EXHIBIT B

SCOPE OF WORK

DEMONSTRATION OF A HIGH RECOVERY AND ENERGY EFFICIENT RO SYSTEM FOR SMALL-SCALE BRACKISH WATER DESALINATION
Detailed Scope of the Proposed Studies

The main objective of this project is to demonstrate the superiority of a parallel RO system over conventional RO technology for small-scale brackish water desalinations. The conventional RO desalination technology is developed primarily for large-scale applications. When it is used for small-scale applications (<100,000 gallon/day), the conventional RO systems are usually characterized by lower recovery and higher energy consumption because of the shorter channel length or small number of membrane elements. The parallel RO system is featured with parallel arrangement of membrane elements and closed concentrate circulation. In principle, the parallel RO system can work efficiently at any recovery that is no longer limited by the length of membrane channel or number of membrane elements. Because of the short channel length, the hydraulic conditions, such as crossflow velocity and driving pressure, can be maintained virtually the same in each membrane channel. In addition, the crossflow velocity in the parallel RO system is decoupled from the feed flow rate and freely adjustable. These two features will significantly improve the performance of the RO system and reduce membrane fouling. Finally, the parallel RO system completely eliminates energy waste associated with concentrate discharge because it is not pressurized during discharge.

A RO system with the configuration as shown in Exhibit A for high recovery and energy efficiency is being fabricated in the Environmental Lab at Texas Tech University with an internal fund. The RO system is designed to be representative for the practical application and executable in a small laboratory environment. For this purpose, the standard 40" long membrane elements of 2.5" in diameter are tentatively chosen for the RO system. An engineering company specializing in RO equipment has been selected and for the RO system fabrication. The detailed design is being finalized through discussions with the engineering company. The RO system will be equipped with the necessary meters for the key parameters, such as salinity, pressures, and flow rates. A computer-based control and automation system will be adapted to the RO system for easy operation and accurate control. The computer-based control system should also have the capacity to record the operation and performance variables at preset time intervals for subsequent analyses. TWDB fund is sought for the necessary resources (manpower and consumables) to demonstrate the parallel RO system as a high recovery and energy efficient desalination technology for small-scale application.

Task 1. Assessment of Energy Efficiency at Different Recoveries. Energy consumption of the parallel

RO system under various operational conditions (especially different salinities and recoveries) will be investigated and critically evaluated. The usage of electricity will be monitored by two electric (watt-hour) meters attached to the high pressure pump and the circulation pump. The energies measured by these meters provide the total electric energy consumed. Because motors and pumps are less than 100% efficient, the useful mechanical energy utilized by the RO system will be smaller than the measured electric energy. The net energy inputs from the high pressure pump and circulation pump to the RO system can be calculated from the measurements of the flow rate and pressure over

the operation period. Synthetic feed waters of 1,000, 2,500, and 5,000 mg/L sodium chloride (NaCl) in de-ionized (DI) water will be used in the experiments to represent the treated wastewater, low salinity brackish water, and high salinity brackish water. Filtration experiments will be carried out for recoveries of 50%, 75%, 80%, and 90%. The electricity consumption measured by the electric meters and the net energy inputs from the high pressure pump and circulation pump will be recorded. The specific energy requirement (energy to produce one unit of permeate) will be analyzed with the test operation conditions and compared with those in the conventional RO process found in the literature.

Task 2. Studies on Effectiveness of Fouling Control with Variable Crossflow Velocity. The ability of the parallel RO system to mitigate fouling will be experimentally investigated and assessed with a model colloid, SNOWTEX ST-ZL Silica (Nissan Chemical, Japan) with particle sizes of 70-100 nm. This type of SNOWTEX silica colloids is selected as the model colloid because it has been intensively studied for their fouling behaviors in membrane processes. The focus of this investigation is to assess the effectiveness of changeable cross flow velocity on fouling control.
In order to observe fouling in a short time, high concentrations of colloids will be added in the feed water of 2,500 mg/L NaCl to simulate various fouling strengths. The feed water will be filtered by the RO system under constant flux mode, and the pressure will be recorded at the preset time intervals. The pressure profile will be compared with the baseline for the feed water without colloids addition. The deviation of the pressure line from the baseline will indicate the occurrence of colloid fouling. Filtration experiments will be conducted at 2 crossflow velocities of 0.1 and 0.2 m/s. The recovery at which deviation starts will be identified. The data will be compared for the effectiveness of crossflow velocity on fouling mitigation.

Task 3. Pilot Demonstration of the RO System with Real Brackish Water. After performance assessments with laboratory experiments, the RO system will be tested on a field site for a sufficient period to demonstrate its intended purpose (high recovery and energy efficiency) with real brackish water. The City of Seminole, Texas, is going to build an exploratory RO plant to explore supplementary water supply by desalination of brackish groundwater from Santa Rosa aquifer (the project is also partially supported by a fund from TWDB). The exploratory RO plant is planned to use a conventional RO train powered by a 50 kW wind turbine. Seminole is about 80 miles southwest of Lubbock and is a convenient site for field demonstration.
The City of Seminole has expressed great interest in our proposed RO system of new configuration for small-scale applications. The city offered its support to have the parallel RO system tested on its desalination site in parallel with the conventional RO system. The performance of the parallel RO system will be evaluated in real world conditions and compared with the conventional RO process.

Task 4. Cost Estimate. From the laboratory and field experiments, the cost of brackish water desalination with the parallel RO system will be calculated. The energy cost can be directly determined from the experimental data. The cost of the equipment cannot be made based on the existing RO system at Texas Tech because it made as a single piece of its kind. The cost should be much smaller when the RO system is being produced in batches. For a more accurate estimate, the prices of the components, such as membrane elements, pressure vessels, and pumps, will be collected from manufacturers and venders. The cost of integration and profit margin of the RO system will be estimated by consulting with the companies specialized in RO system fabrication.