsaturated flow modeling will be used to simulate drainage below the root zone, which is equated to groundwater recharge and assumes that climate and land use/land cover remain constant over timescales required for water to move from the root zone to the water table. Long-term (30 yr) precipitation will be used as the upper boundary condition for the simulations. The simulations focus on the water balance:

$D = P - ET - R_o - DS$ (1)

Where D is deep drainage below the root zone, P is precipitation, ET is evapotranspiration, R_o is surface runoff, and DS is change in water storage.

C. Calculation of Recharge Value: A representative recharge value (30 yr average) will be calculated for Roberts County using 1-d simulations for each different combination of vegetation and soil texture within the county and spatially weighting each of these simulations on the basis of the area covered. Sensitivity analyses will be used to assess different controls on groundwater recharge. Variations in climate, vegetation, and soil texture will be examined using sensitivity analyses.

D. Technical Memorandum: A technical memorandum will be prepared documenting the methodology, data collection, and results of the groundwater recharge modeling.

Work Products

Quarterly technical memorandum will be submitted to the political subdivision and TWDB to report on task progress.

Prepare a draft and final report to include the following sections: executive summary, purpose of study including how the study supports regional water planning, methodology, results, and recommendations, if applicable. The draft report will be submitted to the planning group and the TWDB for review and comment. All comments will be addressed in the final report.

A draft report will be submitted to Region A Regional Water Planning Group for review and comment.

All GIS layers used in study will be submitted to political subdivisions and TWDB.

The report will be submitted per TWDB requirements and results from this study will be included in the 2011 Panhandle Region A regional water plan. The development, analysis, and reporting of results will follow methodologies and guidance according to Exhibit B, and agency rules.

Study 3 - Geochemical Studies

A. Field Investigation: The investigation will use existing wells to date the groundwater using tritium and/or tritium-helium dating in three locations. (Drilling is not expected or included in this part of the proposal.)

Work Products

Quarterly technical memorandum will be submitted to the political subdivision and TWDB to report on task progress.

Prepare a draft and final report to include the following sections: executive summary, purpose of study including how the study supports regional water planning, methodology, results, and recommendations, if applicable. The draft report will be submitted to the planning group and the TWDB for review and comment. All comments will be addressed in the final report.

A draft report will be submitted to Region A Regional Water Planning Group for review and comment.

All GIS layers used in study will be submitted to political subdivisions and TWDB.

Electronic versions of the text (in Microsoft Word format) and graphics (in encapsulated PostScript format) used in the final report.

Presentation of project methods and results to the political subdivision of the Regional Water Planning Group, Groundwater Conservation Districts, and TWDB staff.

Groundwater recharge estimates based on groundwater chloride data and Groundwater age data will be submitted to the political subdivision at conclusion of the study period.

The report will be submitted per TWDB requirements and results from this study will be included in the 2011 Panhandle Region A regional water plan. The development, analysis, and reporting of results will follow methodologies and guidance according to Exhibit B, and agency rules.

Study 4- Plan Consistency and Interregional Coordination

The PWPG will conduct interregional coordination efforts between Region A and Region O. The following tasks are to be conducted:

A. Region A will coordinate results from Ogallala recharge study, and related water management strategy coordination with Region O consultants and political subdivision.

PWPG will conduct interregional coordination activities with Region O regarding the findings of the Ogallala recharge study. The changed conditions for this area are the

reduced availability from the Canadian River Municipal Water Authority regarding the total available yield from the CRMWA system (surface and ground) and refined groundwater availabilities from the Ogallala aquifer. The CRMWA system utilizes conjunctive supply from Region A to meet demands in both A and O. The yields from this system are an important element to both A and O as reduced yields will impact water user groups in both regions. As the drought in Region A has continued beyond the development of the initial scope of work, the resulting effect on the CRMWA system is a changed condition affecting both regions A and O.

B. The consultant will evaluate timing, quantity, location, and impact of water management strategies selected in other regions utilizing source water from within the Panhandle WPA and communicate these to Region A & O political subdivision.

Evaluate potentially feasible water management strategies from Region O that use supply from Region A. This topic is directly related to the topic above as reduced yields from the CRMWA system may force entities in Region O to develop new water management strategies to meet their needs. It is possible that these strategies may focus on supplies in Region A. Should this occur, there will be a direct need for Interregional Coordination as both Regions stand to be directly affected by the proposed strategies. The PWPG believes that it is most appropriate to handle any efforts related to this issue under Interregional Coordination rather than to require the respective regions to dilute their allocated planning funds to address strategies from outside the region.

The responsibilities under this task include attendance at key meetings, communications to planning groups of activities and actions of meetings, and coordination between planning groups. In addition, public information will be developed and posted via the internet and public meetings.

Work Products

Quarterly technical memorandum will be submitted to the political subdivision and TWDB to report on task progress.

Prepare a draft and final report to include the following sections: executive summary, purpose of study including how the study supports regional water planning, methodology, results, and recommendations, if applicable. The draft report will be submitted to the planning group and the TWDB for review and comment. All comments will be addressed in the final report.

A draft report will be submitted to Region A Regional Water Planning Group for review and comment.

All GIS layers used in study will be submitted to political subdivisions and TWDB.

Electronic versions of the text (in Microsoft Word format) and graphics (in encapsulated PostScript format) used in the final report.

Presentation of project methods and results to the political subdivision of the Regional Water Planning Group, Groundwater Conservation Districts, and TWDB staff.

The report will be submitted per TWDB requirements and results from this study will be included in the 2011 Panhandle Region A regional water plan. The development, analysis, and reporting of results will follow methodologies and guidance according to Exhibit B, and agency rules.

Administration and Public Participation

A. Attend regularly scheduled meetings of the LCRWPG even when there is not a specific report by the consultant team.

B. Coordinate with Board staff to determine adequacy of notice for each instance in which notice is required.

C. Provide all required notices of availability for scopes of work, grant applications, and draft and final documents. This includes providing notices in the newspaper of general circulation in each county.

D. Perform other duties as assigned.

Work Products

Work products from this scope will include properly prepared notices of availability of scopes of work and draft and final products, properly prepared newspaper notices, etc.